The Vitess Documentation

Contents

Region-based Sharding

{{< info >}} This guide follows on from the Get Started guides. Please make sure that you have a local installation ready. You should also have already gone through the MoveTables and Resharding tutorials. {{< /info >}}

Preparation

Having gone through the Resharding tutorial, you should be familiar with VSchema and Vindexes. In this tutorial, we will create a sharded keyspace using a location-based vindex. We will create 4 shards (-40, 40-80, 80-c0, c0-). The location will be denoted by a `country` column.

Schema

We will create 2 tables in this example.

```
CREATE TABLE customer (
  id int NOT NULL,
  fullname varbinary(256),
  nationalid varbinary(256),
  country varbinary(256),
  primary key(id)
  );
CREATE TABLE customer_lookup (
  id int NOT NULL,
  keyspace_id varbinary(256),
  primary key(id)
  );
```

The customer table is the main table we want to shard using country. The lookup table will help us do that.

Region Vindex

We will use a `region_json` vindex to compute the keyspace_id for a customer row using the (id, country) fields. Here's what the vindex definition looks like:

```
    "region_vdx": {
    "type": "region_json",
    "params": {
        "region_map": "/vt/examples/region_sharding/countries.json",
        "region_bytes": "1"
    }
    },
```

And we use it thus:

```
    "customer": {
      "column_vindexes": [
        {
            "columns": ["id", "country"],
        "name": "region_vdx"
        },
```

This vindex uses a byte mapping of countries provided in a JSON file and combines that with the id column in the customer table to compute the keyspace_id. In this example, we are using 1 byte. You can use 1 or 2 bytes. With 2 bytes, 65536 distinct locations can be supported. The byte value of the country(or other location identifier) is prefixed to a hash value computed from the id to produce the keyspace_id.

The lookup table is used to store the id to keyspace_id mapping. We connect it to the customer table as follows: We first define a lookup vindex:

```
    "customer_region_lookup": {
        "type": "consistent_lookup_unique",
        "params": {
            "table": "customer_lookup",
            "from": "id",
            "to": "keyspace_id"
        },
        "owner": "customer"
    },
```

Then we create it as a vindex on the customer table:

```
    "customer": {
      "column_vindexes": [
        {
            "columns": ["id", "country"],
        "name": "region_vdx"
        },
    {
            "column": "id",
            "name": "customer_region_lookup"
        }
      ]
    }
```

The lookup table could be unsharded or sharded. In this example, we have chosen to shard the lookup table also. If the goal of region-based sharding is data locality, it makes sense to co-locate the lookup data with the main customer data. We first define an `identity` vindex:

```
      "identity": {
      "type": "binary"
      }
```

Then we create it as a vindex on the lookup table:

```
    "customer_lookup": {
      "column_vindexes": [
    {
            "column": "keyspace_id",
            "name": "identity"
        }
      ]
    },
```

This is what the JSON file contains:

```
{
    "United States": 1,
    "Canada": 2,
    "France": 64,
    "Germany": 65,
    "China": 128,
```

```
    "Japan": 129,
    "India": 192,
    "Indonesia": 193
}
```

The values for the countries have been chosen such that 2 countries fall into each shard.

Start the Cluster

Start by copying the region_sharding example included with Vitess to your preferred location.

```
cp -r /usr/local/vitess/examples/region_sharding ~/my-vitess/examples/region_sharding
cd ~/my-vitess/examples/region_sharding
```

The VSchema for this tutorial uses a config file. You will need to edit the value of the `region_map` parameter in the vschema file `main_vschema.json`. For example:

```
"region_map": "/home/user/my-vitess/examples/region_sharding/countries.json",
```

Now start the cluster

```
./101_initial_cluster.sh
```

You should see output similar to the following:

```
~/my-vitess-example> ./101_initial_cluster.sh
add /vitess/global
add /vitess/zone1
add zone1 CellInfo
etcd start done...
Starting vtctld...
Starting MySQL for tablet zone1-0000000100...
Starting vttablet for zone1-0000000100...
HTTP/1.1 200 OK
Date: Thu, 21 May 2020 01:05:26 GMT
Content-Type: text/html; charset=utf-8

Starting MySQL for tablet zone1-0000000200...
Starting vttablet for zone1-0000000200...
HTTP/1.1 200 OK
Date: Thu, 21 May 2020 01:05:31 GMT
Content-Type: text/html; charset=utf-8

Starting MySQL for tablet zone1-0000000300...
Starting vttablet for zone1-0000000300...
HTTP/1.1 200 OK
Date: Thu, 21 May 2020 01:05:35 GMT
Content-Type: text/html; charset=utf-8

Starting MySQL for tablet zone1-0000000400...
Starting vttablet for zone1-0000000400...
HTTP/1.1 200 OK
Date: Thu, 21 May 2020 01:05:40 GMT
Content-Type: text/html; charset=utf-8

W0520 18:05:40.443933    6824 main.go:64] W0521 01:05:40.443180 reparent.go:185]
   master-elect tablet zone1-0000000100 is not the shard master, proceeding anyway as
   -force was used
```

```
W0520 18:05:40.445230    6824 main.go:64] W0521 01:05:40.443744 reparent.go:191]
   master-elect tablet zone1-0000000100 is not a master in the shard, proceeding anyway as
   -force was used
W0520 18:05:40.496253    6841 main.go:64] W0521 01:05:40.495599 reparent.go:185]
   master-elect tablet zone1-0000000200 is not the shard master, proceeding anyway as
   -force was used
W0520 18:05:40.496508    6841 main.go:64] W0521 01:05:40.495647 reparent.go:191]
   master-elect tablet zone1-0000000200 is not a master in the shard, proceeding anyway as
   -force was used
W0520 18:05:40.537548    6858 main.go:64] W0521 01:05:40.536985 reparent.go:185]
   master-elect tablet zone1-0000000300 is not the shard master, proceeding anyway as
   -force was used
W0520 18:05:40.537758    6858 main.go:64] W0521 01:05:40.537041 reparent.go:191]
   master-elect tablet zone1-0000000300 is not a master in the shard, proceeding anyway as
   -force was used
W0520 18:05:40.577854    6875 main.go:64] W0521 01:05:40.577407 reparent.go:185]
   master-elect tablet zone1-0000000400 is not the shard master, proceeding anyway as
   -force was used
W0520 18:05:40.578042    6875 main.go:64] W0521 01:05:40.577448 reparent.go:191]
   master-elect tablet zone1-0000000400 is not a master in the shard, proceeding anyway as
   -force was used
...
Waiting for vtgate to be up...
vtgate is up!
Access vtgate at http://localhost:15001/debug/status
```

You can also verify that the processes have started with `pgrep`:

```
~/my-vitess-example> pgrep -fl vtdataroot
3920 etcd
4030 vtctld
4173 mysqld_safe
4779 mysqld
4817 vttablet
4901 mysqld_safe
5426 mysqld
5461 vttablet
5542 mysqld_safe
6100 mysqld
6136 vttablet
6231 mysqld_safe
6756 mysqld
6792 vttablet
6929 vtgate
```

The exact list of processes will vary. For example, you may not see `mysqld_safe` listed.

If you encounter any errors, such as ports already in use, you can kill the processes and start over:

```
pkill -9 -e -f '(vtdataroot|VTDATAROOT)' # kill Vitess processes
rm -rf vtdataroot
```

Aliases

For ease-of-use, Vitess provides aliases for `mysql` and `vtctlclient`. These are automatically created when you start the cluster.

```
source ./env.sh
```

Setting up aliases changes `mysql` to always connect to Vitess for your current session. To revert this, type `unalias mysql && unalias vtctlclient` or close your session.

Connect to your cluster

You should now be able to connect to the VTGate server that was started in `101_initial_cluster.sh`:

```
~/my-vitess-example> mysql
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 2
Server version: 5.7.9-Vitess (Ubuntu)

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owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql> show tables;
+------------------+
| Tables_in_vt_main |
+------------------+
| customer          |
| customer_lookup   |
+------------------+
2 rows in set (0.01 sec)
```

Insert some data into the cluster

```
~/my-vitess-example> mysql < insert_customers.sql
```

Examine the data we just inserted

```
mysql> use main/-40;
Database changed

mysql> select * from customer;
+----+-----------------+-------------+---------------+
| id | fullname        | nationalid  | country       |
+----+-----------------+-------------+---------------+
|  1 | Philip Roth     | 123-456-789 | United States |
|  2 | Gary Shteyngart | 234-567-891 | United States |
|  3 | Margaret Atwood | 345-678-912 | Canada        |
|  4 | Alice Munro     | 456-789-123 | Canada        |
+----+-----------------+-------------+---------------+
4 rows in set (0.01 sec)

mysql> select id,hex(keyspace_id) from customer_lookup;
+----+--------------------+
| id | hex(keyspace_id)   |
+----+--------------------+
|  1 | 01166B40B44ABA4BD6 |
```

```
|  2 | 0106E7EA22CE92708F |
|  3 | 024EB190C9A2FA169C |
|  4 | 02D2FD8867D50D2DFE |
+----+--------------------+
4 rows in set (0.00 sec)
```

You can see that only data from US and Canada exists in this shard. Repeat this for the other shards (40-80, 80-c0 and c0-) and see that each shard contains 4 rows in customer table and the 4 corresponding rows in the lookup table.

You can now teardown your example:

```
./201_teardown.sh
rm -rf vtdataroot
```

Concepts

description: Learn core Vitess concepts and terminology

Cell

description: Data center, availability zone or group of computing resources

A *cell* is a group of servers and network infrastructure collocated in an area, and isolated from failures in other cells. It is typically either a full data center or a subset of a data center, sometimes called a *zone* or *availability zone*. Vitess gracefully handles cell-level failures, such as when a cell is cut off the network.

Each cell in a Vitess implementation has a local topology service, which is hosted in that cell. The topology service contains most of the information about the Vitess tablets in its cell. This enables a cell to be taken down and rebuilt as a unit.

Vitess limits cross-cell traffic for both data and metadata. While it may be useful to also have the ability to route read traffic to individual cells, Vitess currently serves reads only from the local cell. Writes will go cross-cell when necessary, to wherever the master for that shard resides.

Execution Plans

Vitess parses queries at both the VTGate and VTTablet layer in order to evaluate the best method to execute a query. This evaluation is known as query planning, and results in a *query execution plan*.

The Execution Plan is dependent on both the query and the associated VSchema. One of the underlying goals of Vitess' planning strategy is to push down as much work as possible to the underlying MySQL instances. When this is not possible, Vitess will use a plan that collects input from multiple sources and merges the results to produce the correct query result.

Evaluation Model An execution plan consists of operators, each of which implements a specific piece of work. The operators combine into a tree-like structure, which represents the overall execution plan. The plan represents each operator as a node in the tree. Each operator takes as input zero or more rows, and produces as output zero or more rows. This means that the output from one operator becomes the input for the next operator. Operators that join two branches in the tree combine input from two incoming streams and produce a single output.

Evaluation of the execution plan begins at the leaf nodes of the tree. Leaf nodes pull in data from VTTablet, the Topology Service, and in some cases are also able to evaluate expression values locally. Each leaf node will not have input from other operators, and pipe in any nodes they produce into their parent nodes. The parents nodes will then pipe in nodes to their parent nodes, all the way up to a root node. The root node produces the final results of the query and delivers the results to the user.

Observing Execution Plans Cached execution plans can be observed at the VTGate level by browsing the `/queryz` end point.

Starting with Vitess 6, individual statement plans can also be observed with `EXPLAIN FORMAT=vitess <query>`.

Related Vitess Documentation

- VTGate

Keyspace ID

The *keyspace ID* is the value that is used to decide on which shard a given row lives. Range-based Sharding refers to creating shards that each cover a particular range of keyspace IDs.

Using this technique means you can split a given shard by replacing it with two or more new shards that combine to cover the original range of keyspace IDs, without having to move any records in other shards.

The keyspace ID itself is computed using a function of some column in your data, such as the user ID. Vitess allows you to choose from a variety of functions (vindexes) to perform this mapping. This allows you to choose the right one to achieve optimal distribution of the data across shards.

Keyspace

A *keyspace* is a logical database. If you're using sharding, a keyspace maps to multiple MySQL databases; if you're not using sharding, a keyspace maps directly to a MySQL database name. In either case, a keyspace appears as a single database from the standpoint of the application.

Reading data from a keyspace is just like reading from a MySQL database. However, depending on the consistency requirements of the read operation, Vitess might fetch the data from a master database or from a replica. By routing each query to the appropriate database, Vitess allows your code to be structured as if it were reading from a single MySQL database.

MoveTables

MoveTables is a new workflow based on VReplication. It enables you to relocate tables between keyspaces, and therefore physical MySQL instances, without downtime.

Identifying Candidate Tables

It is recommended to keep tables that need to join on each other in the same keyspace, so typical candidates for a MoveTables operation are a set of tables which logically group together or are otherwise isolated.

If you have multiple groups of tables as candidates, which makes the most sense to move may depend on the specifics of your environment. For example, a larger table will take more time to move, but in doing so you might be able to utilitize additional or newer hardware which has more headroom before you need to perform additional operations such as sharding.

Similarly, tables that are updated at a more frequent rate could increase the move time.

Impact to Production Traffic Internally, a MoveTables operation is comprised of both a table copy and a subscription to all changes made to the table. Vitess uses batching to improve the performance of both table copying and applying subscription changes, but you should expect that tables with lighter modification rates to move faster.

During the active move process, data is copied from replicas instead of the master server. This helps ensure minimal production traffic impact.

During the `SwitchWrites` phase of the MoveTables operation, Vitess may be briefly unavailable. This unavailability is usually a few seconds, but will be higher in the event that your system has a high replication delay from master to replica(s).

Related Vitess Documentation

- MoveTables User Guide

Query Rewriting

Vitess works hard to create an illusion of the user having a single connection to a single database. In reality, a single query might interact with multiple databases and may use multiple connections to the same database. Here we'll go over what Vitess does and how it might impact you.

Query splitting A complicated query with a cross shard join might need to first fetch information from a tablet keeping vindex lookup tables. Then use this information to query two different shards for more data and subsequently join the incoming results into a single result that the user receives. The queries that MySQL gets are often just pieces of the original query, and the final result will get assembled at the vtgate level.

Connection Pooling When a tablet talks with a MySQL to execute a query on behalf of a user, it does not use a dedicated connection per user, and instead will share the underlying connection between users. This means that it's not safe to store any state in the session as you can't be sure it will continue executing queries on the same connection, and you can't be sure if this connection will be used by other users later on.

User-Defined Variables User defined variables are kept in the session state when working with MySQL. You can assign values to them using SET:

```
SET @my_user_variable = 'foobar'
```

And later there can be queries using for example SELECT:

```
> SELECT @my_user_variable;
+--------------------+
| @my_user_variable |
+--------------------+
| foobar             |
+--------------------+
```

If you execute these queries against a VTGate, the first `SET` query is not sent to MySQL. Instead, it is evaluated in the VTGate, and VTGate will keep this state for you. The second query is also not sent down. Trivial queries such as this one are actually fully executed on VTGate.

If we try a more complicated query that requires data from MySQL, VTGate will rewrite the query before sending it down. If we were to write something like:

```
WHERE col = @my_user_variable
```

What MySQL will see is:

```
WHERE col = 'foobar'
```

This way, no session state is needed to evaluate the query in MySQL.

Server System Variables A user might also want to change one of the many different system variables that MySQL exposes. Vitess handles system variables in one of four different ways:

- *No op.* For some settings, Vitess will just silently ignore the setting. This is for system variables that don't make much sense in a sharded setting, and don't change the behaviour of MySQL in an interesting way.
- *Check and fail if not already set.* These are settings that should not change, but Vitess will allow SET statements that try to set the variable to whatever it already is.
- *Not supported.* For these settings, attempting to change them will always result in an error.
- *Vitess aware.* These are settings that change Vitess' behaviour, and are not sent down to MySQL

- *Reserved connection.* For some settings, it makes sense to allow them to be set, but it also means that we can't use a shared connection for this user. What this means is that every connection done on this users behalf will need to first have these system variables set, and then keep the connection dedicated. Connection pooling is important for the performance of Vitess, and reserved connections can't be pooled, so this should not be the normal way to run applications on Vitess. Just make sure that the global variable is set to the same value the application will set it to, and Vitess can use connection pooling.

Special functions There are a few special functions that Vitess handles without delegating to MySQL.

- `DATABASE()` - The keyspace name and the underlying database names do not have to be equal. Vitess will rewrite these calls to use the literal string for the keyspace name. (This also applies to the synonym `SCHEMA()`)
- `ROW_COUNT()` and `FOUND_ROWS()` - These functions returns how many rows the last query affected/returned. Since this might have been executed on a different connection, these get rewritten to use the literal value of the number of returned rows.
- `LAST_INSERT_ID()` - Much like `FOUND_ROWS()`, we can't trust a pooled connection for these function calls, so they get rewritten before hitting MySQL.

Reference Here is a list of all the system variables that are handled by Vitess and how they are handled.

System variable	*Handled*
autocommit	VitessAware
client_found_rows	VitessAware
skip_query_plan_cache	VitessAware
tx_read_only	VitessAware
transaction_read_only	VitessAware
sql_select_limit	VitessAware
transaction_mode	VitessAware
workload	VitessAware
charset	VitessAware
names	VitessAware
big_tables	NoOp
bulk_insert_buffer_size	NoOp
debug	NoOp
default_storage_engine	NoOp
default_tmp_storage_engine	NoOp
innodb_strict_mode	NoOp
innodb_support_xa	NoOp
innodb_table_locks	NoOp
innodb_tmpdir	NoOp
join_buffer_size	NoOp
keep_files_on_create	NoOp
lc_messages	NoOp
long_query_time	NoOp
low_priority_updates	NoOp
max_delayed_threads	NoOp
max_insert_delayed_threads	NoOp
multi_range_count	NoOp
net_buffer_length	NoOp
new	NoOp
query_cache_type	NoOp
query_cache_wlock_invalidate	NoOp
query_prealloc_size	NoOp
sql_buffer_result	NoOp
transaction_alloc_block_size	NoOp
wait_timeout	NoOp

System variable	*Handled*
audit_log_read_buffer_size	NotSupported
auto_increment_increment	NotSupported
auto_increment_offset	NotSupported
binlog_direct_non_transactional_updates	NotSupported
binlog_row_image	NotSupported
binlog_rows_query_log_events	NotSupported
innodb_ft_enable_stopword	NotSupported
innodb_ft_user_stopword_table	NotSupported
max_points_in_geometry	NotSupported
max_sp_recursion_depth	NotSupported
myisam_repair_threads	NotSupported
myisam_sort_buffer_size	NotSupported
myisam_stats_method	NotSupported
ndb_allow_copying_alter_table	NotSupported
ndb_autoincrement_prefetch_sz	NotSupported
ndb_blob_read_batch_bytes	NotSupported
ndb_blob_write_batch_bytes	NotSupported
ndb_deferred_constraints	NotSupported
ndb_force_send	NotSupported
ndb_fully_replicated	NotSupported
ndb_index_stat_enable	NotSupported
ndb_index_stat_option	NotSupported
ndb_join_pushdown	NotSupported
ndb_log_bin	NotSupported
ndb_log_exclusive_reads	NotSupported
ndb_row_checksum	NotSupported
ndb_use_exact_count	NotSupported
ndb_use_transactions	NotSupported
ndbinfo_max_bytes	NotSupported
ndbinfo_max_rows	NotSupported
ndbinfo_show_hidden	NotSupported
ndbinfo_table_prefix	NotSupported
old_alter_table	NotSupported
preload_buffer_size	NotSupported
rbr_exec_mode	NotSupported
sql_log_off	NotSupported
thread_pool_high_priority_connection	NotSupported
thread_pool_prio_kickup_timer	NotSupported
transaction_write_set_extraction	NotSupported
default_week_format	ReservedConn
end_markers_in_json	ReservedConn
eq_range_index_dive_limit	ReservedConn
explicit_defaults_for_timestamp	ReservedConn
foreign_key_checks	ReservedConn
group_concat_max_len	ReservedConn
max_heap_table_size	ReservedConn
max_seeks_for_key	ReservedConn
max_tmp_tables	ReservedConn
min_examined_row_limit	ReservedConn
old_passwords	ReservedConn
optimizer_prune_level	ReservedConn
optimizer_search_depth	ReservedConn
optimizer_switch	ReservedConn
optimizer_trace	ReservedConn
optimizer_trace_features	ReservedConn

System variable	*Handled*
optimizer_trace_limit	ReservedConn
optimizer_trace_max_mem_size	ReservedConn
transaction_isolation	ReservedConn
tx_isolation	ReservedConn
optimizer_trace_offset	ReservedConn
parser_max_mem_size	ReservedConn
profiling	ReservedConn
profiling_history_size	ReservedConn
query_alloc_block_size	ReservedConn
range_alloc_block_size	ReservedConn
range_optimizer_max_mem_size	ReservedConn
read_buffer_size	ReservedConn
read_rnd_buffer_size	ReservedConn
show_create_table_verbosity	ReservedConn
show_old_temporals	ReservedConn
sort_buffer_size	ReservedConn
sql_big_selects	ReservedConn
sql_mode	ReservedConn
sql_notes	ReservedConn
sql_quote_show_create	ReservedConn
sql_safe_updates	ReservedConn
sql_warnings	ReservedConn
tmp_table_size	ReservedConn
transaction_prealloc_size	ReservedConn
unique_checks	ReservedConn
updatable_views_with_limit	ReservedConn
binlog_format	CheckAndIgnore
block_encryption_mode	CheckAndIgnore
character_set_client	CheckAndIgnore
character_set_connection	CheckAndIgnore
character_set_database	CheckAndIgnore
character_set_filesystem	CheckAndIgnore
character_set_results	CheckAndIgnore
character_set_server	CheckAndIgnore
collation_connection	CheckAndIgnore
collation_database	CheckAndIgnore
collation_server	CheckAndIgnore
completion_type	CheckAndIgnore
div_precision_increment	CheckAndIgnore
innodb_lock_wait_timeout	CheckAndIgnore
interactive_timeout	CheckAndIgnore
lc_time_names	CheckAndIgnore
lock_wait_timeout	CheckAndIgnore
max_allowed_packet	CheckAndIgnore
max_error_count	CheckAndIgnore
max_execution_time	CheckAndIgnore
max_join_size	CheckAndIgnore
max_length_for_sort_data	CheckAndIgnore
max_sort_length	CheckAndIgnore
max_user_connections	CheckAndIgnore
net_read_timeout	CheckAndIgnore
net_retry_count	CheckAndIgnore
net_write_timeout	CheckAndIgnore
session_track_gtids	CheckAndIgnore
session_track_schema", boolean:	CheckAndIgnore

System variable	*Handled*
session_track_state_change", boolean:	CheckAndIgnore
session_track_system_variables	CheckAndIgnore
session_track_transaction_info	CheckAndIgnore
sql_auto_is_null", boolean:	CheckAndIgnore
time_zone	CheckAndIgnore
version_tokens_session	CheckAndIgnore

Related Vitess Documentation

- VTGate

Replication Graph

The *replication graph* identifies the relationships between master databases and their respective replicas. During a master failover, the replication graph enables Vitess to point all existing replicas to a newly designated master database so that replication can continue.

Shard

A *shard* is a division within a keyspace. A shard typically contains one MySQL master and many MySQL replicas.

Each MySQL instance within a shard has the same data (excepting some replication lag). The replicas can serve read-only traffic (with eventual consistency guarantees), execute long-running data analysis tools, or perform administrative tasks (backup, restore, diff, etc.).

An unsharded keyspace has effectively one shard. Vitess names the shard `0` by convention. When sharded, a keyspace has `N` shards with non-overlapping data.

Shard Naming

Shard names have the following characteristics:

- They represent a range, where the left number is included, but the right is not.
- Their notation is hexadecimal.
- They are left justified.
- A `-` prefix means: anything less than the right value.
- A `-` postfix means: anything greater than or equal to the LHS value.
- A plain `-` denotes the full keyrange.

Thus: `-80` == `00-80` == `0000-8000` == `000000-800000`

`80-` is not the same as `80-FF`. This is why:

`80-FF` == `8000-FF00`. Therefore `FFFF` will be out of the `80-FF` range.

`80-` means: 'anything greater than or equal to `0x80`

A `hash` vindex produces an 8-byte number. This means that all numbers less than `0x8000000000000000` will fall in shard `-80`. Any number with the highest bit set will be >= `0x8000000000000000`, and will therefore belong to shard `80-`.

This left-justified approach allows you to have keyspace ids of arbitrary length. However, the most significant bits are the ones on the left.

For example an `md5` hash produces 16 bytes. That can also be used as a keyspace id.

A `varbinary` of arbitrary length can also be mapped as is to a keyspace id. This is what the `binary` vindex does.

Resharding

Vitess supports resharding, in which the number of shards is changed on a live cluster. This can be either splitting one or more shards into smaller pieces, or merging neighboring shards into bigger pieces.

During resharding, the data in the source shards is copied into the destination shards, allowed to catch up on replication, and then compared against the original to ensure data integrity. Then the live serving infrastructure is shifted to the destination shards, and the source shards are deleted.

Related Vitess Documentation

- Resharding User Guide

Tablet

A *tablet* is a combination of a `mysqld` process and a corresponding `vttablet` process, usually running on the same machine. Each tablet is assigned a *tablet type*, which specifies what role it currently performs.

Queries are routed to a tablet via a VTGate server.

Tablet Types

See the user guide VTTablet Modes for more information.

- **master** - A *replica* tablet that happens to currently be the MySQL master for its shard.
- **replica** - A MySQL replica that is eligible to be promoted to *master*. Conventionally, these are reserved for serving live, user-facing requests (like from the website's frontend).
- **rdonly** - A MySQL replica that cannot be promoted to *master*. Conventionally, these are used for background processing jobs, such as taking backups, dumping data to other systems, heavy analytical queries, MapReduce, and resharding.
- **backup** - A tablet that has stopped replication at a consistent snapshot, so it can upload a new backup for its shard. After it finishes, it will resume replication and return to its previous type.
- **restore** - A tablet that has started up with no data, and is in the process of restoring itself from the latest backup. After it finishes, it will begin replicating at the GTID position of the backup, and become either *replica* or *rdonly*.
- **drained** - A tablet that has been reserved by a Vitess background process (such as rdonly tablets for resharding).

Topology Service

description: Also known as the TOPO or lock service

The *Topology Service* is a set of backend processes running on different servers. Those servers store topology data and provide a distributed locking service.

Vitess uses a plug-in system to support various backends for storing topology data, which are assumed to provide a distributed, consistent key-value store. The default topology service plugin is `etcd2`.

The topology service exists for several reasons:

- It enables tablets to coordinate among themselves as a cluster.
- It enables Vitess to discover tablets, so it knows where to route queries.
- It stores Vitess configuration provided by the database administrator that is needed by many different servers in the cluster, and that must persist between server restarts.

A Vitess cluster has one global topology service, and a local topology service in each cell.

Global Topology

The global topology service stores Vitess-wide data that does not change frequently. Specifically, it contains data about keyspaces and shards as well as the master tablet alias for each shard.

The global topology is used for some operations, including reparenting and resharding. By design, the global topology service is not used a lot.

In order to survive any single cell going down, the global topology service should have nodes in multiple cells, with enough to maintain quorum in the event of a cell failure.

Local Topology

Each local topology contains information related to its own cell. Specifically, it contains data about tablets in the cell, the keyspace graph for that cell, and the replication graph for that cell.

The local topology service must be available for Vitess to discover tablets and adjust routing as tablets come and go. However, no calls to the topology service are made in the critical path of serving a query at steady state. That means queries are still served during temporary unavailability of topology.

VSchema

A VSchema allows you to describe how data is organized within keyspaces and shards. This information is used for routing queries, and also during resharding operations.

For a Keyspace, you can specify if it's sharded or not. For sharded keyspaces, you can specify the list of vindexes for each table.

Vitess also supports sequence generators that can be used to generate new ids that work like MySQL auto increment columns. The VSchema allows you to associate table columns to sequence tables. If no value is specified for such a column, then VTGate will know to use the sequence table to generate a new value for it.

VStream

VStream is a change notification service accessible via VTGate. The purpose of VStream is to provide equivalent information to the MySQL binary logs from the underlying MySQL shards of the Vitess cluster. gRPC clients, including Vitess components like VTTablets, can subscribe to a VStream to receive change events from other shards. The VStream pulls events from one or more VStreamer instances on VTTablet instances, which in turn pulls events from the binary log of the underlying MySQL instance. This allows for efficient execution of functions such as VReplication where a subscriber can indirectly receive events from the binary logs of one or more MySQL instance shards, and then apply it to a target instance. An user can leverage VStream to obtain in-depth information about data change events for given Vitess keyspace, shard, and position. A single VStream can also consolidate change events from multiple shards in a keyspace, making it a convenient tool to feed a CDC (Change Data Capture) process downstream from your Vitess datastore.

For reference, please refer to the diagram below:

Note: A VStream is distinct from a VStreamer. The former is located on the VTGate and the latter is located on the VTTablet.

vtctl

vtctl is a command-line tool used to administer a Vitess cluster. It is available as both a standalone tool (`vtctl`) and client-server (`vtctlclient` in combination with `vtctld`). Using client-server is recommended, as it provides an additional layer of security when using the client remotely.

Using vtctl, you can identify master and replica databases, create tables, initiate failovers, perform resharding operations, and so forth.

As vtctl performs operations, the Topology Service is updated as needed. Other Vitess servers observe those changes and react accordingly. For example, if you use vtctl to fail over to a new master database, vtgate sees the change and directs future write operations to the new master.— ## vtctld

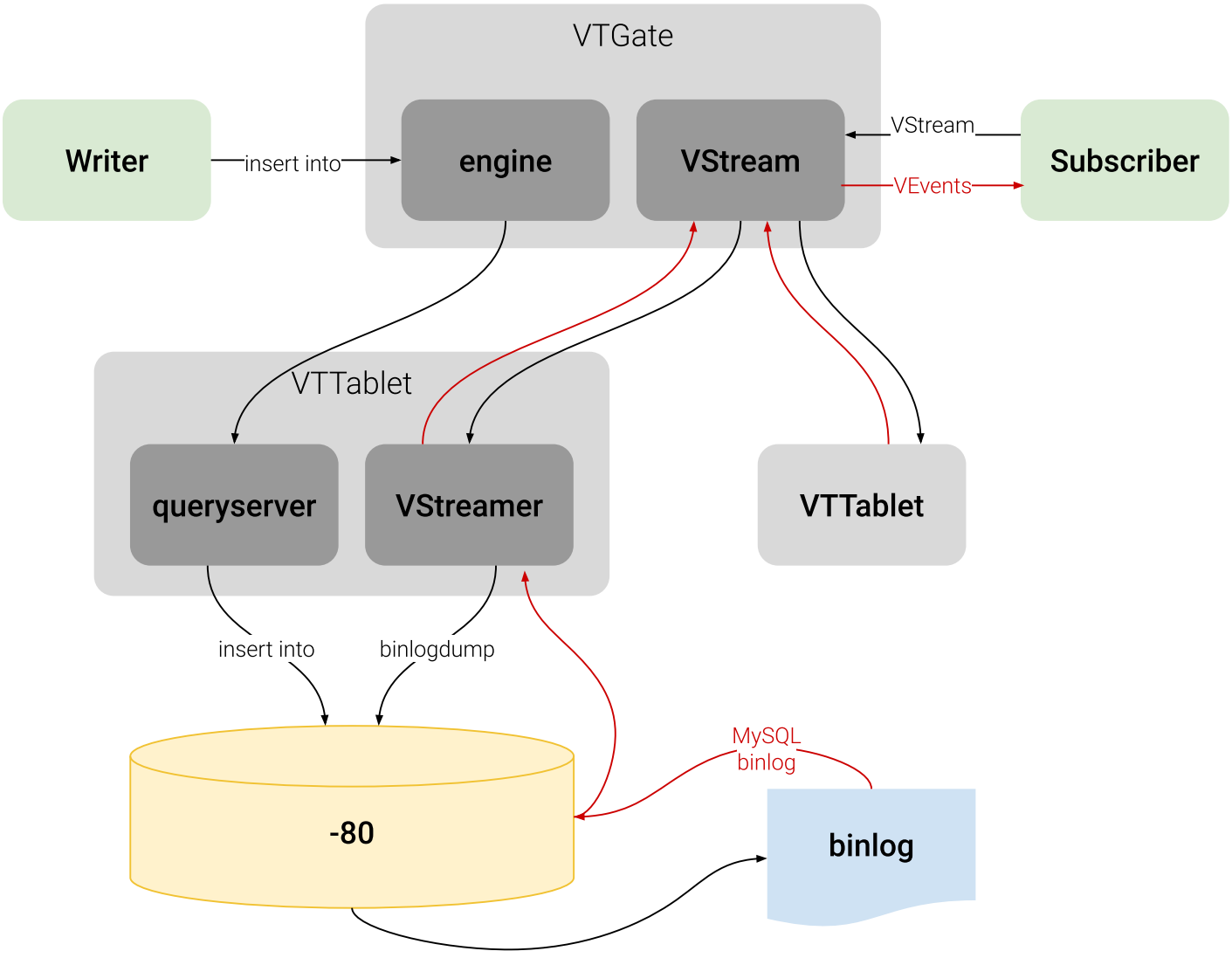

Figure 1: VStream diagram

vtctld is an HTTP server that lets you browse the information stored in the Topology Service. It is useful for troubleshooting or for getting a high-level overview of the servers and their current states.

`vtctld` also acts as the server for `vtctlclient` connections.— ## VTGate

VTGate is a lightweight proxy server that routes traffic to the correct VTTablet servers and returns consolidated results back to the client. It speaks both the MySQL Protocol and the Vitess gRPC protocol. Thus, your applications can connect to VTGate as if it is a MySQL Server.

When routing queries to the appropriate VTTablet servers, VTGate considers the sharding scheme, required latency and the availability of tables and their underlying MySQL instances.

Related Vitess Documentation

- Execution Plans

Contribute

description: Get involved with Vitess development

You want to contribute to Vitess? That's awesome!

In the past we have reviewed and accepted many external contributions. Examples are the Java JDBC driver, the PHP PDO driver or VTGate v3 improvements.

We're looking forward to any contribution! Before you start larger contributions, make sure to reach out first and discuss your plans with us.

This page describes for new contributors how to make yourself familiar with Vitess and the programming language Go.

Learning Go

Vitess was one of the early adaptors of Google's programming language Go. We love it for its simplicity (e.g. compared to C++ or Java) and performance (e.g. compared to Python).

Contributing to our server code will require you to learn Go. We recommend that you follow the Go Tour to get started.

The Go Programming Language Specification is also useful as a reference guide.

Learning Vitess

Before diving into the Vitess codebase, make yourself familiar with the system and run it yourself:

- Read the What is Vitess page, in particular the architecture section.
- Read the Concepts and Sharding pages.
  - We also recommend to look at our latest presentations. They contain many illustrations which help understanding how Vitess works in detail.
  - After studying the pages, try to answer the following question (click expand to see the answer):
    Let's assume a keyspace with 256 range-based shards: What is the name of the first, the second and the last shard?
    -01, 01-02, ff-
- Go through the Kubernetes and local get started guides.
  - While going through the tutorial, look back at the architecture and match the processes you start in Kubernetes with the boxes in the diagram.

Build on CentOS

description: Instructions for building Vitess on your machine for testing and development purposes

{{< info >}} If you run into issues or have questions, we recommend posting in our Slack channel, click the Slack icon in the top right to join. This is a very active community forum and a great place to interact with other users. {{< /info >}}

The following has been verified to work on **CentOS 7**. If you are new to Vitess, it is recommended to start with the local install guide instead.

Install Dependencies

Install Go 1.13+ Download and install Golang 1.13. For example, at writing:

```
curl -O https://dl.google.com/go/go1.13.9.linux-amd64.tar.gz
sudo tar -C /usr/local -xzf go1.13.9.linux-amd64.tar.gz
```

Make sure to add go to your bashrc:

```
export PATH=$PATH:/usr/local/go/bin
```

Packages from CentOS repos The MariaDB version included with CentOS 7 (5.5) is not supported by Vitess. First install the MySQL 5.7 repository from Oracle:

```
sudo yum localinstall -y
   https://dev.mysql.com/get/mysql57-community-release-el7-9.noarch.rpm
sudo yum install -y mysql-community-server
```

Install additional dependencies required to build and run Vitess:

```
sudo yum install -y make unzip g++ etcd curl git wget
```

Notes:

- We will be using etcd as the topology service. The command `make tools` can also install Zookeeper or Consul for you, which requires additional dependencies.
- Vitess currently has some additional tests written in Python, but we will be skipping this step for simplicity.

Disable SELinux SELinux will not allow Vitess to launch MySQL in any data directory by default. You will need to disable it:

```
sudo setenforce 0
```

Build Vitess

Navigate to the directory where you want to download the Vitess source code and clone the Vitess GitHub repo:

```
cd ~
git clone https://github.com/vitessio/vitess.git
cd vitess
```

Set environment variables that Vitess will require. It is recommended to put these in your `.bashrc`:

```
# Additions to ~/.bashrc file

# Add go PATH
export PATH=$PATH:/usr/local/go/bin

# Vitess binaries
export PATH=~/vitess/bin:${PATH}
```

Build Vitess:

```
make build
```

Testing your Binaries

The unit tests require the following additional packages:

```
sudo yum install -y ant maven zip gcc
```

You can then install additional components from `make tools`. If your machine requires a proxy to access the Internet, you will need to set the usual environment variables (e.g. `http_proxy`, `https_proxy`, `no_proxy`) first:

```
make tools
make unit_test
```

In addition to running tests, you can try running the local example.

Common Build Issues

Key Already Exists This error is because etcd was not cleaned up from the previous run of the example. You can manually fix this by running `./401_teardown.sh`, removing vtdataroot and then starting again:

```
Error:  105: Key already exists (/vitess/zone1) [6]
Error:  105: Key already exists (/vitess/global) [6]
```

MySQL Fails to Initialize This error is most likely the result of SELinux enabled:

```
1027 18:28:23.462926   19486 mysqld.go:734] mysqld --initialize-insecure failed:
   /usr/sbin/mysqld: exit status 1, output: mysqld: [ERROR] Failed to open required
   defaults file: /home/morgo/vitess/vtdataroot/vt_0000000102/my.cnf
mysqld: [ERROR] Fatal error in defaults handling. Program aborted!

could not stat mysql error log (/home/morgo/vitess/vtdataroot/vt_0000000102/error.log):
   stat /home/morgo/vitess/vtdataroot/vt_0000000102/error.log: no such file or directory
E1027 18:28:23.464117   19486 mysqlctl.go:254] failed init mysql: /usr/sbin/mysqld: exit
   status 1, output: mysqld: [ERROR] Failed to open required defaults file:
   /home/morgo/vitess/vtdataroot/vt_0000000102/my.cnf
mysqld: [ERROR] Fatal error in defaults handling. Program aborted!
E1027 18:28:23.464780   19483 mysqld.go:734] mysqld --initialize-insecure failed:
   /usr/sbin/mysqld: exit status 1, output: mysqld: [ERROR] Failed to open required
   defaults file: /home/morgo/vitess/vtdataroot/vt_0000000101/my.cnf
mysqld: [ERROR] Fatal error in defaults handling. Program aborted!
```

Build on macOS

description: Instructions for building Vitess on your machine for testing and development purposes

{{< info >}} If you run into issues or have questions, we recommend posting in our Slack channel, click the Slack icon in the top right to join. This is a very active community forum and a great place to interact with other users. {{< /info >}}

The following has been verified to work on **macOS Mojave**. If you are new to Vitess, it is recommended to start with the local install guide instead.

Install Dependencies

Install Xcode Install Xcode.

Install Homebrew and Dependencies Install Homebrew. From here you should be able to install:

```
brew install go@1.13 automake git curl wget mysql@5.7
```

Add `mysql@5.7` and `go@1.13` to your `PATH`:

```
echo 'export PATH="/usr/local/opt/mysql@5.7/bin:$PATH"' >> ~/.bash_profile
echo 'export PATH="/usr/local/opt/go@1.13/bin:$PATH"' >> ~/.bash_profile
```

Do not install etcd via brew otherwise it will not be the version that is supported. Let it be installed when running make build.

Do not setup MySQL or etcd to restart at login.

Build Vitess

Navigate to the directory where you want to download the Vitess source code and clone the Vitess GitHub repo:

```
cd ~
git clone https://github.com/vitessio/vitess.git
cd vitess
```

Set environment variables that Vitess will require. It is recommended to put these in your `~/.bash_profile` file:

```
# Vitess binaries
export PATH=~/vitess/bin:${PATH}
```

Build Vitess:

```
make build
```

Testing your Binaries

The unit tests require that you first install a Java runtime. This is required for running ZooKeeper tests:

```
brew tap adoptopenjdk/openjdk
brew cask install adoptopenjdk8
brew info java
```

You will also need to install `ant` and `maven`:

```
brew install ant maven
```

You can then install additional components from `make tools`. If your machine requires a proxy to access the Internet, you will need to set the usual environment variables (e.g. `http_proxy`, `https_proxy`, `no_proxy`) first:

```
make tools
make unit_test
```

In addition to running tests, you can try running the local example.

Common Build Issues

Key Already Exists This error is because etcd was not cleaned up from the previous run of the example. You can manually fix this by running `./401_teardown.sh`, removing vtdataroot and then starting again:

```
Error:  105: Key already exists (/vitess/zone1) [6]
Error:  105: Key already exists (/vitess/global) [6]
```

/tmp/mysql.sock Already In Use This error occurs because mysql is serving on the same port that vttgate requires. To solve this issue stop mysql service. If you have installed mysql via brew as specified above you should run:

```
brew services stop mysql@5.7
```

Build on Ubuntu/Debian

description: Instructions for building Vitess on your machine for testing and development purposes

{{< info >}} If you run into issues or have questions, we recommend posting in our Slack channel, click the Slack icon in the top right to join. This is a very active community forum and a great place to interact with other users. {{< /info >}}

The following has been verified to work on **Ubuntu 19.10** and **Debian 10**. If you are new to Vitess, it is recommended to start with the local install guide instead.

Install Dependencies

Install Go 1.13+ Download and install Golang 1.13. For example, at writing:

```
curl -O https://dl.google.com/go/go1.13.9.linux-amd64.tar.gz
sudo tar -C /usr/local -xzf go1.13.9.linux-amd64.tar.gz
```

Make sure to add go to your bashrc:

```
export PATH=$PATH:/usr/local/go/bin
```

Packages from apt repos Install dependencies required to build and run Vitess:

```
# Ubuntu
sudo apt-get install -y mysql-server mysql-client make unzip g++ etcd curl git wget

# Debian
sudo apt-get install -y default-mysql-server default-mysql-client make unzip g++ etcd curl
   wget
```

The services `mysqld` and `etcd` should be shutdown, since `etcd` will conflict with the `etcd` started in the examples, and `mysqlctl` will start its own copies of `mysqld`:

```
sudo service mysql stop
sudo service etcd stop
sudo systemctl disable mysql
sudo systemctl disable etcd
```

Notes:

- We will be using etcd as the topology service. The command `make tools` can also install Zookeeper or Consul for you, which requires additional dependencies.
- Vitess currently has some additional tests written in Python, but we will be skipping this step for simplicity.

Disable mysqld AppArmor Profile The `mysqld` AppArmor profile will not allow Vitess to launch MySQL in any data directory by default. You will need to disable it:

```
sudo ln -s /etc/apparmor.d/usr.sbin.mysqld /etc/apparmor.d/disable/
sudo apparmor_parser -R /etc/apparmor.d/usr.sbin.mysqld
```

The following command should return an empty result:

```
sudo aa-status | grep mysqld
```

Build Vitess

Navigate to the directory where you want to download the Vitess source code and clone the Vitess GitHub repo:

```
cd ~
git clone https://github.com/vitessio/vitess.git
cd vitess
```

Set environment variables that Vitess will require. It is recommended to put these in your `.bashrc`:

```
# Additions to ~/.bashrc file

# Add go PATH
export PATH=$PATH:/usr/local/go/bin

# Vitess binaries
export PATH=~/vitess/bin:${PATH}
```

Build Vitess:

```
make build
```

Testing your Binaries

The unit test requires that you first install the following packages:

```
sudo apt-get install -y ant maven default-jdk zip
```

You can then install additional components from `make tools`. If your machine requires a proxy to access the Internet, you will need to set the usual environment variables (e.g. `http_proxy`, `https_proxy`, `no_proxy`) first:

```
make tools
make unit_test
```

In addition to running tests, you can try running the local example.

Common Build Issues

Key Already Exists This error is because etcd was not cleaned up from the previous run of the example. You can manually fix this by running `./401_teardown.sh`, removing vtdataroot and then starting again:

```
Error:  105: Key already exists (/vitess/zone1) [6]
Error:  105: Key already exists (/vitess/global) [6]
```

MySQL Fails to Initialize This error is most likely the result of an AppArmor enforcing profile being present:

```
1027 18:28:23.462926   19486 mysqld.go:734] mysqld --initialize-insecure failed:
   /usr/sbin/mysqld: exit status 1, output: mysqld: [ERROR] Failed to open required
   defaults file: /home/morgo/vitess/vtdataroot/vt_0000000102/my.cnf
mysqld: [ERROR] Fatal error in defaults handling. Program aborted!

could not stat mysql error log (/home/morgo/vitess/vtdataroot/vt_0000000102/error.log):
   stat /home/morgo/vitess/vtdataroot/vt_0000000102/error.log: no such file or directory
E1027 18:28:23.464117   19486 mysqlctl.go:254] failed init mysql: /usr/sbin/mysqld: exit
   status 1, output: mysqld: [ERROR] Failed to open required defaults file:
   /home/morgo/vitess/vtdataroot/vt_0000000102/my.cnf
mysqld: [ERROR] Fatal error in defaults handling. Program aborted!
```

```
E1027 18:28:23.464780   19483 mysqld.go:734] mysqld --initialize-insecure failed:
   /usr/sbin/mysqld: exit status 1, output: mysqld: [ERROR] Failed to open required
   defaults file: /home/morgo/vitess/vtdataroot/vt_0000000101/my.cnf
mysqld: [ERROR] Fatal error in defaults handling. Program aborted!
```

The following command disables the AppArmor profile for `mysqld`:

```
sudo ln -s /etc/apparmor.d/usr.sbin.mysqld /etc/apparmor.d/disable/
sudo apparmor_parser -R /etc/apparmor.d/usr.sbin.mysqld
```

The following command should now return an empty result:

```
sudo aa-status | grep mysqld
```

If this doesn't work, you can try making sure all lurking processes are shutdown, and then restart the example again in the `/tmp` directory:

```
for process in `pgrep -f '(vtdataroot|VTDATAROOT)'`; do
 kill -9 $process
done;

export VTDATAROOT=/tmp/vtdataroot
./101_initial_cluster.sh
```

Coding Standards

Backwards Compatibility

Vitess is being used to power many mission-critical production workloads at very large scale. Moreover, many users deploy directly from the master branch. It is very important the changes made by contributors do not break any existing workloads.

In order to avoid disruption, the following concerns need to be kept in mind: * Does the change affect any external APIs? If so, make sure the change satisfies the compatibility rules. * Can the change introduce a performance regression? If so, it will be good to measure the impact using benchmarks. * If the change is substantial or is a breaking change, you must publish the proposal as an issue with a title like `RFC: Changing behavior of feature xxx`. Following this, sufficient time has to be given for others to give feedback. A breaking change must still satisfy the compatibility rules. * New features that affect existing behavior must be introduced "behind a flag". Users will then be encouraged to enable them, but will have the option to fallback to the old behavior if issues are found.

What does a good PR look like?

Every GitHub pull request must go through a code review and get approved before it will be merged into the master branch.

Every pull request should meet the following requirements: * Adhere to the Go coding guidelines and watch out for these common errors. * Contain a description message that is as detailed as possible. Here is a great example https://github.com/vitessio/vitess/pull/6543. * Pass all CI tests that run on PRs. * For bigger changes, it is a good idea to start by creating an issue - this is where you can discuss the feature and why it's important. Once that is in place, you can create the PR, as a solution to the problem described in the issue. Separating the need and the solution this way makes discussions easier and more focused.

Testing We use unit tests both to test the code and to describe it for other developers.

- Unit tests should:
  - Demonstrate every use case the change covers.
  - Involve all important units being added or changed.

  - Attempt to cover every corner case the change introduces. The thumb rule is: if it can happen in production, it must be covered.

- Integration tests should ensure that the feature works end-to-end. They must cover all the important use cases of the feature.
- A separate pull request into `vitessio/website` that updates the documentation is required if the feature changes or adds to existing behavior.

Bug fixes If you are creating a PR to fix a bug, make sure to create an end-to-end test that fails without your change. This is the important reproduction case that will make sure this particular bug does not show up again, and that clearly shows on your PR what bug you are fixing.

While you are fixing the bug, it's valuable if you take the time to step back and try to think of other places where this problem could have impacted. It's often possible to infer that other similar problems in this or other parts of the code base can be prevented.

Some additional points to keep in mind: * Does this change match an existing design / bug? * Is this change going to log too much? (Error logs should only happen when the component is in bad shape, not because of bad transient state or bad user queries) * Does this match our current patterns? Example include RPC patterns, Retries / Waits / Timeouts patterns using Context, …

We also recommend that every author look over their code change before committing and ensure that the recommendations below are being followed. This can be done by skimming through `git diff --cached` just before committing.

- Scan the diffs as if you're the reviewer.
  - Look for files that shouldn't be checked in (temporary/generated files).
  - Look for temporary code/comments you added while debugging.
  - Example: `fmt.Println("AAAAAAAAAAAAAAAAAA")`
  - Look for inconsistencies in indentation.
  - Use 2 spaces in everything except Go.
  - In Go, just use goimports.
- Commit message format:
  - ```
    <component>: This is a short description of the change.

    If necessary, more sentences follow e.g. to explain the intent of the change, how it fits
       into the bigger picture or which implications it has (e.g. other parts in the system
       have to be adapted.)

    Sometimes this message can also contain more material for reference e.g. benchmark numbers
       to justify why the change was implemented in this way.
    ```
- Comments
  - `// Prefer complete sentences when possible.`
  - Leave a space after the comment marker `//`.

If your reviewer leaves comments, make sure that you address them and then click "Resolve conversation". There should be zero unresolved discussions when the PR merges.

Assigning a Pull Request

Vitess uses code owners to auto-assign reviewers to a particular PR. If you have been granted membership to the Vitess team, you can add additional reviewers using the right-hand side pull request menu.

During discussions, you can also refer to somebody using the *@username* syntax and they'll receive an email as well.

If you want to receive notifications even when you aren't mentioned, you can go to the repository page and click *Watch*.
    ```

Approving a Pull Request

As a reviewer you can approve a pull request through two ways:

- Approve the pull request via GitHub's code review system
- Reply with a comment that contains *LGTM* (Looks Good To Me)

Merging a Pull Request

The Vitess team will merge your pull request after the PR has been approved and CI tests have passed.

GitHub Workflow

If you are new to Git and GitHub, we recommend to read this page. Otherwise, you may skip it.

Our GitHub workflow is a so called triangular workflow:

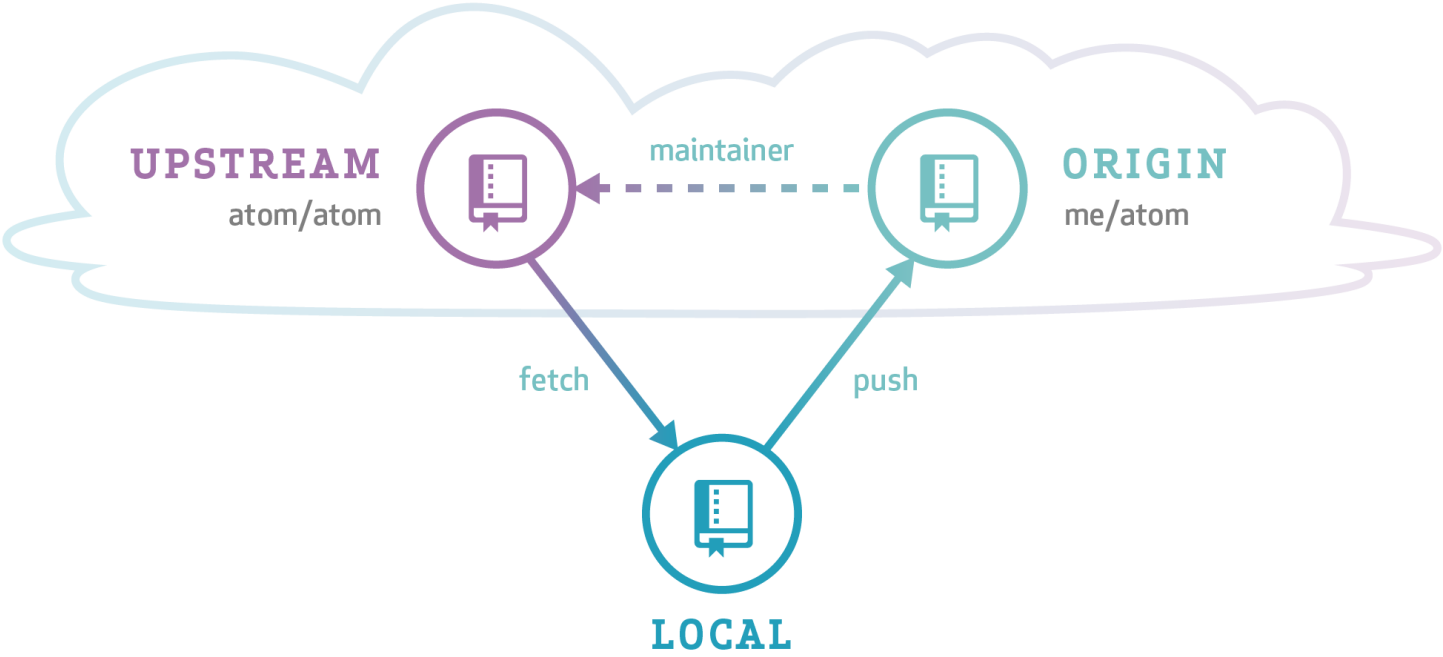

Image Source

The Vitess code is hosted on GitHub. This repository is called *upstream*. You develop and commit your changes in a clone of our upstream repository (shown as *local* in the image above). Then you push your changes to your forked repository (*origin*) and send us a pull request. Eventually, we will merge your pull request back into the *upstream* repository.

Remotes

Since you should have cloned the repository from your fork, the `origin` remote should look like this:

```
$ git remote -v
origin  git@github.com:<yourname>/vitess.git (fetch)
origin  git@github.com:<yourname>/vitess.git (push)
```

To help you keep your fork in sync with the main repo, add an `upstream` remote:

```
$ git remote add upstream git@github.com:vitessio/vitess.git
$ git remote -v
origin  git@github.com:<yourname>/vitess.git (fetch)
origin  git@github.com:<yourname>/vitess.git (push)
upstream        git@github.com:vitessio/vitess.git (fetch)
upstream        git@github.com:vitessio/vitess.git (push)
```

Now to sync your local `master` branch, do this:

```
$ git checkout master
(master) $ git pull upstream master
```

Note: In the example output above we prefixed the prompt with `(master)` to stress the fact that the command must be run from the branch `master`.

You can omit the `upstream master` from the `git pull` command when you let your `master` branch always track the main `vitessio/vitess` repository. To achieve this, run this command once:

```
(master) $ git branch --set-upstream-to=upstream/master
```

Now the following command syncs your local `master` branch as well:

```
(master) $ git pull
```

Topic Branches

Before you start working on changes, create a topic branch:

```
$ git checkout master
(master) $ git pull
(master) $ git checkout -b new-feature
(new-feature) $ # You are now in the new-feature branch.
```

Try to commit small pieces along the way as you finish them, with an explanation of the changes in the commit message. Please see the Code Review page for more guidance.

As you work in a package, you can run just the unit tests for that package by running `go test` from within that package.

When you're ready to test the whole system, run the full test suite with `make test` from the root of the Git tree. If you haven't installed all dependencies for `make test`, you can rely on the Travis CI test results as well. These results will be linked on your pull request.

Committing your work

When running `git commit` use the `-s` option to add a Signed-off-by line. This is needed for the Developer Certificate of Origin.

Sending Pull Requests

Push your branch to the repository (and set it to track with `-u`):

```
(new-feature) $ git push -u origin new-feature
```

You can omit `origin` and `-u new-feature` parameters from the `git push` command with the following two Git configuration changes:

```
$ git config remote.pushdefault origin
$ git config push.default current
```

The first setting saves you from typing `origin` every time. And with the second setting, Git assumes that the remote branch on the GitHub side will have the same name as your local branch.

After this change, you can run `git push` without arguments:

```
(new-feature) $ git push
```

Then go to the repository page and it should prompt you to create a Pull Request from a branch you recently pushed. You can also choose a branch manually.

Addressing Changes

If you need to make changes in response to the reviewer's comments, just make another commit on your branch and then push it again:

```
$ git checkout new-feature
(new-feature) $ git commit
(new-feature) $ git push
```

That is because a pull request always mirrors all commits from your topic branch which are not in the master branch.

Once your pull request is merged:

- close the GitHub issue (if it wasn't automatically closed)
- delete your local topic branch (`git branch -d new-feature`)

FAQ

description: Frequently Asked Questions about Vitess

Configuration

description: Frequently Asked Questions about Configuration

Does the application need to know about the sharding scheme underneath Vitess?

The application does not need to know about how the data is sharded. This information is stored in a VSchema which the VTGate servers use to automatically route your queries. This allows the application to connect to Vitess and use it as if it's a single giant database server.

Can I override the default db name from vt_xxx to my own? Yes. You can start vttablet with the `-init_db_name_override` command line option to specify a different db name. There is no downside to performing this override

How do I connect to vtgate using MySQL protocol? If you look at the example vtgate-up.sh script, you'll see the following lines:

```
-mysql_server_port $mysql_server_port \
-mysql_server_socket_path $mysql_server_socket_path \
-mysql_auth_server_static_file "./mysql_auth_server_static_creds.json" \
```

In this example, vtgate accepts MySQL connections on port 15306 and the authentication info is stored in the json file. So, you should be able to connect to it using the following command:

```
mysql -h 127.0.0.1 -P 15306 -u mysql_user --password=mysql_password
```

I cannot start a cluster, and see these errors in the logs: Could not open required defaults file: /path/to/my.cnf

Most likely this means that AppArmor is running on your server and is preventing Vitess processes from accessing the my.cnf file. The workaround is to uninstall AppArmor:

```
sudo service apparmor stop
sudo service apparmor teardown
sudo update-rc.d -f apparmor remove
```

You may also need to reboot the machine after this. Many programs automatically install AppArmor, so you may need to uninstall again.

Queries

description: Frequently Asked Questions about Queries

Can I address a specific shard if I want to?

If necessary, you can access a specific shard by connecting to it using the shard specific database name. For a keyspace ks and shard -80, you would connect to ks:-80.

How do I choose between master vs. replica for queries?

You can qualify the keyspace name with the desired tablet type using the @ suffix. This can be specified as part of the connection as the database name, or can be changed on the fly through the USE command.

For example, `ks@master` will select `ks` as the default keyspace with all queries being sent to the master. Consequently `ks@replica` will load balance requests across all `REPLICA` tablet types, and `ks@rdonly` will choose `RDONLY`.

You can also specify the database name as `@master`, etc, which instructs Vitess that no default keyspace was specified, but that the requests are for the specified tablet type.

If no tablet type was specified, then VTGate chooses its default, which can be overridden with the `-default_tablet_type` command line argument.

There seems to be a 10 000 row limit per query. What if I want to do a full table scan?

Vitess supports different modes. In OLTP mode, the result size is typically limited to a preset number (10 000 rows by default). This limit can be adjusted based on your needs.

However, OLAP mode has no limit to the number of rows returned. In order to change to this mode, you may issue the following command before executing your query:

```
set workload='olap'
```

You can also set the workload to `dba mode`, which allows you to override the implicit timeouts that exist in vttablet. However, this mode should be used judiciously as it supersedes shutdown and reparent commands.

The general convention is to send OLTP queries to `REPLICA` tablet types, and OLAP queries to `RDONLY`.

Is there a list of supported/unsupported queries?

Please see “SQL Syntax” under MySQL Compatibility.

If I have a log of all queries from my app. Is there a way I can try them against Vitess to see how they'll work?

Yes. The vtexplain tool can be used to preview how your queries will be executed by Vitess. It can also be used to try different sharding scenarios before deciding on one.

Vindexes

description: Frequently Asked Questions about Vindexes

Does the Primary Vindex for a tablet have to be the same as its Primary Key?

It is not necessary that a Primary Vindex be the same as the Primary Key. In fact, there are many use cases where you would not want this. For example, if there are tables with one-to-many relationships, the Primary Vindex of the main table is likely to be the same as the Primary Key. However, if you want the rows of the secondary table to reside in the same shard as the parent row, the Primary Vindex for that table must be the foreign key that points to the main table. A typical example is a user and order table. In this case, the order table has the `user_id` as a foreign key to the `id` of the user table. The `order_id` may be the primary key for `order`, but you may still want to choose `user_id` as Primary Vindex, which will make a user's orders live in the same shard as the user.

Get Started

description: Deploy Vitess on your favorite platform

Vitess supports binary deployment on the following platforms. See also Build On CentOS, Build on MacOS, or Build on Ubuntu if you are interesting in building your own binary, or contributing to Vitess.

Helm Chart (deprecated)

This tutorial is deprecated. We recommend that you use the Operator instead.

This tutorial demonstrates how Vitess can be used with Minikube to deploy Vitess clusters using Helm.

Prerequisites

Before we get started, let's get a few things out of the way:

1. Install Minikube and start a Minikube engine:

   ```
   minikube start
   ```

2. Install kubectl and ensure it is in your `PATH`. For example, on Linux:

   ```
   curl -LO https://storage.googleapis.com/kubernetes-release/release/`curl -s
      https://storage.googleapis.com/kubernetes-release/release/stable.txt`/bin/linux/amd64/kube
   ```

3. Install Helm 3:

   ```
   wget https://get.helm.sh/helm-v3.2.1-linux-amd64.tar.gz
   tar -xzf helm-v3.*
   # copy linux-amd64/helm into your path
   ```

4. Install the MySQL client locally. For example, on Ubuntu:

   ```
   apt install mysql-client
   ```

5. Install vtctlclient locally:

   If you are familiar with Go development, the easiest way to do this is: `bash go get vitess.io/vitess/go/cmd/vtctlclient`
   If not, you can also download the latest Vitess release and extract `vtctlclient` from it.

Start a single keyspace cluster

So you searched keyspace on Google and got a bunch of stuff about NoSQL… what's the deal? It took a few hours, but after diving through the ancient Vitess scrolls you figure out that in the NewSQL world, keyspaces and databases are essentially the same thing when unsharded. Finally, it's time to get started.

Change to the helm example directory:

```
git clone git@github.com:vitessio/vitess.git
cd vitess/examples/helm
```

In this directory, you will see a group of yaml files. The first digit of each file name indicates the phase of example. The next two digits indicate the order in which to execute them. For example, `101_initial_cluster.yaml` is the first file of the first phase. We shall execute that now:

```
helm install vitess ../../helm/vitess -f 101_initial_cluster.yaml
```

You should see output similar to the following:

```
$ helm install vitess ../../helm/vitess -f 101_initial_cluster.yaml

NAME: vitess
LAST DEPLOYED: Tue Apr 14 20:32:18 2020
NAMESPACE: default
STATUS: deployed
REVISION: 1
TEST SUITE: None
NOTES:
Release name: vitess

To access administrative web pages, start a proxy with:
  kubectl proxy --port=8001

Then use the following URLs:

      vtctld: http://localhost:8001/api/v1/namespaces/default/services/vtctld:web/proxy/app/
      vtgate:
         http://localhost:8001/api/v1/namespaces/default/services/vtgate-zone1:web/proxy/
```

Verify cluster You can check the state of your cluster with `kubectl get pods,jobs`. After a few minutes, it should show that all pods are in the status of running:

```
$ kubectl get pods,jobs
NAME                                          READY   STATUS      RESTARTS   AGE
pod/commerce-apply-schema-initial-vlc6k       0/1     Completed   0          2m42s
pod/commerce-apply-vschema-initial-9wb2k      0/1     Completed   0          2m42s
pod/vtctld-58bd955948-pgz7k                   1/1     Running     0          2m43s
pod/vtgate-zone1-c7444bbf6-t5xc6              1/1     Running     3          2m43s
pod/zone1-commerce-0-init-shard-master-gshz9  0/1     Completed   0          2m42s
pod/zone1-commerce-0-replica-0                2/2     Running     0          2m42s
pod/zone1-commerce-0-replica-1                2/2     Running     0          2m42s
pod/zone1-commerce-0-replica-2                2/2     Running     0          2m42s

NAME                                          COMPLETIONS   DURATION   AGE
job.batch/commerce-apply-schema-initial       1/1           94s        2m43s
job.batch/commerce-apply-vschema-initial      1/1           87s        2m43s
job.batch/zone1-commerce-0-init-shard-master  1/1           90s        2m43s
```

Setup Port-forward

For ease-of-use, Vitess provides a script to port-forward from kubernetes to your local machine. This script also recommends setting up aliases for `mysql` and `vtctlclient`:

```
./pf.sh &
sleep 5

alias vtctlclient="vtctlclient -server=localhost:15999"
alias mysql="mysql -h 127.0.0.1 -P 15306"
```

Setting up aliases changes `mysql` to always connect to Vitess for your current session. To revert this, type `unalias mysql && unalias vtctlclient` or close your session.

Connect to your cluster You should now be able to connect to the VTGate Server in your cluster with the MySQL client:

```
~/my-vitess-example> mysql
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 1
Server version: 5.7.9-Vitess Percona Server (GPL), Release 29, Revision 11ad961

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affiliates. Other names may be trademarks of their respective
owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql> SHOW DATABASES;
+-----------+
| Databases |
+-----------+
| commerce  |
+-----------+
1 row in set (0.00 sec)
```

Summary In this example, we deployed a single unsharded keyspace named `commerce`. Unsharded keyspaces have a single shard named `0`. The following schema reflects a common ecommerce scenario that was created by the script:

```
create table product(
  sku varbinary(128),
  description varbinary(128),
  price bigint,
  primary key(sku)
);
create table customer(
  customer_id bigint not null auto_increment,
  email varbinary(128),
  primary key(customer_id)
);
create table corder(
  order_id bigint not null auto_increment,
  customer_id bigint,
  sku varbinary(128),
  price bigint,
```

```
  primary key(order_id)
);
```

The schema has been simplified to include only those fields that are significant to the example:

- The `product` table contains the product information for all of the products.
- The `customer` table has a `customer_id` that has an `auto_increment`. A typical customer table would have a lot more columns, and sometimes additional detail tables.
- The `corder` table (named so because `order` is an SQL reserved word) has an `order_id` auto-increment column. It also has foreign keys into `customer(customer_id)` and `product(sku)`.

Next Steps

You can now proceed with MoveTables.

Or alternatively, if you would like to teardown your example:

```
helm delete vitess
kubectl delete pvc -l "app=vitess"
kubectl delete vitesstoponodes --all
```

Congratulations on completing this exercise!

Local Install via Docker

description: Instructions for using Vitess on your machine for testing purposes

This guide illustrates how to run a local testing Vitess setup via Docker. The Vitess environment is identical to the local setup, but without having to install software on one's host other than Docker.

Check out the vitessio/vitess repository

Clone the GitHub repository via:

- SSH: `git clone git@github.com:vitessio/vitess.git`, or:
- HTTP: `git clone https://github.com/vitessio/vitess.git`

```
cd vitess
```

Build the docker image

In your shell, execute:

```
make docker_local
```

This creates a docker image named `vitess/local` (aka `vitess/local:latest`)

Run the docker image

Execute:

```
./docker/local/run.sh
```

This will set up a MySQL replication topology, as well as `etcd`, `vtctld` and `vtgate` services.

- `vtgate` listens on http://127.0.0.1:15001/debug/status
- `vtctld` listens on http://127.0.0.1:15000/debug/status
- Control panel is available at http://localhost:15000/app/

From within the docker shell, aliases are set up for your convenience. Try the following `mysql` commands to connect to various tablets:

- `mysql commerce`
- `mysql commerce@master`
- `mysql commerce@replica`
- `mysql commerce@rdonly`

You will find that Vitess runs a single keyspace, single shard cluster.

Summary

In this example, we deployed a single unsharded keyspace named `commerce`. Unsharded keyspaces have a single shard named `0`. The following schema reflects a common ecommerce scenario that was created by the script:

```
create table product (
  sku varbinary(128),
  description varbinary(128),
  price bigint,
  primary key(sku)
);
create table customer (
  customer_id bigint not null auto_increment,
  email varbinary(128),
  primary key(customer_id)
);
create table corder (
  order_id bigint not null auto_increment,
  customer_id bigint,
  sku varbinary(128),
  price bigint,
  primary key(order_id)
);
```

The schema has been simplified to include only those fields that are significant to the example:

- The `product` table contains the product information for all of the products.
- The `customer` table has a `customer_id` that has an `auto_increment`. A typical customer table would have a lot more columns, and sometimes additional detail tables.
- The `corder` table (named so because `order` is an SQL reserved word) has an `order_id` auto-increment column. It also has foreign keys into `customer(customer_id)` and `product(sku)`.

Next Steps

You can now proceed with MoveTables.

Exiting the docker shell terminates and destroys the vitess cluster.

Local Install

description: Instructions for using Vitess on your machine for testing purposes

This guide covers installing Vitess locally for testing purposes, from pre-compiled binaries. We will launch multiple copies of `mysqld`, so it is recommended to have greater than 4GB RAM, as well as 20GB of available disk space.

A docker setup is also available, which requires no dependencies on your local host.

Install MySQL and etcd

Vitess supports MySQL 5.6+ and MariaDB 10.0+. We recommend MySQL 5.7 if your installation method provides a choice:

```
# Ubuntu based
sudo apt install -y mysql-server etcd curl

# Debian
sudo apt install -y default-mysql-server default-mysql-client etcd curl

# Yum based
sudo yum -y localinstall
   https://dev.mysql.com/get/mysql57-community-release-el7-9.noarch.rpm
sudo yum -y install mysql-community-server etcd curl
```

On apt-based distributions the services `mysqld` and `etcd` will need to be shutdown, since `etcd` will conflict with the `etcd` started in the examples, and `mysqlctl` will start its own copies of `mysqld`:

```
# Debian and Ubuntu
sudo service mysql stop
sudo service etcd stop
sudo systemctl disable mysql
sudo systemctl disable etcd
```

Disable AppArmor or SELinux

AppArmor/SELinux will not allow Vitess to launch MySQL in any data directory by default. You will need to disable it:

AppArmor:

```
# Debian and Ubuntu
sudo ln -s /etc/apparmor.d/usr.sbin.mysqld /etc/apparmor.d/disable/
sudo apparmor_parser -R /etc/apparmor.d/usr.sbin.mysqld

# The following command should return an empty result:
sudo aa-status | grep mysqld
```

SELinux:

```
# CentOS
sudo setenforce 0
```

Install Vitess

Download the latest binary release for Vitess on Linux. For example with Vitess 6:

```
tar -xzf vitess-6.0.20-20200508-147bc5a.tar.gz
cd vitess-6.0.20-20200508-147bc5a
sudo mkdir -p /usr/local/vitess
sudo mv * /usr/local/vitess/
```

Make sure to add `/usr/local/vitess/bin` to the `PATH` environment variable. You can do this by adding the following to your `$HOME/.bashrc` file:

```
export PATH=/usr/local/vitess/bin:${PATH}
```

You are now ready to start your first cluster! Open a new terminal window to ensure your `.bashrc` file changes take effect.

Start a Single Keyspace Cluster

Start by copying the local examples included with Vitess to your preferred location. For our first example we will deploy a single unsharded keyspace. The file `101_initial_cluster.sh` is for example `1` phase `01`. Lets execute it now:

```
cp -r /usr/local/vitess/examples/local ~/my-vitess-example
cd ~/my-vitess-example
./101_initial_cluster.sh
```

You should see output similar to the following:

```
~/my-vitess-example> ./101_initial_cluster.sh
$ ./101_initial_cluster.sh
add /vitess/global
add /vitess/zone1
add zone1 CellInfo
etcd start done...
Starting vtctld...
Starting MySQL for tablet zone1-0000000100...
Starting vttablet for zone1-0000000100...
HTTP/1.1 200 OK
Date: Wed, 25 Mar 2020 17:32:45 GMT
Content-Type: text/html; charset=utf-8

Starting MySQL for tablet zone1-0000000101...
Starting vttablet for zone1-0000000101...
HTTP/1.1 200 OK
Date: Wed, 25 Mar 2020 17:32:53 GMT
Content-Type: text/html; charset=utf-8

Starting MySQL for tablet zone1-0000000102...
Starting vttablet for zone1-0000000102...
HTTP/1.1 200 OK
Date: Wed, 25 Mar 2020 17:33:01 GMT
Content-Type: text/html; charset=utf-8

W0325 11:33:01.932674   16036 main.go:64] W0325 17:33:01.930970 reparent.go:185]
   master-elect tablet zone1-0000000100 is not the shard master, proceeding anyway as
   -force was used
W0325 11:33:01.933188   16036 main.go:64] W0325 17:33:01.931580 reparent.go:191]
   master-elect tablet zone1-0000000100 is not a master in the shard, proceeding anyway as
   -force was used
..
```

You can also verify that the processes have started with `pgrep`:

```
~/my-vitess-example> pgrep -fl vtdataroot
14119 etcd
14176 vtctld
14251 mysqld_safe
14720 mysqld
```

```
14787 vttablet
14885 mysqld_safe
15352 mysqld
15396 vttablet
15492 mysqld_safe
15959 mysqld
16006 vttablet
16112 vtgate
```

The exact list of processes will vary. For example, you may not see `mysqld_safe` listed.

If you encounter any errors, such as ports already in use, you can kill the processes and start over:

```
pkill -9 -e -f '(vtdataroot|VTDATAROOT)' # kill Vitess processes
rm -rf vtdataroot
```

Setup Aliases

For ease-of-use, Vitess provides aliases for `mysql` and `vtctlclient`:

```
source ./env.sh
```

Setting up aliases changes `mysql` to always connect to Vitess for your current session. To revert this, type `unalias mysql && unalias vtctlclient` or close your session.

Connect to your cluster

You should now be able to connect to the VTGate server that was started in `101_initial_cluster.sh`:

```
~/my-vitess-example> mysql
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 2
Server version: 5.7.9-Vitess (Ubuntu)

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affiliates. Other names may be trademarks of their respective
owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql> show tables;
+-----------------------+
| Tables_in_vt_commerce |
+-----------------------+
| corder                |
| customer              |
| product               |
+-----------------------+
3 rows in set (0.00 sec)
```

You can also browse to the vtctld console using the following URL:

```
http://localhost:15000
```

Summary

In this example, we deployed a single unsharded keyspace named `commerce`. Unsharded keyspaces have a single shard named `0`. The following schema reflects a common ecommerce scenario that was created by the script:

```
create table product (
  sku varbinary(128),
  description varbinary(128),
  price bigint,
  primary key(sku)
);
create table customer (
  customer_id bigint not null auto_increment,
  email varbinary(128),
  primary key(customer_id)
);
create table corder (
  order_id bigint not null auto_increment,
  customer_id bigint,
  sku varbinary(128),
  price bigint,
  primary key(order_id)
);
```

The schema has been simplified to include only those fields that are significant to the example:

- The `product` table contains the product information for all of the products.
- The `customer` table has a `customer_id` that has an `auto_increment`. A typical customer table would have a lot more columns, and sometimes additional detail tables.
- The `corder` table (named so because `order` is an SQL reserved word) has an `order_id` auto-increment column. It also has foreign keys into `customer(customer_id)` and `product(sku)`.

Next Steps

You can now proceed with MoveTables.

Or alternatively, if you would like to teardown your example:

```
./401_teardown.sh
rm -rf vtdataroot
```

Vitess Operator for Kubernetes

PlanetScale provides a Vitess Operator for Kubernetes, released under the Apache 2.0 license. The following steps show how to get started using Minikube:

Prerequisites

Before we get started, let's get a few things out of the way:

1. Install Minikube and start a Minikube engine. We recommend using Kubernetes 1.14, as this is a common denominator across public clouds: `bash minikube start --kubernetes-version=v1.14.10 --cpus=8 --memory=11000 --disk-size=50g`

   If you do not have a machine with 11GB of memory to spare, you could also consider using GKE instead. An equivalent setup can be deployed from the Cloud Shell with: `bash gcloud container clusters create vitess --cluster-version 1.14 --zone us-east1-b --num-nodes 5`

2. Install kubectl and ensure it is in your `PATH`. For example, on Linux:

```
curl -LO
   https://storage.googleapis.com/kubernetes-release/release/v1.14.9/bin/linux/amd64/kubectl
```

3. Install the MySQL client locally. For example, on Ubuntu:

```
apt install mysql-client
```

4. Install vtctlclient locally:

   If you are familiar with Go development, the easiest way to do this is: `bash go get vitess.io/vitess/go/cmd/vtctlclient` If not, you can also download the latest Vitess release and extract `vtctlclient` from it.

Install the Operator

Change to the operator example directory:

```
git clone git@github.com:vitessio/vitess.git
cd vitess/examples/operator
```

Install the operator:

```
kubectl apply -f operator.yaml
```

Bring up an initial cluster

In this directory, you will see a group of yaml files. The first digit of each file name indicates the phase of example. The next two digits indicate the order in which to execute them. For example, `101_initial_cluster.yaml` is the first file of the first phase. We shall execute that now:

```
kubectl apply -f 101_initial_cluster.yaml
```

Verify cluster You can check the state of your cluster with `kubectl get pods`. After a few minutes, it should show that all pods are in the status of running:

```
$ kubectl get pods
NAME                                        READY   STATUS    RESTARTS   AGE
example-etcd-faf13de3-1                     1/1     Running   0          78s
example-etcd-faf13de3-2                     1/1     Running   0          78s
example-etcd-faf13de3-3                     1/1     Running   0          78s
example-vttablet-zone1-2469782763-bfadd780  3/3     Running   1          78s
example-vttablet-zone1-2548885007-46a852d0  3/3     Running   1          78s
example-zone1-vtctld-1d4dcad0-59d8498459-kwz6b  1/1     Running   2          78s
example-zone1-vtgate-bc6cde92-6bd99c6888-vwcj5  1/1     Running   2          78s
vitess-operator-8454d86687-4wfnc            1/1     Running   0          2m29s
```

Setup Port-forward

{{< warning >}} The port-forward will only forward to a specific pod. Currently, `kubectl` does not automatically terminate a port-forward as the pod dissapears due to apply/upgrade operations. You will need to manually restart the port-forward. {{</ warning >}}

For ease-of-use, Vitess provides a script to port-forward from Kubernetes to your local machine. This script also recommends setting up aliases for `mysql` and `vtctlclient`:

```
./pf.sh &
alias vtctlclient="vtctlclient -server=localhost:15999"
alias mysql="mysql -h 127.0.0.1 -P 15306 -u user"
```

Setting up aliases changes `mysql` to always connect to Vitess for your current session. To revert this, type `unalias mysql && unalias vtctlclient` or close your session.

Create Schema

Load our initial schema:

```
vtctlclient ApplySchema -sql="$(cat create_commerce_schema.sql)" commerce
vtctlclient ApplyVSchema -vschema="$(cat vschema_commerce_initial.json)" commerce
```

Connect to your cluster You should now be able to connect to the VTGate Server in your cluster with the MySQL client:

```
~/vitess/examples/operator$ mysql
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 3
Server version: 5.7.9-Vitess MySQL Community Server (GPL)

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owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql> show databases;
+-----------+
| Databases |
+-----------+
| commerce  |
+-----------+
1 row in set (0.00 sec)
```

Summary In this example, we deployed a single unsharded keyspace named `commerce`. Unsharded keyspaces have a single shard named `0`. The following schema reflects a common ecommerce scenario that was created by the script:

```
create table product(
  sku varbinary(128),
  description varbinary(128),
  price bigint,
  primary key(sku)
);
create table customer(
  customer_id bigint not null auto_increment,
  email varbinary(128),
  primary key(customer_id)
);
create table corder(
  order_id bigint not null auto_increment,
  customer_id bigint,
  sku varbinary(128),
```

```
  price bigint,
  primary key(order_id)
);
```

The schema has been simplified to include only those fields that are significant to the example:

- The `product` table contains the product information for all of the products.
- The `customer` table has a `customer_id` that has an `auto_increment`. A typical customer table would have a lot more columns, and sometimes additional detail tables.
- The `corder` table (named so because `order` is an SQL reserved word) has an `order_id` auto-increment column. It also has foreign keys into `customer(customer_id)` and `product(sku)`.

Next Steps

You can now proceed with MoveTables.

Or alternatively, if you would like to teardown your example:

```
kubectl delete -f 101_initial_cluster.yaml
```

Congratulations on completing this exercise!

Overview

description: High-level information about Vitess

The Vitess overview documentation provides general information about Vitess that's less immediately practical than what you'll find in Get Started section and the User Guides.

Architecture

The Vitess platform consists of a number of server processes, command-line utilities, and web-based utilities, backed by a consistent metadata store.

Depending on the current state of your application, you could arrive at a full Vitess implementation through a number of different process flows. For example, if you're building a service from scratch, your first step with Vitess would be to define your database topology. However, if you need to scale your existing database, you'd likely start by deploying a connection proxy.

Vitess tools and servers are designed to help you whether you start with a complete fleet of databases or start small and scale over time. For smaller implementations, vttablet features like connection pooling and query rewriting help you get more from your existing hardware. Vitess' automation tools then provide additional benefits for larger implementations.

The diagram below illustrates Vitess' components:

For additonal details on each of the components, see Concepts.

Cloud Native

Vitess is well-suited for Cloud deployments because it enables databases to incrementally add capacity. The easiest way to run Vitess is via Kubernetes.

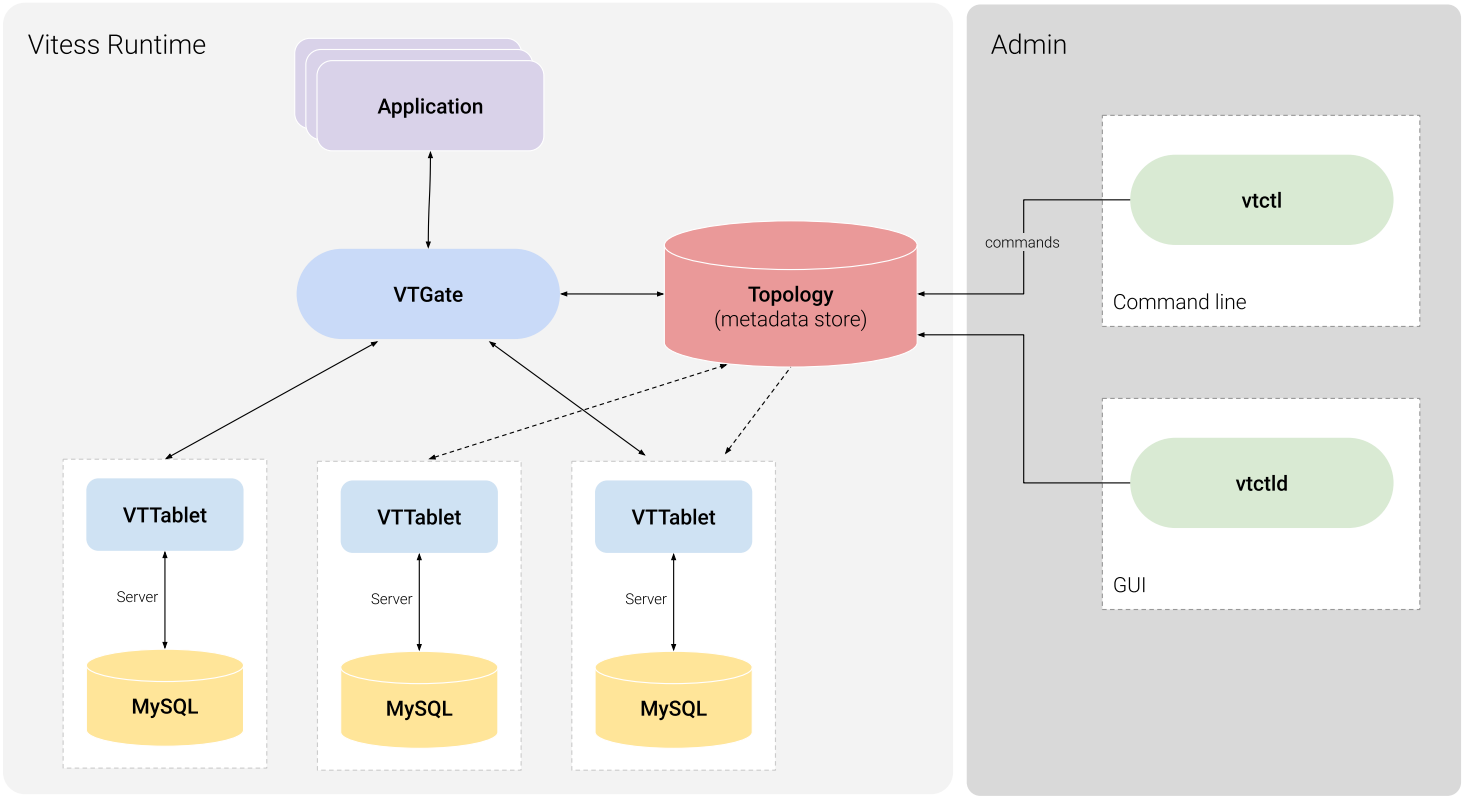

Figure 2: Architecture Diagram

Vitess on Kubernetes

Kubernetes is an open-source orchestration system for Docker containers, and Vitess can run as a Kubernetes-aware cloud native distributed database.

Kubernetes handles scheduling onto nodes in a compute cluster, actively manages workloads on those nodes, and groups containers comprising an application for easy management and discovery. This provides an analogous open-source environment to the way Vitess runs in YouTube, on the predecessor to Kubernetes.

Related Vitess Documentation

- Kubernetes Quickstart

History

description: Born at YouTube, released as Open Source

Vitess was created in 2010 to solve the MySQL scalability challenges that the team at YouTube faced. This section briefly summarizes the sequence of events that led to Vitess' creation:

1. YouTube's MySQL database reached a point when peak traffic would soon exceed the database's serving capacity. To temporarily alleviate the problem, YouTube created a master database for write traffic and a replica database for read traffic.
2. With demand for cat videos at an all-time high, read-only traffic was still high enough to overload the replica database. So YouTube added more replicas, again providing a temporary solution.
3. Eventually, write traffic became too high for the master database to handle, requiring YouTube to shard data to handle incoming traffic. As an aside, sharding would have also become necessary if the overall size of the database became too large for a single MySQL instance.

4. YouTube's application layer was modified so that before executing any database operation, the code could identify the right database shard to receive that particular query.

Vitess let YouTube remove that logic from the source code, introducing a proxy between the application and the database to route and manage database interactions. Since then, YouTube has scaled its user base by a factor of more than 50, greatly increasing its capacity to serve pages, process newly uploaded videos, and more. Even more importantly, Vitess is a platform that continues to scale.

Vitess becomes a CNCF project

The CNCF serves as the vendor-neutral home for many of the fastest-growing open source projects. In February 2018 the Technical Oversight Committee (TOC) voted to accept Vitess as a CNCF incubation project. Vitess became the eighth CNCF project to graduate in November 2019, joining Kubernetes, Prometheus, Envoy, CoreDNS, containerd, Fluentd, and Jaeger.

Scalability Philosophy

Scalability problems can be solved using many approaches. This document describes Vitess' approach to address these problems.

Small instances

When deciding to shard or break databases up into smaller parts, it's tempting to break them just enough that they fit in one machine. In the industry, it's common to run only one MySQL instance per host.

Vitess recommends that instances be broken up into manageable chunks (250GB per MySQL server), and not to shy away from running multiple instances per host. The net resource usage would be about the same. But the manageability greatly improves when MySQL instances are small. There is the complication of keeping track of ports, and separating the paths for the MySQL instances. However, everything else becomes simpler once this hurdle is crossed.

There are fewer lock contentions to worry about, replication is a lot happier, production impact of outages become smaller, backups and restores run faster, and a lot more secondary advantages can be realized. For example, you can shuffle instances around to get better machine or rack diversity leading to even smaller production impact on outages, and improved resource usage.

Durability through replication

Traditional data storage software treated data as durable as soon as it was flushed to disk. However, this approach is impractical in today's world of commodity hardware. Such an approach also does not address disaster scenarios.

The new approach to durability is achieved by copying the data to multiple machines, and even geographical locations. This form of durability addresses the modern concerns of device failures and disasters.

Many of the workflows in Vitess have been built with this approach in mind. For example, turning on semi-sync replication is highly recommended. This allows Vitess to failover to a new replica when a master goes down, with no data loss. Vitess also recommends that you avoid recovering a crashed database. Instead, create a fresh one from a recent backup and let it catch up.

Relying on replication also allows you to loosen some of the disk-based durability settings. For example, you can turn off `sync_binlog`, which greatly reduces the number of IOPS to the disk thereby increasing effective throughput.

Consistency model

Before sharding or moving tables to different keyspaces, the application needs to be verified (or changed) such that it can tolerate the following changes:

- Cross-shard reads may not be consistent with each other. Conversely, the sharding decision should also attempt to minimize such occurrences because cross-shard reads are more expensive.

- In "best-effort mode", cross-shard transactions can fail in the middle and result in partial commits. You could instead use "2PC mode" transactions that give you distributed atomic guarantees. However, choosing this option increases the write cost by approximately 50%.

Single shard transactions continue to remain ACID, just like MySQL supports it.

If there are read-only code paths that can tolerate slightly stale data, the queries should be sent to REPLICA tablets for OLTP, and RDONLY tablets for OLAP workloads. This allows you to scale your read traffic more easily, and gives you the ability to distribute them geographically.

This trade-off allows for better throughput at the expense of stale or possibly inconsistent reads, since the reads may be lagging behind the master, as data changes (and possibly with varying lag on different shards). To mitigate this, VTGate servers are capable of monitoring replica lag and can be configured to avoid serving data from instances that are lagging beyond X seconds.

For a true snapshot, queries must be sent to the master within a transaction. For read-after-write consistency, reading from the master without a transaction is sufficient.

To summarize, these are the various levels of consistency supported:

- `REPLICA/RDONLY` read: Servers can be scaled geographically. Local reads are fast, but can be stale depending on replica lag.
- `MASTER` read: There is only one worldwide master per shard. Reads coming from remote locations will be subject to network latency and reliability, but the data will be up-to-date (read-after-write consistency). The isolation level is `READ_COMMITTED`.
- `MASTER` transactions: These exhibit the same properties as MASTER reads. However, you get REPEATABLE_READ consistency and ACID writes for a single shard. Support is underway for cross-shard Atomic transactions.

As for atomicity, the following levels are supported:

- `SINGLE`: disallow multi-db transactions.
- `MULTI`: multi-db transactions with best effort commit.
- `TWOPC`: multi-db transactions with 2PC commit.

No multi-master Vitess doesn't support multi-master setup. It has alternate ways of addressing most of the use cases that are typically solved by multi-master:

- Scalability: There are situations where multi-master gives you a little bit of additional runway. However, since the statements have to eventually be applied to all masters, it's not a sustainable strategy. Vitess addresses this problem through sharding, which can scale indefinitely.
- High availability: Vitess integrates with Orchestrator, which is capable of performing a failover to a new master within seconds of failure detection. This is usually sufficient for most applications.
- Low-latency geographically distributed writes: This is one case that is not addressed by Vitess. The current recommendation is to absorb the latency cost of long-distance round-trips for writes. If the data distribution allows, you still have the option of sharding based on geographic affinity. You can then setup masters for different shards to be in different geographic location. This way, most of the master writes can still be local.

Multi-cell

Vitess is meant to run in multiple data centers / regions / cells. In this part, we'll use "cell" to mean a set of servers that are very close together, and share the same regional availability.

A cell typically contains a set of tablets, a vtgate pool, and app servers that use the Vitess cluster. With Vitess, all components can be configured and brought up as needed:

- The master for a shard can be in any cell. If cross-cell master access is required, vtgate can be configured to do so easily (by passing the cell that contains the master as a cell to watch).

- It is not uncommon to have the cells that can contain the master be more provisioned than read-only serving cells. These *master-capable* cells may need one more replica to handle a possible failover, while still maintaining the same replica serving capacity.
- Failing over from a master in one cell to a master in a different cell is no different than a local failover. It has an implication on traffic and latency, but if the application traffic also gets re-directed to the new cell, the end result is stable.
- It is also possible to have some shards with a master in one cell, and some other shards with their master in another cell. vtgate will just route the traffic to the right place, incurring extra latency cost only on the remote access. For instance, creating U.S. user records in a database with masters in the U.S. and European user records in a database with masters in Europe is easy to do. Replicas can exist in every cell anyway, and serve the replica traffic quickly.
- Replica serving cells are a good compromise to reduce user-visible latency: they only contain replica servers, and master access is always done remotely. If the application profile is mostly reads, this works really well.
- Not all cells need `rdonly` (or batch) instances. Only the cells that run batch jobs, or OLAP jobs, really need them.

Note Vitess uses local-cell data first, and is very resilient to any cell going down (most of our processes handle that case gracefully).

Supported Databases

Vitess deploys, scales and manages clusters of open-source SQL database instances. Currently, Vitess supports the MySQL, Percona and MariaDB databases.

The VTGate proxy server advertises its version as MySQL 5.7.

MySQL versions 5.6 to 8.0

Vitess supports the core features of MySQL versions 5.6 to 8.0, with some limitations. Vitess also supports Percona Server for MySQL versions 5.6 to 8.0.

With MySQL 5.6 reaching end of life in February 2021, it is recommended to deploy MySQL 5.7 and later.

MariaDB versions 10.0 to 10.3

Vitess supports the core features of MariaDB versions 10.0 to 10.3. Vitess does not yet support version 10.4 of MariaDB.

See also

- MySQL Compatibility

What Is Vitess

Vitess is a database solution for deploying, scaling and managing large clusters of open-source database instances. It currently supports MySQL and MariaDB. It's architected to run as effectively in a public or private cloud architecture as it does on dedicated hardware. It combines and extends many important SQL features with the scalability of a NoSQL database. Vitess can help you with the following problems:

1. Scaling a SQL database by allowing you to shard it, while keeping application changes to a minimum.
2. Migrating from baremetal to a private or public cloud.
3. Deploying and managing a large number of SQL database instances.

Vitess includes compliant JDBC and Go database drivers using a native query protocol. Additionally, it implements the MySQL server protocol which is compatible with virtually any other language.

Vitess served all YouTube database traffic for over five years. Many enterprises have now adopted Vitess for their production needs.

Features

- Performance
  - Connection pooling - Multiplex front-end application queries onto a pool of MySQL connections to optimize performance.
  - Query de-duping – Reuse results of an in-flight query for any identical requests received while the in-flight query was still executing.
  - Transaction manager – Limit number of concurrent transactions and manage deadlines to optimize overall throughput.
- Protection
  - Query rewriting and sanitization – Add limits and avoid non-deterministic updates.
  - Query blacklisting – Customize rules to prevent potentially problematic queries from hitting your database.
  - Query killer – Terminate queries that take too long to return data.
  - Table ACLs – Specify access control lists (ACLs) for tables based on the connected user.
- Monitoring
  - Performance analysis tools let you monitor, diagnose, and analyze your database performance.
- Topology Management Tools
  - Master management tools (handles reparenting)
  - Web-based management GUI
  - Designed to work in multiple data centers / regions
- Sharding
  - Virtually seamless dynamic re-sharding
  - Vertical and Horizontal sharding support
  - Multiple sharding schemes, with the ability to plug-in custom ones

Comparisons to other storage options

The following sections compare Vitess to two common alternatives, a vanilla MySQL implementation and a NoSQL implementation.

Vitess vs. Vanilla MySQL Vitess improves a vanilla MySQL implementation in several ways:

Vanilla MySQL	Vitess
Every MySQL connection has a memory overhead that ranges between 256KB and almost 3MB, depending on which MySQL release you're using. As your user base grows, you need to add RAM to support additional connections, but the RAM does not contribute to faster queries. In addition, there is a significant CPU cost associated with obtaining the connections.	Vitess creates very lightweight connections. Vitess' connection pooling feature uses Go's concurrency support to map these lightweight connections to a small pool of MySQL connections. As such, Vitess can easily handle thousands of connections.
Poorly written queries, such as those that don't set a LIMIT, can negatively impact database performance for all users.	Vitess employs a SQL parser that uses a configurable set of rules to rewrite queries that might hurt database performance.
Sharding is a process of partitioning your data to improve scalability and performance. MySQL lacks native sharding support, requiring you to write sharding code and embed sharding logic in your application.	Vitess supports a variety of sharding schemes. It can also migrate tables into different databases and scale up or down the number of shards. These functions are performed non-intrusively, completing most data transitions with just a few seconds of read-only downtime.
A MySQL cluster using replication for availability has a master database and a few replicas. If the master fails, a replica should become the new master. This requires you to manage the database lifecycle and communicate the current system state to your application.	Vitess helps to manage the lifecycle of your database scenarios. It supports and automatically handles various scenarios, including master failover and data backups.

Vanilla MySQL	Vitess
A MySQL cluster can have custom database configurations for different workloads, like a master database for writes, fast read-only replicas for web clients, slower read-only replicas for batch jobs, and so forth. If the database has horizontal sharding, the setup is repeated for each shard, and the app needs baked-in logic to know how to find the right database.	Vitess uses a topology backed by a consistent data store, like etcd or ZooKeeper. This means the cluster view is always up-to-date and consistent for different clients. Vitess also provides a proxy that routes queries efficiently to the most appropriate MySQL instance.

Vitess vs. NoSQL If you're considering a NoSQL solution primarily because of concerns about the scalability of MySQL, Vitess might be a more appropriate choice for your application. While NoSQL provides great support for unstructured data, Vitess still offers several benefits not available in NoSQL datastores:

NoSQL	Vitess
NoSQL databases do not define relationships between database tables, and only support a subset of the SQL language.	Vitess is not a simple key-value store. It supports complex query semantics such as where clauses, JOINS, aggregation functions, and more.
NoSQL datastores do not usually support transactions.	Vitess supports transactions.
NoSQL solutions have custom APIs, leading to custom architectures, applications, and tools.	Vitess adds very little variance to MySQL, a database that most people are already accustomed to working with.
NoSQL solutions provide limited support for database indexes compared to MySQL.	Vitess allows you to use all of MySQL's indexing functionality to optimize query performance.

Older Version Docs

description: PDFs of vitess.io/docs at the time of previous versions

To view a PDF of the state of the Vitess Documentation for previous versions of Vitess please follow the links below:

- Vitess Docs 5.0 on April 17, 2020
- Vitess Docs 6.0 on July 28, 2020— ## Reference description: Detailed information about specific Vitess functionality

Features

description: Reference documents for Vitess features

Messaging

Vitess messaging gives the application an easy way to schedule and manage work that needs to be performed asynchronously. Under the covers, messages are stored in a traditional MySQL table and therefore enjoy the following properties:

- **Scalable**: Because of vitess's sharding abilities, messages can scale to very large QPS or sizes.
- **Guaranteed delivery**: A message will be indefinitely retried until a successful ack is received.
- **Non-blocking**: If the sending is backlogged, new messages continue to be accepted for eventual delivery.
- **Adaptive**: Messages that fail delivery are backed off exponentially.
- **Analytics**: The retention period for messages is dictated by the application. One could potentially choose to never delete any messages and use the data for performing analytics.
- **Transactional**: Messages can be created or acked as part of an existing transaction. The action will complete only if the commit succeeds.

The properties of a message are chosen by the application. However, every message needs a uniquely identifiable key. If the messages are stored in a sharded table, the key must also be the primary vindex of the table.

Although messages will generally be delivered in the order they're created, this is not an explicit guarantee of the system. The focus is more on keeping track of the work that needs to be done and ensuring that it was performed. Messages are good for:

- Handing off work to another system.
- Recording potentially time-consuming work that needs to be done asynchronously.
- Scheduling for future delivery.
- Accumulating work that could be done during off-peak hours.

Messages are not a good fit for the following use cases:

- Broadcasting of events to multiple subscribers.
- Ordered delivery.
- Real-time delivery.

Creating a message table

The current implementation requires a fixed schema. This will be made more flexible in the future. There will also be a custom DDL syntax. For now, a message table must be created like this:

```
create table my_message(
  time_scheduled bigint,
  id bigint,
  time_next bigint,
  epoch bigint,
  time_created bigint,
  time_acked bigint,
  message varchar(128),
  primary key(time_scheduled, id),
  unique index id_idx(id),
  index next_idx(time_next, epoch)
) comment
   'vitess_message,vt_ack_wait=30,vt_purge_after=86400,vt_batch_size=10,vt_cache_size=10000,vt_po
```

The application-related columns are as follows:

- `id`: can be any type. Must be unique.
- `message`: can be any type.
- `time_scheduled`: must be a bigint. It will be used to store unix time in nanoseconds. If unspecified, the `Now` value is inserted.

The above indexes are recommended for optimum performance. However, some variation can be allowed to achieve different performance trade-offs.

The comment section specifies additional configuration parameters. The fields are as follows:

- `vitess_message`: Indicates that this is a message table.
- `vt_ack_wait=30`: Wait for 30s for the first message ack. If one is not received, resend.
- `vt_purge_after=86400`: Purge acked messages that are older than 86400 seconds (1 day).
- `vt_batch_size=10`: Send up to 10 messages per RPC packet.
- `vt_cache_size=10000`: Store up to 10000 messages in the cache. If the demand is higher, the rest of the items will have to wait for the next poller cycle.
- `vt_poller_interval=30`: Poll every 30s for messages that are due to be sent.

If any of the above fields are missing, vitess will fail to load the table. No operation will be allowed on a table that has failed to load.

Enqueuing messages

The application can enqueue messages using an insert statement:

```
insert into my_message(id, message) values(1, 'hello world')
```

These inserts can be part of a regular transaction. Multiple messages can be inserted to different tables. Avoid accumulating too many big messages within a transaction as it consumes memory on the VTTablet side. At the time of commit, memory permitting, all messages are instantly enqueued to be sent.

Messages can also be created to be sent in the future:

```
insert into my_message(id, message, time_scheduled) values(1, 'hello world', :future_time)
```

`future_time` must be the unix time expressed in nanoseconds.

Receiving messages

Processes can subscribe to receive messages by sending a `MessageStream` request to VTGate. If there are multiple subscribers, the messages will be delivered in a round-robin fashion. Note that this is not a broadcast; Each message will be sent to at most one subscriber.

The format for messages is the same as a vitess `Result`. This means that standard database tools that understand query results can also be message recipients. Currently, there is no SQL format for subscribing to messages, but one will be provided soon.

Subsetting It's possible that you may want to subscribe to specific shards or groups of shards while requesting messages. This is useful for partitioning or load balancing. The `MessageStream` API allows you to specify these constraints. The request parameters are as follows:

- `Name`: Name of the message table.
- `Keyspace`: Keyspace where the message table is present.
- `Shard`: For unsharded keyspaces, this is usually "0". However, an empty shard will also work. For sharded keyspaces, a specific shard name can be specified.
- `KeyRange`: If the keyspace is sharded, streaming will be performed only from the shards that match the range. This must be an exact match.

Acknowledging messages

A received (or processed) message can be acknowledged using the `MessageAck` API call. This call accepts the following parameters:

- `Name`: Name of the message table.
- `Keyspace`: Keyspace where the message table is present. This field can be empty if the table name is unique across all keyspaces.
- `Ids`: The list of ids that need to be acked.

Once a message is successfully acked, it will never be resent.

Exponential backoff

A message that was successfully sent will wait for the specified ack wait time. If no ack is received by then, it will be resent. The next attempt will be 2x the previous wait, and this delay is doubled for every attempt.

Purging

Messages that have been successfully acked will be deleted after their age exceeds the time period specified by `vt_purge_after`.

Advanced usage

The `MessageAck` functionality is currently an API call and cannot be used inside a transaction. However, you can ack messages using a regular DML. It should look like this:

```
update my_message set time_acked = :time_acked, time_next = null where id in ::ids and
   time_acked is null
```

You can manually change the schedule of existing messages with a statement like this:

```
update my_message set time_next = :time_next, epoch = :epoch where id in ::ids and
   time_acked is null
```

This comes in handy if a bunch of messages had chronic failures and got postponed to the distant future. If the root cause of the problem was fixed, the application could reschedule them to be delivered immediately. You can also optionally change the epoch. Lower epoch values increase the priority of the message and the back-off is less aggressive.

You can also view messages using regular `select` queries.

Undocumented features

These are features that were previously known limitations, but have since been supported and are awaiting further documentation.

- Flexible columns: Allow any number of application defined columns to be in the message table.
- No ACL check for receivers: To be added.
- Monitoring support: To be added.
- Dropped tables: The message engine does not currently detect dropped tables.

Known limitations

The message feature is currently in alpha, and can be improved. Here is the list of possible limitations/improvements:

- Proactive scheduling: Upcoming messages can be proactively scheduled for timely delivery instead of waiting for the next polling cycle.
- Changed properties: Although the engine detects new message tables, it does not refresh properties of an existing table.
- A `SELECT` style syntax for subscribing to messages.
- No rate limiting.
- Usage of partitions for efficient purging.

Replication

{{< warning >}} Vitess requires the use of Row-Based Replication with GTIDs enabled. In addition, Vitess only supports the default `binlog_row_image` of `FULL`. {{< /warning >}}

Vitess makes use of MySQL Replication for both high availability and to receive a feed of changes to database tables. This feed is then used in features such as VReplication, and to identify schema changes so that caches can be updated.

Semi-Sync

Vitess strongly recommends the use of Semi-synchronous replication for High Availability. When enabled in Vitess, *semi-sync* has the following characteristics:

- The master will only accept writes if it has at least one replica connected, and configured correctly to send semi-sync ACKs. Vitess configures the semi-sync timeout to essentially an unlimited number so that it will never fallback to asyncronous replication. This is important to prevent split brain (or alternate futures) in case of a network partition. If we can verify all replicas have stopped replicating, we know the old master is not accepting writes, even if we are unable to contact the old master itself.

- Tablets of type rdonly will not send semi-sync ACKs. This is intentional because rdonly tablets are not eligible to be promoted to master, so Vitess avoids the case where a rdonly tablet is the single best candidate for election at the time of master failure.

These behaviors combine to give you the property that, in case of master failure, there is at least one other replica that has every transaction that was ever reported to clients as having completed. You can then (manually, or using Orchestrator to pick the replica that is farthest ahead in GTID position and promote that to be the new master.

Thus, you can survive sudden master failure without losing any transactions that were reported to clients as completed. In MySQL 5.7+, this guarantee is strengthened slightly to preventing loss of any transactions that were ever **committed** on the original master, eliminating so-called phantom reads.

On the other hand these behaviors also give a requirement that each shard must have at least 2 tablets with type *replica* (with addition of the master that can be demoted to type *replica* this gives a minimum of 3 tablets with initial type *replica*). This will allow for the master to have a semi-sync acker when one of the replica tablets is down for any reason (for a version update, machine reboot, schema swap or anything else).

With regard to replication lag, note that this does **not** guarantee there is always at least one replica from which queries will always return up-to-date results. Semi-sync guarantees that at least one replica has the transaction in its relay log, but it has not necessarily been applied yet. The only way Vitess guarantees a fully up-to-date read is to send the request to the master.

Database Schema Considerations

- Row-based replication requires that replicas have the same schema as the master, and corruption will likely occur if the column order does not match. Earlier versions of Vitess which used Statement-Based replication recommended applying schema changes on replicas first, and then swapping their role to master. This method is no longer recommended and a tool such as `gh-ost` or `pt-online-schema-change` should be used instead.
- Using a column of type `FLOAT` or `DOUBLE` as part of a Primary Key is not supported. This limitation is because Vitess may try to execute a query for a value (for example 2.2) which MySQL will return zero results, even when the approximate value is present.
- It is not recommended to change the schema at the same time a resharding operation is being performed. This limitation exists because interpreting RBR events requires accurate knowledge of the table's schema, and Vitess does not always correctly handle the case that the schema has changed.

Point In Time Recovery

Point in Time Recovery

Supported Databases

- MySQL 5.7 #### Believed to work, but untested
- MySQL 8.0

Introduction The Point in Time Recovery feature in Vitess enables recovery of data to a specific point time (timestamp). There can be multiple recovery requests active at the same time. It is possible to recover across sharding actions, i.e. you can recover to a time when there were two shards even though at present there are four.

Point in Time Recovery leverages two Vitess features: 1. The use of `SNAPSHOT` keyspaces for recovery of the last backup before a requested specific timestamp to restore to. 2. Integration with a binlog server to allow vttablet to apply binary logs from the recovered backup up to the specified timestamp.

Use cases

- Accidental deletion of data, e.g. dropping a table by mistake, running an UPDATE or DELETE with an incorrect WHERE clause, etc.
- Corruption of data due to application bugs.
- Corruption of data due to MySQL bugs or underlying hardware (e.g. storage) problems.

Preconditions

- There should be a Vitess backup taken before the desired point in time.
- There should be continuous binlogs available from the backup time to the desired point in time.
- This feature is tested using Ripple as the binlog server. However, it should be possible to use a MySQL instance as source for the binlogs as well.

Example usage To use this feature, you need a usable backup of Vitess data and continuous binlogs.

Here is how you can create a backup.

```
$ vtctlclient -server <vtctld_host>:<vtctld_port> Backup zone1-101
```

Here `zone1-101` is the tablet alias of a replica tablet in the shard that you want to back up. Note that you can also use `vtctlclient BackupShard` to just specify a keyspace and shard, and have Vitess choose the tablet to run the backup for you, instead of having to specify the tablet alias explicitly.

To maintain continuous binlogs, you need to have a binlog server pointing to the master (or a replica, assuming that the replica is also maintaining its own binlogs, which is the default Vitess configuration). You can use Ripple as a binlog server, although there are other options; and you could use an existing MySQL server as well.

If you use Ripple, you will need to configure it yourself, and ensure you take care of the following: - You should have a highly available binlog server setup. If the binlog server goes down, you need to ensure that it is back up and able to synchronize the MySQL binary logs from its upstream MySQL server before the upstream server deletes the current binlog. If you do not do this, you will end up with gaps in your binlogs, which could make restoring to a specific point in time impossible. Make sure that you setup your operational and monitoring procedures accordingly. - The binlog files should be safely kept at some reliable and recoverable location (e.g. AWS S3, remote file storage).

Once the above is done, you can proceed with doing a recovery.

Recovery Procedure First, you need to create a `SNAPSHOT` keyspace with a `base_keyspace` pointing to the original keyspace you are recovering the backup of. This can be done by using following:

```
$ vtctlclient -server <vtctld_host>:<vtctld_port> CreateKeyspace -keyspace_type=SNAPSHOT
   -base_keyspace=originalks -snapshot_time=2020-07-17T18:25:20Z restoreks
```

Here: - `originalks` is the base keyspace, i.e. the keyspace we took a backup of, and are trying to recover. - `snapshot_time` is the timestamp of the point in time to we want to recover to. Note the use of the `Z` in the timestamp, indicating it is expressed in UTC. - `restoreks` is the name of recovery keyspace, i.e. the keyspace to which we are restoring our backup.

Next, you can launch the vttablet, which as part of vttablet's normal initialization procedure will look for a backup to restore. It will detect the meta-information you added on the keyspace topology node when creating the keyspace above. It will then use that information to restore the last backup earlier than the timestamp provided for the specific shard the vttablet is in.

Here are the command line arguments vttablet uses in this process. You may already be using some of these as part of your normal vttablet initialization parameters (e.g. if you are using the Vitess K8s operator): - `-init_keyspace restoreks` - here `restoreks` is the recovery keyspace name which we created earlier - `-init_db_name_override vt_originalks` - here `vt_originalks` is the name of the original underlying database for the keyspace that you backed up and want to restore. Usually, this takes the form of `vt_` prepended to the keyspace name. However, the original underlying database could also have been using an `-init_db_name_override` directive of its own, and this value should then be set to match that. - `-init_shard 0` - here `0` is the shard name (or range) which we want to recover. - `-binlog_host x.x.x.x` - hostname or IP address of

binlog server. - `-binlog_port XXXX` - TCP port of binlog server. - `-binlog_user XXXX` - username to access binlog server. - `-binlog_password YYYY` - password to access binlog server. - `-pitr_gtid_lookup_timeout duration` - See below for details.

And then, depending on your backup storage implementation, you can use a variety of flags: - `-backup_storage_implementation file` - for plain file backup type. If you use this option, you will also need to specify: - `-file_backup_storage_root` - with a path pointing to your backup storage location. - `-backup_storage_implementation s3` - for backing up to S3. If you use this option, you may need additional flags like: - `-s3_backup_aws_region` - `-s3_backup_storage_bucket` - `-s3_backup_storage_root` - There are more `-backup_storage_implementation` options like `gcs` and others.

You will also probably want to use other flags for backup and restore like: - `-backup_engine_implementation xtrabackup` - Use Percona Xtrabackup to take online backups. Without this flag, the mysql instance on the replica being backed up will be shut down during the backup. - `-backup_storage_compress true` - gzip compress the backup (default is true). You need to be consistent in your use of these flags for backup and restore.

Once the restore of the last backup earlier than the `snapshot_time` timestamp is completed, the vttablet proceeds to use the `binlog_*` parameters to connect to the binlog server and then apply all binlog events from the time of the backup until the timestamp provided.

Since the last backup for each shard making up the keyspace could be taken at different points in time, the amount of time that it takes to apply these events may differ between restores of different shards in the keyspace.

Note that to restore to the specified `snapshot_time` timestamp, vttablet needs to find the GTID corresponding to the last event before this timestamp from the binlog server. This is an expensive operation and may take some time. By default the timeout for this operation is one minute (1m). This can be changed by setting the vttablet `-pitr_gtid_lookup_timeout` flag.

VTGate will automatically exclude tablets belonging to snapshot keyspaces from query routing unless they are specifically addressed using `USE restoreks` or by using queries of the form `SELECT ... FROM restoreks.table`.

The base keyspace's vschema will be copied over to the new snapshot keyspace as a default. If desired this can be overwritten by the user. Care needs to be taken to set `require_explicit_routing` to true when modifying a snapshot keyspace's vschema, or you will bypass the VTGate routing safety feature described above.

Schema Management

Using Vitess requires you to work with two different types of schemas:

1. The MySQL database schema. This is the schema of the individual MySQL instances.
2. The VSchema, which describes all the keyspaces and how they're sharded.

The workflow for the `VSchema` is as follows:

1. Apply the `VSchema` for each keyspace using the `ApplyVschema` command. This saves the VSchemas in the global topology service.
2. Execute `RebuildVSchemaGraph` for each cell (or all cells). This command propagates a denormalized version of the combined VSchema to all the specified cells. The main purpose for this propagation is to minimize the dependency of each cell from the global topology. The ability to push a change to only specific cells allows you to canary the change to make sure that it's good before deploying it everywhere.

This document describes the `vtctl` commands that you can use to review or update your schema in Vitess.

Note that this functionality is not recommended for long-running schema changes. It is recommended to use a tool such as `pt-online-schema-change` or `gh-ost` instead.

Reviewing your schema

This section describes the following vtctl commands, which let you look at the schema and validate its consistency across tablets or shards:

- GetSchema
- ValidateSchemaShard
- ValidateSchemaKeyspace
- GetVSchema
- GetSrvVSchema

GetSchema The GetSchema command displays the full schema for a tablet or a subset of the tablet's tables. When you call `GetSchema`, you specify the tablet alias that uniquely identifies the tablet. The `<tablet alias>` argument value has the format `<cell name>-<uid>`.

Note: You can use the `vtctl ListAllTablets` command to retrieve a list of tablets in a cell and their unique IDs.

The following example retrieves the schema for the tablet with the unique ID test-000000100:

```
GetSchema test-000000100
```

ValidateSchemaShard The `ValidateSchemaShard` command confirms that for a given keyspace, all of the replica tablets in a specified shard have the same schema as the master tablet in that shard. When you call `ValidateSchemaShard`, you specify both the keyspace and the shard that you are validating.

The following command confirms that the master and replica tablets in shard `0` all have the same schema for the `user` keyspace:

```
ValidateSchemaShard user/0
```

ValidateSchemaKeyspace The `ValidateSchemaKeyspace` command confirms that all of the tablets in a given keyspace have the the same schema as the master tablet on shard `0` in that keyspace. Thus, whereas the `ValidateSchemaShard` command confirms the consistency of the schema on tablets within a shard for a given keyspace, `ValidateSchemaKeyspace` confirms the consistency across all tablets in all shards for that keyspace.

The following command confirms that all tablets in all shards have the same schema as the master tablet in shard 0 for the user keyspace:

```
ValidateSchemaKeyspace user
```

GetVSchema The `GetVSchema` command displays the global VSchema for the specified keyspace.

GetSrvVSchema The `GetSrvVSchema` command displays the combined VSchema for a given cell.

Changing your schema

This section describes the following commands:

- ApplySchema
- ApplyVSchema
- RebuildVSchemaGraph

ApplySchema Vitess' schema modification functionality is designed the following goals in mind:

- Enable simple updates that propagate to your entire fleet of servers.
- Require minimal human interaction.
- Minimize errors by testing changes against a temporary database.
- Guarantee very little downtime (or no downtime) for most schema updates.
- Do not store permanent schema data in the topology service.

Note that, at this time, Vitess only supports data definition statements that create, modify, or delete database tables. For instance, `ApplySchema` does not affect stored procedures or grants.

The ApplySchema command applies a schema change to the specified keyspace on every master tablet, running in parallel on all shards. Changes are then propagated to replicas. The command format is: `ApplySchema {-sql=<sql> || -sql_file=<filename>} <keyspace>`

When the `ApplySchema` action actually applies a schema change to the specified keyspace, it performs the following steps:

1. It finds shards that belong to the keyspace, including newly added shards if a resharding event has taken place.
2. It validates the SQL syntax and determines the impact of the schema change. If the scope of the change is too large, Vitess rejects it. See the permitted schema changes section for more detail.
3. It employs a pre-flight check to ensure that a schema update will succeed before the change is actually applied to the live database. In this stage, Vitess copies the current schema into a temporary database, applies the change there to validate it, and retrieves the resulting schema. By doing so, Vitess verifies that the change succeeds without actually touching live database tables.
4. It applies the SQL command on the master tablet in each shard.

The following sample command applies the SQL in the **user_table.sql** file to the **user** keyspace:

```
ApplySchema -sql_file=user_table.sql user
```

Permitted schema changes The `ApplySchema` command supports a limited set of DDL statements. In addition, Vitess rejects some schema changes because large changes can slow replication and may reduce the availability of your overall system.

The following list identifies types of DDL statements that Vitess supports:

- `CREATE TABLE`
- `CREATE INDEX`
- `CREATE VIEW`
- `ALTER TABLE`
- `ALTER VIEW`
- `RENAME TABLE`
- `DROP TABLE`
- `DROP INDEX`
- `DROP VIEW`

In addition, Vitess applies the following rules when assessing the impact of a potential change:

- `DROP` statements are always allowed, regardless of the table's size.
- `ALTER` statements are only allowed if the table on the shard's master tablet has 100,000 rows or less.
- For all other statements, the table on the shard's master tablet must have 2 million rows or less.

If a schema change gets rejected because it affects too many rows, you can specify the flag `-allow_long_unavailability` to tell `ApplySchema` to skip this check. However, we do not recommend this. Instead, you should apply large schema changes by using an external tool such as `gh-ost` or `pt-online-schema-change`.

ApplyVSchema The `ApplyVSchema` command applies the specified VSchema to the keyspace. The VSchema can be specified as a string or in a file.

RebuildVSchemaGraph The `RebuildVSchemaGraph` command propagates the global VSchema to a specific cell or the list of specified cells.

Schema Routing Rules

The Vitess routing rules feature is a powerful mechanism for directing traffic to the right keyspaces, shards or tablet types. It fulfils the following use cases:

- **Routing traffic during resharding**: During resharding, you can specify rules that decide where to send reads and writes. For example, you can move traffic from the source shard to the destination shards, but only for the `rdonly` or `replica` types. This gives you the option to try out the new shards and make sure they will work as intended before committing to move the rest of the traffic.
- **Table equivalence**: The new VReplication feature allows you to materialize tables in different keyspaces. In this situation, you can specify that two tables are 'equivalent'. This will allow VTGate to use the best possible plan depending on the input query.

ApplyRoutingRules

You can use the vtctlclient command to apply routing rules:

```
ApplyRoutingRules {-rules=<rules> || -rules_file=<rules_file=<sql file>} [-cells=c1,c2,...]
    [-skip_rebuild] [-dry-run]
```

Syntax

Resharding Routing rules can be specified using JSON format. Here's an example:

```
{"rules": [
  {
    "from_table": "t@rdonly",
    "to_tables": ["target.t"]
  }, {
    "from_table": "target.t",
    "to_tables": ["source.t"]
  }, {
    "from_table": "t",
    "to_tables": ["source.t"]
  }
]}
```

The above JSON specifies the following rules: * If you sent a query accessing `t` for an `rdonly` instance, then it would be sent to table `t` in the `target` keyspace. * If you sent a query accessing `target.t` for anything other than `rdonly`, it would be sent `t` in the `source` keyspace. * If you sent a query accessing `t` without any qualification, it would be sent to `t` in the `source` keyspace.

These rules are an example of how they can be used to shift traffic for a table during a vertical resharding process. In this case, the assumption is that we are moving `t` from `source` to `target`, and so far, we've shifted traffic for just the `rdonly` tablet types.

By updating these rules, you can eventually move all traffic to `target.t`

The rules are applied only once. The resulting targets need to specify fully qualified table names.

Table equivalence The routing rules allow you to specify table equivalence. Here's an example:

```
{"rules": [
  {
    "from_table": "product",
    "to_tables": ["lookup.product", "user.uproduct"]
  }
]}
```

In the above case, we are declaring that the `product` table is present in both `lookup` and `user`. If a query is issued using the unqualified `product` table, then VTGate will consider sending the query to both `lookup.product` as well as `user.uproduct` (note the name change).

For example, if `user` was a sharded keyspace, and the query joined a `user` table with `product`, then vtgate will know that it's better to send the query to the `user` keyspace instead of `lookup`.

Typically, table equivalence makes sense when a view table is materialized from a source table using VReplication.

Orthogonality The tablet type targeting and table equivalence features are orthogonal to each other and can be combined. Although there's no immediate use case for this, it's a possibility we can consider if the use case arises.

Sharding

description: Shard widely, shard often.

Sharding is a method of horizontally partitioning a database to store data across two or more database servers. This document explains how sharding works in Vitess and the types of sharding that Vitess supports.

Overview

A keyspace in Vitess can be sharded or unsharded. An unsharded keyspace maps directly to a MySQL database. If sharded, the rows of the keyspace are partitioned into different databases of identical schema.

For example, if an application's "user" keyspace is split into two shards, each shard contains records for approximately half of the application's users. Similarly, each user's information is stored in only one shard.

Note that sharding is orthogonal to (MySQL) replication. A Vitess shard typically contains one MySQL master and many MySQL replicas. The master handles write operations, while replicas handle read-only traffic, batch processing operations, and other tasks. Each MySQL instance within the shard should have the same data, excepting some replication lag.

Supported Operations Vitess supports the following types of sharding operations:

- **Horizontal sharding:** Splitting or merging shards in a sharded keyspace
- **Vertical sharding:** Moving tables from an unsharded keyspace to a different keyspace.

With these features, you can start with a single keyspace that contains all of your data (in multiple tables). As your database grows, you can move tables to different keyspaces (vertical split) and shard some or all of those keyspaces (horizontal split) without any real downtime for your application.

Sharding scheme

Vitess allows you to choose the type of sharding scheme by the choice of your Primary Vindex for the tables of a shard. Once you have chosen the Primary Vindex, you can choose the partitions depending on how the resulting keyspace IDs are distributed.

Vitess calculates the sharding key or keys for each query and then routes that query to the appropriate shards. For example, a query that updates information about a particular user might be directed to a single shard in the application's "user" keyspace. On the other hand, a query that retrieves information about several products might be directed to one or more shards in the application's "product" keyspace.

Key Ranges and Partitions Vitess uses key ranges to determine which shards should handle any particular query.

- A **key range** is a series of consecutive keyspace ID values. It has starting and ending values. A key falls inside the range if it is equal to or greater than the start value and strictly less than the end value.
- A **partition** represents a set of key ranges that covers the entire space.

When building the serving graph for a sharded keyspace, Vitess ensures that each shard is valid and that the shards collectively constitute a full partition. In each keyspace, one shard must have a key range with an empty start value and one shard, which could be the same shard, must have a key range with an empty end value.

- An empty start value represents the lowest value, and all values are greater than it.
- An empty end value represents a value larger than the highest possible value, and all values are strictly lower than it.

Vitess always converts sharding keys to a left-justified binary string for computing a shard. This left-justification makes the right-most zeroes insignificant and optional. Therefore, the value `0x80` is always the middle value for sharding keys. So, in a keyspace with two shards, sharding keys that have a binary value lower than 0x80 are assigned to one shard. Keys with a binary value equal to or higher than 0x80 are assigned to the other shard.

Several sample key ranges are shown below:

```
Start=[], End=[]: Full Key Range
Start=[], End=[0x80]: Lower half of the Key Range.
Start=[0x80], End=[]: Upper half of the Key Range.
Start=[0x40], End=[0x80]: Second quarter of the Key Range.
Start=[0xFF00], End=[0xFF80]: Second to last 1/512th of the Key Range.
```

Two key ranges are consecutive if the end value of one range equals the start value of the other range.

Shard Names A shard's name identifies the start and end of the shard's key range, printed in hexadecimal and separated by a hyphen. For instance, if a shard's key range is the array of bytes beginning with [0x80] and ending, noninclusively, with [0xc0], then the shard's name is `80-c0`.

Using this naming convention, the following four shards would be a valid full partition:

- -40
- 40-80
- 80-c0
- c0-

Shards do not need to handle the same size portion of the key space. For example, the following five shards would also be a valid full partition, possibly with a highly uneven distribution of keys.

- -80
- 80-c0
- c0-dc00
- dc00-dc80
- dc80-

Resharding

Resharding describes the process of updating the sharding scheme for a keyspace and dynamically reorganizing data to match the new scheme. During resharding, Vitess copies, verifies, and keeps data up-to-date on new shards while the existing shards continue to serve live read and write traffic. When you're ready to switch over, the migration occurs with only a few seconds of read-only downtime. During that time, existing data can be read, but new data cannot be written.

The table below lists the sharding (or resharding) processes that you would typically perform for different types of requirements:

Requirement	Action
Uniformly increase read capacity	Add replicas or split shards
Uniformly increase write capacity	Split shards
Reclaim overprovisioned resources	Merge shards and/or keyspaces
Increase geo-diversity	Add new cells and replicas
Cool a hot tablet	For read access, add replicas or split shards. For write access, split shards.

Additional Tools and Processes Vitess provides the following tools to help manage range-based shards:

- The vtctl command-line tool supports functions for managing keyspaces, shards, tablets, and more.
- Client APIs account for sharding operations.— ## Table lifecycle

Vitess manages a table lifecycle flow, an abstraction and automation for a `DROP TABLE` operation.

Problems with DROP TABLE

Vitess inherits the same issues that MySQL has with `DROP TABLE`. Doing a direct `DROP TABLE my_table` in production can be a risky operation. In busy environments this can lead to a complete lockdown of the database for the duration of seconds, to minutes and more. This is typically less of a problem in Vitess than it might be in normal MySQL, if you are keeping your shard instances (and thus shard table instances) small, but could still be a problem.

There are two locking aspects to dropping tables:

- Purging dropped table's pages from the InnoDB buffer pool(s)
- Removing table's data file (`.ibd`) from the filesystem.

The exact locking behavior and duration can vary depending on various factors: - Which filesystem is used - Whether the MySQL adaptive hash index is used - Whether you are attempting to hack around some of the MySQL `DROP TABLE` performance problems using hard links

It is common practice to avoid direct `DROP TABLE` statements and to follow a more elaborate table lifecycle.

Vitess table lifecycle

The lifecycle offered by Vitess consists of the following stages or some subset:

> *in use* -> hold -> purge -> evac -> drop -> *removed*

To understand the flow better, consider the following breakdown:

- *In use*: the table is serving traffic, like a normal table.
- `hold`: the table is renamed to some arbitrary new name. The application cannot see it, and considers it as gone. However, the table still exists, with all of its data intact. It is possible to reinstate it (e.g. in case we realize some application still requires it) by renaming it back to its original name.
- `purge`: the table is in the process of being purged (i.e. rows are being deleted). The purge process completes when the table is completely empty. At the end of the purge process the table no longer has any pages in the buffer pool(s). However, the purge process itself loads the table pages to cache in order to delete rows. Vitess purges the table a few rows at a time, and uses a throttling mechanism to reduce load. Vitess disables binary logging for the purge. The deletes are not written to the binary logs and are not replicated. This reduces load from disk IO, network, and replication lag. Data is not purged on the replicas. Experience shows that dropping a table populated with data on a replica has lower performance impact than on the primary, and the tradeoff is worthwhile.

- `evac`: a waiting period during which we expect normal production traffic to slowly evacuate the (now inactive) table's pages from the buffer pool. Vitess hard codes this period for `72` hours. The time is heuristic, there is no tracking of table pages in the buffer pool.
- `drop`: an actual `DROP TABLE` is imminent
- *removed*: table is dropped. When using InnoDB and `innodb_file_per_table` this means the `.ibd` data file backing the table is removed, and disk space is reclaimed.

Lifecycle subsets and configuration

Different environments and users have different requirements and workflows. For example:

- Some wish to immediately start purging the table, wait for pages to evacuate, then drop it.
- Some want to keep the table's data for a few days, then directly drop it.
- Some just wish to directly drop the table, they see no locking issues (e.g. smaller table).

Vitess supports all subsets via `-table_gc_lifecycle` flag to `vttablet`. The default is `"hold,purge,evac,drop"` (the complete cycle). Users may configure any subset, e.g. `"purge,drop"`, `"hold,drop"`, `"hold,evac,drop"` or even just `"drop"`.

Vitess will always work the steps in this order: `hold -> purge -> evac -> drop`. For example, setting `-table_gc_lifecycle "drop,hold"` still first *holds*, then *drops*

All subsets end with a `drop`, even if not explicitly mentioned. Thus, `"purge"` is interpreted as `"purge,drop"`.

Automated lifecycle

Vitess internally uses the above table lifecycle for online, managed schema migrations. Online schema migration tools `gh-ost` and `pt-online-schema-change` create artifact tables or end with leftover tables: Vitess automatically collects those tables. The artifact or leftover tables are immediate moved to `purge` state. Depending on `-table_gc_lifecycle`, they may spend time in this state, getting purged, or immediately transitioned to the next state.

User-facing DROP TABLE lifecycle

Table lifecycle is not yet available directly to the application user. Vitess will introduce a special syntax to allow users to indicate they want Vitess to manage a table's lifecycle.

Tablet throttler

VTTablet runs a cooperative throttling service. This service probes the shard's MySQL topology and observes replication lag on servers. This throttler is derived from GitHub's freno.

Note: the Vitess documentation is transitioning from the term "Master" (with regard to MySQL replication) to "Primary". this document reflects this transition.

Why throttler: maintaining low replication lag

Vitess uses MySQL with asynchronous or semi-synchronous replication. In these modes, each shard has a primary instance that applies changes and logs them to the binary log. The replicas for that shard will get binary log entries from the primary, potentially acknowledge them (if semi-synchronous replication is enabled), and apply them. A running replica normally applies the entries as soon as possible, unless it is stopped or configured to delay. However, if the replica is busy, then it may not have the resources to apply events in a timely fashion, and can therefore start lagging. For example, if the replica is serving traffic, it may lack the necessary disk I/O or CPU to avoid lagging behind the primary.

Maintaining low replication lag is important in production for two reasons:

- A lagging replica may not be representative of the data on the primary. Reads from the replica reflect data that is not consistent with the data on the primary. This is noticeable on web services following read-after-write from the replica, and this can produce results not reflecting the write.
- An up-to-date replica makes for a good failover experience. If all replicas are lagging, then a failover process must choose between waiting for a replica to catch up or losing data.

Some common database operations include mass writes to the database, including the following:

- Online schema migrations duplicating entire tables
- Mass population of columns, such as populating the new column with derived values following an `ADD COLUMN` migration
- Purging of old data
- Purging of tables as part of safe table `DROP` operation

These operations can easily incur replication lag. However, these operations are typically not time-limited. It is possible to rate-limit them to reduce database load.

This is where a throttler becomes useful. A throttler can detect when replication lag is low, a cluster is healthy, and operations can proceed. It can also detect when replication lag is high and advise applications to hold the next operation.

Applications are expected to break down their tasks into small sub-tasks. For example, instead of deleting `1,000,000` rows, an application should only delete `50` at a time. Between these sub-tasks, the application should check in with the throttler.

The throttler is only intended for use with operations such as the above mass write cases. It should not be used for ongoing, normal OLTP queries.

Throttler overview

Each `vttablet` runs an internal throttler service, and provides API endpoints to the throttler. Only the primary throttler is doing actual work at any given time. The throttlers on the replicas are mostly dormant, and wait for their turn to become "leaders," such as when the tablet transitions into `MASTER` (primary) type.

The primary tablet's throttler continuously does the following things:

- The throttler confirms it is still the primary tablet for its shard.
- Every `10sec`, the throttler uses the topology server to refresh the shard's tablets list.
- The throttler probes all `REPLICA` tablets for their replication lag. This is done by querying the `_vt.heartbeat` table.
  - The throttler begins in dormant probe mode. As long as no application or client is actually looking for metrics, it probes the servers at multi-second intervals.
  - When applications check for throttle advice, the throttler begins probing servers in subsecond intervals. It reverts to dormant probe mode if no requests are made in the duration of `1min`.
- The throttler aggregates the last probed values from all relevant tablets. This is *the cluster's metric* .

The cluster's metric is only as accurate as the following metrics:

- The probe interval
- The heartbeat injection interval
- The aggregation interval

The error margin equals approximately the sum of the above values, plus additional overhead. The defaults for these intervals are as follows: + Probe interval: `100ms` + Aggregation interval: `100ms` + Heartbeat interval: `250ms`

The user may override the heartbeat interval by sending `-heartbeat_interval` flag to `vttablet`.

Thus, the aggregated interval can be off, by default, by some `500ms`. This makes it inaccurate for evaluations that require high resolution lag evaluation. This resolution is sufficient for throttling purposes.

The throttler allows clients and applications to `check` for throttle advice. The check is an `HTTP` request, `HEAD` method, or `GET` method. Throttler returns one of the following HTTP response codes as an answer:

- `200` (OK): The application may write to the data store. This is the desired response.
- `404` (Not Found): The check contains an unknown metric name. This can take place immediately upon startup or immediately after failover, and should resolve within 10 seconds.
- `417` (Expectation Failed): The requesting application is explicitly forbidden to write. The throttler does not implement this at this time.
- `429` (Too Many Requests): Do not write. A normal, expected state indicating there is replication lag. This is the hint for applications or clients to withhold writes.
- `500` (Internal Server Error): An internal error has occurred. Do not write.

Normally, apps will see either `200` or `429`. An app should only ever proceed to write to the database when it receives a `200` response code.

The throttler chooses the response by comparing the replication lag with a pre-defined *threshold*. If the lag is lower than the threshold, response can be `200` (OK). If the lag is higher than the threshold, the response would be `429` (Too Many Requests).

The throttler only collects and evaluates lag on a set of predefined tablet types. By default, this tablet type set is `REPLICA`. See Configuration.

When the throttler sees no relevant replicas in the shard, it allows writes by responding with `HTTP 200 OK`.

Configuration

- The throttler is currently disabled by default. Use the `vttablet` option `-enable-lag-throttler` to enable the throttler. When the throttler is disabled, it still serves `/throttler/check` API and responds with `HTTP 200 OK` to all requests. When the throttler is enabled, it implicitly also runs heartbeat injections.
- Use the `vttablet` flag `-throttle_threshold` to set a lag threshold value. The default threshold is `1sec` and is set upon tablet startup. For example, to set a half-second lag threshold, use the flag `-throttle_threshold=0.5s`.
- To set the tablet types that the throttler queries for lag, use the `vttablet` flag `-throttle_tablet_types="replica,rdonly"`. The default tablet type is `replica`; this type is always implicitly included in the tablet types list. You may add any other tablet type. Any type not specified is ignored by the throttler.

API & usage

Applicaitons use the API `/throttler/check`.

- Applications may indicate their identity via `?app=<name>` parameter.
- Applications may also declare themselves to be *low priority* via `?p=low` param. Managed online schema migrations (`gh-ost`, `pt-online-schema-change`) do so, as does the table purge process.

Examples:

- `gh-ost` uses this throttler endpoint: `/throttler/check?app=gh-ost&p=low`
- A data backfill application may use this parameter: `/throttler/check?app=backfill` (using *normal* priority)

A `HEAD` request is sufficient. A `GET` request also provides a `JSON` output. For example:

- `{"StatusCode":200,"Value":0.207709,"Threshold":1,"Message":""}`
- `{"StatusCode":429,"Value":3.494452,"Threshold":1,"Message":"Threshold exceeded"}`
- `{"StatusCode":404,"Value":0,"Threshold":0,"Message":"No such metric"}`

In the first two above examples we can see that the tablet is configured to throttle at `1sec`

Tablet also provides `/throttler/status` endpoint. This is useful for monitoring and management purposes.

Example: Healthy primary tablet

The following command gets throttler status on a tablet hosted on `tablet1`, serving on port `15100`.

```
$ curl -s http://tablet1:15100/throttler/status | jq .
```

This API call returns the following JSON object:

```
{
  "Keyspace": "commerce",
  "Shard": "80-c0",
  "IsLeader": true,
  "IsOpen": true,
  "IsDormant": false,
  "AggregatedMetrics": {
    "mysql/local": {
      "Value": 0.193576
    }
  },
  "MetricsHealth": {}
}
```

`"IsLeader": true` indicates this tablet is active, is the `primary`, and is running probes. `"IsDormant": false,` means that an application has recently issued a `check`, and the throttler is probing for lag at high frequency.

Example: replica tablet

The following command gets throttler status on a tablet hosted on `tablet2`, serving on port `15100`.

```
$ curl -s http://tablet2:15100/throttler/status | jq .
```

This API call returns the following JSON object:

```
{
  "Keyspace": "commerce",
  "Shard": "80-c0",
  "IsLeader": false,
  "IsOpen": true,
  "IsDormant": true,
  "AggregatedMetrics": {},
  "MetricsHealth": {}
}
```

Resources

- freno project page
- Mitigating replication lag and reducing read load with freno, a GitHub Engineering blog post

Topology Service

This document describes the Topology Service, a key part of the Vitess architecture. This service is exposed to all Vitess processes, and is used to store small pieces of configuration data about the Vitess cluster, and provide cluster-wide locks. It also supports watches, and master election.

Vitess uses a plugin implementation to support multiple backend technologies for the Topology Service (etcd, ZooKeeper, Consul). Concretely, the Topology Service handles two functions: it is both a distributed lock manager and a repository for topology metadata. In earlier versions of Vitess, the Topology Serice was also referred to as the Lock Service.

Requirements and usage

The Topology Service is used to store information about the Keyspaces, the Shards, the Tablets, the Replication Graph, and the Serving Graph. We store small data structures (a few hundred bytes) per object.

The main contract for the Topology Service is to be very highly available and consistent. It is understood it will come at a higher latency cost and very low throughput.

We never use the Topology Service as an RPC or queuing mechanism or as a storage system for logs. We never depend on the Topology Service being responsive and fast to serve every query.

The Topology Service must also support a Watch interface, to signal when certain conditions occur on a node. This is used, for instance, to know when the Keyspace topology changes (e.g. for resharding).

Global vs Local We differentiate two instances of the Topology Service: the Global instance, and the per-cell Local instance:

- The Global instance is used to store global data about the topology that doesn't change very often, e.g. information about Keyspaces and Shards. The data is independent of individual instances and cells, and needs to survive a cell going down entirely.
- There is one Local instance per cell, that contains cell-specific information, and also rolled-up data from the Global + Local cell to make it easier for clients to find the data. The Vitess local processes should not use the Global topology instance, but instead the rolled-up data in the Local topology server as much as possible.

The Global instance can go down for a while and not impact the local cells (an exception to that is if a reparent needs to be processed, it might not work). If a Local instance goes down, it only affects the local tablets in that instance (and then the cell is usually in bad shape, and should not be used).

Vitess will not use the global or local topology service as part of serving individual queries. The Topology Service is only used to get the topology information at startup and in the background.

Recovery If a Local Topology Service dies and is not recoverable, it can be wiped out. All the tablets in that cell then need to be restarted so they re-initialize their topology records (but they won't lose any MySQL data).

If the Global Topology Service dies and is not recoverable, this is more of a problem. All the Keyspace / Shard objects have to be recreated or be restored. Then the cells should recover.

Global data

This section describes the data structures stored in the Global instance of the topology service.

Keyspace The Keyspace object contains various information, mostly about sharding: how is this Keyspace sharded, what is the name of the sharding key column, is this Keyspace serving data yet, how to split incoming queries, …

An entire Keyspace can be locked. We use this during resharding for instance, when we change which Shard is serving what inside a Keyspace. That way we guarantee only one operation changes the Keyspace data concurrently.

Shard A Shard contains a subset of the data for a Keyspace. The Shard record in the Global topology service contains:

- the Master tablet alias for this shard (that has the MySQL master).
- the sharding key range covered by this Shard inside the Keyspace.
- the tablet types this Shard is serving (master, replica, batch, …), per cell if necessary.
- if using filtered replication, the source shards this shard is replicating from.
- the list of cells that have tablets in this shard.
- shard-global tablet controls, like blacklisted tables no tablet should serve in this shard.

A Shard can be locked. We use this during operations that affect either the Shard record, or multiple tablets within a Shard (like reparenting), so multiple tasks cannot concurrently alter the data.

VSchema data The VSchema data contains sharding and routing information for the VTGate V3 API.

Local data

This section describes the data structures stored in the Local instance (per cell) of the topology service.

Tablets The Tablet record has a lot of information about each vttablet process making up each tablet (along with the MySQL process):

- the Tablet Alias (cell+unique id) that uniquely identifies the Tablet.
- the Hostname, IP address and port map of the Tablet.
- the current Tablet type (master, replica, batch, spare, …).
- which Keyspace / Shard the tablet is part of.
- the sharding Key Range served by this Tablet.
- user-specified tag map (e.g. to store per-installation data).

A Tablet record is created before a tablet can be running (either by `vtctl InitTablet` or by passing the `init_*` parameters to the vttablet process). The only way a Tablet record will be updated is one of:

- The vttablet process itself owns the record while it is running, and can change it.
- At init time, before the tablet starts.
- After shutdown, when the tablet gets deleted.
- If a tablet becomes unresponsive, it may be forced to spare to make it unhealthy when it restarts.

Replication graph The Replication Graph allows us to find Tablets in a given Cell / Keyspace / Shard. It used to contain information about which Tablet is replicating from which other Tablet, but that was too complicated to maintain. Now it is just a list of Tablets.

Serving graph The Serving Graph is what the clients use to find the per-cell topology of a Keyspace. It is a roll-up of global data (Keyspace + Shard). vtgates only open a small number of these objects and get all the information they need quickly.

SrvKeyspace It is the local representation of a Keyspace. It contains information on what shard to use for getting to the data (but not information about each individual shard):

- the partitions map is keyed by the tablet type (master, replica, batch, …) and the value is a list of shards to use for serving.
- it also contains the global Keyspace fields, copied for fast access.

It can be rebuilt by running `vtctl RebuildKeyspaceGraph <keyspace>`. It is automatically rebuilt when a tablet starts up in a cell and the SrvKeyspace for that cell / keyspace does not exist yet. It will also be changed during horizontal and vertical splits.

SrvVSchema It is the local roll-up for the VSchema. It contains the VSchema for all keyspaces in a single object.

It can be rebuilt by running `vtctl RebuildVSchemaGraph`. It is automatically rebuilt when using `vtctl ApplyVSchema` (unless prevented by flags).

Workflows involving the Topology Service

The Topology Service is involved in many Vitess workflows.

When a Tablet is initialized, we create the Tablet record, and add the Tablet to the Replication Graph. If it is the master for a Shard, we update the global Shard record as well.

Administration tools need to find the tablets for a given Keyspace / Shard. To retrieve this:

- first we get the list of Cells that have Tablets for the Shard (global topology Shard record has these)
- then we use the Replication Graph for that Cell / Keyspace / Shard to find all the tablets then we can read each tablet record.

When a Shard is reparented, we need to update the global Shard record with the new master alias.

Finding a tablet to serve the data is done in two stages:

- vtgate maintains a health check connection to all possible tablets, and they report which Keyspace / Shard / Tablet type they serve.
- vtgate also reads the SrvKeyspace object, to find out the shard map.

With these two pieces of information, vtgate can route the query to the right vttablet.

During resharding events, we also change the topology significantly. A horizontal split will change the global Shard records, and the local SrvKeyspace records. A vertical split will change the global Keyspace records, and the local SrvKeyspace records.

Exploring the data in a Topology Service

We store the proto3 serialized binary data for each object.

We use the following paths for the data, in all implementations:

Global Cell:

- CellInfo path: `cells/<cell name>/CellInfo`
- Keyspace: `keyspaces/<keyspace>/Keyspace`
- Shard: `keyspaces/<keyspace>/shards/<shard>/Shard`
- VSchema: `keyspaces/<keyspace>/VSchema`

Local Cell:

- Tablet: `tablets/<cell>-<uid>/Tablet`
- Replication Graph: `keyspaces/<keyspace>/shards/<shard>/ShardReplication`
- SrvKeyspace: `keyspaces/<keyspace>/SrvKeyspace`
- SrvVSchema: `SvrVSchema`

The `vtctl TopoCat` utility can decode these files when using the `-decode_proto` option:

```
TOPOLOGY="-topo_implementation zk2 -topo_global_server_address
   global_server1,global_server2 -topo_global_root /vitess/global"

$ vtctl $TOPOLOGY TopoCat -decode_proto -long /keyspaces/*/Keyspace
path=/keyspaces/ks1/Keyspace version=53
sharding_column_name: "col1"
path=/keyspaces/ks2/Keyspace version=55
sharding_column_name: "col2"
```

The `vtctld` web tool also contains a topology browser (use the `Topology` tab on the left side). It will display the various proto files, decoded.

Implementations

The Topology Service interfaces are defined in our code in `go/vt/topo/`, specific implementations are in `go/vt/topo/<name>`, and we also have a set of unit tests for it in `go/vt/topo/test`.

This part describes the implementations we have, and their specific behavior.

If starting from scratch, please use the `zk2`, `etcd2` or `consul` implementations. We deprecated the old `zookeeper` and `etcd` implementations. See the migration section below if you want to migrate.

Zookeeper `zk2` implementation This is the current implementation when using Zookeeper. (The old `zookeeper` implementation is deprecated).

The global cell typically has around 5 servers, distributed one in each cell. The local cells typically have 3 or 5 servers, in different server racks / sub-networks for higher resilience. For our integration tests, we use a single ZK server that serves both global and local cells.

We provide the `zk` utility for easy access to the topology data in Zookeeper. It can list, read and write files inside any Zoopeeker server. Just specify the `-server` parameter to point to the Zookeeper servers. Note the vtctld UI can also be used to see the contents of the topology data.

To configure a Zookeeper installation, let's start with the global cell service. It is described by the addresses of the servers (comma separated list), and by the root directory to put the Vitess data in. For instance, assuming we want to use servers `global_server1,global_server2` in path `/vitess/global`:

```
# The root directory in the global server will be created
# automatically, same as when running this command:
# zk -server global_server1,global_server2 touch -p /vitess/global

# Set the following flags to let Vitess use this global server:
# -topo_implementation zk2
# -topo_global_server_address global_server1,global_server2
# -topo_global_root /vitess/global
```

Then to add a cell whose local topology service `cell1_server1,cell1_server2` will store their data under the directory `/vitess/cell1`:

```
TOPOLOGY="-topo_implementation zk2 -topo_global_server_address
   global_server1,global_server2 -topo_global_root /vitess/global"

# Reference cell1 in the global topology service:
vtctl $TOPOLOGY AddCellInfo \
  -server_address cell1_server1,cell1_server2 \
  -root /vitess/cell1 \
  cell1
```

If only one cell is used, the same Zookeeper instance can be used for both global and local data. A local cell record still needs to be created, just use the same server address, and very importantly a *different* root directory.

Zookeeper Observers can also be used to limit the load on the global Zookeeper. They are configured by specifying the addresses of the observers in the server address, after a `|`, for instance: `global_server1:p1,global_server2:p2|observer1:po1,observer2:po2`.

Implementation details We use the following paths for Zookeeper specific data, in addition to the regular files:

- Locks sub-directory: `locks/` (for instance: `keyspaces/<keyspace>/Keyspace/locks/` for a keyspace)
- Master election path: `elections/<name>`

Both locks and master election are implemented using ephemeral, sequential files which are stored in their respective directory.

etcd etcd2 implementation (new version of etcd) This topology service plugin is meant to use etcd clusters as storage backend for the topology data. This topology service supports version 3 and up of the etcd server.

This implementation is named `etcd2` because it supersedes our previous implementation `etcd`. Note that the storage format has been changed with the `etcd2` implementation, i.e. existing data created by the previous `etcd` implementation must be migrated manually (See migration section below).

To configure an `etcd2` installation, let's start with the global cell service. It is described by the addresses of the servers (comma separated list), and by the root directory to put the Vitess data in. For instance, assuming we want to use servers `http://global_server1,http://global_server2` in path `/vitess/global`:

```
# Set the following flags to let Vitess use this global server,
# and simplify the example below:
# -topo_implementation etcd2
# -topo_global_server_address http://global_server1,http://global_server2
# -topo_global_root /vitess/global
TOPOLOGY="-topo_implementation etcd2 -topo_global_server_address
   http://global_server1,http://global_server2 -topo_global_root /vitess/global
```

Then to add a cell whose local topology service `http://cell1_server1,http://cell1_server2` will store their data under the directory `/vitess/cell1`:

```
# Reference cell1 in the global topology service:
# (the TOPOLOGY variable is defined in the previous section)
vtctl $TOPOLOGY AddCellInfo \
  -server_address http://cell1_server1,http://cell1_server2 \
  -root /vitess/cell1 \
  cell1
```

If only one cell is used, the same etcd instances can be used for both global and local data. A local cell record still needs to be created, just use the same server address and, very importantly, a *different* root directory.

Implementation details For locks, we use a subdirectory named `locks` in the directory to lock, and an ephemeral file in that subdirectory (it is associated with a lease, whose TTL can be set with the `-topo_etcd_lease_duration` flag, defaults to 30 seconds). The ephemeral file with the lowest ModRevision has the lock, the others wait for files with older ModRevisions to disappear.

Master elections also use a subdirectory, named after the election Name, and use a similar method as the locks, with ephemeral files.

We store the proto3 binary data for each object (as the v3 API allows us to store binary data). Note that this means that if you want to interact with etcd using the `etcdctl` tool, you will have to tell it to use the v3 API, e.g.:

```
ETCDCTL_API=3 etcdctl get / --prefix --keys-only
```

Consul consul implementation This topology service plugin is meant to use Consul clusters as storage backend for the topology data.

To configure a `consul` installation, let's start with the global cell service. It is described by the address of a server, and by the root node path to put the Vitess data in (it cannot start with `/`). For instance, assuming we want to use servers `global_server:global_port` with node path `vitess/global`:

```
# Set the following flags to let Vitess use this global server,
# and simplify the example below:
# -topo_implementation consul
# -topo_global_server_address global_server:global_port
# -topo_global_root vitess/global
TOPOLOGY="-topo_implementation consul -topo_global_server_address global_server:global_port
   -topo_global_root vitess/global
```

Then to add a cell whose local topology service `cell1_server1:cell1_port` will store their data under the directory `vitess/cell1`:

```
# Reference cell1 in the global topology service:
# (the TOPOLOGY variable is defined in the previous section)
vtctl $TOPOLOGY AddCellInfo \
  -server_address cell1_server1:cell1_port \
  -root vitess/cell1 \
  cell1
```

If only one cell is used, the same consul instances can be used for both global and local data. A local cell record still needs to be created, just use the same server address and, very importantly, a *different* root node path.

Implementation details For locks, we use a file named `Lock` in the directory to lock, and the regular Consul Lock API.

Master elections use a single lock file (the Election path) and the regular Consul Lock API. The contents of the lock file is the ID of the current master.

Watches use the Consul long polling Get call. They cannot be interrupted, so we use a long poll whose duration is set by the `-topo_consul_watch_poll_duration` flag. Canceling a watch may have to wait until the end of a polling cycle with that duration before returning.

Running in only one cell

The topology service is meant to be distributed across multiple cells, and survive single cell outages. However, one common usage is to run a Vitess cluster in only one cell / region. This part explains how to do this, and later on upgrade to multiple cells / regions.

If running in a single cell, the same topology service can be used for both global and local data. A local cell record still needs to be created, just use the same server address and, very importantly, a *different* root node path.

In that case, just running 3 servers for topology service quorum is probably sufficient. For instance, 3 etcd servers. And use their address for the local cell as well. Let's use a short cell name, like `local`, as the local data in that topology service will later on be moved to a different topology service, which will have the real cell name.

Extending to more cells To then run in multiple cells, the current topology service needs to be split into a global instance and one local instance per cell. Whereas, the initial setup had 3 topology servers (used for global and local data), we recommend to run 5 global servers across all cells (for global topology data) and 3 local servers per cell (for per-cell topology data).

To migrate to such a setup, start by adding the 3 local servers in the second cell and run `vtctl AddCellinfo` as was done for the first cell. Tablets and vtgates can now be started in the second cell, and used normally.

vtgate can then be configured with a list of cells to watch for tablets using the `-cells_to_watch` command line parameter. It can then use all tablets in all cells to route traffic. Note this is necessary to access the master in another cell.

After the extension to two cells, the original topo service contains both the global topology data, and the first cell topology data. The more symmetrical configuration we are after would be to split that original service into two: a global one that only contains the global data (spread across both cells), and a local one to the original cells. To achieve that split:

- Start up a new local topology service in that original cell (3 more local servers in that cell).
- Pick a name for that cell, different from `local`.
- Use `vtctl AddCellInfo` to configure it.
- Make sure all vtgates can see that new local cell (again, using `-cells_to_watch`).
- Restart all vttablets to be in that new cell, instead of the `local` cell name used before.
- Use `vtctl RemoveKeyspaceCell` to remove all mentions of the `local` cell in all keyspaces.
- Use `vtctl RemoveCellInfo` to remove the global configurations for that `local` cell.
- Remove all remaining data in the global topology service that are in the old local server root.

After this split, the configuration is completely symmetrical:

- a global topology service, with servers in all cells. Only contains global topology data about Keyspaces, Shards and VSchema. Typically it has 5 servers across all cells.
- a local topology service to each cell, with servers only in that cell. Only contains local topology data about Tablets, and roll-ups of global data for efficient access. Typically, it has 3 servers in each cell.

Migration between implementations

We provide the `topo2topo` utility to migrate between one implementation and another of the topology service.

The process to follow in that case is:

- Start from a stable topology, where no resharding or reparenting is ongoing.
- Configure the new topology service so it has at least all the cells of the source topology service. Make sure it is running.
- Run the `topo2topo` program with the right flags. `-from_implementation`, `-from_root`, `-from_server` describe the source (old) topology service. `-to_implementation`, `-to_root`, `-to_server` describe the destination (new) topology service.
- Run `vtctl RebuildKeyspaceGraph` for each keyspace using the new topology service flags.
- Run `vtctl RebuildVSchemaGraph` using the new topology service flags.
- Restart all `vtgate` processes using the new topology service flags. They will see the same Keyspaces / Shards / Tablets / VSchema as before, as the topology was copied over.
- Restart all `vttablet` processes using the new topology service flags. They may use the same ports or not, but they will update the new topology when they start up, and be visible from `vtgate`.
- Restart all `vtctld` processes using the new topology service flags. So that the UI also shows the new data.

Sample commands to migrate from deprecated `zookeeper` to `zk2` topology would be:

```
# Let's assume the zookeeper client config file is already
# exported in $ZK_CLIENT_CONFIG, and it contains a global record
# pointing to: global_server1,global_server2
# an a local cell cell1 pointing to cell1_server1,cell1_server2
#
# The existing directories created by Vitess are:
# /zk/global/vt/...
# /zk/cell1/vt/...
#
# The new zk2 implementation can use any root, so we will use:
# /vitess/global in the global topology service, and:
# /vitess/cell1 in the local topology service.

# Create the new topology service roots in global and local cell.
zk -server global_server1,global_server2 touch -p /vitess/global
zk -server cell1_server1,cell1_server2 touch -p /vitess/cell1

# Store the flags in a shell variable to simplify the example below.
TOPOLOGY="-topo_implementation zk2 -topo_global_server_address
   global_server1,global_server2 -topo_global_root /vitess/global"

# Reference cell1 in the global topology service:
vtctl $TOPOLOGY AddCellInfo \
  -server_address cell1_server1,cell1_server2 \
  -root /vitess/cell1 \
  cell1

# Now copy the topology. Note the old zookeeper implementation does not need
# any server or root parameter, as it reads ZK_CLIENT_CONFIG.
topo2topo \
  -from_implementation zookeeper \
```

```
  -to_implementation zk2 \
  -to_server global_server1,global_server2 \
  -to_root /vitess/global \

# Rebuild SvrKeyspace objects in new service, for each keyspace.
vtctl $TOPOLOGY RebuildKeyspaceGraph keyspace1
vtctl $TOPOLOGY RebuildKeyspaceGraph keyspace2

# Rebuild SrvVSchema objects in new service.
vtctl $TOPOLOGY RebuildVSchemaGraph

# Now restart all vtgate, vttablet, vtctld processes replacing:
# -topo_implementation zookeeper
# With:
# -topo_implementation zk2
# -topo_global_server_address global_server1,global_server2
# -topo_global_root /vitess/global
#
# After this, the ZK_CLIENT_CONF file and environment variables are not needed
# any more.
```

Migration using the `Tee` implementation If your migration is more complex, or has special requirements, we also support a 'tee' implementation of the topo service interface. It is defined in `go/vt/topo/helpers/tee.go`. It allows communicating to two topo services, and the migration uses multiple phases:

- Start with the old topo service implementation we want to replace.
- Bring up the new topo service, with the same cells.
- Use `topo2topo` to copy the current data from the old to the new topo.
- Configure a `Tee` topo implementation to maintain both services.
  - Note we do not expose a plugin for this, so a small code change is necessary.
  - all updates will go to both services.
  - the `primary` topo service is the one we will get errors from, if any.
  - the `secondary` topo service is just kept in sync.
  - at first, use the old topo service as `primary`, and the new one as `secondary`.
  - then, change the configuration to use the new one as `primary`, and the old one as `secondary`. Reverse the lock order here.
  - then rollout a configuration to just use the new service.

Transport Security Model

Vitess exposes a few RPC services and internally uses RPCs. These RPCs can optionally utilize secure transport options to use TLS over the gRPC HTTP/2 transport protocol. This document explains how to use these features. Finally, we briefly cover how to secure the MySQL protocol transport to VTGate.

Overview

The following diagram represents all the RPCs we use in a Vitess cluster via gRPC:

There are two main categories:

- Internal RPCs: They are used to connect Vitess components.
- Externally visible RPCs: They are used by the app to talk to Vitess. Note that it is not necessary to use this gRPC interface. It is still possible to instead use the MySQL protocol to VTGate, which is not covered in this document.

A few features in the Vitess ecosystem depend on authentication including Caller ID and table ACLs.

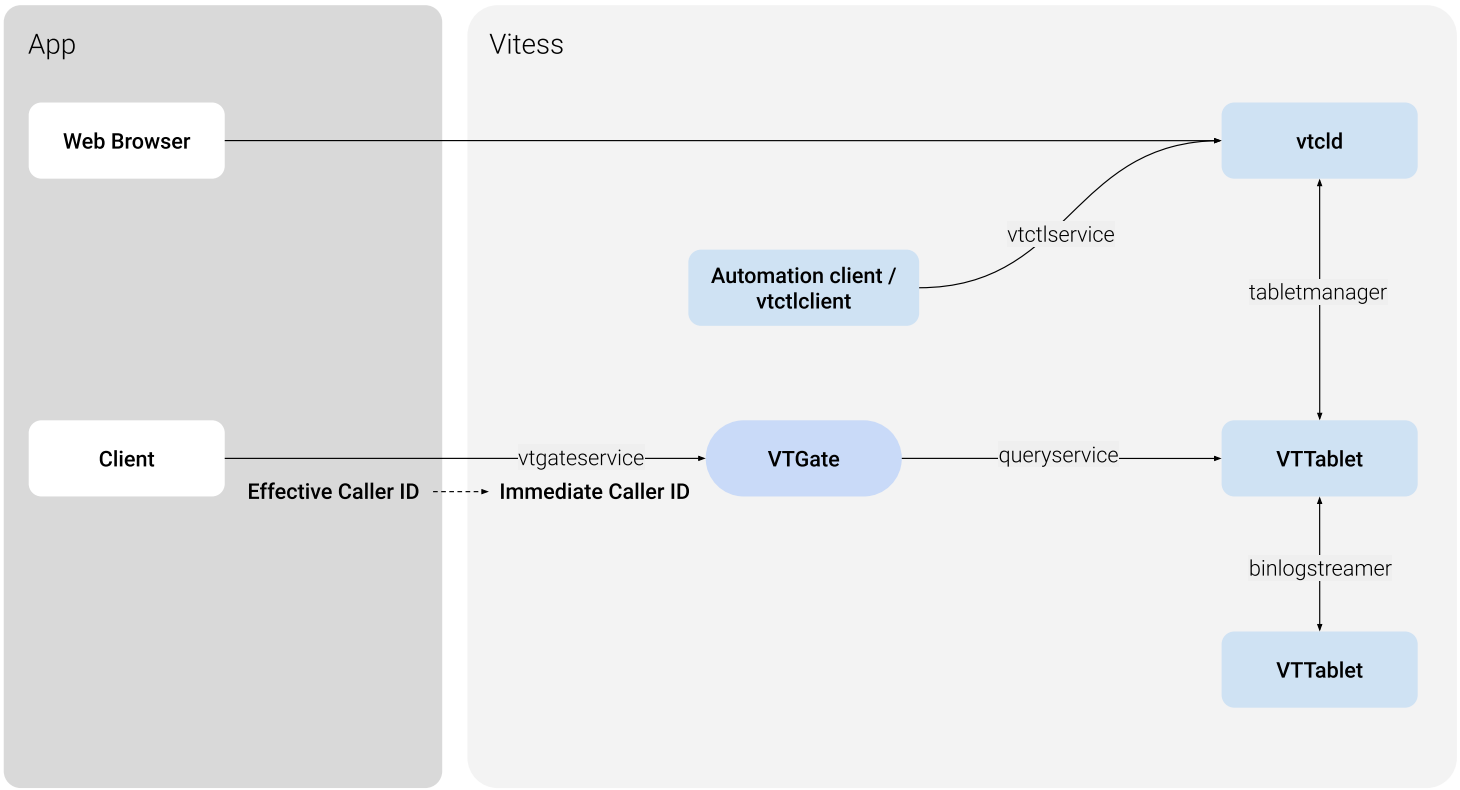

Figure 3: Vitess Transport Security Model Diagram

Caller ID

Caller ID is a feature provided by the Vitess stack to identify the source of queries. There are two different Caller IDs:

- Immediate Caller ID: It represents the secure client identity when it enters the Vitess side:
  - It is a single string representing the user connecting to Vitess (VTGate).
  - It is authenticated by the transport layer used.
  - It can be used by the Vitess TableACL feature.
- Effective Caller ID: It provides detailed information on the individual caller process:
  - It contains more information about the caller: principal, component, and sub-component.
  - It is provided by the application layer.
  - It is not authenticated.
  - It is exposed in query logs. Enabling it can be useful for debugging issues like the source of a slow query.

gRPC Transport

gRPC Encrypted Transport When using gRPC transport, Vitess can use the usual TLS security features. Please note that familiarity with TLS is necessary here:

- Any Vitess server can be configured to use TLS with the following command line parameters:
  - `grpc_cert`, `grpc_key`: server cert and key to use.
  - `grpc_ca` (optional): client cert chains to trust. If specified, the client must then use a certificate signed by one of the CA certs in the provided file.
- A Vitess go client can be configured with symmetrical parameters to enable TLS:

- `xxxx_grpc_ca`: list of server cert signers to trust. I.E. the client will only connect to servers presenting a cert signed by one of the CAs in this file.
- `xxxx_grpc_server_name`: common name of the server cert to trust. Instead of the hostname used to connect or IP SAN if using an IP to connect.
- `xxxx_grpc_cert`, `xxxx_grpc_key`: client side cert and key to use in cases when the server requires client authentication.
- Other clients can take similar parameters, in various ways. Please view each client's parameters for more information.

With these options, it is possible to use TLS-secured connections for all parts of the gRPC system. This enables the server side to authenticate the client, and/or the client to authenticate the server.

This is not enabled by default, as usually the different Vitess servers will run on a private network. It is also important to note, that in a Cloud environment, for example, usually all local traffic is already secured between VMs.

Options for vtctld

Name	Type	Definition
-tablet_grpc_ca	string	the server ca to use to validate servers when connecting
-tablet_grpc_cert	string	the cert to use to connect
-tablet_grpc_key	string	the key to use to connect
-tablet_grpc_server_name	string	the server name to use to validate server certificate
-tablet_manager_grpc_ca	string	the server ca to use to validate servers when connecting
-tablet_manager_grpc_cert	string	the cert to use to connect
-tablet_manager_grpc_key	string	the key to use to connect
-tablet_manager_grpc_server_name	string	the server name to use to validate server certificate
-throttler_client_grpc_ca	string	the server ca to use to validate servers when connecting
-throttler_client_grpc_cert	string	the cert to use to connect
-throttler_client_grpc_key	string	the key to use to connect
-throttler_client_grpc_server_name	string	the server name to use to validate server certificate
-vtgate_grpc_ca	string	the server ca to use to validate servers when connecting
-vtgate_grpc_cert	string	the cert to use to connect
-vtgate_grpc_key	string	the key to use to connect
-vtgate_grpc_server_name	string	the server name to use to validate server certificate
-vtworker_client_grpc_ca	string	the server ca to use to validate servers when connecting
-vtworker_client_grpc_cert	string	the cert to use to connect
-vtworker_client_grpc_key	string	the key to use to connect
-vtworker_client_grpc_server_name	string	the server name to use to validate server certificate

Options for vtgate

Name	Type	Definition
-tablet_grpc_ca	string	the server ca to use to validate servers when connecting
-tablet_grpc_cert	string	the cert to use to connect

Name	Type	Definition
-tablet_grpc_key	string	the key to use to connect
-tablet_grpc_server_name	string	the server name to use to validate server certificate

Options for vttablet

Name	Type	Definition
-binlog_player_grpc_ca	string	the server ca to use to validate servers when connecting
-binlog_player_grpc_cert	string	the cert to use to connect
-binlog_player_grpc_key	string	the key to use to connect
-binlog_player_grpc_server_name	string	the server name to use to validate server certificate
-tablet_grpc_ca	string	the server ca to use to validate servers when connecting
-tablet_grpc_cert	string	the cert to use to connect
-tablet_grpc_key	string	the key to use to connect
-tablet_grpc_server_name	string	the server name to use to validate server certificate
-tablet_manager_grpc_ca	string	the server ca to use to validate servers when connecting
-tablet_manager_grpc_cert	string	the cert to use to connect
-tablet_manager_grpc_key	string	the key to use to connect
-tablet_manager_grpc_server_name	string	the server name to use to validate server certificate

Certificates and Caller ID Additionally, if a client uses a certificate to connect to Vitess (VTGate) via gRPC, the common name of that certificate is passed to vttablet as the Immediate Caller ID. It can then be used by table ACLs to grant read, write or admin access to individual tables. This should be used if different clients should have different access to Vitess tables.

Caller ID Override In a private network, where TLS security is not required, it might still be desirable to use table ACLs as a safety mechanism to prevent a user from accessing sensitive data. The gRPC connector provides the `grpc_use_effective_callerid` flag for this purpose: if specified when running vtgate, the Effective Caller ID's principal is copied into the Immediate Caller ID, and then used throughout the Vitess stack.

Important: This is not secure. Any user code can provide any value for the Effective Caller ID's principal, and therefore access any data. This is intended as a safety feature to make sure some applications do not misbehave. Therefore, this flag is not enabled by default.

Example For a concrete example, see encrypted_transport_test.go in the source tree.

It first sets up all the certificates, some table ACLs, and then uses the golang client to connect with TLS. It also exercises the `grpc_use_effective_callerid` flag, by connecting without TLS.

MySQL Transport to VTGate

To get VTGate to support TLS use the `-mysql_server_ssl_cert` and `-mysql_server_ssl_key` VTGate options. To require client certificates, you can set `-mysql_server_ssl_ca`, containing the CA certificate you expect the client TLS certificates to be verified against.

Finally, if you want to require all VTGate clients to only be able to connect using TLS, you can use the `-mysql_server_require_secure_` flag.

Two-Phase Commit

{{< warning >}} Transaction commit is much slower when using 2PC. The authors of Vitess recommend that you design your VSchema so that cross-shard updates (and 2PC) are not required. {{< /warning >}}

Vitess 2PC allows you to perform atomic distributed commits. The feature is implemented using traditional MySQL transactions, and hence inherits the same guarantees. With this addition, Vitess can be configured to support the following three levels of atomicity:

1. **Single database**: At this level, only single database transactions are allowed. Any transaction that tries to go beyond a single database will fail.
2. **Multi database**: A transaction can span multiple databases, but the commit will be best effort. Partial commits are possible.
3. **2PC**: This is the same as Multi-database, but the commit will be atomic.

2PC commits are more expensive than multi-database because the system has to save away the statements before starting the commit process, and also clean them up after a successful commit. This is the reason why it is a separate option instead of being always on.

Isolation

2PC transactions guarantee atomicity: either the whole transaction commits, or it is rolled back entirely. It does not guarantee Isolation (in the ACID sense). This means that a third party that performs cross-database reads can observe partial commits while a 2PC transaction is in progress.

Guaranteeing ACID Isolation is very contentious and has high costs. Providing it by default would have made Vitess impractical for the most common use cases.

Configuring VTGate The atomicity policy is controlled by the `transaction_mode` flag. The default value is multi, and will set it in multi-database mode. This is the same as the previous legacy behavior.

To enforce single-database transactions, the VTGates can be started by specifying `transaction_mode=single`.

To enable 2PC, the VTGates need to be started with `transaction_mode=twopc`. The VTTablets will require additional flags, which will be explained below.

The VTGate `transaction_mode` flag decides what to allow. The application can independently request a specific atomicity for each transaction. The request will be honored by VTGate only if it does not exceed what is allowed by the `transaction_mode`. For example, `transaction_mode=single` will only allow single-db transactions. On the other hand, `transaction_mode=twopc` will allow all three levels of atomicity.

Driver APIs

The way to request atomicity from the application is driver-specific.

MySQL Protocol Clients can set the transaction mode via a session-variable:

```
set transaction_mode='twopc';
```

gRPC Clients

Go driver For the Go driver, you request the atomicity by adding it to the context using the WithAtomicity function. For more details, please refer to the respective GoDocs.

Python driver For Python, the begin function of the cursor has an optional single_db flag. If the flag is True, then the request is for a single-db transaction. If False (or unspecified), then the following commit call's twopc flag decides if the commit is 2PC or Best Effort (multi).

Adding support in a new driver The VTGate RPC API extends the Begin and Commit functions to specify atomicity. The API mimics the Python driver: The BeginRequest message provides a single_db flag and the CommitRequest message provides an atomic flag which is synonymous to twopc.

Configuring VTTablet

The following flags need to be set to enable 2PC support in VTTablet:

- **twopc_enable**: This flag needs to be turned on.
- **twopc_coordinator_address**: This should specify the address (or VIP) of the VTGate that VTTablet will use to resolve abandoned transactions.
- **twopc_abandon_age**: This is the time in seconds that specifies how long to wait before asking a VTGate to resolve an abandoned transaction.

With the above flags specified, every master VTTablet also turns into a watchdog. If any 2PC transaction is left lingering for longer than twopc_abandon_age seconds, then VTTablet invokes VTGate and requests it to resolve it. Typically, the abandon_age needs to be substantially longer than the time it takes for a typical 2PC commit to complete (10s of seconds).

Configuring MySQL

The usual default values of MySQL are sufficient. However, it is important to verify that the `wait_timeout` (28800) has not been changed. If this value was changed to be too short, then MySQL could prematurely kill a prepared transaction causing data loss.

Monitoring

A few additional variables have been added to /debug/vars. Failures described below should be rare. But these variables are present so you can build an alert mechanism if anything were to go wrong.

Critical failures

The following errors are not expected to happen. If they do, it means that 2PC transactions have failed to commit atomically:

- **InternalErrors.TwopcCommit**: This is a counter that shows the number of times a prepared transaction failed to fulfil a commit request.
- **InternalErrors.TwopcResurrection**: This counter is incremented if a new master failed to resurrect a previously prepared (and unresolved) transaction.

Alertable failures

The following failures are not urgent, but require investigation:

- **InternalErrors.WatchdogFail**: This counter is incremented if there are failures in the watchdog thread of VTTablet. This means that the watchdog is not able to alert VTGate of abandoned transactions.
- **Unresolved.Prepares**: This is a gauge that is set based on the number of lingering Prepared transactions that have been alive for longer than 5x the abandon age. This usually means that a distributed transaction has repeatedly failed to resolve. A more serious condition is when the metadata for a distributed transaction has been lost and this Prepare is now permanently orphaned.

Repairs

If any of the alerts fire, it is time to investigate. Once you identify the dtid or the VTTablet that originated the alert, you can navigate to the /twopcz URL. This will display three lists:

- **Failed Transactions**: A transaction reaches this state if it failed to commit. The only action allowed for such transactions is that you can discard it. However, you can record the DMLs that were involved and have someone come up with a plan to repair the partial commit.
- **Prepared Transactions**: Prepared transactions can be rolled back or committed. Prepared transactions must be remedied only if their root Distributed Transaction has been lost or resolved.
- **Distributed Transactions**: Distributed transactions can only be Concluded (marked as resolved).

Vindexes

A Vindex maps column values to keyspace IDs

A Vindex provides a way to map a column value to a `keyspace ID`. Since each shard in Vitess covers a range of `keyspace ID` values, this mapping can be used to identify which shard contains a row. A variety of vindexes are available to choose from with different trade-offs, and you can choose one that best suits your needs.

The Sharding Key is a concept that was introduced by NoSQL datastores. It is based on the fact that, in NoSQL databases, there is only one access path to the data, which is the Key. However, relational databases are more versatile with respect to the data stored and their relationships. So, sharding a database by only designating a single sharding key is often insufficient.

If one were to draw an analogy, the indexes in a database would be the equivalent of the key in a NoSQL datastore, except that databases allow multiple indexes per table, and there are many types of indexes. Extending this analogy to a sharded database results in different types of cross-shard indexes. In Vitess, these are called Vindexes.

Advantages

The advantages of Vindexes stem from their flexibility:

- A table can have multiple Vindexes.
- Vindexes can be NonUnique, which allows a column value to yield multiple keyspace IDs.
- Vindexes can be a simple function or be based on a lookup table.
- Vindexes can be shared across multiple tables.
- Custom Vindexes can be created and used, and Vitess will still know how to reshard using such Vindexes.

The Primary Vindex The Primary Vindex for a table is analogous to a database primary key. Every sharded table must have one defined. A Primary Vindex must be unique: given an input value, it must produce a single keyspace ID. At the time of an insert to the table, the unique mapping produced by the Primary Vindex determines the target shard for the inserted row. Conceptually, this is equivalent to a NoSQL Sharding Key, and we often informally refer to the Primary Vindex as the Sharding Key.

However, there is a subtle difference: NoSQL datastores allow a choice of the Sharding Key, but the Sharding Strategy or Function is generally hardcoded in the engine. In Vitess, the choice of Vindex allows control of how a column value maps to a keyspace ID. In other words, a Primary Vindex in Vitess not only defines the Sharding Key, but also decides the Sharding Strategy.

Uniqueness for a Primary Vindex does not mean that the column has to be a primary key or unique key in the MySQL schema for the underlying shard. You can have multiple rows that map to the same keyspace ID. The Vindex uniqueness constraint only ensures that all rows for a keyspace ID end up in the same shard.

Vindexes come in many varieties. Some of them can be used as Primary Vindex, and others have different purposes. We will describe their properties in the Predefined Vindexes section.

Secondary Vindexes Secondary Vindexes are additional vindexes against other columns of a table offering optimizations for WHERE clauses that do not use the Primary Vindex. Secondary Vindexes return a single or a limited set of `keyspace IDs` which will allow VTGate to only target shards where the relevant data is present. In the absence of a Secondary Vindex, VTGate would have to send the query to all shards (called a scatter query).

It is important to note that Secondary Vindexes are only used for making routing decisions. The underlying database shards will most likely need traditional indexes on those same columns, to allow efficient retrieval from the table on the underlying MySQL instances.

Unique and NonUnique Vindex A Unique Vindex is a vindex that yields at most one keyspace ID for a given input. Knowing that a Vindex is Unique is useful because VTGate can push down certain complex queries into VTTablet if it knows that the scope of that query can be limited to a single shard. Uniqueness is also a prerequisite for a Vindex to be used as Primary Vindex.

A NonUnique Vindex is analogous to a database non-unique index. It is a secondary index for searching by an alternate WHERE clause. An input value could yield multiple keyspace IDs, and rows could be matched from multiple shards. For example, if a table has a `name` column that allows duplicates, you can define a cross-shard NonUnique Vindex for it, and this will allow an efficient search for users that match a certain `name`.

Functional and Lookup Vindex A **Functional Vindex** is a vindex where the column value to keyspace ID mapping is pre-established, typically through an algorithmic function. In contrast, a **Lookup Vindex** is a vindex that provides the ability to create an association between a value and a keyspace ID, and recall it later when needed. Lookup Vindexes are sometimes also informally referred to as cross-shard indexes.

Typically, the Primary Vindex for a table is Functional. In some cases, it is the identity function where the input value yields itself as the keyspace id. However, other algorithms like a hashing function can also be used.

A Lookup Vindex is implemented as a MySQL lookup table that maps a column value to the keyspace id. This is usually needed when database user needs to efficiently find a row using a WHERE clause that does not contain the Primary Vindex. At the time of insert, the computed keyspace ID of the row is stored in the lookup table against the column value.

Lookup Vindex types The lookup table that implements a Lookup Vindex can be sharded or unsharded. Note that the lookup row is most likely not going to be in the same shard as the keyspace id it points to.

Vitess allows for the transparent population of these lookup table rows by assigning an owner table, which is the main table that requires this lookup. When a row is inserted into this owner table, the lookup row for it is created in the lookup table. The lookup row is also deleted upon a delete of the corresponding row in the owner table. These essentially result in distributed transactions, which traditionally require 2PC to guarantee atomicity.

Consistent lookup vindexes use an alternate approach that makes use of careful locking and transaction sequences to guarantee consistency without using 2PC. This gives the best of both worlds, with the benefit of a consistent cross-shard vindex without paying the price of 2PC.

There are currently two vindex types in Vitess for consistent lookup: * `consistent_lookup_unique` * `consistent_lookup`

Shared Vindexes Relational databases encourage normalization, which allows the splitting of data into different tables to avoid duplication in the case of one-to-many relationships. In such cases, a key is shared between the two tables to indicate that the rows are related, a.k.a. `Foreign Key`.

In a sharded environment, it is often beneficial to keep those rows in the same shard. If a Lookup Vindex was created on the foreign key column of each of those tables, the backing tables would actually be identical. In such cases, Vitess allows sharing a single Lookup Vindex for multiple tables. One of these tables is designated as the owner of the Lookup Vindex, and is responsible for creating and deleting these associations. The other tables just reuse these associations.

An existing `lookup_unique` vindex can be trivially switched to a `consistent_lookup_unique` by changing the vindex type in the VSchema. This is because the data is compatible. Caveat: If you delete a row from the owner table, Vitess will not perform cascading deletes. This is mainly for efficiency reasons; the application is likely capable of doing this more efficiently.

As for a `lookup` vindex, it can be changed it to a `consistent_lookup` only if the `from` columns can uniquely identify the owner row. Without this, many potentially valid inserts would fail.

Functional Vindexes can be also be shared. However, there is no concept of ownership because the column to keyspace ID mapping is pre-established.

Lookup Vindex guidance The guidance for implementing lookup vindexes has been to create a two-column table. The first column (`from` column) should match the type of the column of the main table that needs the vindex. The second column (`to` column) should be a `BINARY` or a `VARBINARY` large enough to accommodate the keyspace id.

This guidance remains the same for unique lookup vindexes.

For non-unique lookup Vindexes, the lookup table should consist of multiple columns. The first column continues to be the input for computing the keyspace IDs. Beyond this, additional columns are needed to uniquely identify the owner row. This should typically be the primary key of the owner table. But it can be any other column that can be combined with the `from` column to uniquely identify the owner row. The last column remains the keyspace ID like before.

For example, if a user table had the columns `(user_id, email)`, where `user_id` was the primary key and `email` needed a non-unique lookup vindex, the lookup table would have the columns `(email, user_id, keyspace_id)`.

Indepedence The previously described properties are mostly independent of each other. Combining them gives rise to the following valid categories:

- **Functional Unique**: The most popular category because it is the one best suited to be a Primary Vindex.
- **Functional NonUnique**: There are currently no use cases that need this category.
- **Lookup Unique Owned**: Used for optimizing high QPS read queries that do not use the Primary Vindex columns in their WHERE clause. There is a price to pay: an extra write to the lookup table for insert and delete operations, and an extra lookup for read operations. However, it may be worth it to avoid high QPS read queries to be sent to all shards. The overheard of maintaining the lookup table is amortized as the number of shards grow.
- **Lookup Unique Unowned**: Can be used as an optimization as described in the Shared Vindexes section.
- **Lookup NonUnique Owned**: Used for high QPS queries on columns that are non-unique.
- **Lookup NonUnique Unowned**: You would rarely have to use this category because it is unlikely that you will be using a column as foreign key that is not unique within a shard. But it is theoretically possible.

Of the above categories, `Functional Unique` and `Lookup Unique Unowned` Vindexes can be a Primary Vindex. This is because those are the only ones that are unique and have the column to keyspace ID mapping pre-established. This is required because the Primary Vindex is responsible for assigning the keyspace ID for a row when it is created.

However, it is generally not recommended to use a Lookup Vindex as a Primary Vindex because it is too slow for resharding. If absolutely unavoidable, it is recommended to add a `keyspace ID` column to the tables that need this level of control of the row-to-shard mapping. While resharding, Vitess can use that column to efficiently compute the target shard. Vitess can also be configured to auto-populate that column on inserts. This is done using the reverse map feature explained below.

How Vindexes are used

Cost Vindexes have costs. For routing a query, the applicable Vindex with the lowest cost is chosen. The current general costs for the different Vindex Types are as follows:

Vindex Type	Cost
Identity	0
Functional	1
Lookup Unique	10
Lookup NonUnique	20

Select In the case of a simple select, Vitess scans the WHERE clause to match references to Vindex columns and chooses the best one to use. If there is no match and the query is simple without complex constructs like aggregates, etc., it is sent to all shards.

Vitess can handle more complex queries. For now, refer to the design doc for background information on how it handles them.

Insert

- The Primary Vindex is used to generate a keyspace ID.
- The keyspace ID is validated against the rest of the Vindexes on the table. There must exist a mapping from the column value(s) for these Secondary Vindexes to the keyspace ID.
- If a column value was not provided for a Vindex and the Vindex is capable of reverse mapping a keyspace ID to an input value, that function is used to auto-fill the column. If there is no reverse map, it is an error.

Update The WHERE clause is used to route the update. Updating the value of a Vindex column is supported, but with a restriction: the change in the column value should not result in the row being moved from one shard to another. A workaround is to perform a delete followed by insert, which works as expected.

Delete If the table owns lookup vindexes, then the rows to be deleted are first read and the associated Vindex entries are deleted. Following this, the query is routed according to the WHERE clause.

Predefined Vindexes Vitess provides the following predefined Vindexes:

Name	Type	Description	Primary	Reversible	Cost	Data types
binary	Functional Unique	Identity	Yes	Yes	0	Any
binary_md5	Functional Unique	MD5 hash	Yes	No	1	Any
consistent_lookup	Lookup NonUnique	Lookup table non-unique values	No	No	20	Any
consistent_lookup_unique	Lookup Unique	Lookup table unique values	If unowned	No	10	Any
hash	Functional Unique	DES null-key hash	Yes	Yes	1	64 bit or smaller numeric or equivalent type
lookup	Lookup NonUnique	Lookup table non-unique values	No	No	20	Any
lookup_unique	Lookup Unique	Lookup table unique values	If unowned	No	10	Any
null	Functional Unique	Always map to keyspace ID 0	Yes	No	100	Any
numeric	Functional Unique	Identity	Yes	Yes	0	64 bit or smaller numeric or equivalent type
numeric_static_map	Functional Unique	JSON file statically mapping input string values to keyspace IDs	Yes	No	1	Any
region_experimental	Functional Unique	Multi-column prefix-based hash for use in geo-partitioning	Yes	No	1	String and numeric type

Name	Type	Description	Primary	Reversible	Cost	Data types
region_json	Functional Unique	Multi-column prefix-based hash combined with a JSON map for key-to-region mapping, for use in geo-partitioning	Yes	No	1	String and numeric type
reverse_bits	Functional Unique	Bit reversal	Yes	Yes	1	64 bit or smaller numeric or equivalent type
unicode_loose_md5	Functional Unique	Case-insensitive (UCA level 1) MD5 hash	Yes	No	1	String or binary types
unicode_loose_xxhash	Functional Unique	Case-insensitive (UCA level 1) xxHash64 hash	Yes	No	1	String or binary types
xxhash	Functional Unique	xxHash64 hash	Yes	No	1	Any

Consistent lookup vindexes, as described above, are a new category of Vindexes that are meant to replace the existing lookup Vindexes implementation. For the time being, they have a different name to allow for users to switch back and forth.

Custom Vindexes can also be created as needed. At the moment there is no formal plugin system for custom Vindexes, but the interface is well-defined, and thus custom implementations including code performing arbitary lookups in other systems can be accomodated.

There are also the following legacy (deprecated) Vindexes. **Do not use these**:

Name	Type	Primary	Reversible	Cost
lookup_hash	Lookup NonUnique	No	No	20
lookup_hash_unique	Lookup Unique	If unowned	No	10
lookup_unicodeloosemd5_hash	Lookup NonUnique	No	No	20
lookup_unicodeloosemd5_hash_unique	Lookup Unique	If unowned	No	10

Sequences

This document describes the Vitess Sequences feature, and how to use it.

Motivation

MySQL provides the `auto-increment` feature to assign monotonically incrementing IDs to a column in a table. However, when a table is sharded across multiple instances, maintaining the same feature is a lot more tricky.

Vitess Sequences fill that gap:

- Inspired from the usual SQL sequences (implemented in different ways by Oracle, SQL Server and PostgreSQL).
- Very high throughput for ID creation, using a configurable in-memory block allocation.
- Transparent use, similar to MySQL auto-increment: when the field is omitted in an `insert` statement, the next sequence value is used.

When *not* to Use Auto-Increment

Before we go any further, an auto-increment column has limitations and drawbacks. let's explore this topic a bit here.

Security Considerations Using auto-increment can leak confidential information about a service. Let's take the example of a web site that store user information, and assign user IDs to its users as they sign in. The user ID is then passed in a cookie for all subsequent requests.

The client then knows their own user ID. It is now possible to:

- Try other user IDs and expose potential system vulnerabilities.
- Get an approximate number of users of the system (using the user ID).
- Get an approximate number of sign-ins during a week (creating two accounts a week apart, and diffing the two IDs).

Auto-incrementing IDs should be reserved for either internal applications, or exposed to the clients only when safe.

Alternatives Alternative to auto-incrementing IDs are:

- use a 64 bits random generator number. Try to insert a new row with that ID. If taken (because the statement returns an integrity error), try another ID.
- use a UUID scheme, and generate truely unique IDs.

Now that this is out of the way, let's get to MySQL auto-increment.

MySQL Auto-increment Feature

Let's start by looking at the MySQL auto-increment feature:

- A row that has no value for the auto-increment value will be given the next ID.
- The current value is stored in the table metadata.
- Values may be 'burned' (by rolled back transactions).
- Inserting a row with a given value that is higher than the current value will set the current value.
- The value used by the master in a statement is sent in the replication stream, so replicas will have the same value when re-playing the stream.
- There is no strict guarantee about ordering: two concurrent statements may have their commit time in one order, but their auto-incrementing ID in the opposite order (as the value for the ID is reserved when the statement is issued, not when the transaction is committed).
- MySQL has multiple options for auto-increment, like only using every N number (for multi-master configurations), or performance related features (locking that table's current ID may have concurrency implications).
- When inserting a row in a table with an auto-increment column, if the value for the auto-increment row is not set, the value for the column is returned to the client alongside the statement result.

Vitess Sequences

An early design was to use a single unsharded database and a table with an auto-increment value to generate new values. However, this has serious limitations, in particular throughtput, and storing one entry for each value in that table, for no reason.

So we decided instead to base sequences on a MySQL table, and use a single value in that table to describe which values the sequence should have next. To increase performance, we also support block allocation of IDs: each update to the MySQL table is only done every N IDs (N being configurable), and in between only memory structures in vttablet are updated, making the QPS only limited by RPC latency.

The sequence table then is an unsharded single row table that Vitess can use to generate monotonically increasing ids. The VSchema allows you to associate a column of a table with the sequence table. Once they are associated, an insert on that table will transparently fetch an id from the sequence table, fill in the value, and route the row to the appropriate shard.

Since sequences are unsharded tables, they will be stored in the database (in our tutorial example, this is the commerce database).

The final goal is to have Sequences supported with SQL statements, like:

```
/* DDL support */
CREATE SEQUENCE my_sequence;

SELECT NEXT VALUE FROM my_sequence;

ALTER SEQUENCE my_sequence ...;

DROP SEQUENCE my_sequence;

SHOW CREATE SEQUENCE my_sequence;
```

In the current implementation, we support the query access to Sequences, but not the administration commands yet.

Creating a Sequence *Note*: The names in this section are extracted from the examples/demo sample application.

To create a Sequence, a backing table must first be created and initialized with a single row. The columns for that table have to be respected.

This is an example:

```
create table user_seq(id int, next_id bigint, cache bigint, primary key(id)) comment
   'vitess_sequence';

insert into user_seq(id, next_id, cache) values(0, 1, 100);
```

Then, the Sequence has to be defined in the VSchema for that keyspace:

```
{
  "sharded": false,
  "tables": {
    "user_seq": {
      "type": "sequence"
    },
    ...
  }
}
```

And the table it is going to be using it can also reference the Sequence in its VSchema:

```
{
  ...
  "tables" : {
    "user": {
```

```
      "column_vindexes": [
          ...
      ],
      "auto_increment": {
        "column": "user_id",
        "sequence": "user_seq"
      }
    },
```

After this done (and the Schema has been reloaded on master tablet, and the VSchema has been pushed), the sequence can be used.

Accessing a Sequence If a Sequence is used to fill in a column for a table, nothing further needs to be done. Just sending no value for the column will make vtgate insert the next Sequence value in its place.

It is also possible to access the Sequence directly with the following SQL constructs:

```
/* Returns the next value for the sequence */
select next value from my_sequence;

/* Returns the next value for the sequence, and also reserve 4 values after that. */
select next 5 values from my_sequence;
```

VReplication

VReplication is a core component of Vitess that can be used to compose many features. It can be used for the following use cases:

- **Resharding**: Legacy workflows of vertical and horizontal resharding. New workflows of resharding from an unsharded to a sharded keyspace and vice-versa. Resharding from an unsharded to an unsharded keyspace using a different vindex than the source keyspace.
- **Materialized Views**: You can specify a materialization rule that creates a view of the source table into a target keyspace. This materialization can use a different primary vindex than the source. It can also materialize a subset of the source columns, or add new expressions from the source. This view will be kept up-to-date in real time. One can also materialize reference tables onto all shards and have Vitess perform efficient local joins with those materialized tables.
- **Realtime rollups**: The materialization expression can include aggregation expressions in which case, Vitess will create a rolled up version of the source table which can be used for realtime analytics.
- **Backfilling lookup vindexes**: VReplication can be used to backfill a newly created lookup vindex. Workflows can be built to manage the switching from a backfill mode to the vindex itself keeping it up-to-date.
- **Schema deployment**: We can use VReplication to recreate the workflow performed by gh-ost and thereby support zero-downtime schema deployments in Vitess natively.
- **Data migration**: VReplication can be setup to migrate data from an existing system into Vitess. The replication could also be reversed after a cutover giving you the option to rollback a migration if something went wrong.
- **Change notification**: The streamer component of VReplication can be used for the application or a systems operator to subscribe to change notification and use it to keep downstream systems up-to-date with the source.

The VReplication feature itself is a fairly low level one that is expected to be used as a building block for the above use cases. However, it's still possible to directly issue commands to do some of the activities.

Feature description

VReplication works as a stream or combination of streams. Each stream establishes a replication from a source keyspace/shard into a target keyspace/shard.

A given stream can replicate multiple tables. For each table, you can specify a `select` statement that represents both the transformation rule and the filtering rule. The select expressions specify the transformation, and the where clause specifies the filtering.

The select expressions can be any non-aggregate MySQL expression, or they can also be `count` or `sum` as aggregate expressions. Aggregate expressions combined with the corresponding `group by` clauses will allow you to materialize real-time rollups of the source table, which can be used for analytics. The target table can have a different name from the source.

For a sharded system like Vitess, multiple VReplication streams may be needed to achieve the necessary goals. This is because there will be multiple source shards as well as destination shards, and the relationship between them may not be one to one.

VReplication performs the following essential functions:

- Copy data from the source to the destination table in a consistent fashion. For large data, this copy can be long-running. It can be interrupted and resumed. If interrupted, VReplication can keep the copied portion up-to-date with respect to the source, and it can resume the copy process at a point that's consistent with the current replication position.
- After copying is finished, it can continuously replicate the data from the source to destination.
- The copying rule can be expressed as a `select` statement. The statement should be simple enough that the materialized table can be kept up-to-date from the data coming from the binlog. For example, joins are not supported.
- Correctness verification: VReplication can verify that the target table is an exact representation of the select statement from the source by capturing consistent snapshots of the source and target and comparing them against each other. This step can be done without the need to create special snapshot replicas.
- Journaling: If there is any kind of traffic cut-over where we start writing to a different table than we used to before, VReplication will save the current binlog positions into a journal table. This can be used by other streams to resume replication from the new source.
- Routing rules: Although this feature is itself not a direct functionality of VReplication, it works hand in hand with it. It allows you to specify sophisticated rules about where to route queries depending on the type of workflow being performed. For example, it can be used to control the cut-over during resharding. In the case of materialized views, it can be used to establish equivalence of tables, which will allow VTGate to compute the most optimal plans given the available options.

VReplicationExec

The `VReplicationExec` command is used to manage vreplication streams. The commands are issued as SQL statements. For example, a `select` can be used to see the current list of streams. An `insert` can be used to create one, etc. By design, the metadata for vreplication streams are stored in a `vreplication` table in the `vt` database. VReplication uses the 'pull' model. This means that a stream is created on the target side, and the target pulls the data by finding the appropriate source.

The table schema is as follows:

```
CREATE TABLE _vt.vreplication (
  id INT AUTO_INCREMENT,
  workflow VARBINARY(1000),
  source VARBINARY(10000) NOT NULL,
  pos VARBINARY(10000) NOT NULL,
  stop_pos VARBINARY(10000) DEFAULT NULL,
  max_tps BIGINT(20) NOT NULL,
  max_replication_lag BIGINT(20) NOT NULL,
  cell VARBINARY(1000) DEFAULT NULL,
  tablet_types VARBINARY(100) DEFAULT NULL,
  time_updated BIGINT(20) NOT NULL,
  transaction_timestamp BIGINT(20) NOT NULL,
  state VARBINARY(100) NOT NULL,
  message VARBINARY(1000) DEFAULT NULL,
  db_name VARBINARY(255) NOT NULL,
  PRIMARY KEY (id)
)
```

The fields are explained in the following section.

This is the syntax of the command:

```
VReplicationExec [-json] <tablet alias> <sql command>
```

Here's an example of the command to list all existing streams for a given tablet.

```
lvtctl.sh VReplicationExec 'tablet-100' 'select * from _vt.vreplication'
```

Creating a stream It's generally easier to send the VReplication command programmatically instead of a bash script. This is because of the number of nested encodings involved:

- One of the arguments is an SQL statement, which can contain quoted strings as values.
- One of the strings in the SQL statement is a string encoded protobuf, which can contain quotes.
- One of the parameters within the protobuf is an SQL select expression for the materialized view.

However, you can use vreplgen.go to generate a fully escaped bash command.

Alternately, you can use a python program. Here's an example:

```
cmd = [
  './lvtctl.sh',
  'VReplicationExec',
  'test-200',
  """insert into _vt.vreplication
  (db_name, source, pos, max_tps, max_replication_lag, tablet_types, time_updated,
     transaction_timestamp, state) values
  ('vt_keyspace', 'keyspace:"lookup" shard:"0" filter:<rules:<match:"uproduct"
     filter:"select * from product" > >', '', 99999, 99999, 'master', 0, 0, 'Running')""",
]
```

The first argument to the command is the master tablet id of the target keyspace/shard.

The second argument is the SQL command. To start a new stream, you need an insert statement. The parameters are as follows:

- `db_name`: This name must match the name of the MySQL database. In the future, this will not be required, and will be automatically filled in by the vttablet.
- `source`: The protobuf representation of the stream source, explained below.
- `pos`: For a brand new stream, this should be empty. To start from a specific position, a flavor-encoded position must be specified. A typical position would look like this `MySQL56/ac6c45eb-71c2-11e9-92ea-0a580a1c1026:1-1296`.
- `max_tps`: 99999, reserved.
- `max_replication_lag`: 99999, reserved.
- `tablet_types`: specifies a comma separated list of tablet types to replicate from. If empty, the default tablet type specified by the `-vreplication_tablet_type` command line flag is used.
- `time_updated`: 0, reserved.
- `transaction_timestamp`: 0, reserved.
- `state`: 'Running' or 'Stopped'.
- `cell`: is an optional parameter that specifies the cell from which the stream can be sourced.

The source field The source field is a proto-encoding of the following structure:

```
message BinlogSource {
  // the source keyspace
  string keyspace = 1;
  // the source shard
  string shard = 2;
  // list of filtering rules
  Filter filter = 6;
  // what to do if a DDL is encountered
  OnDDLAction on_ddl = 7;
```

```
}

message Filter {
  repeated Rule rules = 1;
}

message Rule {
  // match can be a table name or a regular expression
  // delineated by '/' and '/'.
  string match = 1;
  // filter can be an empty string or keyrange if the match
  // is a regular expression. Otherwise, it must be a select
  // query.
  string filter = 2;
}

enum OnDDLAction {
  IGNORE = 0;
  STOP = 1;
  EXEC = 2;
  EXEC_IGNORE = 3;
}
```

Here are some examples of proto encodings:

```
keyspace:"lookup" shard:"0" filter:<rules:<match:"uproduct" filter:"select * from product"
   > >
```

Meaning: replicate all columns and rows of product from `lookup/0.product` into the `uproduct` table in target keyspace.

```
keyspace:"user" shard:"-80" filter:<rules:<match:"morder" filter:"select * from uorder
   where in_keyrange(mname, \\'unicode_loose_md5\\', \\'-80\\')" > >
```

The double-backslash for the strings inside the select will first be escaped by the python script, which will cause the expression to internally be `\'unicode_loose_md5\'`. Since the entire source is surrounded by single quotes when being sent as a value inside the outer insert statement, the single `\` will escape the single quotes that follow. The final value in the source will therefore be:

```
keyspace:"user" shard:"-80" filter:<rules:<match:"morder" filter:"select * from uorder
   where in_keyrange(mname, 'unicode_loose_md5', '-80')" > >
```

Meaning: replicate all columns of `user/-80.uorder` where `unicode_loose_md5(mname)` is within `-80` keyrange, into `morder`.

This particular stream generally wouldn't make sense in isolation. This would typically be one of four streams that combine together to create a materialized view of `uorder` from the `user` keyspace into the target (`merchant`) keyspace, but sharded by using `mname` as the primary vindex. The vindex used would be `unicode_loose_md5` which should also match the primary vindex of other tables in the target keyspace.

```
keyspace:"user" shard:"-80" filter:<rules:<match:"sales" filter:"select pid, count(*) as
   kount, sum(price) as amount from uorder group by pid" > >
```

Meaning: create a materialized view of `user/-80.uorder` into `sales` of the target keyspace using the expression: `select pid, count(*)as kount, sum(price)as amount from uorder group by pid`.

This represents only one stream from source shard `-80`. Presumably, there will be one more for the other `-80` shard.

The 'select' features The select statement has the following features (and restrictions):

- The Select expressions can be any deterministic MySQL expression. Subqueries are not supported. Among aggregate expressions, only `count(*)` and `sum(col)` are supported.

- The where clause can only contain the `in_keyrange` construct. It has two forms:
  - `in_keyrange('-80')`: The row's source keyrange matched against `-80`.
  - `in_keyrange(col, 'hash', '-80')`: The keyrange is computed using `hash(col)` and matched against `-80`.
- `group by`: can be specified if using aggregations. The group by expressions are expected to cover the non-aggregated columns just like regular SQL requires.
- No other constructs like `order by`, `limit`, joins, etc. are allowed.

The pos field For starting a brand new vreplication stream, the `pos` field must be empty. The empty string signifies that there's no starting point for the vreplication. This causes VReplication to copy the contents of the source table first, and then start the replication.

For large tables, this is done in chunks. After each chunk is copied, replication is resumed until it's caught up. VReplication ensures that only changes that affect existing rows are applied. Following this another chunk is copied, and so on, until all tables are completed. After that, replication runs indefinitely.

It's a shared row The vreplication row is shared between the operator and Vreplication itself. Once the row is created, the VReplication stream updates various fields of the row to save and report on its own status. For example, the `pos` field is continuously updated as it makes forward progress.

While copying, the `state` field is updated as `Init` or `Copying`.

Updating a stream You can change any field of the stream by issuing a `VReplicationExec` with an `update` statement. You are required to specify the id of the row you intend to update. You can only update one row at a time.

Typically, you can update the row and change the state to `Stopped` to stop a stream, or to `Running` to restart a stopped stream.

You can also update the row to set a `stop_pos`, which will make the replication stop once it reaches the specified position.

Deleting a stream You can delete a stream by issuing a `delete` statement. This will stop the replication and delete the row. This statement is destructive. All data about the replication state will be permanently deleted.

Other properties of VReplication

Fast replay VReplication has the capability to batch transactions if the send rate of the source exceeds the replay rate of the destination. This allows it to catch up very quickly when there is a backlog. Load tests have shown a 3-20X improvement over traditional MySQL replication depending on the workload.

Accurate lag tracking The source vttablet sends its current time along with every event. This allows the target to correct for clock skew while estimating replication lag. Additionally, the source starts sending heartbeats if there is nothing to send. If the target receives no events from the source at all, it knows that it's definitely lagged and starts reporting itself accordingly.

Self-replication VReplication allows you to set the source keyspace/shard to be the same as the target. This is especially useful for performing schema rollouts: you can create the target table with the intended schema and vreplicate from the source table to the new target. Once caught up, you can cutover to write to the target table. In this situation, an apply on the target generates a binlog event that will be picked up by the source and sent to the target. Typically, it will be an empty transaction. In such cases, the target does not generally apply these transactions, because such an application will generate yet another event. However, there are situations where one needs to apply empty transactions, especially if it's a required stopping point. VReplication can differentiate between these situations and apply events only as needed.

Deadlocks and lock wait timeouts It is possible that multiple streams can conflict with each other and cause deadlocks or lock waits. When such things happen, VReplication silently retries such transactions without reporting an error. It does increment a counter so that the frequency of such occurrences can be tracked.

Automatic retries If any other error is encountered, the replication is retried after a short wait. Each time, the stream searches from the full list of available sources and picks one at random.

on_ddl The source specification allows you to specify a value for `on_ddl`. This allows you to specify what to do with DDL SQL statements when they are encountered in the replication stream from the source. The values can be as follows:

- `IGNORE`: Ignore all DDLs (this is also the default, if a value for `on_ddl` is not provided).
- `STOP`: Stop when DDL is encountered. This allows you to make any necessary changes to the target. Once changes are made, updating the state to `Running` will cause VReplication to continue from just after the point where it encountered the DDL.
- `EXEC`: Apply the DDL, but stop if an error is encountered while applying it.
- `EXEC_IGNORE`: Apply the DDL, but ignore any errors and continue replicating.

Failover continuation If a failover is performed on the target keyspace/shard, the new master will automatically resume VReplication from where the previous master left off.

Monitoring and troubleshooting

VTTablet /debug/status The first place to look at is the `/debug/status` page of the target master vttablet. The bottom of the page shows the status of all the VReplication streams.

Typically, if there is a problem, the `Last Message` column will display the error. Sometimes, it's possible that the stream cannot find a source. If so, the `Source Tablet` would be empty.

VTTablet logfile If the errors are not clear or if they keep disappearing, the VTTablet logfile will contain information about what it's been doing with each stream.

VReplicationExec select The current status of the streams can also be fetched by issuing a VReplicationExec command with `select * from _vt.vreplication`.

Monitoring variables VReplication also reports the following variables that can be scraped by monitoring tools like prometheus:

- VReplicationStreamCount: Number of VReplication streams.
- VReplicationSecondsBehindMasterMax: Max vreplication seconds behind master.
- VReplicationSecondsBehindMaster: vreplication seconds behind master per stream.
- VReplicationSource: The source for each VReplication stream.
- VReplicationSourceTablet: The source tablet for each VReplication stream.

Thresholds and alerts can be set to draw attention to potential problems.

VSchema

VSchemas describe how to shard data

VSchema stands for Vitess Schema. In contrast to a traditional database schema that contains metadata about tables, a VSchema contains metadata about how tables are organized across keyspaces and shards. Simply put, it contains the information needed to make Vitess look like a single database server.

For example, the VSchema will contain the information about the sharding key for a sharded table. When the application issues a query with a WHERE clause that references the key, the VSchema information will be used to route the query to the appropriate shard.

Sharded keyspaces require a VSchema

A VSchema is needed to tie together all the databases that Vitess manages. For a very trivial setup where there is only one unsharded keyspace, there is no need to specify a VSchema because Vitess will know that there is no other place to route a query.

If you have multiple unsharded keyspaces, you can still avoid defining a VSchema in one of two ways:

1. Connect to a keyspace and all queries are sent to it.
2. Connect to Vitess without specifying a keyspace, but use qualified names for tables, like `keyspace.table` in your queries.

However, once the setup exceeds the above complexity, VSchemas become a necessity. Vitess has a working demo of VSchemas.

Sharding Model

In Vitess, a `keyspace` is sharded by `keyspace ID` ranges. Each row is assigned a keyspace ID, which acts like a street address, and it determines the shard where the row lives. In some respect, one could say that the `keyspace ID` is the equivalent of a NoSQL sharding key. However, there are some differences:

1. The `keyspace ID` is a concept that is internal to Vitess. The application does not need to know anything about it.
2. There is no physical column that stores the actual `keyspace ID`. This value is computed as needed.

This difference is significant enough that we do not refer to the keyspace ID as the sharding key. A Primary Vindex more closely resembles the NoSQL sharding key.

Mapping to a `keyspace ID`, and then to a shard, gives us the flexibility to reshard the data with minimal disruption because the `keyspace ID` of each row remains unchanged through the process.

Vindexes

The Vschema contains the Vindex for any sharded tables. The Vindex tells Vitess where to find the shard that contains a particular row for a sharded table. Every VSchema must have at least one Vindex, called the Primary Vindex, defined. The Primary Vindex is unique: given an input value, it produces a single keyspace ID, or value in the keyspace used to shard the table. The Primary Vindex is typically a functional Vindex: Vitess computes the keyspace ID as needed from a column in the sharded table.

Sequences

Auto-increment columns do not work very well for sharded tables. Vitess sequences solve this problem. Sequence tables must be specified in the VSchema, and then tied to table columns. At the time of insert, if no value is specified for such a column, VTGate will generate a number for it using the sequence table.

Reference tables

Vitess allows you to create an unsharded table and deploy it into all shards of a sharded keyspace. The data in such a table is assumed to be identical for all shards. In this case, you can specify that the table is of type `reference`, and should not specify any vindex for it. Any joins of this table with an unsharded table will be treated as a local join.

Typically, such a table has a canonical source in an unsharded keyspace, and the copies in the sharded keyspace are kept up-to-date through VReplication.

Configuration

The configuration of your VSchema reflects the desired sharding configuration for your database, including whether or not your tables are sharded and whether you want to implement a secondary Vindex.

Unsharded Table The following snippets show the necessary configs for creating a table in an unsharded keyspace:

Schema:

```
# lookup keyspace
create table name_user_idx(name varchar(128), user_id bigint, primary key(name, user_id));
```

VSchema:

```
// lookup keyspace
{
  "sharded": false,
  "tables": {
    "name_user_idx": {}
  }
}
```

For a normal unsharded table, the VSchema only needs to know the table name. No additional metadata is needed.

Sharded Table With Simple Primary Vindex To create a sharded table with a simple Primary Vindex, the VSchema requires more information:

Schema:

```
# user keyspace
create table user(user_id bigint, name varchar(128), primary key(user_id));
```

VSchema:

```
// user keyspace
{
  "sharded": true,
  "vindexes": {
    "hash": {
      "type": "hash"
    }
  },
  "tables": {
    "user": {
      "column_vindexes": [
        {
          "column": "user_id",
          "name": "hash"
        }
      ]
    }
  }
}
```

Because Vindexes can be shared, the JSON requires them to be specified in a separate `vindexes` section, and then referenced by name from the `tables` section. The VSchema above simply states that `user_id` uses `hash` as Primary Vindex. The first Vindex of every table must be the Primary Vindex.

Specifying A Sequence Since user is a sharded table, it will be beneficial to tie it to a Sequence. However, the sequence must be defined in the lookup (unsharded) keyspace. It is then referred from the user (sharded) keyspace. In this example, we are designating the `user_id` (Primary Vindex) column as the auto-increment.

Schema:

```
# lookup keyspace
create table user_seq(id int, next_id bigint, cache bigint, primary key(id)) comment
    'vitess_sequence';
insert into user_seq(id, next_id, cache) values(0, 1, 3);
```

For the sequence table, `id` is always 0. `next_id` starts off as 1, and the cache is usually a medium-sized number like 1000. In our example, we are using a small number to showcase how it works.

VSchema:

```
// lookup keyspace
{
  "sharded": false,
  "tables": {
    "user_seq": {
      "type": "sequence"
    }
  }
}

// user keyspace
{
  "sharded": true,
  "vindexes": {
    "hash": {
      "type": "hash"
    }
  },
  "tables": {
    "user": {
      "column_vindexes": [
        {
          "column": "user_id",
          "name": "hash"
        }
      ],
      "auto_increment": {
        "column": "user_id",
        "sequence": "user_seq"
      }
    }
  }
}
```

Specifying A Secondary Vindex The following snippet shows how to configure a Secondary Vindex that is backed by a lookup table. In this case, the lookup table is configured to be in the unsharded lookup keyspace:

Schema:

```
# lookup keyspace
create table name_user_idx(name varchar(128), user_id bigint, primary key(name, user_id));
```

VSchema:

```
// lookup keyspace
{
  "sharded": false,
  "tables": {
```

```
    "name_user_idx": {}
  }
}

// user keyspace
{
  "sharded": true,
  "vindexes": {
    "name_user_idx": {
      "type": "lookup_hash",
      "params": {
        "table": "name_user_idx",
        "from": "name",
        "to": "user_id"
      },
      "owner": "user"
    }
  },
  "tables": {
    "user": {
      "column_vindexes": [
        {
          "column": "name",
          "name": "name_user_idx"
        }
      ]
    }
  }
}
```

To recap, a checklist for creating the shared Secondary Vindex is:

- Create physical `name_user_idx` table in lookup database.
- Define a routing for it in the lookup VSchema.
- Define a Vindex as type `lookup_hash` that points to it. Ensure that the `params` match the table name and columns.
- Define the owner for the Vindex as the `user` table.
- Specify that `name` uses the Vindex.

Currently, these steps have to be currently performed manually. However, extended DDLs backed by improved automation will simplify these tasks in the future.

Advanced usage The examples/demo also shows more tricks you can perform:

- The `music` table uses a secondary lookup vindex `music_user_idx`. However, this lookup vindex is itself a sharded table.
- `music_extra` shares `music_user_idx` with `music`, and uses it as Primary Vindex.
- `music_extra` defines an additional Functional Vindex called `keyspace_id` which the demo auto-populates using the reverse mapping capability.
- There is also a `name_info` table that showcases a case-insensitive Vindex `unicode_loose_md5`.

MySQL Compatibility

VTGate servers speak both gRPC and the MySQL server protocol. This allows you to connect to Vitess as if it were a MySQL Server without any changes to application code. This document refers to known compatibility issues where Vitess differs from MySQL.

Transaction Model

Vitess provides `READ COMMITTED` semantics when executing cross-shard queries. This differs to MySQL, which defaults to `REPEATABLE READ`.

SQL Syntax

The following describes some of the major differences in SQL Syntax handling between Vitess and MySQL. For a list of unsupported queries, check out the test-suite cases.

DDL Vitess supports MySQL DDL, and will send `ALTER TABLE` statements to each of the underlying tablet servers. For large tables it is recommended to use an external schema deployment tool and apply directly to the underlying MySQL shard instances. This is discussed further in Applying MySQL Schema.

Join Queries Vitess supports `INNER JOIN` including cross-shard joins. `LEFT JOIN` is supported as long as there are not expressions that compare columns on the outer table to the inner table in sharded keyspaces.

Aggregation Vitess supports a subset of `GROUP BY` operations, including cross-shard operations. The VTGate servers are capable of scatter-gather operations, but can only stream results. Thus, a query that performs a `GROUP BY colx ORDER BY coly` may be refused if the intermediate result set is larger than VTGate's in-memory limit.

Subqueries Vitess supports a subset of subqueries. For example, a subquery combined with a `GROUP BY` operation is not supported.

Stored Procedures Vitess does not yet support MySQL Stored Procedures.

Window Functions and CTEs Vitess does not yet support Window Functions or Common Table Expressions.

Killing running queries Vitess does not yet support killing running shard queries via the `KILL` command through VTGate. Vitess does have strict query timeouts for OLTP workloads (see below). If you need a query, you can connect to the underlying MySQL shard instance and run `KILL` from there.

Cross-shard Transactions By default, Vitess does not support transactions that span across shards. While Vitess can support this with the use of Two-Phase Commit, it is usually recommended to design the VSchema in such a way that cross-shard modifications are not required.

OLAP Workload By default, Vitess sets some intentional restrictions on the execution time and number of rows that a query can return. This default workload mode is called `OLTP`. This can be disabled by setting the workload to `OLAP`:

```
SET workload='olap'
```

SELECT ... INTO Statement The `SELECT ... INTO` form of `SELECT` in MySQL enables a query result to be stored in variables or written to a file. Vitess supports `SELECT ... INTO DUMFILE` and `SELECT ... INTO OUTFILE` constructs for unsharded keyspaces but does not support storing results in variable. Moreover, the position of `INTO` must be towards the end of the query and not in the middle. An example of a correct query is as follows:

```
SELECT * FROM <tableName> INTO OUTFILE 'x.txt' FIELDS TERMINATED BY ';' OPTIONALLY ENCLOSED
   BY '"' ESCAPED BY '\t' LINES TERMINATED BY ' '
```

For sharded keyspaces this statement can still be used but only after specifying the exact shard with a USE Statement.

LOAD DATA Statement `LOAD DATA` is the complement of `SELECT ... INTO OUTFILE` that reads rows from a text file into a table at a very high speed. Just like `SELECT ... INTO` statement, `LOAD DATA` is also supported in unsharded keyspaces. An example of a correct query is as follows:

```
LOAD DATA INFILE 'x.txt' INTO REPLACE TABLE <tableName> FIELDS TERMINATED BY ';' OPTIONALLY
   ENCLOSED BY '"' ESCAPED BY '\t' LINES TERMINATED BY ' '
```

For sharded keyspaces this statement can still be used but only after specifying the exact shard with a USE Statement.

Network Protocol

Prepared Statements Starting with version 4.0, Vitess features experimental support for prepared statements via the MySQL protocol. Session-based commands using the `PREPARE` and `EXECUTE` SQL statements are not supported.

Authentication Plugins Vitess supports the `mysql_native_password` authentication plugin. Support for `caching_sha2_password` can be tracked in #5399.

Transport Security To configure VTGate to support `TLS` set `-mysql_server_ssl_cert` and `-mysql_server_ssl_key`. Client certificates can also be mandated by setting `-mysql_server_ssl_ca`. If there is no CA specified then TLS is optional.

Temporary Tables

Vitess does not support the use of temporary tables.

Character Set and Collation

Vitess only supports `utf8` and variants such as `utf8mb4`.

SQL Mode

Vitess behaves similar to the `STRICT_TRANS_TABLES` sql mode, and does not recommend changing the SQL Mode setting.

Data Types

Vitess supports all of the data types available in MySQL. Using the `FLOAT` data type as part of a `PRIMARY KEY` is strongly discouraged, since features such as filtered replication and VReplication will not correctly be able to detect which rows should be included as part of a modification.

Auto Increment

Tables in sharded keyspaces do not support the `auto_increment` column attribute, as the values generated would be local only to each shard. Vitess Sequences are provided as an alternative, which have very close semantics to `auto_increment`.

Extensions to MySQL Syntax

SHOW Statements Vitess supports a few additional options with the SHOW statement.

- `SHOW keyspaces` – A list of keyspaces available.
- `SHOW vitess_tablets` – Information about the current Vitess tablets such as the keyspace, key ranges, tablet type, hostname, and status.
- `SHOW vitess_shards` – A list of shards that are available.

- `SHOW vschema tables` – A list of tables available in the current keyspace's vschema.
- `SHOW vschema vindexes` – Information about the current keyspace's vindexes such as the keyspace, name, type, params, and owner. Optionally supports an "ON" clause with a table name.

USE Statements Vitess allows you to select a keyspace using the MySQL `USE` statement, and corresponding binary API used by client libraries. SQL statements can refer to a table in another keyspace by using the standard *dot* notation:

```
SELECT * FROM my_other_keyspace.table;
```

Vitess extends this functionality further by allowing you to select a specific shard and tablet-type within a `USE` statement (backticks are important):

```
-- `KeyspaceName:shardKeyRange@tabletType`
USE `mykeyspace:-80@rdonly`
```

A similar effect can be achieved by using a database name like `mykeyspace:-80@rdonly` in your MySQL application client connection string.

Programs

description: Reference documents for list of Vitess programs

mysqlctl

`mysqlctl` is a command-line tool used for starting `mysqld` binaries. It is responsible for bootstrapping tasks such as generating a configuration file for `mysqld` and ensuring that `mysql_upgrade` is run in the data directory when restoring from backup.

`mysqld_safe` will be also be utilized when present. This helps ensure that `mysqld` is automatically restarted after failures.

Commands

init [-wait_time=5m] [-init_db_sql_file=(default)] Bootstraps a new `mysqld` instance. The MySQL version and flavor will be auto-detected, with a minimal configuration file applied. For example:

```
export VTDATAROOT=/tmp
mysqlctl \
 -alsologtostderr \
 -tablet_uid 101 \
 -mysql_port 12345 \
 init
```

init_config Bootstraps the configuration for a new `mysqld` instance. This command is the same as `init` except the `mysqld` server will not be started. For example:

```
export VTDATAROOT=/tmp
mysqlctl \
 -alsologtostderr \
 -tablet_uid 101 \
 -mysql_port 12345 \
 init_config
```

reinit_config Regenerate new configuration files for an existing `mysqld` instance. This could be helpful to revert configuration changes, or to pick up changes made to the bundled config in newer Vitess versions. For example:

```
export VTDATAROOT=/tmp
mysqlctl \
 -alsologtostderr \
 -tablet_uid 101 \
 -mysql_port 12345 \
 reinit_config
```

teardown [-wait_time=5m] [-force] Remove the data files for a previously shutdown `mysqld` instance. This is a destructive operation:

```
export VTDATAROOT=/tmp
mysqlctl -tablet_uid 101 -alsologtostderr teardown
```

start [-wait_time=5m] Resume an existing `mysqld` instance that was previously bootstrapped with `init` or `init_config`:

```
export VTDATAROOT=/tmp
mysqlctl -tablet_uid 101 -alsologtostderr start
```

shutdown [-wait_time=5m] Stop a `mysqld` instance that was previously started with `init` or `start`.

For large `mysqld` instances, you may need to extend the `-wait_time` as flushing dirty pages.

```
export VTDATAROOT=/tmp
mysqlctl -tablet_uid 101 -alsologtostderr shutdown
```

Options

The following global parameters apply to `mysqlctl`:

Name	Type	Definition
alsologtostderr	boolean	log to standard error as well as files
app_idle_timeout	duration	Idle timeout for app connections (default 1m0s)
app_pool_size	int	Size of the connection pool for app connections (default 40)
backup_engine_implementation	string	Specifies which implementation to use for creating new backups (builtin or xtrabackup). Restores will always be done with whichever engine created a given backup. (default “builtin”)
backup_storage_block_size	int	if backup_storage_compress is true, backup_storage_block_size sets the byte size for each block while compressing (default is 250000). (default 250000)
backup_storage_compress	boolean	if set, the backup files will be compressed (default is true). Set to false for instance if a backup_storage_hook is specified and it compresses the data. (default true)
backup_storage_hook	string	if set, we send the contents of the backup files through this hook.

Name	Type	Definition
backup_storage_implementation	string	which implementation to use for the backup storage feature
backup_storage_number_blocks	int	if backup_storage_compress is true, backup_storage_number_blocks sets the number of blocks that can be processed, at once, before the writer blocks, during compression (default is 2). It should be equal to the number of CPUs available for compression (default 2)
cpu_profile	string	write cpu profile to file
datadog-agent-host	string	host to send spans to. if empty, no tracing will be done
datadog-agent-port	string	port to send spans to. if empty, no tracing will be done
db-credentials-file	string	db credentials file; send SIGHUP to reload this file
db-credentials-server	string	db credentials server type (use 'file' for the file implementation) (default "file")
db_charset	string	Character set. Only utf8 or latin1 based character sets are supported.
db_connect_timeout_ms	int	connection timeout to mysqld in milliseconds (0 for no timeout)
db_dba_password	string	db dba password
db_dba_use_ssl	boolean	Set this flag to false to make the dba connection to not use ssl (default true)
db_dba_user	string	db dba user userKey (default "vt_dba")
db_flags	uint	Flag values as defined by MySQL.
db_flavor	string	Flavor overrid. Valid value is FilePos.
db_host	string	The host name for the tcp connection.
db_port	int	tcp port
db_server_name	string	server name of the DB we are connecting to.
db_socket	string	The unix socket to connect on. If this is specified, host and port will not be used.
db_ssl_ca	string	connection ssl ca
db_ssl_ca_path	string	connection ssl ca path
db_ssl_cert	string	connection ssl certificate
db_ssl_key	string	connection ssl key
dba_idle_timeout	duration	Idle timeout for dba connections (default 1m0s)
dba_pool_size	int	Size of the connection pool for dba connections (default 20)
disable_active_reparents	boolean	if set, do not allow active reparents. Use this to protect a cluster using external reparents.
emit_stats	boolean	true iff we should emit stats to push-based monitoring/stats backends
grpc_auth_mode	string	Which auth plugin implementation to use (eg: static)
grpc_auth_mtls_allowed_substrings	string	List of substrings of at least one of the client certificate names (separated by colon).

Name	Type	Definition
grpc_auth_static_client_creds	string	when using grpc_static_auth in the server, this file provides the credentials to use to authenticate with server
grpc_auth_static_password_file	string	JSON File to read the users/passwords from.
grpc_ca	string	ca to use, requires TLS, and enforces client cert check
grpc_cert	string	certificate to use, requires grpc_key, enables TLS
grpc_compression	string	how to compress gRPC, default: nothing, supported: snappy
grpc_enable_tracing	boolean	Enable GRPC tracing
grpc_initial_conn_window_size	int	grpc initial connection window size
grpc_initial_window_size	int	grpc initial window size
grpc_keepalive_time	duration	After a duration of this time, if the client doesn't see any activity, it pings the server to see if the transport is still alive. (default 10s)
grpc_keepalive_timeout	duration	After having pinged for keepalive check, the client waits for a duration of Timeout and if no activity is seen even after that the connection is closed. (default 10s)
grpc_key	string	key to use, requires grpc_cert, enables TLS
grpc_max_connection_age	duration	Maximum age of a client connection before GoAway is sent. (default 2562047h47m16.854775807s)
grpc_max_connection_age_grace	duration	Additional grace period after grpc_max_connection_age, after which connections are forcibly closed. (default 2562047h47m16.854775807s)
grpc_max_message_size	int	Maximum allowed RPC message size. Larger messages will be rejected by gRPC with the error 'exceeding the max size'. (default 16777216)
grpc_port	int	Port to listen on for gRPC calls
grpc_prometheus	boolean	Enable gRPC monitoring with Prometheus
grpc_server_initial_conn_window_size	int	gRPC server initial connection window size
grpc_server_initial_window_size	int	gRPC server initial window size
grpc_server_keepalive_enforcement_policy_min_time	duration	gRPC server minimum keepalive time (default 5m0s)
grpc_server_keepalive_enforcement_policy_permit_without_stream	boolean	gRPC server permit client keepalive pings even when there are no active streams (RPCs)
jaeger-agent-host	string	host and port to send spans to. if empty, no tracing will be done
keep_logs	duration	keep logs for this long (using ctime) (zero to keep forever)
keep_logs_by_mtime	duration	keep logs for this long (using mtime) (zero to keep forever)

Name	Type	Definition
lameduck-period	duration	keep running at least this long after SIGTERM before stopping (default 50ms)
log_backtrace_at	value	when logging hits line file:N, emit a stack trace
log_dir	string	If non-empty, write log files in this directory
log_err_stacks	boolean	log stack traces for errors
log_rotate_max_size	uint	size in bytes at which logs are rotated (glog.MaxSize) (default 1887436800)
logtostderr	boolean	log to standard error instead of files
master_connect_retry	duration	how long to wait in between replica reconnect attempts. Only precise to the second. (default 10s)
mem-profile-rate	int	profile every n bytes allocated (default 524288)
mutex-profile-fraction	int	profile every n mutex contention events (see runtime.SetMutexProfileFraction)
mysql_auth_server_static_file	string	JSON File to read the users/passwords from.
mysql_auth_server_static_string	string	JSON representation of the users/passwords config.
mysql_auth_static_reload_interval	duration	Ticker to reload credentials
mysql_clientcert_auth_method	string	client-side authentication method to use. Supported values: mysql_clear_password, dialog. (default “mysql_clear_password”)
mysql_port	int	mysql port (default 3306)
mysql_server_flush_delay	duration	Delay after which buffered response will be flushed to the client. (default 100ms)
mysql_socket	string	path to the mysql socket
mysqlctl_client_protocol	string	the protocol to use to talk to the mysqlctl server (default “grpc”)
mysqlctl_mycnf_template	string	template file to use for generating the my.cnf file during server init
mysqlctl_socket	string	socket file to use for remote mysqlctl actions (empty for local actions)
onterm_timeout	duration	wait no more than this for OnTermSync handlers before stopping (default 10s)
pid_file	string	If set, the process will write its pid to the named file, and delete it on graceful shutdown.
pool_hostname_resolve_interval	duration	if set force an update to all hostnames and reconnect if changed, defaults to 0 (disabled)
port	int	vttablet port (default 6612)
purge_logs_interval	duration	how often try to remove old logs (default 1h0m0s)
remote_operation_timeout	duration	time to wait for a remote operation (default 30s)

Name	Type	Definition
security_policy	string	the name of a registered security policy to use for controlling access to URLs - empty means allow all for anyone (built-in policies: deny-all, read-only)
service_map	value	comma separated list of services to enable (or disable if prefixed with '-') Example: grpc-vtworker
sql-max-length-errors	int	truncate queries in error logs to the given length (default unlimited)
sql-max-length-ui	int	truncate queries in debug UIs to the given length (default 512) (default 512)
stats_backend	string	The name of the registered push-based monitoring/stats backend to use
stats_combine_dimensions	string	List of dimensions to be combined into a single "all" value in exported stats vars
stats_drop_variables	string	Variables to be dropped from the list of exported variables.
stats_emit_period	duration	Interval between emitting stats to all registered backends (default 1m0s)
stderrthreshold	value	logs at or above this threshold go to stderr (default 1)
tablet_dir	string	The directory within the vtdataroot to store vttablet/mysql files. Defaults to being generated by the tablet uid.
tablet_manager_protocol	string	the protocol to use to talk to vttablet (default "grpc")
tablet_uid	uint	tablet uid (default 41983)
topo_global_root	string	the path of the global topology data in the global topology server
topo_global_server_address	string	the address of the global topology server
topo_implementation	string	the topology implementation to use
tracer	string	tracing service to use (default "noop")
tracing-sampling-rate	float	sampling rate for the probabilistic jaeger sampler (default 0.1)
v	value	log level for V logs
version	boolean	print binary version
vmodule	value	comma-separated list of pattern=N settings for file-filtered logging
xbstream_restore_flags	string	flags to pass to xbstream command during restore. These should be space separated and will be added to the end of the command. These need to match the ones used for backup e.g. –compress / –decompress, –encrypt / –decrypt
xtrabackup_backup_flags	string	flags to pass to backup command. These should be space separated and will be added to the end of the command
xtrabackup_prepare_flags	string	flags to pass to prepare command. These should be space separated and will be added to the end of the command

Name	Type	Definition
xtrabackup_root_path	string	directory location of the xtrabackup executable, e.g., /usr/bin
xtrabackup_stream_mode	string	which mode to use if streaming, valid values are tar and xbstream (default "tar")
xtrabackup_stripe_block_size	uint	Size in bytes of each block that gets sent to a given stripe before rotating to the next stripe (default 102400)
xtrabackup_stripes	uint	If greater than 0, use data striping across this many destination files to parallelize data transfer and decompression
xtrabackup_user	string	User that xtrabackup will use to connect to the database server. This user must have all necessary privileges. For details, please refer to xtrabackup documentation.

vtctl Cell Aliases Command Reference

series: vtctl

The following `vtctl` commands are available for administering Cell Aliases.

Commands

AddCellsAlias Defines a group of cells within which replica/rdonly traffic can be routed across cells. By default, Vitess does not allow traffic between replicas that are part of different cells. Between cells that are not in the same group (alias), only master traffic can be routed.

Example

Flags

Name	Type	Definition
cells	string	The list of cell names that are members of this alias.

Arguments

- <alias> – Required. Alias name for this grouping.

Errors

- the <alias> argument is required for the <AddCellsAlias> command This error occurs if the command is not called with exactly one argument.

UpdateCellsAlias Updates the content of a CellAlias with the provided parameters. Empty values and intersections with other aliases are not supported.

Example

Flags

Name	Type	Definition
cells	string	The list of cell names that are members of this alias.

Arguments

- <alias> – Required. Alias name group to update.

Errors

- the <alias> argument is required for the <UpdateCellsAlias> command This error occurs if the command is not called with exactly one argument.

DeleteCellsAlias Deletes the CellsAlias for the provided alias. After deleting an alias, cells that were part of the group are not going to be able to route replica/rdonly traffic to the rest of the cells that were part of the grouping.

Example

Errors

- the <alias> argument is required for the <DeleteCellsAlias> command This error occurs if the command is not called with exactly one argument.

GetCellsAliases Fetches in json format all the existent cells alias groups.

Example

See Also

- vtctl command index

vtctl Cell Command Reference

series: vtctl

The following `vtctl` commands are available for administering Cells.

Commands

AddCellInfo Registers a local topology service in a new cell by creating the CellInfo with the provided parameters. The address will be used to connect to the topology service, and we'll put Vitess data starting at the provided root.

Example

Flags

Name	Type	Definition
root	string	The root path the topology service is using for that cell.
server_address	string	The address the topology service is using for that cell.

Arguments

- <addr> – Required.
- <cell> – Required. A cell is a location for a service. Generally, a cell resides in only one cluster. In Vitess, the terms "cell" and "data center" are interchangeable. The argument value is a string that does not contain whitespace.

Errors

- the <cell> argument is required for the <AddCellInfo> command This error occurs if the command is not called with exactly one argument.

DeleteCellInfo Deletes the CellInfo for the provided cell. The cell cannot be referenced by any Shard record.

Example

Errors

- the <cell> argument is required for the <DeleteCellInfo> command This error occurs if the command is not called with exactly one argument.

GetCellInfo Prints a JSON representation of the CellInfo for a cell.

Example

Errors

- the <cell> argument is required for the <GetCellInfo> command This error occurs if the command is not called with exactly one argument.

GetCellInfoNames Lists all the cells for which we have a CellInfo object, meaning we have a local topology service registered.

Example

Errors

- <GetCellInfoNames> command takes no parameter This error occurs if the command is not called with exactly 0 arguments.

UpdateCellInfo Updates the content of a CellInfo with the provided parameters. If a value is empty, it is not updated. The CellInfo will be created if it doesn't exist.

Example

Flags

Name	Type	Definition
root	string	The root path the topology service is using for that cell.
server_address	string	The address the topology service is using for that cell.

Arguments

- <addr> – Required.
- <cell> – Required. A cell is a location for a service. Generally, a cell resides in only one cluster. In Vitess, the terms "cell" and "data center" are interchangeable. The argument value is a string that does not contain whitespace.

Errors

- the <cell> argument is required for the <UpdateCellInfo> command This error occurs if the command is not called with exactly one argument.

GetCellInfo Prints a JSON representation of the CellInfo for a cell.

Example

Errors

- the <cell> argument is required for the <GetCellInfo> command This error occurs if the command is not called with exactly one argument.

See Also

- vtctl command index

vtctl Generic Command Reference

series: vtctl

The following generic `vtctl` commands are available for administering Vitess.

Commands

Validate Validates that all nodes reachable from the global replication graph and that all tablets in all discoverable cells are consistent.

Example

Flags

Name	Type	Definition
ping-tablets	Boolean	Indicates whether all tablets should be pinged during the validation process

ListAllTablets Lists all tablets in an awk-friendly way.

Example

Arguments

- <cell name> – Required. A cell is a location for a service. Generally, a cell resides in only one cluster. In Vitess, the terms "cell" and "data center" are interchangeable. The argument value is a string that does not contain whitespace.

Errors

- the <cell name> argument is required for the <ListAllTablets> command This error occurs if the command is not called with exactly one argument.

ListTablets Lists specified tablets in an awk-friendly way.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>. To specify multiple values for this argument, separate individual values with a space.

Errors

- the <tablet alias> argument is required for the <ListTablets> command This error occurs if the command is not called with at least one argument.

Help Provides help for a command.

```
Help [command name]
```

See Also

- vtctl command index

vtctl Keyspace Command Reference

series: vtctl

The following `vtctl` commands are available for administering Keyspaces.

Commands

CreateKeyspace Creates the specified keyspace.

Example

Flags

Name	Type	Definition
force	Boolean	Proceeds even if the keyspace already exists
served_from	string	Specifies a comma-separated list of dbtype:keyspace pairs used to serve traffic
sharding_column_name	string	Specifies the column to use for sharding operations
sharding_column_type	string	Specifies the type of the column to use for sharding operations

Arguments

- <keyspace name> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- the <keyspace name> argument is required for the <CreateKeyspace> command This error occurs if the command is not called with exactly one argument.

DeleteKeyspace Deletes the specified keyspace. In recursive mode, it also recursively deletes all shards in the keyspace. Otherwise, there must be no shards left in the keyspace.

Example

Flags

Name	Type	Definition
recursive	Boolean	Also recursively delete all shards in the keyspace.

Arguments

- <keyspace> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- must specify the <keyspace> argument for <DeleteKeyspace> This error occurs if the command is not called with exactly one argument.

RemoveKeyspaceCell Removes the cell from the Cells list for all shards in the keyspace, and the SrvKeyspace for that keyspace in that cell.

Example

Flags

Name	Type	Definition
force	Boolean	Proceeds even if the cell's topology service cannot be reached. The assumption is that you turned down the entire cell, and just need to update the global topo data.
recursive	Boolean	Also delete all tablets in that cell belonging to the specified keyspace.

Arguments

- <keyspace> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.
- <cell> – Required. A cell is a location for a service. Generally, a cell resides in only one cluster. In Vitess, the terms "cell" and "data center" are interchangeable. The argument value is a string that does not contain whitespace.

Errors

- the <keyspace> and <cell> arguments are required for the <RemoveKeyspaceCell> command This error occurs if the command is not called with exactly 2 arguments.

GetKeyspace Outputs a JSON structure that contains information about the Keyspace.

Example

Arguments

- <keyspace> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- the <keyspace> argument is required for the <GetKeyspace> command This error occurs if the command is not called with exactly one argument.

GetKeyspaces Outputs a sorted list of all keyspaces.

Errors

- the <destination keyspace/shard> and <served tablet type> arguments are both required for the <MigrateServedFrom> command This error occurs if the command is not called with exactly 2 arguments.

SetKeyspaceShardingInfo Updates the sharding information for a keyspace.

Example

Flags

Name	Type	Definition
force	Boolean	Updates fields even if they are already set. Use caution before calling this command.

Arguments

- <keyspace name> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.
- <column name> – Optional.
- <column type> – Optional.

Errors

- the <keyspace name> argument is required for the <SetKeyspaceShardingInfo> command. The <column name> and <column type> arguments are both optional This error occurs if the command is not called with between 1 and 3 arguments.
- both <column name> and <column type> must be set, or both must be unset

SetKeyspaceServedFrom Changes the ServedFromMap manually. This command is intended for emergency fixes. This field is automatically set when you call the *MigrateServedFrom* command. This command does not rebuild the serving graph.

Example

Flags

Name	Type	Definition
cells	string	Specifies a comma-separated list of cells to affect

Name	Type	Definition
remove	Boolean	Indicates whether to add (default) or remove the served from record
source	string	Specifies the source keyspace name

Arguments

- <keyspace name> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.
- <tablet type> – Required. The vttablet's role. Valid values are:
  - backup – A replicated copy of data that is offline to queries other than for backup purposes
  - batch – A replicated copy of data for OLAP load patterns (typically for MapReduce jobs)
  - drained – A tablet that is reserved for a background process. For example, a tablet used by a vtworker process, where the tablet is likely lagging in replication.
  - experimental – A replicated copy of data that is ready but not serving query traffic. The value indicates a special characteristic of the tablet that indicates the tablet should not be considered a potential master. Vitess also does not worry about lag for experimental tablets when reparenting.
  - master – A primary copy of data
  - rdonly – A replicated copy of data for OLAP load patterns
  - replica – A replicated copy of data ready to be promoted to master
  - restore – A tablet that is restoring from a snapshot. Typically, this happens at tablet startup, then it goes to its right state.
  - spare – A replicated copy of data that is ready but not serving query traffic. The data could be a potential master tablet.

Errors

- the <keyspace name> and <tablet type> arguments are required for the <SetKeyspaceServedFrom> command This error occurs if the command is not called with exactly 2 arguments.

RebuildKeyspaceGraph Rebuilds the serving data for the keyspace. This command may trigger an update to all connected clients.

Example

Flags

Name	Type	Definition
cells	string	Specifies a comma-separated list of cells to update

Arguments

- <keyspace> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace. To specify multiple values for this argument, separate individual values with a space.

Errors

- the <keyspace> argument must be used to specify at least one keyspace when calling the <RebuildKeyspaceGraph> command This error occurs if the command is not called with at least one argument.

ValidateKeyspace Validates that all nodes reachable from the specified keyspace are consistent.

Example

Flags

Name	Type	Definition
ping-tablets	Boolean	Specifies whether all tablets will be pinged during the validation process

Arguments

- <keyspace name> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- the <keyspace name> argument is required for the <ValidateKeyspace> command This error occurs if the command is not called with exactly one argument.

```
Reshard  [-skip_schema_copy] <keyspace.workflow> <source_shards> <target_shards>
Start a Resharding process. Example: Reshard -cells='zone1,alias1'
   -tablet_types='master,replica,rdonly'  ks.workflow001 '0' '-80,80-'.
```

```
MoveTables  [-cell=<cell>] [-tablet_types=<source_tablet_types>] -workflow=<workflow>
   <source_keyspace> <target_keyspace> <table_specs>
Move table(s) to another keyspace, table_specs is a list of tables or the tables section of
   the vschema for the target keyspace. Example: '{"t1":{"column_vindexes": [{"column":
   "id1", "name": "hash"}]}, "t2":{"column_vindexes": [{"column": "id2", "name":
   "hash"}]}}'.  In the case of an unsharded target keyspace the vschema for each table may
   be empty. Example: '{"t1":{}, "t2":{}}'.
```

```
DropSources  [-dry_run] <keyspace.workflow>
After a MoveTables or Resharding workflow cleanup unused artifacts like source tables,
   source shards and blacklists.
```

```
CreateLookupVindex  [-cell=<cell>] [-tablet_types=<source_tablet_types>] <keyspace>
   <json_spec>
Create and backfill a lookup vindex. the json_spec must contain the vindex and colvindex
   specs for the new lookup.
```

```
ExternalizeVindex  <keyspace>.<vindex>
Externalize a backfilled vindex.
```

```
Materialize  <json_spec>, example : '{"workflow": "aaa", "source_keyspace": "source",
   "target_keyspace": "target", "table_settings": [{"target_table": "customer",
   "source_expression": "select * from customer", "create_ddl": "copy"}]}'
Performs materialization based on the json spec. Is used directly to form VReplication
   rules, with an optional step to copy table structure/DDL.
```

```
SplitClone  <keyspace> <from_shards> <to_shards>
Start the SplitClone process to perform horizontal resharding. Example: SplitClone ks '0'
   '-80,80-'
```

```
VerticalSplitClone  <from_keyspace> <to_keyspace> <tables>
Start the VerticalSplitClone process to perform vertical resharding. Example: SplitClone
   from_ks to_ks 'a,/b.*/'
```

```
VDiff  [-source_cell=<cell>] [-target_cell=<cell>] [-tablet_types=replica]
   [-filtered_replication_wait_time=30s] <keyspace.workflow>
Perform a diff of all tables in the workflow
```

MigrateServedTypes Migrates a serving type from the source shard to the shards that it replicates to. This command also rebuilds the serving graph. The <keyspace/shard> argument can specify any of the shards involved in the migration.

Example

Flags

Name	Type	Definition
cells	string	Specifies a comma-separated list of cells to update
filtered_replication_wait_time	Duration	Specifies the maximum time to wait, in seconds, for filtered replication to catch up on master migrations
reverse	Boolean	Moves the served tablet type backward instead of forward. Use in case of trouble
skip-refresh-state	Boolean	Skips refreshing the state of the source tablets after the migration, meaning that the refresh will need to be done manually, replica and rdonly only)
reverse_replication	Boolean	For master migration, enabling this flag reverses replication which allows you to rollback

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.
- <served tablet type> – Required. The vttablet's role. Valid values are:
  - backup – A replicated copy of data that is offline to queries other than for backup purposes
  - batch – A replicated copy of data for OLAP load patterns (typically for MapReduce jobs)
  - drained – A tablet that is reserved for a background process. For example, a tablet used by a vtworker process, where the tablet is likely lagging in replication.
  - experimental – A replicated copy of data that is ready but not serving query traffic. The value indicates a special characteristic of the tablet that indicates the tablet should not be considered a potential master. Vitess also does not worry about lag for experimental tablets when reparenting.
  - master – A primary copy of data
  - rdonly – A replicated copy of data for OLAP load patterns
  - replica – A replicated copy of data ready to be promoted to master
  - restore – A tablet that is restoring from a snapshot. Typically, this happens at tablet startup, then it goes to its right state.
  - spare – A replicated copy of data that is ready but not serving query traffic. The data could be a potential master tablet.

Errors

- the <source keyspace/shard> and <served tablet type> arguments are both required for the <MigrateServedTypes> command This error occurs if the command is not called with exactly 2 arguments.
- the <skip-refresh-state> flag can only be specified for non-master migrations

MigrateServedFrom Makes the <destination keyspace/shard> serve the given type. This command also rebuilds the serving graph.

Example

Flags

Name	Type	Definition
cells	string	Specifies a comma-separated list of cells to update
filtered_replication_wait_time	Duration	Specifies the maximum time to wait, in seconds, for filtered replication to catch up on master migrations
reverse	Boolean	Moves the served tablet type backward instead of forward. Use in case of trouble

Arguments

- <destination keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.
- <served tablet type> – Required. The vttablet's role. Valid values are:

- backup – A replicated copy of data that is offline to queries other than for backup purposes
- batch – A replicated copy of data for OLAP load patterns (typically for MapReduce jobs)
- drained – A tablet that is reserved for a background process. For example, a tablet used by a vtworker process, where the tablet is likely lagging in replication.
- experimental – A replicated copy of data that is ready but not serving query traffic. The value indicates a special characteristic of the tablet that indicates the tablet should not be considered a potential master. Vitess also does not worry about lag for experimental tablets when reparenting.
- master – A primary copy of data
- rdonly – A replicated copy of data for OLAP load patterns
- replica – A replicated copy of data ready to be promoted to master
- restore – A tablet that is restoring from a snapshot. Typically, this happens at tablet startup, then it goes to its right state.
- spare – A replicated copy of data that is ready but not serving query traffic. The data could be a potential master tablet.

Errors

- the <destination keyspace/shard> and <served tablet type> arguments are both required for the <MigrateServedFrom> command This error occurs if the command is not called with exactly 2 arguments.

```
SwitchReads  [-cells=c1,c2,...] [-reverse] -tablet_type={replica|rdonly} [-dry-run]
   <keyspace.workflow>
Switch read traffic for the specified workflow.
```

```
SwitchWrites  [-filtered_replication_wait_time=30s] [-cancel] [-reverse_replication=false]
   [-dry-run] <keyspace.workflow>
Switch write traffic for the specified workflow.
```

CancelResharding Permanently cancels a resharding in progress. All resharding related metadata will be deleted.

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

ShowResharding Displays all metadata about a resharding in progress.

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

FindAllShardsInKeyspace Displays all of the shards in the specified keyspace.

Example

Arguments

- <keyspace> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- the <keyspace> argument is required for the <FindAllShardsInKeyspace> command This error occurs if the command is not called with exactly one argument.

WaitForDrain Blocks until no new queries were observed on all tablets with the given tablet type in the specified keyspace. This can be used as sanity check to ensure that the tablets were drained after running vtctl MigrateServedTypes and vtgate is no longer using them. If -timeout is set, it fails when the timeout is reached.

Example

Flags

Name	Type	Definition
cells	string	Specifies a comma-separated list of cells to look for tablets
initial_wait	Duration	Time to wait for all tablets to check in
retry_delay	Duration	Time to wait between two checks
timeout	Duration	Timeout after which the command fails

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.
- <served tablet type> – Required. The vttablet's role. Valid values are:
  - backup – A replicated copy of data that is offline to queries other than for backup purposes
  - batch – A replicated copy of data for OLAP load patterns (typically for MapReduce jobs)
  - drained – A tablet that is reserved for a background process. For example, a tablet used by a vtworker process, where the tablet is likely lagging in replication.
  - experimental – A replicated copy of data that is ready but not serving query traffic. The value indicates a special characteristic of the tablet that indicates the tablet should not be considered a potential master. Vitess also does not worry about lag for experimental tablets when reparenting.
  - master – A primary copy of data
  - rdonly – A replicated copy of data for OLAP load patterns
  - replica – A replicated copy of data ready to be promoted to master
  - restore – A tablet that is restoring from a snapshot. Typically, this happens at tablet startup, then it goes to its right state.
  - spare – A replicated copy of data that is ready but not serving query traffic. The data could be a potential master tablet.

Errors

- the <keyspace/shard> and <tablet type> arguments are both required for the <WaitForDrain> command This error occurs if the command is not called with exactly 2 arguments.

See Also

- vtctl command index

vtctl Query Command Reference

series: vtctl

The following `vtctl` commands are available for administering queries.

Commands

VtGateExecute Executes the given SQL query with the provided bound variables against the vtgate server.

Example

Flags

Name	Type	Definition
json	Boolean	Output JSON instead of human-readable table
options	string	execute options values as a text encoded proto of the ExecuteOptions structure
server	string	VtGate server to connect to
target	string	keyspace:shard@tablet_type

Arguments

- <vtgate> – Required.
- <sql> – Required.

Errors

- the <sql> argument is required for the <VtGateExecute> command This error occurs if the command is not called with exactly one argument.
- query commands are disabled (set the -enable_queries flag to enable)
- error connecting to vtgate '%v': %v
- Execute failed: %v

VtTabletExecute Executes the given query on the given tablet. -transaction_id is optional. Use VtTabletBegin to start a transaction.

Example

Flags

Name	Type	Definition
json	Boolean	Output JSON instead of human-readable table
options	string	execute options values as a text encoded proto of the ExecuteOptions structure
transaction_id	Int	transaction id to use, if inside a transaction.
username	string	If set, value is set as immediate caller id in the request and used by vttablet for TableACL check

Arguments

- <TableACL user> – Required.
- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.
- <sql> – Required.

Errors

- the <tablet_alias> and <sql> arguments are required for the <VtTabletExecute> command This error occurs if the command is not called with exactly 2 arguments.
- query commands are disabled (set the -enable_queries flag to enable)
- cannot connect to tablet %v: %v
- Execute failed: %v

VtTabletBegin Starts a transaction on the provided server.

Example

Flags

Name	Type	Definition
username	string	If set, value is set as immediate caller id in the request and used by vttablet for TableACL check

Arguments

- <TableACL user> – Required.
- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet_alias> argument is required for the <VtTabletBegin> command This error occurs if the command is not called with exactly one argument.
- query commands are disabled (set the -enable_queries flag to enable)

- cannot connect to tablet %v: %v
- Begin failed: %v

VtTabletCommit Commits the given transaction on the provided server.

Example

Flags

Name	Type	Definition
username	string	If set, value is set as immediate caller id in the request and used by vttablet for TableACL check

Arguments

- <TableACL user> – Required.
- <transaction_id> – Required.

Errors

- the <tablet_alias> and <transaction_id> arguments are required for the <VtTabletCommit> command This error occurs if the command is not called with exactly 2 arguments.
- query commands are disabled (set the -enable_queries flag to enable)
- cannot connect to tablet %v: %v

VtTabletRollback Rollbacks the given transaction on the provided server.

Example

Flags

Name	Type	Definition
username	string	If set, value is set as immediate caller id in the request and used by vttablet for TableACL check

Arguments

- <TableACL user> – Required.
- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.
- <transaction_id> – Required.

Errors

- the <tablet_alias> and <transaction_id> arguments are required for the <VtTabletRollback> command This error occurs if the command is not called with exactly 2 arguments.

- query commands are disabled (set the -enable_queries flag to enable)
- cannot connect to tablet %v: %v

VtTabletStreamHealth Executes the StreamHealth streaming query to a vttablet process. Will stop after getting <count> answers.

Example

Flags

Name	Type	Definition
count	Int	number of responses to wait for

Arguments

- <count default 1> – Required.
- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet alias> argument is required for the <VtTabletStreamHealth> command This error occurs if the command is not called with exactly one argument.
- query commands are disabled (set the -enable_queries flag to enable)
- cannot connect to tablet %v: %v

See Also

- vtctl command index

vtctl Replication Graph Command Reference

series: vtctl

The following `vtctl` commands are available for administering the Replication Graph.

Commands

GetShardReplication Outputs a JSON structure that contains information about the ShardReplication.

Example

Arguments

- <cell> – Required. A cell is a location for a service. Generally, a cell resides in only one cluster. In Vitess, the terms "cell" and "data center" are interchangeable. The argument value is a string that does not contain whitespace.
- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <cell> and <keyspace/shard> arguments are required for the <GetShardReplication> command This error occurs if the command is not called with exactly 2 arguments.

See Also

- vtctl command index

vtctl Resharding Throttler Command Reference

series: vtctl

The following `vtctl` commands are available for administering Resharding Throttler.

Commands

ThrottlerMaxRates Returns the current max rate of all active resharding throttlers on the server.

Example

Flags

Name	Type	Definition
server	string	vtworker or vttablet to connect to

Arguments

- <vtworker or vttablet> – Required.

Errors

- the ThrottlerSetMaxRate command does not accept any positional parameters This error occurs if the command is not called with exactly 0 arguments.
- error creating a throttler client for <server> '%v': %v
- failed to get the throttler rate from <server> '%v': %v

ThrottlerSetMaxRate Sets the max rate for all active resharding throttlers on the server.

Example

Flags

Name	Type	Definition
server	string	vtworker or vttablet to connect to

Arguments

- <vtworker or vttablet> – Required.
- <rate> – Required.

Errors

- the <rate> argument is required for the <ThrottlerSetMaxRate> command This error occurs if the command is not called with exactly one argument.
- failed to parse rate '%v' as integer value: %v
- error creating a throttler client for <server> '%v': %v
- failed to set the throttler rate on <server> '%v': %v

GetThrottlerConfiguration Returns the current configuration of the MaxReplicationLag module. If no throttler name is specified, the configuration of all throttlers will be returned.

Example

Flags

Name	Type	Definition
server	string	vtworker or vttablet to connect to

Arguments

- <vtworker or vttablet> – Required.
- <throttler name> – Optional.

Errors

- the <GetThrottlerConfiguration> command accepts only <throttler name> as optional positional parameter This error occurs if the command is not called with more than 1 arguments.
- error creating a throttler client for <server> '%v': %v
- failed to get the throttler configuration from <server> '%v': %v

UpdateThrottlerConfiguration Updates the configuration of the MaxReplicationLag module. The configuration must be specified as protobuf text. If a field is omitted or has a zero value, it will be ignored unless -copy_zero_values is specified. If no throttler name is specified, all throttlers will be updated.

Example

Flags

Name	Type	Definition
copy_zero_values	Boolean	If true, fields with zero values will be copied as well
server	string	vtworker or vttablet to connect to

Arguments

- <vtworker or vttablet> – Required.
- <throttler name> – Optional.

Errors

- Failed to unmarshal the configuration protobuf text (%v) into a protobuf instance: %v
- error creating a throttler client for <server> '%v': %v
- failed to update the throttler configuration on <server> '%v': %v

ResetThrottlerConfiguration Resets the current configuration of the MaxReplicationLag module. If no throttler name is specified, the configuration of all throttlers will be reset.

Example

Flags

Name	Type	Definition
server	string	vtworker or vttablet to connect to

Arguments

- <vtworker or vttablet> – Required.
- <throttler name> – Optional.

Errors

- the <ResetThrottlerConfiguration> command accepts only <throttler name> as optional positional parameter This error occurs if the command is not called with more than 1 arguments.
- error creating a throttler client for <server> '%v': %v
- failed to get the throttler configuration from <server> '%v': %v

See Also

- vtctl command index

vtctl Schema, Version, Permissions Command Reference

series: vtctl

The following `vtctl` commands are available for administering Schema, Versions and Permissions.

Commands

GetSchema Displays the full schema for a tablet, or just the schema for the specified tables in that tablet.

Example

Flags

Name	Type	Definition
exclude_tables	string	Specifies a comma-separated list of tables to exclude. Each is either an exact match, or a regular expression of the form /regexp/
include-views	Boolean	Includes views in the output
table_names_only	Boolean	Only displays table names that match
tables	string	Specifies a comma-separated list of tables for which we should gather information. Each is either an exact match, or a regular expression of the form /regexp/

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet alias> argument is required for the <GetSchema> command This error occurs if the command is not called with exactly one argument.

ReloadSchema Reloads the schema on a remote tablet.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet alias> argument is required for the <ReloadSchema> command This error occurs if the command is not called with exactly one argument.

ReloadSchemaShard Reloads the schema on all the tablets in a shard.

Example

Flags

Name	Type	Definition
concurrency	Int	How many tablets to reload in parallel
include_master	Boolean	Include the master tablet

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <keyspace/shard> argument is required for the <ReloadSchemaShard> command This error occurs if the command is not called with exactly one argument.

ReloadSchemaKeyspace Reloads the schema on all the tablets in a keyspace.

Example

Flags

Name	Type	Definition
concurrency	Int	How many tablets to reload in parallel
include_master	Boolean	Include the master tablet(s)

Arguments

- <keyspace> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- the <keyspace> argument is required for the <ReloadSchemaKeyspace> command This error occurs if the command is not called with exactly one argument.

ValidateSchemaShard Validates that the master schema matches all of the replicas.

Example

Flags

Name	Type	Definition
exclude_tables	string	Specifies a comma-separated list of tables to exclude. Each is either an exact match, or a regular expression of the form /regexp/
include-views	Boolean	Includes views in the validation

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <keyspace/shard> argument is required for the <ValidateSchemaShard> command This error occurs if the command is not called with exactly one argument.

ValidateSchemaKeyspace Validates that the master schema from shard 0 matches the schema on all of the other tablets in the keyspace.

Example

Flags

Name	Type	Definition
exclude_tables	string	Specifies a comma-separated list of tables to exclude. Each is either an exact match, or a regular expression of the form /regexp/
include-views	Boolean	Includes views in the validation

Arguments

- <keyspace name> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- the <keyspace name> argument is required for the <ValidateSchemaKeyspace> command This error occurs if the command is not called with exactly one argument.

ApplySchema Applies the schema change to the specified keyspace on every master, running in parallel on all shards. The changes are then propagated to replicas via replication. If -allow_long_unavailability is set, schema changes affecting a large number of rows (and possibly incurring a longer period of unavailability) will not be rejected.

Example

Flags

Name	Type	Definition
allow_long_unavailability	Boolean	Allow large schema changes which incur a longer unavailability of the database.
sql	string	A list of semicolon-delimited SQL commands

Name	Type	Definition
sql-file	string	Identifies the file that contains the SQL commands
wait_replicas_timeout	Duration	The amount of time to wait for replicas to receive the schema change via replication.

Arguments

- <keyspace> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- the <keyspace> argument is required for the command<ApplySchema> command This error occurs if the command is not called with exactly one argument.

CopySchemaShard Copies the schema from a source shard's master (or a specific tablet) to a destination shard. The schema is applied directly on the master of the destination shard, and it is propagated to the replicas through binlogs.

Example

Flags

Name	Type	Definition
exclude_tables	string	Specifies a comma-separated list of tables to exclude. Each is either an exact match, or a regular expression of the form /regexp/
include-views	Boolean	Includes views in the output
tables	string	Specifies a comma-separated list of tables to copy. Each is either an exact match, or a regular expression of the form /regexp/
wait_replicas_timeout	Duration	The amount of time to wait for replicas to receive the schema change via replication.

Arguments

- <source tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.
- <destination keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <source keyspace/shard> and <destination keyspace/shard> arguments are both required for the <CopySchemaShard> command. Instead of the <source keyspace/shard> argument, you can also specify <tablet alias> which refers to a specific tablet of the shard in the source keyspace This error occurs if the command is not called with exactly 2 arguments.

ValidateVersionShard Validates that the master version matches all of the replicas.

Example

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <keyspace/shard> argument is required for the <ValidateVersionShard> command This error occurs if the command is not called with exactly one argument.

ValidateVersionKeyspace Validates that the master version from shard 0 matches all of the other tablets in the keyspace.

Example

Arguments

- <keyspace name> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- the <keyspace name> argument is required for the <ValidateVersionKeyspace> command This error occurs if the command is not called with exactly one argument.

GetPermissions Displays the permissions for a tablet.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet alias> argument is required for the <GetPermissions> command This error occurs if the command is not called with exactly one argument.

ValidatePermissionsShard Validates that the master permissions match all the replicas.

Example

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <keyspace/shard> argument is required for the <ValidatePermissionsShard> command This error occurs if the command is not called with exactly one argument.

ValidatePermissionsKeyspace Validates that the master permissions from shard 0 match those of all of the other tablets in the keyspace.

Example

Arguments

- <keyspace name> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- the <keyspace name> argument is required for the <ValidatePermissionsKeyspace> command This error occurs if the command is not called with exactly one argument.

GetVSchema Displays the VTGate routing schema.

Example

Arguments

- <keyspace> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- the <keyspace> argument is required for the <GetVSchema> command This error occurs if the command is not called with exactly one argument.

ApplyVSchema Applies the VTGate routing schema to the provided keyspace. Shows the result after application.

Example

Flags

Name	Type	Definition
cells	string	If specified, limits the rebuild to the cells, after upload. Ignored if skipRebuild is set.
skip_rebuild	Boolean	If set, do no rebuild the SrvSchema objects.
vschema	string	Identifies the VTGate routing schema
vschema_file	string	Identifies the VTGate routing schema file

Arguments

- <keyspace> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- the <keyspace> argument is required for the <ApplyVSchema> command This error occurs if the command is not called with exactly one argument.
- either the <vschema> or <vschema>File flag must be specified when calling the <ApplyVSchema> command

```
GetRoutingRules
```

```
ApplyRoutingRules  {-rules=<rules>
| -rules_file=<rules_file>} [-cells=c1,c2,...] [-skip_rebuild] [-dry-run]
```

RebuildVSchemaGraph Rebuilds the cell-specific SrvVSchema from the global VSchema objects in the provided cells (or all cells if none provided).

Example

Flags

Name	Type	Definition
cells	string	Specifies a comma-separated list of cells to look for tablets

Errors

- <RebuildVSchemaGraph> doesn't take any arguments This error occurs if the command is not called with exactly 0 arguments.

See Also

- vtctl command index

vtctl Serving Graph Command Reference

series: vtctl

The following `vtctl` commands are available for administering the Serving Graph.

Commands

GetSrvKeyspaceNames Outputs a list of keyspace names.

Example

Arguments

- <cell> – Required. A cell is a location for a service. Generally, a cell resides in only one cluster. In Vitess, the terms "cell" and "data center" are interchangeable. The argument value is a string that does not contain whitespace.

Errors

- the <cell> argument is required for the <GetSrvKeyspaceNames> command This error occurs if the command is not called with exactly one argument.

GetSrvKeyspace Outputs a JSON structure that contains information about the SrvKeyspace.

Example

Arguments

- <cell> – Required. A cell is a location for a service. Generally, a cell resides in only one cluster. In Vitess, the terms "cell" and "data center" are interchangeable. The argument value is a string that does not contain whitespace.
- <keyspace> – Required. The name of a sharded database that contains one or more tables. Vitess distributes keyspace shards into multiple machines and provides an SQL interface to query the data. The argument value must be a string that does not contain whitespace.

Errors

- the <cell> and <keyspace> arguments are required for the <GetSrvKeyspace> command This error occurs if the command is not called with exactly 2 arguments.

GetSrvVSchema Outputs a JSON structure that contains information about the SrvVSchema.

Example

Arguments

- <cell> – Required. A cell is a location for a service. Generally, a cell resides in only one cluster. In Vitess, the terms "cell" and "data center" are interchangeable. The argument value is a string that does not contain whitespace.

Errors

- the <cell> argument is required for the <GetSrvVSchema> command This error occurs if the command is not called with exactly one argument.

```
DeleteSrvVSchema  <cell>
```

See Also

- vtctl command index

vtctl Shard Command Reference

series: vtctl

The following `vtctl` commands are available for administering shards.

Commands

CreateShard Creates the specified shard.

Example

Flags

Name	Type	Definition
force	Boolean	Proceeds with the command even if the keyspace already exists
parent	Boolean	Creates the parent keyspace if it doesn't already exist

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <keyspace/shard> argument is required for the <CreateShard> command This error occurs if the command is not called with exactly one argument.

GetShard Outputs a JSON structure that contains information about the Shard.

Example

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <keyspace/shard> argument is required for the <GetShard> command This error occurs if the command is not called with exactly one argument.

ValidateShard Validates that all nodes that are reachable from this shard are consistent.

Example

Flags

Name	Type	Definition
ping-tablets	Boolean	Indicates whether all tablets should be pinged during the validation process

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <keyspace/shard> argument is required for the <ValidateShard> command This error occurs if the command is not called with exactly one argument.

ShardReplicationPositions Shows the replication status of each replica machine in the shard graph. In this case, the status refers to the replication lag between the master vttablet and the replica vttablet. In Vitess, data is always written to the master vttablet first and then replicated to all replica vttablets. Output is sorted by tablet type, then replication position. Use ctrl-C to interrupt command and see partial result if needed.

Example

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <keyspace/shard> argument is required for the <ShardReplicationPositions> command This error occurs if the command is not called with exactly one argument.

ListShardTablets Lists all tablets in the specified shard.

Example

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <keyspace/shard> argument is required for the <ListShardTablets> command This error occurs if the command is not called with exactly one argument.

```
SetShardIsMasterServing <keyspace/shard> <is_master_serving>
```

SetShardTabletControl Sets the TabletControl record for a shard and type. Only use this for an emergency fix or after a finished vertical split. The *MigrateServedFrom* and *MigrateServedType* commands set this field appropriately already. Always specify the blacklisted_tables flag for vertical splits, but never for horizontal splits.To set the DisableQueryServiceFlag, keep 'blacklisted_tables' empty, and set 'disable_query_service' to true or false. Useful to fix horizontal splits gone wrong.To change the blacklisted tables list, specify the 'blacklisted_tables' parameter with the new list. Useful to fix tables that are being blocked after a vertical split.To just remove the ShardTabletControl entirely, use the 'remove' flag, useful after a vertical split is finished to remove serving restrictions.

Example

Flags

Name	Type	Definition
blacklisted_tables	string	Specifies a comma-separated list of tables to blacklist (used for vertical split). Each is either an exact match, or a regular expression of the form '/regexp/'.
cells	string	Specifies a comma-separated list of cells to update
disable_query_service	Boolean	Disables query service on the provided nodes. This flag requires 'blacklisted_tables' and 'remove' to be unset, otherwise it's ignored.
remove	Boolean	Removes cells for vertical splits.

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.
- <tablet type> – Required. The vttablet's role. Valid values are:
  - backup – A replicated copy of data that is offline to queries other than for backup purposes
  - batch – A replicated copy of data for OLAP load patterns (typically for MapReduce jobs)
  - drained – A tablet that is reserved for a background process. For example, a tablet used by a vtworker process, where the tablet is likely lagging in replication.
  - experimental – A replicated copy of data that is ready but not serving query traffic. The value indicates a special characteristic of the tablet that indicates the tablet should not be considered a potential master. Vitess also does not worry about lag for experimental tablets when reparenting.
  - master – A primary copy of data
  - rdonly – A replicated copy of data for OLAP load patterns
  - replica – A replicated copy of data ready to be promoted to master
  - restore – A tablet that is restoring from a snapshot. Typically, this happens at tablet startup, then it goes to its right state.
  - spare – A replicated copy of data that is ready but not serving query traffic. The data could be a potential master tablet.

Errors

- the <keyspace/shard> and <tablet type> arguments are both required for the <SetShardTabletControl> command This error occurs if the command is not called with exactly 2 arguments.

```
UpdateSrvKeyspacePartition [--cells=c1,c2,...] [--remove] <keyspace/shard> <tablet type>
```

SourceShardDelete Deletes the SourceShard record with the provided index. This is meant as an emergency cleanup function. It does not call RefreshState for the shard master.

Example

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.
- <uid> – Required.

Errors

- the <keyspace/shard> and <uid> arguments are both required for the <SourceShardDelete> command This error occurs if the command is not called with at least 2 arguments.

SourceShardAdd Adds the SourceShard record with the provided index. This is meant as an emergency function. It does not call RefreshState for the shard master.

Example

Flags

Name	Type	Definition
key_range	string	Identifies the key range to use for the SourceShard
tables	string	Specifies a comma-separated list of tables to replicate (used for vertical split). Each is either an exact match, or a regular expression of the form /regexp/

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.
- <uid> – Required.
- <source keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <keyspace/shard>, <uid>, and <source keyspace/shard> arguments are all required for the <SourceShardAdd> command This error occurs if the command is not called with exactly 3 arguments.

ShardReplicationFix Walks through a ShardReplication object and fixes the first error that it encounters.

Example

Arguments

- <cell> – Required. A cell is a location for a service. Generally, a cell resides in only one cluster. In Vitess, the terms "cell" and "data center" are interchangeable. The argument value is a string that does not contain whitespace.
- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <cell> and <keyspace/shard> arguments are required for the ShardReplicationRemove command This error occurs if the command is not called with exactly 2 arguments.

WaitForFilteredReplication Blocks until the specified shard has caught up with the filtered replication of its source shard.

Example

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <keyspace/shard> argument is required for the <WaitForFilteredReplication> command This error occurs if the command is not called with exactly one argument.

RemoveShardCell Removes the cell from the shard's Cells list.

Example

Flags

Name	Type	Definition
force	Boolean	Proceeds even if the cell's topology service cannot be reached. The assumption is that you turned down the entire cell, and just need to update the global topo data.
recursive	Boolean	Also delete all tablets in that cell belonging to the specified shard.

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.
- <cell> – Required. A cell is a location for a service. Generally, a cell resides in only one cluster. In Vitess, the terms "cell" and "data center" are interchangeable. The argument value is a string that does not contain whitespace.

Errors

- the <keyspace/shard> and <cell> arguments are required for the <RemoveShardCell> command This error occurs if the command is not called with exactly 2 arguments.

DeleteShard Deletes the specified shard(s). In recursive mode, it also deletes all tablets belonging to the shard. Otherwise, there must be no tablets left in the shard.

Example

Flags

Name	Type	Definition
even_if_serving	Boolean	Remove the shard even if it is serving. Use with caution.
recursive	Boolean	Also delete all tablets belonging to the shard.

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>. To specify multiple values for this argument, separate individual values with a space.

Errors

- the <keyspace/shard> argument must be used to identify at least one keyspace and shard when calling the <DeleteShard> command This error occurs if the command is not called with at least one argument.

ListBackups Lists all the backups for a shard.

Example

Errors

- action <ListBackups> requires <keyspace/shard> This error occurs if the command is not called with exactly one argument.

```
BackupShard [-allow_master=false] <keyspace/shard>
```

RemoveBackup Removes a backup for the BackupStorage.

Example

Arguments

- <backup name> – Required.

Errors

- action <RemoveBackup> requires <keyspace/shard> <backup name> This error occurs if the command is not called with exactly 2 arguments.

InitShardMaster Sets the initial master for a shard. Will make all other tablets in the shard replicas of the provided master. WARNING: this could cause data loss on an already replicating shard. PlannedReparentShard or EmergencyReparentShard should be used instead.

Example

Flags

Name	Type	Definition
force	Boolean	will force the reparent even if the provided tablet is not a master or the shard master
wait_replicas_timeout	Duration	time to wait for replicas to catch up in reparenting

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.
- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- action <InitShardMaster> requires <keyspace/shard> <tablet alias> This error occurs if the command is not called with exactly 2 arguments.
- active reparent commands disabled (unset the -disable_active_reparents flag to enable)

PlannedReparentShard Reparents the shard to a new master that can either be explicitly specified, or chosen by Vitess. Both the existing master and new master need to be up and running to use this command. If the existing master for the shard is down, you should use EmergencyReparentShard instead.

If the `new_master` flag is not provided, Vitess will try to automatically choose a replica to promote to master, avoiding any replicas specified in the `avoid_master` flag, if provided. Note that Vitess **will not consider any replicas outside the cell the current master is in for promotion**, therefore you **must** pass the `new_master` flag if you need to promote a replica in a different cell from the master. In the automated selection mode Vitess will prefer the most advanced replica for promotion, to minimize failover time.

Example

Flags

Name	Type	Definition
avoid_master	string	alias of a tablet that should not be the master, i.e. reparent to any replica other than this one
keyspace_shard	string	keyspace/shard of the shard that needs to be reparented
new_master	string	alias of a tablet that should be the new master
wait_replicas_timeout	Duration	time to wait for replicas to catch up in reparenting

Errors

- action <PlannedReparentShard> requires -keyspace_shard=<keyspace/shard> [-new_master=<tablet alias>] [-avoid_master=<tablet alias>] This error occurs if the command is not called with exactly 0 arguments.
- active reparent commands disabled (unset the -disable_active_reparents flag to enable)
- cannot use legacy syntax and flags -<keyspace_shard> and -<new_master> for action <PlannedReparentShard> at the same time

EmergencyReparentShard Reparents the shard to the new master. Assumes the old master is dead and not responding.

Example

Flags

Name	Type	Definition
keyspace_shard	string	keyspace/shard of the shard that needs to be reparented
new_master	string	alias of a tablet that should be the new master
wait_replicas_timeout	Duration	time to wait for replicas to catch up in reparenting

Errors

- action <EmergencyReparentShard> requires -keyspace_shard=<keyspace/shard> -new_master=<tablet alias> This error occurs if the command is not called with exactly 0 arguments.
- active reparent commands disabled (unset the -disable_active_reparents flag to enable)
- cannot use legacy syntax and flag -<new_master> for action <EmergencyReparentShard> at the same time

TabletExternallyReparented Changes metadata in the topology service to acknowledge a shard master change performed by an external tool. See Reparenting for more information.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet alias> argument is required for the <TabletExternallyReparented> command This error occurs if the command is not called with exactly one argument.

See Also

- vtctl command index

vtctl Tablet Command Reference

series: vtctl

The following `vtctl` commands are available for administering tablets.

Commands

InitTablet Initializes a tablet in the topology.

Example

Flags

Name	Type	Definition
allow_master_override	Boolean	Use this flag to force initialization if a tablet is created as master, and a master for the keyspace/shard already exists. Use with caution.
allow_update	Boolean	Use this flag to force initialization if a tablet with the same name already exists. Use with caution.
db_name_override	string	Overrides the name of the database that the vttablet uses
grpc_port	Int	The gRPC port for the vttablet process
hostname	string	The server on which the tablet is running
keyspace	string	The keyspace to which this tablet belongs
mysql_host	string	The mysql host for the mysql server
mysql_port	Int	The mysql port for the mysql server
parent	Boolean	Creates the parent shard and keyspace if they don't yet exist
port	Int	The main port for the vttablet process
shard	string	The shard to which this tablet belongs
tags	string	A comma-separated list of key:value pairs that are used to tag the tablet

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.
- <tablet type> – Required. The vttablet's role. Valid values are:
  - backup – A replicated copy of data that is offline to queries other than for backup purposes
  - batch – A replicated copy of data for OLAP load patterns (typically for MapReduce jobs)
  - drained – A tablet that is reserved for a background process. For example, a tablet used by a vtworker process, where the tablet is likely lagging in replication.
  - experimental – A replicated copy of data that is ready but not serving query traffic. The value indicates a special characteristic of the tablet that indicates the tablet should not be considered a potential master. Vitess also does not worry about lag for experimental tablets when reparenting.
  - master – A primary copy of data
  - rdonly – A replicated copy of data for OLAP load patterns

  - replica – A replicated copy of data ready to be promoted to master
  - restore – A tablet that is restoring from a snapshot. Typically, this happens at tablet startup, then it goes to its right state.
  - spare – A replicated copy of data that is ready but not serving query traffic. The data could be a potential master tablet.

Errors

- the <tablet alias> and <tablet type> arguments are both required for the <InitTablet> command This error occurs if the command is not called with exactly 2 arguments.

GetTablet Outputs a JSON structure that contains information about the Tablet.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet alias> argument is required for the <GetTablet> command This error occurs if the command is not called with exactly one argument.

IgnoreHealthError Sets the regexp for health check errors to ignore on the specified tablet. The pattern has implicit ^$ anchors. Set to empty string or restart vttablet to stop ignoring anything.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.
- <ignore regexp> – Required.

Errors

- the <tablet alias> and <ignore regexp> arguments are required for the <IgnoreHealthError> command This error occurs if the command is not called with exactly 2 arguments.

UpdateTabletAddrs Updates the IP address and port numbers of a tablet.

Example

Flags

Name	Type	Definition
grpc-port	Int	The gRPC port for the vttablet process
hostname	string	The fully qualified host name of the server on which the tablet is running.
mysql-port	Int	The mysql port for the mysql daemon
mysql_host	string	The mysql host for the mysql server
vt-port	Int	The main port for the vttablet process

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet alias> argument is required for the <UpdateTabletAddrs> command This error occurs if the command is not called with exactly one argument.

DeleteTablet Deletes tablet(s) from the topology.

Example

Flags

Name	Type	Definition
allow_master	Boolean	Allows for the master tablet of a shard to be deleted. Use with caution.

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>. To specify multiple values for this argument, separate individual values with a space.

Errors

- the <tablet alias> argument must be used to specify at least one tablet when calling the <DeleteTablet> command This error occurs if the command is not called with at least one argument.

SetReadOnly Sets the tablet as read-only.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet alias> argument is required for the <SetReadOnly> command This error occurs if the command is not called with exactly one argument.
- failed reading tablet %v: %v

SetReadWrite Sets the tablet as read-write.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet alias> argument is required for the <SetReadWrite> command This error occurs if the command is not called with exactly one argument.
- failed reading tablet %v: %v

StartReplication Starts replication on the specified tablet.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- action <StartReplication> requires <tablet alias> This error occurs if the command is not called with exactly one argument.
- failed reading tablet %v: %v

StopReplication Stops replication on the specified tablet.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- action <StopReplication> requires <tablet alias> This error occurs if the command is not called with exactly one argument.
- failed reading tablet %v: %v

ChangeTabletType Changes the db type for the specified tablet, if possible. This command is used primarily to arrange replicas, and it will not convert a master.NOTE: This command automatically updates the serving graph.

Example

Flags

Name	Type	Definition
dry-run	Boolean	Lists the proposed change without actually executing it

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.
- <tablet type> – Required. The vttablet's role. Valid values are:
  - backup – A replicated copy of data that is offline to queries other than for backup purposes
  - batch – A replicated copy of data for OLAP load patterns (typically for MapReduce jobs)
  - drained – A tablet that is reserved for a background process. For example, a tablet used by a vtworker process, where the tablet is likely lagging in replication.
  - experimental – A replicated copy of data that is ready but not serving query traffic. The value indicates a special characteristic of the tablet that indicates the tablet should not be considered a potential master. Vitess also does not worry about lag for experimental tablets when reparenting.
  - master – A primary copy of data
  - rdonly – A replicated copy of data for OLAP load patterns
  - replica – A replicated copy of data ready to be promoted to master
  - restore – A tablet that is restoring from a snapshot. Typically, this happens at tablet startup, then it goes to its right state.
  - spare – A replicated copy of data that is ready but not serving query traffic. The data could be a potential master tablet.

Errors

- the <tablet alias> and <db type> arguments are required for the <ChangeTabletType> command This error occurs if the command is not called with exactly 2 arguments.
- failed reading tablet %v: %v
- invalid type transition %v: %v -> %v

Ping hecks that the specified tablet is awake and responding to RPCs. This command can be blocked by other in-flight operations.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet alias> argument is required for the <Ping> command This error occurs if the command is not called with exactly one argument.

RefreshState Reloads the tablet record on the specified tablet.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet alias> argument is required for the <RefreshState> command This error occurs if the command is not called with exactly one argument.

RefreshStateByShard Runs 'RefreshState' on all tablets in the given shard.

Example

Flags

Name	Type	Definition
cells	string	Specifies a comma-separated list of cells whose tablets are included. If empty, all cells are considered.

Arguments

- <keyspace/shard> – Required. The name of a sharded database that contains one or more tables as well as the shard associated with the command. The keyspace must be identified by a string that does not contain whitespace, while the shard is typically identified by a string in the format <range start>-<range end>.

Errors

- the <keyspace/shard> argument is required for the <RefreshStateByShard> command This error occurs if the command is not called with exactly one argument.

RunHealthCheck Runs a health check on a remote tablet.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <tablet alias> argument is required for the <RunHealthCheck> command This error occurs if the command is not called with exactly one argument.

IgnoreHealthError Sets the regexp for health check errors to ignore on the specified tablet. The pattern has implicit ^$ anchors. Set to empty string or restart vttablet to stop ignoring anything.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.
- <ignore regexp> – Required.

Errors

- the <tablet alias> and <ignore regexp> arguments are required for the <IgnoreHealthError> command This error occurs if the command is not called with exactly 2 arguments.

Sleep Blocks the action queue on the specified tablet for the specified amount of time. This is typically used for testing.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.
- <duration> – Required. The amount of time that the action queue should be blocked. The value is a string that contains a possibly signed sequence of decimal numbers, each with optional fraction and a unit suffix, such as "300ms" or "1h45m". See the definition of the Go language's ParseDuration function for more details. Note that, in practice, the value should be a positively signed value.

Errors

- the <tablet alias> and <duration> arguments are required for the <Sleep> command This error occurs if the command is not called with exactly 2 arguments.

ExecuteHook Runs the specified hook on the given tablet. A hook is a script that resides in the $VTROOT/vthook directory. You can put any script into that directory and use this command to run that script.For this command, the param=value arguments are parameters that the command passes to the specified hook.

Example

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.
- <hook name> – Required.
- <param1=value1> <param2=value2> . – Optional.

Errors

- the <tablet alias> and <hook name> arguments are required for the <ExecuteHook> command This error occurs if the command is not called with at least 2 arguments.

```
ExecuteFetchAsApp [-max_rows=10000] [-json] [-use_pool] <tablet alias> <sql command>
```

ExecuteFetchAsDba Runs the given SQL command as a DBA on the remote tablet.

Example

Flags

Name	Type	Definition
disable_binlogs	Boolean	Disables writing to binlogs during the query
json	Boolean	Output JSON instead of human-readable table
max_rows	Int	Specifies the maximum number of rows to allow in reset
reload_schema	Boolean	Indicates whether the tablet schema will be reloaded after executing the SQL command. The default value is false, which indicates that the tablet schema will not be reloaded.

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.
- <sql command> – Required.

Errors

- the <tablet alias> and <sql command> arguments are required for the <ExecuteFetchAsDba> command This error occurs if the command is not called with exactly 2 arguments.

```
VReplicationExec [-json] <tablet alias> <sql command>
```

Backup Stops mysqld and uses the BackupStorage service to store a new backup. This function also remembers if the tablet was replicating so that it can restore the same state after the backup completes.

Example

Flags

Name	Type	Definition
concurrency	Int	Specifies the number of compression/checksum jobs to run simultaneously

Arguments

- <tablet alias> – Required. A Tablet Alias uniquely identifies a vttablet. The argument value is in the format <cell name>-<uid>.

Errors

- the <Backup> command requires the <tablet alias> argument This error occurs if the command is not called with exactly one argument.

ChangeSlaveType Changes the db type for the specified tablet, if possible. This command is used primarily to arrange replicas, and it will not convert a master.NOTE: This command automatically updates the serving graph.

Example

Flags

Name	Type	Definition
dry-run	Boolean	Lists the proposed change without actually executing it

RestoreFromBackup Stops mysqld and restores the data from the latest backup.

Example

Errors

- the <RestoreFromBackup> command requires the <tablet alias> argument This error occurs if the command is not called with exactly one argument.

ReparentTablet Reparent a tablet to the current master in the shard. This only works if the current replication position matches the last known reparent action.

Example

Errors

- action <ReparentTablet> requires <tablet alias> This error occurs if the command is not called with exactly one argument.
- active reparent commands disabled (unset the -disable_active_reparents flag to enable)

See Also

- vtctl command index

vtctl Topo Command Reference

series: vtctl

The following `vtctl` commands are available for administering Topology Services.

Commands

TopoCat Retrieves the file(s) at <path> from the topo service, and displays it. It can resolve wildcards, and decode the proto-encoded data.

Example

Flags

Name	Type	Definition
cell	string	topology cell to cat the file from. Defaults to global cell.
decode_proto	Boolean	decode proto files and display them as text
long	Boolean	long listing.

Arguments

- <cell> – Required. A cell is a location for a service. Generally, a cell resides in only one cluster. In Vitess, the terms "cell" and "data center" are interchangeable. The argument value is a string that does not contain whitespace.
- <path> – Required.
- <path>. – Optional.

Errors

- <TopoCat>: no path specified This error occurs if the command is not called with at least one argument.
- <TopoCat>: invalid wildcards: %v
- <TopoCat>: some paths had errors

```
TopoCp  [-cell <cell>] [-to_topo] <src> <dst>
```

See Also

- vtctl command index

vtctl Workflow Command Reference

series: vtctl

The following `vtctl` commands are available for administering workflows.

Commands

WorkflowCreate Creates the workflow with the provided parameters. The workflow is also started, unless -skip_start is specified.

Example

Flags

Name	Type	Definition
skip_start	Boolean	If set, the workflow will not be started.

Arguments

- <factoryName> – Required.

Errors

- the <factoryName> argument is required for the <WorkflowCreate> command This error occurs if the command is not called with at least one argument.
- no workflow.Manager registered

WorkflowStart Starts the workflow.

Example

Errors

- the <uuid> argument is required for the <WorkflowStart> command This error occurs if the command is not called with exactly one argument.
- no workflow.Manager registered

WorkflowStop Stops the workflow.

Example

Errors

- the <uuid> argument is required for the <WorkflowStop> command This error occurs if the command is not called with exactly one argument.
- no workflow.Manager registered

WorkflowDelete Deletes the finished or not started workflow.

Example

Errors

- the <uuid> argument is required for the <WorkflowDelete> command This error occurs if the command is not called with exactly one argument.
- no workflow.Manager registered

```
WorkflowWait  <uuid>
```

WorkflowTree Displays a JSON representation of the workflow tree.

Example

Errors

- the <WorkflowTree> command takes no parameter This error occurs if the command is not called with exactly 0 arguments.
- no workflow.Manager registered

```
WorkflowAction  <path> <name>
```

See Also

- vtctl command index

vtctl

description: vtctl Command Index

`vtctl` is a command-line tool used to administer a Vitess cluster. It is available as both a standalone tool (`vtctl`) and client-server (`vtctlclient` in combination with `vtctld`). Using client-server is recommended, as it provides an additional layer of security when using the client remotely.

Commands

Tablets

Name	Example Usage
InitTablet	`InitTablet [-allow_update] [-allow_different_shard] [-allow_master_override] [-parent] [-db_name_override=<db name>] [-hostname=<hostname>] [-mysql_port=<port>] [-port=<port>] [-grpc_port=<port>] [-tags=tag1:value1,tag2:value2] -keyspace=<keyspace> -shard=<shard> <tablet alias> <tablet type>`
GetTablet	`GetTablet <tablet alias>`
UpdateTabletAddrs	`UpdateTabletAddrs [-hostname <hostname>] [-ip-addr <ip addr>] [-mysql-port <mysql port>] [-vt-port <vt port>] [-grpc-port <grpc port>] <tablet alias>`
DeleteTablet	`DeleteTablet [-allow_master] <tablet alias> ...`
SetReadOnly	`SetReadOnly <tablet alias>`
SetReadWrite	`SetReadWrite <tablet alias>`
StartReplication	`StartReplication <tablet alias>`
StartSlave	`DEPRECATED -- Use StartReplication <tablet alias>`
StopReplication	`StopReplication <tablet alias>`
StopSlave	`DEPRECATED -- Use StopReplication <tablet alias>`
ChangeTabletType	`ChangeTabletType [-dry-run] <tablet alias> <tablet type>`
ChangeSlaveType	`DEPRECATED -- Use ChangeTabletType [-dry-run] <tablet alias> <tablet type>`
Ping	`Ping <tablet alias>`
RefreshState	`RefreshState <tablet alias>`
RefreshStateByShard	`RefreshStateByShard [-cells=c1,c2,...] <keyspace/shard>`
RunHealthCheck	`RunHealthCheck <tablet alias>`
IgnoreHealthError	`IgnoreHealthError <tablet alias> <ignore regexp>`
Sleep	`Sleep <tablet alias> <duration>`
ExecuteHook	`ExecuteHook <tablet alias> <hook name> [<param1=value1> <param2=value2> ...]`
ExecuteFetchAsApp	`ExecuteFetchAsApp [-max_rows=10000] [-json] [-use_pool] <tablet alias> <sql command>`
ExecuteFetchAsDba	`ExecuteFetchAsDba [-max_rows=10000] [-disable_binlogs] [-json] <tablet alias> <sql command>`
VReplicationExec	`VReplicationExec [-json] <tablet alias> <sql command>`
Backup	`Backup [-concurrency=4] [-allow_master=false] <tablet alias>`
RestoreFromBackup	`RestoreFromBackup <tablet alias>`
ReparentTablet	`ReparentTablet <tablet alias>`

Shards

Name	Example Usage
CreateShard	`CreateShard [-force] [-parent] <keyspace/shard>`
GetShard	`GetShard <keyspace/shard>`
ValidateShard	`ValidateShard [-ping-tablets] <keyspace/shard>`
ShardReplicationPositions	`ShardReplicationPositions <keyspace/shard>`
ListShardTablets	`ListShardTablets <keyspace/shard>`
SetShardIsMasterServing	`SetShardIsMasterServing <keyspace/shard> <is_master_serving>`
SetShardTabletControl	`SetShardTabletControl [--cells=c1,c2,...] [--blacklisted_tables=t1,t2,...] [--remove] [--disable_query_service] <keyspace/shard> <tablet type>`
UpdateSrvKeyspacePartition	`UpdateSrvKeyspacePartition [--cells=c1,c2,...] [--remove] <keyspace/shard> <tablet type>`
SourceShardDelete	`SourceShardDelete <keyspace/shard> <uid>`

Name	Example Usage
SourceShardAdd	`SourceShardAdd [--key_range=<keyrange>] [--tables=<table1,table2,...>] <keyspace/shard> <uid> <source keyspace/shard>`
ShardReplicationFix	`ShardReplicationFix <cell> <keyspace/shard>`
WaitForFilteredReplication	`WaitForFilteredReplication [-max_delay <max_delay, default 30s>] <keyspace/shard>`
RemoveShardCell	`RemoveShardCell [-force] [-recursive] <keyspace/shard> <cell>`
DeleteShard	`DeleteShard [-recursive] [-even_if_serving] <keyspace/shard> ...`
ListBackups	`ListBackups <keyspace/shard>`
BackupShard	`BackupShard [-allow_master=false] <keyspace/shard>`
RemoveBackup	`RemoveBackup <keyspace/shard> <backup name>`
InitShardMaster	`InitShardMaster [-force] [-wait_replicas_timeout=<duration>] <keyspace/shard> <tablet alias>`
PlannedReparentShard	`PlannedReparentShard -keyspace_shard=<keyspace/shard> [-new_master=<tablet alias>] [-avoid_master=<tablet alias>] [-wait_replicas_timeout=<duration>]`
EmergencyReparentShard	`EmergencyReparentShard -keyspace_shard=<keyspace/shard> -new_master=<tablet alias>`
TabletExternallyReparented	`TabletExternallyReparented <tablet alias>`

Keyspaces

Name	Example Usage
CreateKeyspace	`CreateKeyspace [-sharding_column_name=name] [-sharding_column_type=type] [-served_from=tablettype1:ks1,tablettype2:ks2,...] [-force] [-keyspace_type=type] [-base_keyspace=base_keyspace] [-snapshot_time=time] <keyspace name>`
DeleteKeyspace	`DeleteKeyspace [-recursive] <keyspace>`
RemoveKeyspaceCell	`RemoveKeyspaceCell [-force] [-recursive] <keyspace> <cell>`
GetKeyspace	`GetKeyspace <keyspace>`
GetKeyspaces	`GetKeyspaces`
SetKeyspaceShardingInfo	`SetKeyspaceShardingInfo [-force] <keyspace name> [<column name>] [<column type>]`
SetKeyspaceServedFrom	`SetKeyspaceServedFrom [-source=<source keyspace name>] [-remove] [-cells=c1,c2,...] <keyspace name> <tablet type>`
RebuildKeyspaceGraph	`RebuildKeyspaceGraph [-cells=c1,c2,...] <keyspace> ...`
ValidateKeyspace	`ValidateKeyspace [-ping-tablets] <keyspace name>`
Reshard	`Reshard [-skip_schema_copy] <keyspace.workflow> <source_shards> <target_shards>`
MoveTables	`MoveTables [-cell=<cell>] [-tablet_types=<source_tablet_types>] -workflow=<workflow> <source_keyspace> <target_keyspace> <table_specs>`
DropSources	`DropSources [-dry_run] <keyspace.workflow>`
CreateLookupVindex	`CreateLookupVindex [-cell=<cell>] [-tablet_types=<source_tablet_types>] <keyspace> <json_spec>`
ExternalizeVindex	`ExternalizeVindex <keyspace>.<vindex>`
Materialize	`Materialize <json_spec>, example : '{"workflow": "aaa", "source_keyspace": "source", "target_keyspace": "target", "table_settings": [{"target_table": "customer", "source_expression": "select * from customer", "create_ddl": "copy"}]}'`

Name	Example Usage
SplitClone	`SplitClone <keyspace> <from_shards> <to_shards>`
VerticalSplitClone	`VerticalSplitClone <from_keyspace> <to_keyspace> <tables>`
VDiff	`VDiff [-source_cell=<cell>] [-target_cell=<cell>] [-tablet_types=replica] [-filtered_replication_wait_time=30s] <keyspace.workflow>`
MigrateServedTypes	`MigrateServedTypes [-cells=c1,c2,...] [-reverse] [-skip-refresh-state] <keyspace/shard> <served tablet type>`
MigrateServedFrom	`MigrateServedFrom [-cells=c1,c2,...] [-reverse] <destination keyspace/shard> <served tablet type>`
SwitchReads	`SwitchReads [-cells=c1,c2,...] [-reverse] -tablet_type={replica|rdonly} [-dry-run] <keyspace.workflow>`
SwitchWrites	`SwitchWrites [-filtered_replication_wait_time=30s] [-cancel] [-reverse_replication=false] [-dry-run] <keyspace.workflow>`
CancelResharding	`CancelResharding <keyspace/shard>`
ShowResharding	`ShowResharding <keyspace/shard>`
FindAllShardsInKeyspace	`FindAllShardsInKeyspace <keyspace>`
WaitForDrain	`WaitForDrain [-timeout <duration>] [-retry_delay <duration>] [-initial_wait <duration>] <keyspace/shard> <served tablet type>`

Generic

Name	Example Usage
Validate	`Validate [-ping-tablets]`
ListAllTablets	`ListAllTablets <cell name1>, <cell name2>, ...`
ListTablets	`ListTablets <tablet alias> ...`
Help	`Help [command name]`

Schema, Version, Permissions

Name	Example Usage
GetSchema	`GetSchema [-tables=<table1>,<table2>,...] [-exclude_tables=<table1>,<table2>,...] [-include-views] <tablet alias>`
ReloadSchema	`ReloadSchema <tablet alias>`
ReloadSchemaShard	`ReloadSchemaShard [-concurrency=10] [-include_master=false] <keyspace/shard>`
ReloadSchemaKeyspace	`ReloadSchemaKeyspace [-concurrency=10] [-include_master=false] <keyspace>`
ValidateSchemaShard	`ValidateSchemaShard [-exclude_tables=''] [-include-views] <keyspace/shard>`
ValidateSchemaKeyspace	`ValidateSchemaKeyspace [-exclude_tables=''] [-include-views] <keyspace name>`
ApplySchema	`ApplySchema [-allow_long_unavailability] [-wait_replicas_timeout=10s] {-sql=<sql> || -sql-file=<filename>} <keyspace>`
CopySchemaShard	`CopySchemaShard [-tables=<table1>,<table2>,...] [-exclude_tables=<table1>,<table2>,...] [-include-views] [-skip-verify] [-wait_replicas_timeout=10s] {<source keyspace/shard> || <source tablet alias>} <destination keyspace/shard>`
ValidateVersionShard	`ValidateVersionShard <keyspace/shard>`

Name	Example Usage
ValidateVersionKeyspace	`ValidateVersionKeyspace <keyspace name>`
GetPermissions	`GetPermissions <tablet alias>`
ValidatePermissionsShard	`ValidatePermissionsShard <keyspace/shard>`
ValidatePermissionsKeyspace	`ValidatePermissionsKeyspace <keyspace name>`
GetVSchema	`GetVSchema <keyspace>`
ApplyVSchema	`ApplyVSchema {-vschema=<vschema> || -vschema_file=<vschema file> || -sql=<sql> || -sql_file=<sql file>} [-cells=c1,c2,...] [-skip_rebuild] [-dry-run] <keyspace>`
GetRoutingRules	`GetRoutingRules`
ApplyRoutingRules	`ApplyRoutingRules {-rules=<rules> || -rules_file=<rules_file>} [-cells=c1,c2,...] [-skip_rebuild] [-dry-run]`
RebuildVSchemaGraph	`RebuildVSchemaGraph [-cells=c1,c2,...]`

Serving Graph

Name	Example Usage
GetSrvKeyspaceNames	`GetSrvKeyspaceNames <cell>`
GetSrvKeyspace	`GetSrvKeyspace <cell> <keyspace>`
GetSrvVSchema	`GetSrvVSchema <cell>`
DeleteSrvVSchema	`DeleteSrvVSchema <cell>`

Replication Graph

Name	Example Usage
GetShardReplication	`GetShardReplication <cell> <keyspace/shard>`

Cells

Name	Example Usage
AddCellInfo	`AddCellInfo [-server_address <addr>] [-root <root>] <cell>`
UpdateCellInfo	`UpdateCellInfo [-server_address <addr>] [-root <root>] <cell>`
DeleteCellInfo	`DeleteCellInfo [-force] <cell>`
GetCellInfoNames	`GetCellInfoNames`
GetCellInfo	`GetCellInfo <cell>`

CellsAliases

Name	Example Usage
AddCellsAlias	`AddCellsAlias [-cells <cell,cell2...>] <alias>`
UpdateCellsAlias	`UpdateCellsAlias [-cells <cell,cell2,...>] <alias>`
DeleteCellsAlias	`DeleteCellsAlias <alias>`
GetCellsAliases	`GetCellsAliases`

Queries

Name	Example Usage
VtGateExecute	`VtGateExecute -server <vtgate> [-bind_variables <JSON map>] [-keyspace <default keyspace>] [-tablet_type <tablet type>] [-options <proto text options>] [-json] <sql>`
VtTabletExecute	`VtTabletExecute [-username <TableACL user>] [-transaction_id <transaction_id>] [-options <proto text options>] [-json] <tablet alias> <sql>`
VtTabletBegin	`VtTabletBegin [-username <TableACL user>] <tablet alias>`
VtTabletCommit	`VtTabletCommit [-username <TableACL user>] <transaction_id>`
VtTabletRollback	`VtTabletRollback [-username <TableACL user>] <tablet alias> <transaction_id>`
VtTabletStreamHealth	`VtTabletStreamHealth [-count <count, default 1>] <tablet alias>`

Resharding Throttler

Name	Example Usage
ThrottlerMaxRates	`ThrottlerMaxRates -server <vtworker or vttablet>`
ThrottlerSetMaxRate	`ThrottlerSetMaxRate -server <vtworker or vttablet> <rate>`
GetThrottlerConfiguration	`GetThrottlerConfiguration -server <vtworker or vttablet> [<throttler name>]`
UpdateThrottlerConfiguration	`UpdateThrottlerConfiguration -server <vtworker or vttablet> [-copy_zero_values] "<configuration protobuf text>" [<throttler name>]`
ResetThrottlerConfiguration	`ResetThrottlerConfiguration -server <vtworker or vttablet> [<throttler name>]`

Topo

Name	Example Usage
TopoCat	`TopoCat [-cell <cell>] [-decode_proto] [-decode_proto_json] [-long] <path> [<path>...]`
TopoCp	`TopoCp [-cell <cell>] [-to_topo] <src> <dst>`

Workflows

Name	Example Usage
WorkflowCreate	`WorkflowCreate [-skip_start] <factoryName> [parameters...]`
WorkflowStart	`WorkflowStart <uuid>`
WorkflowStop	`WorkflowStop <uuid>`
WorkflowDelete	`WorkflowDelete <uuid>`
WorkflowWait	`WorkflowWait <uuid>`
WorkflowTree	`WorkflowTree`
WorkflowAction	`WorkflowAction <path> <name>`

Options

The following global options apply to `vtctl`:

Name	Type	Definition
-alsologtostderr		log to standard error as well as files
-app_idle_timeout	duration	Idle timeout for app connections (default 1m0s)
-app_pool_size	int	Size of the connection pool for app connections (default 40)
-azblob_backup_account_key_file	string	Path to a file containing the Azure Storage account key; if this flag is unset, the environment variable VT_AZBLOB_ACCOUNT_KEY will be used as the key itself (NOT a file path)
-azblob_backup_account_name	string	Azure Storage Account name for backups; if this flag is unset, the environment variable VT_AZBLOB_ACCOUNT_NAME will be used
-azblob_backup_container_name	string	Azure Blob Container Name
-azblob_backup_parallelism	int	Azure Blob operation parallelism (requires extra memory when increased) (default 1)
-azblob_backup_storage_root	string	Root prefix for all backup-related Azure Blobs; this should exclude both initial and trailing '/' (e.g. just 'a/b' not '/a/b/')
-backup_engine_implementation	string	Specifies which implementation to use for creating new backups (builtin or xtrabackup). Restores will always be done with whichever engine created a given backup. (default "builtin")
-backup_storage_block_size	int	if backup_storage_compress is true, backup_storage_block_size sets the byte size for each block while compressing (default is 250000). (default 250000)
-backup_storage_compress		if set, the backup files will be compressed (default is true). Set to false for instance if a backup_storage_hook is specified and it compresses the data. (default true)
-backup_storage_hook	string	if set, we send the contents of the backup files through this hook.
-backup_storage_implementation	string	which implementation to use for the backup storage feature
-backup_storage_number_blocks	int	if backup_storage_compress is true, backup_storage_number_blocks sets the number of blocks that can be processed, at once, before the writer blocks, during compression (default is 2). It should be equal to the number of CPUs available for compression (default 2)
-binlog_player_protocol	string	the protocol to download binlogs from a vttablet (default "grpc")
-binlog_use_v3_resharding_mode		True iff the binlog streamer should use V3-style sharding, which doesn't require a preset sharding key column. (default true)
-ceph_backup_storage_config	string	Path to JSON config file for ceph backup storage (default "ceph_backup_config.json")
-consul_auth_static_file	string	JSON File to read the topos/tokens from.
-cpu_profile	string	write cpu profile to file
-datadog-agent-host	string	host to send spans to. if empty, no tracing will be done
-datadog-agent-port	string	port to send spans to. if empty, no tracing will be done
-db-credentials-file	string	db credentials file; send SIGHUP to reload this file
-db-credentials-server	string	db credentials server type (use 'file' for the file implementation) (default "file")
-dba_idle_timeout	duration	Idle timeout for dba connections (default 1m0s)
-dba_pool_size	int	Size of the connection pool for dba connections (default 20)
-detach		detached mode - run vtcl detached from the terminal
-disable_active_reparents		if set, do not allow active reparents. Use this to protect a cluster using external reparents.
-discovery_high_replication_lag_minimum_serving	duration	the replication lag that is considered too high when selecting the minimum num vttablets for serving (default 2h0m0s)
-discovery_low_replication_lag	duration	the replication lag that is considered low enough to be healthy (default 30s)
-emit_stats		true iff we should emit stats to push-based monitoring/stats backends
-enable-consolidator		This option enables the query consolidator. (default true)
-enable-consolidator-replicas		This option enables the query consolidator only on replicas.

Name	Type	Definition
-enable-query-plan-field-caching		This option fetches & caches fields (columns) when storing query plans (default true)
-enable-tx-throttler		If true replication-lag-based throttling on transactions will be enabled.
-enable_hot_row_protection		If true, incoming transactions for the same row (range) will be queued and cannot consume all txpool slots.
-enable_hot_row_protection_dry_run		If true, hot row protection is not enforced but logs if transactions would have been queued.
-enable_queries		if set, allows vtgate and vttablet queries. May have security implications, as the queries will be run from this process.
-enable_transaction_limit		If true, limit on number of transactions open at the same time will be enforced for all users. User trying to open a new transaction after exhausting their limit will receive an error immediately, regardless of whether there are available slots or not.
-enable_transaction_limit_dry_run		If true, limit on number of transactions open at the same time will be tracked for all users, but not enforced.
-enforce_strict_trans_tables		If true, vttablet requires MySQL to run with STRICT_TRANS_TABLES or STRICT_ALL_TABLES on. It is recommended to not turn this flag off. Otherwise MySQL may alter your supplied values before saving them to the database. (default true)
-file_backup_storage_root	string	root directory for the file backup storage
-gcs_backup_storage_bucket	string	Google Cloud Storage bucket to use for backups
-gcs_backup_storage_root	string	root prefix for all backup-related object names
-grpc_auth_mode	string	Which auth plugin implementation to use (eg: static)
-grpc_auth_mtls_allowed_substrings	string	List of substrings of at least one of the client certificate names (separated by colon).
-grpc_auth_static_client_creds	string	when using grpc_static_auth in the server, this file provides the credentials to use to authenticate with server
-grpc_auth_static_password_file	string	JSON File to read the users/passwords from.
-grpc_ca	string	ca to use, requires TLS, and enforces client cert check
-grpc_cert	string	certificate to use, requires grpc_key, enables TLS
-grpc_compression	string	how to compress gRPC, default: nothing, supported: snappy
-grpc_enable_tracing		Enable GRPC tracing
-grpc_initial_conn_window_size	int	grpc initial connection window size
-grpc_initial_window_size	int	grpc initial window size
-grpc_keepalive_time	duration	After a duration of this time if the client doesn't see any activity it pings the server to see if the transport is still alive. (default 10s)
-grpc_keepalive_timeout	duration	After having pinged for keepalive check, the client waits for a duration of Timeout and if no activity is seen even after that the connection is closed. (default 10s)
-grpc_key	string	key to use, requires grpc_cert, enables TLS
-grpc_max_connection_age	duration	Maximum age of a client connection before GoAway is sent. (default 2562047h47m16.854775807s)
-grpc_max_connection_age_grace	duration	Additional grace period after grpc_max_connection_age, after which connections are forcibly closed. (default 2562047h47m16.854775807s)
-grpc_max_message_size	int	Maximum allowed RPC message size. Larger messages will be rejected by gRPC with the error 'exceeding the max size'. (default 16777216)
-grpc_port	int	Port to listen on for gRPC calls
-grpc_prometheus		Enable gRPC monitoring with Prometheus
-grpc_server_initial_conn_window_size	int	grpc server initial connection window size
-grpc_server_initial_window_size	int	grpc server initial window size

Name	Type	Definition
-grpc_server_keepalive_enforcement_policy_min_time	duration	grpc server minimum keepalive time (default 5m0s)
-grpc_server_keepalive_enforcement_policy_permit_without_stream		grpc server permit client keepalive pings even when there are no active streams (RPCs)
-heartbeat_enable		If true, vttablet records (if master) or checks (if replica) the current time of a replication heartbeat in the table _vt.heartbeat. The result is used to inform the serving state of the vttablet via healthchecks.
-heartbeat_interval	duration	How frequently to read and write replication heartbeat. (default 1s)
-hot_row_protection_concurrent_transactions	int	Number of concurrent transactions let through to the txpool/MySQL for the same hot row. Should be > 1 to have enough 'ready' transactions in MySQL and benefit from a pipelining effect. (default 5)
-hot_row_protection_max_global_queue_size	int	Global queue limit across all row (ranges). Useful to prevent that the queue can grow unbounded. (default 1000)
-hot_row_protection_max_queue_size	int	Maximum number of BeginExecute RPCs which will be queued for the same row (range). (default 20)
-jaeger-agent-host	string	host and port to send spans to. if empty, no tracing will be done
-keep_logs	duration	keep logs for this long (using ctime) (zero to keep forever)
-keep_logs_by_mtime	duration	keep logs for this long (using mtime) (zero to keep forever)
-lameduck-period	duration	keep running at least this long after SIGTERM before stopping (default 50ms)
-legacy_replication_lag_algorithm		use the legacy algorithm when selecting the vttablets for serving (default true)
-log_backtrace_at	value	when logging hits line file:N, emit a stack trace
-log_dir	string	If non-empty, write log files in this directory
-log_err_stacks		log stack traces for errors
-log_rotate_max_size	uint	size in bytes at which logs are rotated (glog.MaxSize) (default 1887436800)
-logtostderr		log to standard error instead of files
-master_connect_retry	duration	how long to wait in between replica reconnect attempts. Only precise to the second. (default 10s)
-mem-profile-rate	int	profile every n bytes allocated (default 524288)
-min_number_serving_vttablets	int	the minimum number of vttablets that will be continue to be used even with low replication lag (default 2)
-mutex-profile-fraction	int	profile every n mutex contention events (see runtime.SetMutexProfileFraction)
-mysql_auth_server_static_file	string	JSON File to read the users/passwords from.
-mysql_auth_server_static_string	string	JSON representation of the users/passwords config.
-mysql_auth_static_reload_interval	duration	Ticker to reload credentials
-mysql_clientcert_auth_method	string	client-side authentication method to use. Supported values: mysql_clear_password, dialog. (default "mysql_clear_password")
-mysql_server_flush_delay	duration	Delay after which buffered response will flushed to client. (default 100ms)
-mysqlctl_client_protocol	string	the protocol to use to talk to the mysqlctl server (default "grpc")
-mysqlctl_mycnf_template	string	template file to use for generating the my.cnf file during server init
-mysqlctl_socket	string	socket file to use for remote mysqlctl actions (empty for local actions)
-onterm_timeout	duration	wait no more than this for OnTermSync handlers before stopping (default 10s)
-pid_file	string	If set, the process will write its pid to the named file, and delete it on graceful shutdown.
-pool_hostname_resolve_interval	duration	if set force an update to all hostnames and reconnect if changed, defaults to 0 (disabled)
-purge_logs_interval	duration	how often try to remove old logs (default 1h0m0s)
-query-log-stream-handler	string	URL handler for streaming queries log (default "/debug/querylog")

Name	Type	Definition
-querylog-filter-tag	string	string that must be present in the query as a comment for the query to be logged, works for both vtgate and vttablet
-querylog-format	string	format for query logs (“text” or “json”) (default “text”)
-queryserver-config-acl-exempt-acl	string	an acl that exempt from table acl checking (this acl is free to access any vitess tables).
-queryserver-config-enable-table-acl-dry-run		If this flag is enabled, tabletserver will emit monitoring metrics and let the request pass regardless of table acl check results
-queryserver-config-idle-timeout	int	query server idle timeout (in seconds), vttablet manages various mysql connection pools. This config means if a connection has not been used in given idle timeout, this connection will be removed from pool. This effectively manages number of connection objects and optimize the pool performance. (default 1800)
-queryserver-config-max-dml-rows	int	query server max dml rows per statement, maximum number of rows allowed to return at a time for an update or delete with either 1) an equality where clauses on primary keys, or 2) a subselect statement. For update and delete statements in above two categories, vttablet will split the original query into multiple small queries based on this configuration value.
-queryserver-config-max-result-size	int	query server max result size, maximum number of rows allowed to return from vttablet for non-streaming queries. (default 10000)
-queryserver-config-message-conn-pool-prefill-parallelism	int	DEPRECATED: Unused.
-queryserver-config-message-conn-pool-size	int	DEPRECATED
-queryserver-config-message-postpone-cap	int	query server message postpone cap is the maximum number of messages that can be postponed at any given time. Set this number to substantially lower than transaction cap, so that the transaction pool isn’t exhausted by the message subsystem. (default 4)
-queryserver-config-passthrough-dmls		query server pass through all dml statements without rewriting
-queryserver-config-pool-prefill-parallelism	int	query server read pool prefill parallelism, a non-zero value will prefill the pool using the specified parallism.
-queryserver-config-pool-size	int	query server read pool size, connection pool is used by regular queries (non streaming, not in a transaction) (default 16)
-queryserver-config-query-cache-size	int	query server query cache size, maximum number of queries to be cached. vttablet analyzes every incoming query and generate a query plan, these plans are being cached in a lru cache. This config controls the capacity of the lru cache. (default 5000)
-queryserver-config-query-pool-timeout	int	query server query pool timeout (in seconds), it is how long vttablet waits for a connection from the query pool. If set to 0 (default) then the overall query timeout is used instead.
-queryserver-config-query-pool-waiter-cap	int	query server query pool waiter limit, this is the maximum number of queries that can be queued waiting to get a connection (default 5000)
-queryserver-config-query-timeout	int	query server query timeout (in seconds), this is the query timeout in vttablet side. If a query takes more than this timeout, it will be killed. (default 30)
-queryserver-config-schema-reload-time	int	query server schema reload time, how often vttablet reloads schemas from underlying MySQL instance in seconds. vttablet keeps table schemas in its own memory and periodically refreshes it from MySQL. This config controls the reload time. (default 1800)
-queryserver-config-stream-buffer-size	int	query server stream buffer size, the maximum number of bytes sent from vttablet for each stream call. It’s recommended to keep this value in sync with vtgate’s stream_buffer_size. (default 32768)
-queryserver-config-stream-pool-prefill-parallelism	int	query server stream pool prefill parallelism, a non-zero value will prefill the pool using the specified parallelism

Name	Type	Definition
-queryserver-config-stream-pool-size	int	query server stream connection pool size, stream pool is used by stream queries: queries that return results to client in a streaming fashion (default 200)
-queryserver-config-strict-table-acl		only allow queries that pass table acl checks
-queryserver-config-terse-errors		prevent bind vars from escaping in returned errors
-queryserver-config-transaction-cap	int	query server transaction cap is the maximum number of transactions allowed to happen at any given point of a time for a single vttablet. E.g. by setting transaction cap to 100, there are at most 100 transactions will be processed by a vttablet and the 101th transaction will be blocked (and fail if it cannot get connection within specified timeout) (default 20)
-queryserver-config-transaction-prefill-parallelism	int	query server transaction prefill parallelism, a non-zero value will prefill the pool using the specified parallism.
-queryserver-config-transaction-timeout	int	query server transaction timeout (in seconds), a transaction will be killed if it takes longer than this value (default 30)
-queryserver-config-txpool-timeout	int	query server transaction pool timeout, it is how long vttablet waits if tx pool is full (default 1)
-queryserver-config-txpool-waiter-cap	int	query server transaction pool waiter limit, this is the maximum number of transactions that can be queued waiting to get a connection (default 5000)
-queryserver-config-warn-result-size	int	query server result size warning threshold, warn if number of rows returned from vttablet for non-streaming queries exceeds this
-redact-debug-ui-queries		redact full queries and bind variables from debug UI
-remote_operation_timeout	duration	time to wait for a remote operation (default 30s)
-s3_backup_aws_endpoint	string	endpoint of the S3 backend (region must be provided)
-s3_backup_aws_region	string	AWS region to use (default “us-east-1”)
-s3_backup_aws_retries	int	AWS request retries (default -1)
-s3_backup_force_path_style		force the s3 path style
-s3_backup_log_level	string	determine the S3 loglevel to use from LogOff, LogDebug, LogDebugWithSigning, LogDebugWithHTTPBody, LogDebugWithRequestRetries, LogDebugWithRequestErrors (default “LogOff”)
-s3_backup_server_side_encryption	string	server-side encryption algorithm (e.g., AES256, aws:kms)
-s3_backup_storage_bucket	string	S3 bucket to use for backups
-s3_backup_storage_root	string	root prefix for all backup-related object names
-s3_backup_tls_skip_verify_cert		skip the ‘certificate is valid’ check for SSL connections
-security_policy	string	the name of a registered security policy to use for controlling access to URLs - empty means allow all for anyone (built-in policies: deny-all, read-only)
-service_map	value	comma separated list of services to enable (or disable if prefixed with ‘-’) Example: grpc-vtworker
-sql-max-length-errors	int	truncate queries in error logs to the given length (default unlimited)
-sql-max-length-ui	int	truncate queries in debug UIs to the given length (default 512) (default 512)
-srv_topo_cache_refresh	duration	how frequently to refresh the topology for cached entries (default 1s)
-srv_topo_cache_ttl	duration	how long to use cached entries for topology (default 1s)
-stats_backend	string	The name of the registered push-based monitoring/stats backend to use
-stats_combine_dimensions	string	List of dimensions to be combined into a single “all” value in exported stats vars
-stats_drop_variables	string	Variables to be dropped from the list of exported variables.
-stats_emit_period	duration	Interval between emitting stats to all registered backends (default 1m0s)
-stderrthreshold	value	logs at or above this threshold go to stderr (default 1)
-tablet_dir	string	The directory within the vtdataroot to store vttablet/mysql files. Defaults to being generated by the tablet uid.
-tablet_grpc_ca	string	the server ca to use to validate servers when connecting
-tablet_grpc_cert	string	the cert to use to connect

Name	Type	Definition
-tablet_grpc_key	string	the key to use to connect
-tablet_grpc_server_name	string	the server name to use to validate server certificate
-tablet_manager_grpc_ca	string	the server ca to use to validate servers when connecting
-tablet_manager_grpc_cert	string	the cert to use to connect
-tablet_manager_grpc_concurrency	int	concurrency to use to talk to a vttablet server for performance-sensitive RPCs (like ExecuteFetchAs{Dba,AllPrivs,App}) (default 8)
-tablet_manager_grpc_key	string	the key to use to connect
-tablet_manager_grpc_server_name	string	the server name to use to validate server certificate
-tablet_manager_protocol	string	the protocol to use to talk to vttablet (default “grpc”)
-tablet_protocol	string	how to talk to the vttablets (default “grpc”)
-tablet_url_template	string	format string describing debug tablet url formatting. See the Go code for getTabletDebugURL() how to customize this. (default “http://{{.GetTabletHostPort}}”)
-throttler_client_grpc_ca	string	the server ca to use to validate servers when connecting
-throttler_client_grpc_cert	string	the cert to use to connect
-throttler_client_grpc_key	string	the key to use to connect
-throttler_client_grpc_server_name	string	the server name to use to validate server certificate
-throttler_client_protocol	string	the protocol to use to talk to the integrated throttler service (default “grpc”)
-topo_consul_watch_poll_duration	duration	time of the long poll for watch queries. (default 30s)
-topo_etcd_lease_ttl	int	Lease TTL for locks and master election. The client will use KeepAlive to keep the lease going. (default 30)
-topo_etcd_tls_ca	string	path to the ca to use to validate the server cert when connecting to the etcd topo server
-topo_etcd_tls_cert	string	path to the client cert to use to connect to the etcd topo server, requires topo_etcd_tls_key, enables TLS
-topo_etcd_tls_key	string	path to the client key to use to connect to the etcd topo server, enables TLS
-topo_global_root	string	the path of the global topology data in the global topology server
-topo_global_server_address	string	the address of the global topology server
-topo_implementation	string	the topology implementation to use
-topo_k8s_context	string	The kubeconfig context to use, overrides the ‘current-context’ from the config
-topo_k8s_kubeconfig	string	Path to a valid kubeconfig file.
-topo_k8s_namespace	string	The kubernetes namespace to use for all objects. Default comes from the context or in-cluster config
-topo_zk_auth_file	string	auth to use when connecting to the zk topo server, file contents should be :, e.g., digest:user:pass
-topo_zk_base_timeout	duration	zk base timeout (see zk.Connect) (default 30s)
-topo_zk_max_concurrency	int	maximum number of pending requests to send to a Zookeeper server. (default 64)
-topo_zk_tls_ca	string	the server ca to use to validate servers when connecting to the zk topo server
-topo_zk_tls_cert	string	the cert to use to connect to the zk topo server, requires topo_zk_tls_key, enables TLS
-topo_zk_tls_key	string	the key to use to connect to the zk topo server, enables TLS
-tracer	string	tracing service to use (default “noop”)
-tracing-sampling-rate	float	sampling rate for the probabilistic jaeger sampler (default 0.1)
-transaction-log-stream-handler	string	URL handler for streaming transactions log (default “/debug/txlog”)
-transaction_limit_by_component		Include CallerID.component when considering who the user is for the purpose of transaction limit.
-transaction_limit_by_principal		Include CallerID.principal when considering who the user is for the purpose of transaction limit. (default true)
-transaction_limit_by_subcomponent		Include CallerID.subcomponent when considering who the user is for the purpose of transaction limit.

Name	Type	Definition
-transaction_limit_by_username		Include VTGateCallerID.username when considering who the user is for the purpose of transaction limit. (default true)
-transaction_limit_per_user	float	Maximum number of transactions a single user is allowed to use at any time, represented as fraction of -transaction_cap. (default 0.4)
-transaction_shutdown_grace_period	int	how long to wait (in seconds) for transactions to complete during graceful shutdown.
-twopc_abandon_age	float	time in seconds. Any unresolved transaction older than this time will be sent to the coordinator to be resolved.
-twopc_coordinator_address	string	address of the (VTGate) process(es) that will be used to notify of abandoned transactions.
-twopc_enable		if the flag is on, 2pc is enabled. Other 2pc flags must be supplied.
-tx-throttler-config	string	The configuration of the transaction throttler as a text formatted throttlerdata.Configuration protocol buffer message (default "target_replication_lag_sec: 2 max_replication_lag_sec: 10 initial_rate: 100 max_increase: 1 emergency_decrease: 0.5 min_duration_between_increases_sec: 40 max_duration_between_increases_sec: 62 min_duration_between_decreases_sec: 20 spread_backlog_across_sec: 20 age_bad_rate_after_sec: 180 bad_rate_increase: 0.1 max_rate_approach_threshold: 0.9")
-tx-throttler-healthcheck-cells	value	A comma-separated list of cells. Only tabletservers running in these cells will be monitored for replication lag by the transaction throttler.
-v	value	log level for V logs
-version		print binary version
-vmodule	value	comma-separated list of pattern=N settings for file-filtered logging
-vreplication_healthcheck_retry_delay	duration	healthcheck retry delay (default 5s)
-vreplication_healthcheck_timeout	duration	healthcheck retry delay (default 1m0s)
-vreplication_healthcheck_topology_refresh	duration	refresh interval for re-reading the topology (default 30s)
-vreplication_retry_delay	duration	delay before retrying a failed binlog connection (default 5s)
-vreplication_tablet_type	string	comma separated list of tablet types used as a source (default "REPLICA")
-vstream_packet_size	int	Suggested packet size for VReplication streamer. This is used only as a recommendation. The actual packet size may be more or less than this amount. (default 30000)
-vtctl_healthcheck_retry_delay	duration	delay before retrying a failed healthcheck (default 5s)
-vtctl_healthcheck_timeout	duration	the health check timeout period (default 1m0s)
-vtctl_healthcheck_topology_refresh	duration	refresh interval for re-reading the topology (default 30s)
-vtgate_grpc_ca	string	the server ca to use to validate servers when connecting
-vtgate_grpc_cert	string	the cert to use to connect
-vtgate_grpc_key	string	the key to use to connect
-vtgate_grpc_server_name	string	the server name to use to validate server certificate
-vtgate_protocol	string	how to talk to vtgate (default "grpc")
-wait-time	duration	time to wait on an action (default 24h0m0s)
-wait_for_drain_sleep_rdonly	duration	time to wait before shutting the query service on old RDONLY tablets during MigrateServedTypes (default 5s)
-wait_for_drain_sleep_replica	duration	time to wait before shutting the query service on old REPLICA tablets during MigrateServedTypes (default 15s)
-watch_replication_stream		When enabled, vttablet will stream the MySQL replication stream from the local server, and use it to support the include_event_token ExecuteOptions.

Name	Type	Definition
-xbstream_restore_flags	string	flags to pass to xbstream command during restore. These should be space separated and will be added to the end of the command. These need to match the ones used for backup e.g. –compress / –decompress, –encrypt / –decrypt
-xtrabackup_backup_flags	string	flags to pass to backup command. These should be space separated and will be added to the end of the command
-xtrabackup_prepare_flags	string	flags to pass to prepare command. These should be space separated and will be added to the end of the command
-xtrabackup_root_path	string	directory location of the xtrabackup executable, e.g., /usr/bin
-xtrabackup_stream_mode	string	which mode to use if streaming, valid values are tar and xbstream (default “tar”)
-xtrabackup_stripe_block_size	uint	Size in bytes of each block that gets sent to a given stripe before rotating to the next stripe (default 102400)
-xtrabackup_stripes	uint	If greater than 0, use data striping across this many destination files to parallelize data transfer and decompression
-xtrabackup_user	string	User that xtrabackup will use to connect to the database server. This user must have all necessary privileges. For details, please refer to xtrabackup documentation.

vtctld

description: The Vitess Admin GUI

`vtctld` is a webserver interface to administer a Vitess cluster. It is usually the first Vitess component to be started after a valid global topology service has been created.

Example Usage

The following example launches the `vtctld` daemon on port 15000:

```
export TOPOLOGY_FLAGS="-topo_implementation etcd2 -topo_global_server_address
   localhost:2379 -topo_global_root /vitess/global"
export VTDATAROOT="/tmp"

vtctld \
 $TOPOLOGY_FLAGS \
 -workflow_manager_init \
 -workflow_manager_use_election \
 -service_map 'grpc-vtctl' \
 -backup_storage_implementation file \
 -file_backup_storage_root $VTDATAROOT/backups \
 -log_dir $VTDATAROOT/tmp \
 -port 15000 \
 -grpc_port 15999
```

Options

Name	Type	Definition
-action_timeout	duration	time to wait for an action before resorting to force (default 2m0s)
-alsologtostderr		log to standard error as well as files
-app_idle_timeout	duration	Idle timeout for app connections (default 1m0s)
-app_pool_size	int	Size of the connection pool for app connections (default 40)

Name	Type	Definition
-azblob_backup_account_key_file	string	Path to a file containing the Azure Storage account key; if this flag is unset, the environment variable VT_AZBLOB_ACCOUNT_KEY will be used as the key itself (NOT a file path)
-azblob_backup_account_name	string	Azure Storage Account name for backups; if this flag is unset, the environment variable VT_AZBLOB_ACCOUNT_NAME will be used
-azblob_backup_container_name	string	Azure Blob Container Name
-azblob_backup_parallelism	int	Azure Blob operation parallelism (requires extra memory when increased) (default 1)
-azblob_backup_storage_root	string	Root prefix for all backup-related Azure Blobs; this should exclude both initial and trailing '/' (e.g. just 'a/b' not '/a/b/')
-backup_engine_implementation	string	Specifies which implementation to use for creating new backups (builtin or xtrabackup). Restores will always be done with whichever engine created a given backup. (default "builtin")
-backup_storage_block_size	int	if backup_storage_compress is true, backup_storage_block_size sets the byte size for each block while compressing (default is 250000). (default 250000)
-backup_storage_compress	boolean	if set, the backup files will be compressed (default is true). Set to false for instance if a backup_storage_hook is specified and it compresses the data. (default true)
-backup_storage_hook	string	if set, we send the contents of the backup files through this hook.
-backup_storage_implementation	string	which implementation to use for the backup storage feature
-backup_storage_number_blocks	int	if backup_storage_compress is true, backup_storage_number_blocks sets the number of blocks that can be processed, at once, before the writer blocks, during compression (default is 2). It should be equal to the number of CPUs available for compression (default 2)
-binlog_player_protocol	string	the protocol to download binlogs from a vttablet (default "grpc")
-binlog_use_v3_resharding_mode	boolean	True iff the binlog streamer should use V3-style sharding, which doesn't require a preset sharding key column. (default true)
-cell	string	cell to use
-ceph_backup_storage_config	string	Path to JSON config file for ceph backup storage (default "ceph_backup_config.json")
-consul_auth_static_file	string	JSON File to read the topos/tokens from.
-cpu_profile	string	write cpu profile to file
-datadog-agent-host	string	host to send spans to. if empty, no tracing will be done
-datadog-agent-port	string	port to send spans to. if empty, no tracing will be done
-db-credentials-file	string	db credentials file; send SIGHUP to reload this file
-db-credentials-server	string	db credentials server type (use 'file' for the file implementation) (default "file")
-dba_idle_timeout	duration	Idle timeout for dba connections (default 1m0s)
-dba_pool_size	int	Size of the connection pool for dba connections (default 20)
-disable_active_reparents	boolean	if set, do not allow active reparents. Use this to protect a cluster using external reparents.
-discovery_high_replication_lag_minimum_serving	duration	the replication lag that is considered too high when selecting the minimum num vttablets for serving (default 2h0m0s)
-discovery_low_replication_lag	duration	the replication lag that is considered low enough to be healthy (default 30s)
-emit_stats	boolean	true iff we should emit stats to push-based monitoring/stats backends
-enable-consolidator	boolean	This option enables the query consolidator. (default true)
-enable-consolidator-replicas	boolean	This option enables the query consolidator only on replicas.
-enable-query-plan-field-caching	boollean	This option fetches & caches fields (columns) when storing query plans (default true)
-enable-tx-throttler	boolean	If true replication-lag-based throttling on transactions will be enabled.

Name	Type	Definition
-enable_hot_row_protection	boolean	If true, incoming transactions for the same row (range) will be queued and cannot consume all txpool slots.
-enable_hot_row_protection_dry_run	boolean	If true, hot row protection is not enforced but logs if transactions would have been queued.
-enable_queries	boolean	if set, allows vtgate and vttablet queries. May have security implications, as the queries will be run from this process.
-enable_realtime_stats	boolean	Required for the Realtime Stats view. If set, vtctld will maintain a streaming RPC to each tablet (in all cells) to gather the realtime health stats.
-enable_transaction_limit	boolean	If true, limit on number of transactions open at the same time will be enforced for all users. User trying to open a new transaction after exhausting their limit will receive an error immediately, regardless of whether there are available slots or not.
-enable_transaction_limit_dry_run	boolean	If true, limit on number of transactions open at the same time will be tracked for all users, but not enforced.
-enforce_strict_trans_tables	boolean	If true, vttablet requires MySQL to run with STRICT_TRANS_TABLES or STRICT_ALL_TABLES on. It is recommended to not turn this flag off. Otherwise MySQL may alter your supplied values before saving them to the database. (default true)
-file_backup_storage_root	string	root directory for the file backup storage
-gcs_backup_storage_bucket	string	Google Cloud Storage bucket to use for backups
-gcs_backup_storage_root	string	root prefix for all backup-related object names
-grpc_auth_mode	string	Which auth plugin implementation to use (eg: static)
-grpc_auth_mtls_allowed_substrings	string	List of substrings of at least one of the client certificate names (separated by colon).
-grpc_auth_static_client_creds	string	when using grpc_static_auth in the server, this file provides the credentials to use to authenticate with server
-grpc_auth_static_password_file	string	JSON File to read the users/passwords from.
-grpc_ca	string	ca to use, requires TLS, and enforces client cert check
-grpc_cert	string	certificate to use, requires grpc_key, enables TLS
-grpc_compression	string	how to compress gRPC, default: nothing, supported: snappy
-grpc_enable_tracing	boolean	Enable GRPC tracing
-grpc_initial_conn_window_size	int	grpc initial connection window size
-grpc_initial_window_size	int	grpc initial window size
-grpc_keepalive_time	duration	After a duration of this time if the client doesn't see any activity it pings the server to see if the transport is still alive. (default 10s)
-grpc_keepalive_timeout	duration	After having pinged for keepalive check, the client waits for a duration of Timeout and if no activity is seen even after that the connection is closed. (default 10s)
-grpc_key	string	key to use, requires grpc_cert, enables TLS
-grpc_max_connection_age	duration	Maximum age of a client connection before GoAway is sent. (default 2562047h47m16.854775807s)
-grpc_max_connection_age_grace	duration	Additional grace period after grpc_max_connection_age, after which connections are forcibly closed. (default 2562047h47m16.854775807s)
-grpc_max_message_size	int	Maximum allowed RPC message size. Larger messages will be rejected by gRPC with the error 'exceeding the max size'. (default 16777216)
-grpc_port	int	Port to listen on for gRPC calls
-grpc_prometheus	boolean	Enable gRPC monitoring with Prometheus
-grpc_server_initial_conn_window_size	int	grpc server initial connection window size
-grpc_server_initial_window_size	int	grpc server initial window size

Name	Type	Definition
-grpc_server_keepalive_enforcement_policy_min_time	duration	grpc server minimum keepalive time (default 5m0s)
-grpc_server_keepalive_enforcement_policy_permit_without_stream	m	grpc server permit client keepalive pings even when there are no active streams (RPCs)
-heartbeat_enable	boolean	If true, vttablet records (if master) or checks (if replica) the current time of a replication heartbeat in the table _vt.heartbeat. The result is used to inform the serving state of the vttablet via healthchecks.
-heartbeat_interval	duration	How frequently to read and write replication heartbeat. (default 1s)
-hot_row_protection_concurrent_transactions	int	Number of concurrent transactions let through to the txpool/MySQL for the same hot row. Should be > 1 to have enough 'ready' transactions in MySQL and benefit from a pipelining effect. (default 5)
-hot_row_protection_max_global_queue_size	int	Global queue limit across all row (ranges). Useful to prevent that the queue can grow unbounded. (default 1000)
-hot_row_protection_max_queue_size	int	Maximum number of BeginExecute RPCs which will be queued for the same row (range). (default 20)
-jaeger-agent-host	string	host and port to send spans to. if empty, no tracing will be done
-keep_logs	duration	keep logs for this long (using ctime) (zero to keep forever)
-keep_logs_by_mtime	duration	keep logs for this long (using mtime) (zero to keep forever)
-lameduck-period	duration	keep running at least this long after SIGTERM before stopping (default 50ms)
-legacy_replication_lag_algorithm	boolean	use the legacy algorithm when selecting the vttablets for serving (default true)
-log_backtrace_at	value	when logging hits line file:N, emit a stack trace
-log_dir	string	If non-empty, write log files in this directory
-log_err_stacks	boolean	log stack traces for errors
-log_rotate_max_size	uint	size in bytes at which logs are rotated (glog.MaxSize) (default 1887436800)
-logtostderr	boolean	log to standard error instead of files
-master_connect_retry	duration	how long to wait in between replica reconnect attempts. Only precise to the second. (default 10s)
-mem-profile-rate	int	profile every n bytes allocated (default 524288)
-min_number_serving_vttablets	int	the minimum number of vttablets that will be continue to be used even with low replication lag (default 2)
-mutex-profile-fraction	int	profile every n mutex contention events (see runtime.SetMutexProfileFraction)
-mysql_auth_server_static_file	string	JSON File to read the users/passwords from.
-mysql_auth_server_static_string	string	JSON representation of the users/passwords config.
-mysql_auth_static_reload_interval	duration	Ticker to reload credentials
-mysql_clientcert_auth_method	string	client-side authentication method to use. Supported values: mysql_clear_password, dialog. (default "mysql_clear_password")
-mysql_server_flush_delay	duration	Delay after which buffered response will flushed to client. (default 100ms)
-mysqlctl_client_protocol	string	the protocol to use to talk to the mysqlctl server (default "grpc")
-mysqlctl_mycnf_template	string	template file to use for generating the my.cnf file during server init
-mysqlctl_socket	string	socket file to use for remote mysqlctl actions (empty for local actions)
-onterm_timeout	duration	wait no more than this for OnTermSync handlers before stopping (default 10s)
-opentsdb_uri	string	URI of opentsdb /api/put method
-pid_file	string	If set, the process will write its pid to the named file, and delete it on graceful shutdown.
-pool_hostname_resolve_interval	duration	if set force an update to all hostnames and reconnect if changed, defaults to 0 (disabled)
-port	int	port for the server

Name	Type	Definition
-proxy_tablets	boolean	Setting this true will make vtctld proxy the tablet status instead of redirecting to them
-purge_logs_interval	duration	how often try to remove old logs (default 1h0m0s)
-query-log-stream-handler	string	URL handler for streaming queries log (default "/debug/querylog")
-querylog-filter-tag	string	string that must be present in the query as a comment for the query to be logged, works for both vtgate and vttablet
-querylog-format	string	format for query logs ("text" or "json") (default "text")
-queryserver-config-acl-exempt-acl	string	an acl that exempt from table acl checking (this acl is free to access any vitess tables).
-queryserver-config-enable-table-acl-dry-run	boolean	If this flag is enabled, tabletserver will emit monitoring metrics and let the request pass regardless of table acl check results
-queryserver-config-idle-timeout	int	query server idle timeout (in seconds), vttablet manages various mysql connection pools. This config means if a connection has not been used in given idle timeout, this connection will be removed from pool. This effectively manages number of connection objects and optimize the pool performance. (default 1800)
-queryserver-config-max-dml-rows	int	query server max dml rows per statement, maximum number of rows allowed to return at a time for an update or delete with either 1) an equality where clauses on primary keys, or 2) a subselect statement. For update and delete statements in above two categories, vttablet will split the original query into multiple small queries based on this configuration value.
-queryserver-config-max-result-size	int	query server max result size, maximum number of rows allowed to return from vttablet for non-streaming queries. (default 10000)
-queryserver-config-message-postpone-cap	int	query server message postpone cap is the maximum number of messages that can be postponed at any given time. Set this number to substantially lower than transaction cap, so that the transaction pool isn't exhausted by the message subsystem. (default 4)
-queryserver-config-passthrough-dmls	boolean	query server pass through all dml statements without rewriting
-queryserver-config-pool-prefill-parallelism	int	query server read pool prefill parallelism, a non-zero value will prefill the pool using the specified parallism.
-queryserver-config-pool-size	int	query server read pool size, connection pool is used by regular queries (non streaming, not in a transaction) (default 16)
-queryserver-config-query-cache-size	int	query server query cache size, maximum number of queries to be cached. vttablet analyzes every incoming query and generate a query plan, these plans are being cached in a lru cache. This config controls the capacity of the lru cache. (default 5000)
-queryserver-config-query-pool-timeout	int	query server query pool timeout (in seconds), it is how long vttablet waits for a connection from the query pool. If set to 0 (default) then the overall query timeout is used instead.
-queryserver-config-query-pool-waiter-cap	int	query server query pool waiter limit, this is the maximum number of queries that can be queued waiting to get a connection (default 5000)
-queryserver-config-query-timeout	int	query server query timeout (in seconds), this is the query timeout in vttablet side. If a query takes more than this timeout, it will be killed. (default 30)
-queryserver-config-schema-reload-time	int	query server schema reload time, how often vttablet reloads schemas from underlying MySQL instance in seconds. vttablet keeps table schemas in its own memory and periodically refreshes it from MySQL. This config controls the reload time. (default 1800)
-queryserver-config-stream-buffer-size	int	query server stream buffer size, the maximum number of bytes sent from vttablet for each stream call. It's recommended to keep this value in sync with vtgate's stream_buffer_size. (default 32768)
-queryserver-config-stream-pool-prefill-parallelism	int	query server stream pool prefill parallelism, a non-zero value will prefill the pool using the specified parallelism

Name	Type	Definition
-queryserver-config-stream-pool-size	int	query server stream connection pool size, stream pool is used by stream queries: queries that return results to client in a streaming fashion (default 200)
-queryserver-config-strict-table-acl	boolean	only allow queries that pass table acl checks
-queryserver-config-terse-errors	boolean	prevent bind vars from escaping in returned errors
-queryserver-config-transaction-cap	int	query server transaction cap is the maximum number of transactions allowed to happen at any given point of a time for a single vttablet. E.g. by setting transaction cap to 100, there are at most 100 transactions will be processed by a vttablet and the 101th transaction will be blocked (and fail if it cannot get connection within specified timeout) (default 20)
-queryserver-config-transaction-prefill-parallelism	int	query server transaction prefill parallelism, a non-zero value will prefill the pool using the specified parallism.
-queryserver-config-transaction-timeout	int	query server transaction timeout (in seconds), a transaction will be killed if it takes longer than this value (default 30)
-queryserver-config-txpool-timeout	int	query server transaction pool timeout, it is how long vttablet waits if tx pool is full (default 1)
-queryserver-config-txpool-waiter-cap	int	query server transaction pool waiter limit, this is the maximum number of transactions that can be queued waiting to get a connection (default 5000)
-queryserver-config-warn-result-size	int	query server result size warning threshold, warn if number of rows returned from vttablet for non-streaming queries exceeds this
-redact-debug-ui-queries	boolean	redact full queries and bind variables from debug UI
-remote_operation_timeout	duration	time to wait for a remote operation (default 30s)
-s3_backup_aws_endpoint	string	endpoint of the S3 backend (region must be provided)
-s3_backup_aws_region	string	AWS region to use (default “us-east-1”)
-s3_backup_aws_retries	int	AWS request retries (default -1)
-s3_backup_force_path_style	boolean	force the s3 path style
-s3_backup_log_level	string	determine the S3 loglevel to use from LogOff, LogDebug, LogDebugWithSigning, LogDebugWithHTTPBody, LogDebugWithRequestRetries, LogDebugWithRequestErrors (default “LogOff”)
-s3_backup_server_side_encryption	string	server-side encryption algorithm (e.g., AES256, aws:kms)
-s3_backup_storage_bucket	string	S3 bucket to use for backups
-s3_backup_storage_root	string	root prefix for all backup-related object names
-s3_backup_tls_skip_verify_cert	boolean	skip the ‘certificate is valid’ check for SSL connections
-schema_change_check_interval	int	this value decides how often we check schema change dir, in seconds (default 60)
-schema_change_controller	string	schema change controller is responsible for finding schema changes and responding to schema change events
-schema_change_dir	string	directory contains schema changes for all keyspaces. Each keyspace has its own directory and schema changes are expected to live in ‘$KEYSPACE/input’ dir. e.g. test_keyspace/input/*sql, each sql file represents a schema change
-schema_change_slave_timeout	duration	how long to wait for replicas to receive the schema change (default 10s)
-schema_change_user	string	The user who submits this schema change.
-schema_swap_admin_query_timeout	duration	timeout for SQL queries used to save and retrieve meta information for schema swap process (default 30s)
-schema_swap_backup_concurrency	int	number of simultaneous compression/checksum jobs to run for seed backup during schema swap (default 4)
-schema_swap_delay_between_errors	duration	time to wait after a retryable error happened in the schema swap process (default 1m0s)

Name	Type	Definition
-schema_swap_reparent_timeout	duration	timeout to wait for replicas when doing reparent during schema swap (default 30s)
-security_policy	string	the name of a registered security policy to use for controlling access to URLs - empty means allow all for anyone (built-in policies: deny-all, read-only)
-service_map	value	comma separated list of services to enable (or disable if prefixed with '-') Example: grpc-vtworker
-sql-max-length-errors	int	truncate queries in error logs to the given length (default unlimited)
-sql-max-length-ui	int	truncate queries in debug UIs to the given length (default 512) (default 512)
-srv_topo_cache_refresh	duration	how frequently to refresh the topology for cached entries (default 1s)
-srv_topo_cache_ttl	duration	how long to use cached entries for topology (default 1s)
-stats_backend	string	The name of the registered push-based monitoring/stats backend to use
-stats_combine_dimensions	string	List of dimensions to be combined into a single "all" value in exported stats vars
-stats_drop_variables	string	Variables to be dropped from the list of exported variables.
-stats_emit_period	duration	Interval between emitting stats to all registered backends (default 1m0s)
-stderrthreshold	value	logs at or above this threshold go to stderr (default 1)
-tablet_dir	string	The directory within the vtdataroot to store vttablet/mysql files. Defaults to being generated by the tablet uid.
-tablet_grpc_ca	string	the server ca to use to validate servers when connecting
-tablet_grpc_cert	string	the cert to use to connect
-tablet_grpc_key	string	the key to use to connect
-tablet_grpc_server_name	string	the server name to use to validate server certificate
-tablet_health_keep_alive	duration	close streaming tablet health connection if there are no requests for this long (default 5m0s)
-tablet_manager_grpc_ca	string	the server ca to use to validate servers when connecting
-tablet_manager_grpc_cert	string	the cert to use to connect
-tablet_manager_grpc_concurrency	int	concurrency to use to talk to a vttablet server for performance-sensitive RPCs (like ExecuteFetchAs{Dba,AllPrivs,App}) (default 8)
-tablet_manager_grpc_key	string	the key to use to connect
-tablet_manager_grpc_server_name	string	the server name to use to validate server certificate
-tablet_manager_protocol	string	the protocol to use to talk to vttablet (default "grpc")
-tablet_protocol	string	how to talk to the vttablets (default "grpc")
-tablet_url_template	string	format string describing debug tablet url formatting. See the Go code for getTabletDebugURL() how to customize this. (default "http://{{.GetTabletHostPort}}")
-throttler_client_grpc_ca	string	the server ca to use to validate servers when connecting
-throttler_client_grpc_cert	string	the cert to use to connect
-throttler_client_grpc_key	string	the key to use to connect
-throttler_client_grpc_server_name	string	the server name to use to validate server certificate
-throttler_client_protocol	string	the protocol to use to talk to the integrated throttler service (default "grpc")
-topo_consul_watch_poll_duration	duration	time of the long poll for watch queries. (default 30s)
-topo_etcd_lease_ttl	int	Lease TTL for locks and master election. The client will use KeepAlive to keep the lease going. (default 30)
-topo_etcd_tls_ca	string	path to the ca to use to validate the server cert when connecting to the etcd topo server
-topo_etcd_tls_cert	string	path to the client cert to use to connect to the etcd topo server, requires topo_etcd_tls_key, enables TLS
-topo_etcd_tls_key	string	path to the client key to use to connect to the etcd topo server, enables TLS
-topo_global_root	string	the path of the global topology data in the global topology server
-topo_global_server_address	string	the address of the global topology server
-topo_implementation	string	the topology implementation to use

Name	Type	Definition
-topo_k8s_context	string	The kubeconfig context to use, overrides the 'current-context' from the config
-topo_k8s_kubeconfig	string	Path to a valid kubeconfig file.
-topo_k8s_namespace	string	The kubernetes namespace to use for all objects. Default comes from the context or in-cluster config
-topo_zk_auth_file	string	auth to use when connecting to the zk topo server, file contents should be :, e.g., digest:user:pass
-topo_zk_base_timeout	duration	zk base timeout (see zk.Connect) (default 30s)
-topo_zk_max_concurrency	int	maximum number of pending requests to send to a Zookeeper server. (default 64)
-topo_zk_tls_ca	string	the server ca to use to validate servers when connecting to the zk topo server
-topo_zk_tls_cert	string	the cert to use to connect to the zk topo server, requires topo_zk_tls_key, enables TLS
-topo_zk_tls_key	string	the key to use to connect to the zk topo server, enables TLS
-tracer	string	tracing service to use (default "noop")
-tracing-sampling-rate	float	sampling rate for the probabilistic jaeger sampler (default 0.1)
-transaction-log-stream-handler	string	URL handler for streaming transactions log (default "/debug/txlog")
-transaction_limit_by_component	boolean	Include CallerID.component when considering who the user is for the purpose of transaction limit.
-transaction_limit_by_principal	boolean	Include CallerID.principal when considering who the user is for the purpose of transaction limit. (default true)
-transaction_limit_by_subcomponent	boolean	Include CallerID.subcomponent when considering who the user is for the purpose of transaction limit.
-transaction_limit_by_username	boolean	Include VTGateCallerID.username when considering who the user is for the purpose of transaction limit. (default true)
-transaction_limit_per_user	float	Maximum number of transactions a single user is allowed to use at any time, represented as fraction of -transaction_cap. (default 0.4)
-transaction_shutdown_grace_period	int	how long to wait (in seconds) for transactions to complete during graceful shutdown.
-twopc_abandon_age	float	time in seconds. Any unresolved transaction older than this time will be sent to the coordinator to be resolved.
-twopc_coordinator_address	string	address of the (VTGate) process(es) that will be used to notify of abandoned transactions.
-twopc_enable	boolean	if the flag is on, 2pc is enabled. Other 2pc flags must be supplied.
-tx-throttler-config	string	The configuration of the transaction throttler as a text formatted throttlerdata.Configuration protocol buffer message (default "target_replication_lag_sec: 2 max_replication_lag_sec: 10 initial_rate: 100 max_increase: 1 emergency_decrease: 0.5 min_duration_between_increases_sec: 40 max_duration_between_increases_sec: 62 min_duration_between_decreases_sec: 20 spread_backlog_across_sec: 20 age_bad_rate_after_sec: 180 bad_rate_increase: 0.1 max_rate_approach_threshold: 0.9")
-tx-throttler-healthcheck-cells	value	A comma-separated list of cells. Only tabletservers running in these cells will be monitored for replication lag by the transaction throttler.
-v	value	log level for V logs
-version		print binary version
-vmodule	value	comma-separated list of pattern=N settings for file-filtered logging
-vreplication_healthcheck_retry_delay	duration	healthcheck retry delay (default 5s)
-vreplication_healthcheck_timeout	duration	healthcheck retry delay (default 1m0s)
-vreplication_healthcheck_topology_refresh	duration	refresh interval for re-reading the topology (default 30s)
-vreplication_retry_delay	duration	delay before retrying a failed binlog connection (default 5s)

Name	Type	Definition
-vreplication_tablet_type	string	comma separated list of tablet types used as a source (default “REPLICA”)
-vstream_packet_size	int	Suggested packet size for VReplication streamer. This is used only as a recommendation. The actual packet size may be more or less than this amount. (default 30000)
-vtctl_client_protocol	string	the protocol to use to talk to the vtctl server (default “grpc”)
-vtctl_healthcheck_retry_delay	duration	delay before retrying a failed healthcheck (default 5s)
-vtctl_healthcheck_timeout	duration	the health check timeout period (default 1m0s)
-vtctl_healthcheck_topology_refresh	duration	refresh interval for re-reading the topology (default 30s)
-vtctld_show_topology_crud	boolean	Controls the display of the CRUD topology actions in the vtctld UI. (default true)
-vtgate_grpc_ca	string	the server ca to use to validate servers when connecting
-vtgate_grpc_cert	string	the cert to use to connect
-vtgate_grpc_key	string	the key to use to connect
-vtgate_grpc_server_name	string	the server name to use to validate server certificate
-vtgate_protocol	string	how to talk to vtgate (default “grpc”)
-vtworker_client_grpc_ca	string	the server ca to use to validate servers when connecting
-vtworker_client_grpc_cert	string	the cert to use to connect
-vtworker_client_grpc_key	string	the key to use to connect
-vtworker_client_grpc_server_name	string	the server name to use to validate server certificate
-vtworker_client_protocol	string	the protocol to use to talk to the vtworker server (default “grpc”)
-wait_for_drain_sleep_rdonly	duration	time to wait before shutting the query service on old RDONLY tablets during MigrateServedTypes (default 5s)
-wait_for_drain_sleep_replica	duration	time to wait before shutting the query service on old REPLICA tablets during MigrateServedTypes (default 15s)
-watch_replication_stream	boolean	When enabled, vttablet will stream the MySQL replication stream from the local server, and use it to support the include_event_token ExecuteOptions.
-workflow_manager_disable	value	comma separated list of workflow types to disable
-workflow_manager_init	boolean	Initialize the workflow manager in this vtctld instance.
-workflow_manager_use_election	boolean	if specified, will use a topology server-based master election to ensure only one workflow manager is active at a time.
-xbstream_restore_flags	string	flags to pass to xbstream command during restore. These should be space separated and will be added to the end of the command. These need to match the ones used for backup e.g. –compress / –decompress, –encrypt / –decrypt
-xtrabackup_backup_flags	string	flags to pass to backup command. These should be space separated and will be added to the end of the command
-xtrabackup_prepare_flags	string	flags to pass to prepare command. These should be space separated and will be added to the end of the command
-xtrabackup_root_path	string	directory location of the xtrabackup executable, e.g., /usr/bin
-xtrabackup_stream_mode	string	which mode to use if streaming, valid values are tar and xbstream (default “tar”)
-xtrabackup_stripe_block_size	uint	Size in bytes of each block that gets sent to a given stripe before rotating to the next stripe (default 102400)
-xtrabackup_stripes	uint	If greater than 0, use data striping across this many destination files to parallelize data transfer and decompression
-xtrabackup_user	string	User that xtrabackup will use to connect to the database server. This user must have all necessary privileges. For details, please refer to xtrabackup documentation.

vtexplain

`vtexplain` is a command line tool which provides information on how Vitess plans to execute a particular query. It can be used to validate queries for compatibility with Vitess.

For a user guide that describes how to use the `vtexplain` tool to explain how Vitess executes a particular SQL statement, see Analyzing a SQL statement.

Example Usage

Explain how Vitess will execute the query `SELECT * FROM users` using the VSchema contained in `vschemas.json` and the database schema `schema.sql`:

```
vtexplain -vschema-file vschema.json -schema-file schema.sql  -sql "SELECT * FROM users"
```

Explain how the example will execute on 128 shards using Row-based replication:

```
vtexplain -shards 128 -vschema-file vschema.json -schema-file schema.sql -replication-mode
   "ROW" -output-mode text -sql "INSERT INTO users (user_id, name) VALUES(1, 'john')"
```

Options

The following parameters apply to `mysqlctl`:

Name	Type	Definition
-output-mode	string	Output in human-friendly text or json (default “text”)
-normalize		Whether to enable vtgate normalization (default false)
-shards	int	Number of shards per keyspace (default 2)
-replication-mode	string	The replication mode to simulate – must be set to either ROW or STATEMENT (default “ROW”)
-schema	string	The SQL table schema (default ””)
-schema-file	string	Identifies the file that contains the SQL table schema (default ””)
-sql	string	A list of semicolon-delimited SQL commands to analyze (default ””)
-sql-file	string	Identifies the file that contains the SQL commands to analyze (default ””)
-vschema	string	Identifies the VTGate routing schema (default ””)
-vschema-file	string	Identifies the VTGate routing schema file (default ””)
-ks-shard-map	string	Identifies the shard keyranges for unevenly-sharded keyspaces (default ””)
-ks-shard-map-file	string	Identifies the shard keyranges file (default ””)
-dbname	string	Optional database target to override normal routing (default ””)
-queryserver-config-passthrough-dmls		query server pass through all dml statements without rewriting (default false)

Please note that `-ks-shard-map` and `ks-shard-map-file` will supercede `-shards`. If you attempt to `vtexplain` on a keyspace that is included in the keyspace shard map, the shards as defined in the mapping will be used and `-shards` will be ignored.

Limitations

The VSchema must use a keyspace name. VTExplain requires a keyspace name for each keyspace in an input VSChema:

```
"keyspace_name": {
    "_comment": "Keyspace definition goes here."
}
```

If no keyspace name is present, VTExplain will return the following error:

```
ERROR: initVtgateExecutor: json: cannot unmarshal bool into Go value of type
   map[string]json.RawMessage
```  ---
vtgate

VTGate is a stateless proxy responsible for accepting requests from applications and
   routing them to the appropriate tablet server(s) for query execution. It speaks both the
   MySQL Protocol and a gRPC protocol.

Example Usage

Start a vtgate proxy:

```bash
export TOPOLOGY_FLAGS="-topo_implementation etcd2 -topo_global_server_address
   localhost:2379 -topo_global_root /vitess/global"
export VTDATAROOT="/tmp"

vtgate \
  $TOPOLOGY_FLAGS \
  -log_dir $VTDATAROOT/tmp \
  -port 15001 \
  -grpc_port 15991 \
  -mysql_server_port 15306 \
  -cell test \
  -cells_to_watch test \
  -tablet_types_to_wait MASTER,REPLICA \
  -gateway_implementation discoverygateway \
  -service_map 'grpc-vtgateservice' \
  -pid_file $VTDATAROOT/tmp/vtgate.pid \
  -mysql_auth_server_impl none
```

Options

The following global options apply to `vtgate`:

Name	Type	Definition
-allowed_tablet_types	value	Specifies the tablet types this vtgate is allowed to route queries to
-alsologtostderr	boolean	log to standard error as well as files
-buffer_drain_concurrency	int	Maximum number of requests retried simultaneously. More concurrency will increase the load on the MASTER vttablet when draining the buffer. (default 1)
-buffer_keyspace_shards	string	If not empty, limit buffering to these entries (comma separated). Entry format: keyspace or keyspace/shard. Requires –enable_buffer=true.
-buffer_max_failover_duration	duration	Stop buffering completely if a failover takes longer than this duration. (default 20s)
-buffer_min_time_between_failovers	duration	Minimum time between the end of a failover and the start of the next one (tracked per shard). Faster consecutive failovers will not trigger buffering. (default 1m0s)
-buffer_size	int	Maximum number of buffered requests in flight (across all ongoing failovers). (default 10)
-buffer_window	duration	Duration for how long a request should be buffered at most. (default 10s)
-cell	string	cell to use (default “test_nj”)
-cells_to_watch	string	comma-separated list of cells for watching tablets

Name	Type	Definition
-consul_auth_static_file	string	JSON File to read the topos/tokens from.
-cpu_profile	string	write cpu profile to file
-datadog-agent-host	string	host to send spans to. if empty, no tracing will be done
-datadog-agent-port	string	port to send spans to. if empty, no tracing will be done
-default_tablet_type	value	The default tablet type to set for queries, when one is not explicitly selected (default MASTER)
-discovery_high_replication_lag_minimum_serving	duration	the replication lag that is considered too high when selecting the minimum num vttablets for serving (default 2h0m0s)
-discovery_low_replication_lag	duration	the replication lag that is considered low enough to be healthy (default 30s)
-emit_stats	boolean	true iff we should emit stats to push-based monitoring/stats backends
-enable_buffer	boolean	Enable buffering (stalling) of master traffic during failovers.
-enable_buffer_dry_run	boolean	Detect and log failover events, but do not actually buffer requests.
-gate_query_cache_size	int	gate server query cache size, maximum number of queries to be cached. vtgate analyzes every incoming query and generate a query plan, these plans are being cached in a lru cache. This config controls the capacity of the lru cache. (default 10000)
-gateway_implementation	string	The implementation of gateway (default “discoverygateway”)
-gateway_initial_tablet_timeout	duration	At startup, the gateway will wait up to that duration to get one tablet per keyspace/shard/tablettype (default 30s)
-grpc_auth_mode	string	Which auth plugin implementation to use (eg: static)
-grpc_auth_mtls_allowed_substrings	string	List of substrings of at least one of the client certificate names (separated by colon).
-grpc_auth_static_client_creds	string	when using grpc_static_auth in the server, this file provides the credentials to use to authenticate with server
-grpc_auth_static_password_file	string	JSON File to read the users/passwords from.
-grpc_ca	string	ca to use, requires TLS, and enforces client cert check
-grpc_cert	string	certificate to use, requires grpc_key, enables TLS
-grpc_compression	string	how to compress gRPC, default: nothing, supported: snappy
-grpc_enable_tracing	boolean	Enable GRPC tracing
-grpc_initial_conn_window_size	int	grpc initial connection window size
-grpc_initial_window_size	int	grpc initial window size
-grpc_keepalive_time	duration	After a duration of this time if the client doesn’t see any activity it pings the server to see if the transport is still alive. (default 10s)
-grpc_keepalive_timeout	duration	After having pinged for keepalive check, the client waits for a duration of Timeout and if no activity is seen even after that the connection is closed. (default 10s)
-grpc_key	string	key to use, requires grpc_cert, enables TLS
-grpc_max_connection_age	duration	Maximum age of a client connection before GoAway is sent. (default 2562047h47m16.854775807s)
-grpc_max_connection_age_grace	duration	Additional grace period after grpc_max_connection_age, after which connections are forcibly closed. (default 2562047h47m16.854775807s)
-grpc_max_message_size	int	Maximum allowed RPC message size. Larger messages will be rejected by gRPC with the error ‘exceeding the max size’. (default 16777216)
-grpc_port	int	Port to listen on for gRPC calls
-grpc_prometheus	boolean	Enable gRPC monitoring with Prometheus
-grpc_server_initial_conn_window_size	int	grpc server initial connection window size
-grpc_server_initial_window_size	int	grpc server initial window size
-grpc_server_keepalive_enforcement_policy_min_time	duration	grpc server minimum keepalive time (default 5m0s)

Name	Type	Definition
-grpc_server_keepalive_enforcement_policy_permit_without_stream	boolean	grpc server permit client keepalive pings even when there are no active streams (RPCs)
-grpc_use_effective_callerid	boolean	If set, and SSL is not used, will set the immediate caller id from the effective caller id's principal.
-healthcheck_retry_delay	duration	health check retry delay (default 2ms)
-healthcheck_timeout	duration	the health check timeout period (default 1m0s)
-jaeger-agent-host	string	host and port to send spans to. if empty, no tracing will be done
-keep_logs	duration	keep logs for this long (using ctime) (zero to keep forever)
-keep_logs_by_mtime	duration	keep logs for this long (using mtime) (zero to keep forever)
-keyspaces_to_watch	value	Specifies which keyspaces this vtgate should have access to while routing queries or accessing the vschema
-lameduck-period	duration	keep running at least this long after SIGTERM before stopping (default 50ms)
-legacy_replication_lag_algorithm	boolean	use the legacy algorithm when selecting the vttablets for serving (default true)
-log_backtrace_at	value	when logging hits line file:N, emit a stack trace
-log_dir	string	If non-empty, write log files in this directory
-log_err_stacks	boolean	log stack traces for errors
-log_queries_to_file	string	Enable query logging to the specified file
-log_rotate_max_size	uint	size in bytes at which logs are rotated (glog.MaxSize) (default 1887436800)
-logtostderr	boolean	log to standard error instead of files
-max_memory_rows	int	Maximum number of rows that will be held in memory for intermediate results as well as the final result. (default 300000)
-mem-profile-rate	int	profile every n bytes allocated (default 524288)
-message_stream_grace_period	duration	the amount of time to give for a vttablet to resume if it ends a message stream, usually because of a reparent. (default 30s)
-min_number_serving_vttablets	int	the minimum number of vttablets that will be continue to be used even with low replication lag (default 2)
-mutex-profile-fraction	int	profile every n mutex contention events (see runtime.SetMutexProfileFraction)
-mysql_allow_clear_text_without_tls	boolean	If set, the server will allow the use of a clear text password over non-SSL connections.
-mysql_auth_server_impl	string	Which auth server implementation to use. (default "static")
-mysql_auth_server_static_file	string	JSON File to read the users/passwords from.
-mysql_auth_server_static_string	string	JSON representation of the users/passwords config.
-mysql_auth_static_reload_interval	duration	Ticker to reload credentials
-mysql_clientcert_auth_method	string	client-side authentication method to use. Supported values: mysql_clear_password, dialog. (default "mysql_clear_password")
-mysql_default_workload	string	Default session workload (OLTP, OLAP, DBA) (default "UNSPECIFIED")
-mysql_ldap_auth_config_file	string	JSON File from which to read LDAP server config.
-mysql_ldap_auth_config_string	string	JSON representation of LDAP server config.
-mysql_ldap_auth_method	string	client-side authentication method to use. Supported values: mysql_clear_password, dialog. (default "mysql_clear_password")
-mysql_server_bind_address	string	Binds on this address when listening to MySQL binary protocol. Useful to restrict listening to 'localhost' only for instance.
-mysql_server_flush_delay	duration	Delay after which buffered response will flushed to client. (default 100ms)
-mysql_server_port	int	If set, also listen for MySQL binary protocol connections on this port. (default -1)
-mysql_server_query_timeout	duration	mysql query timeout
-mysql_server_read_timeout	duration	connection read timeout

Name	Type	Definition
-mysql_server_require_secure_transport	boolean	Reject insecure connections but only if mysql_server_ssl_cert and mysql_server_ssl_key are provided
-mysql_server_socket_path	string	This option specifies the Unix socket file to use when listening for local connections. By default it will be empty and it won't listen to a unix socket
-mysql_server_ssl_ca	string	Path to ssl CA for mysql server plugin SSL. If specified, server will require and validate client certs.
-mysql_server_ssl_cert	string	Path to the ssl cert for mysql server plugin SSL
-mysql_server_ssl_key	string	Path to ssl key for mysql server plugin SSL
-mysql_server_version	string	MySQL server version to advertise. (default "5.7.9-Vitess")
-mysql_server_write_timeout	duration	connection write timeout
-mysql_slow_connect_warn_threshold	duration	Warn if it takes more than the given threshold for a mysql connection to establish
-mysql_tcp_version	string	Select tcp, tcp4, or tcp6 to control the socket type. (default "tcp")
-normalize_queries	boolean	Rewrite queries with bind vars. Turn this off if the app itself sends normalized queries with bind vars. (default true)
-onterm_timeout	duration	wait no more than this for OnTermSync handlers before stopping (default 10s)
-opentsdb_uri	string	URI of opentsdb /api/put method
-pid_file	string	If set, the process will write its pid to the named file, and delete it on graceful shutdown.
-port	int	port for the server
-proxy_protocol	boolean	Enable HAProxy PROXY protocol on MySQL listener socket
-purge_logs_interval	duration	how often try to remove old logs (default 1h0m0s)
-querylog-filter-tag	string	string that must be present in the query as a comment for the query to be logged, works for both vtgate and vttablet
-querylog-format	string	format for query logs ("text" or "json") (default "text")
-redact-debug-ui-queries	boolean	redact full queries and bind variables from debug UI
-remote_operation_timeout	duration	time to wait for a remote operation (default 30s)
-retry-count	int	retry count (default 2)
-security_policy	string	the name of a registered security policy to use for controlling access to URLs - empty means allow all for anyone (built-in policies: deny-all, read-only)
-service_map	value	comma separated list of services to enable (or disable if prefixed with '-') Example: grpc-vtworker
-sql-max-length-errors	int	truncate queries in error logs to the given length (default unlimited)
-sql-max-length-ui	int	truncate queries in debug UIs to the given length (default 512) (default 512)
-srv_topo_cache_refresh	duration	how frequently to refresh the topology for cached entries (default 1s)
-srv_topo_cache_ttl	duration	how long to use cached entries for topology (default 1s)
-stats_backend	string	The name of the registered push-based monitoring/stats backend to use
-stats_combine_dimensions	string	List of dimensions to be combined into a single "all" value in exported stats vars
-stats_drop_variables	string	Variables to be dropped from the list of exported variables.
-stats_emit_period	duration	Interval between emitting stats to all registered backends (default 1m0s)
-stderrthreshold	value	logs at or above this threshold go to stderr (default 1)
-stream_buffer_size	int	the number of bytes sent from vtgate for each stream call. It's recommended to keep this value in sync with vttablet's query-server-config-stream-buffer-size. (default 32768)
-tablet_filters	value	Specifies a comma-separated list of 'keyspace
-tablet_grpc_ca	string	the server ca to use to validate servers when connecting
-tablet_grpc_cert	string	the cert to use to connect
-tablet_grpc_key	string	the key to use to connect
-tablet_grpc_server_name	string	the server name to use to validate server certificate
-tablet_protocol	string	how to talk to the vttablets (default "grpc")
-tablet_refresh_interval	duration	tablet refresh interval (default 1m0s)
-tablet_refresh_known_tablets	boolean	tablet refresh reloads the tablet address/port map from topo in case it changes (default true)

Name	Type	Definition
-tablet_types_to_wait	string	wait till connected for specified tablet types during Gateway initialization
-tablet_url_template	string	format string describing debug tablet url formatting. See the Go code for getTabletDebugURL() how to customize this. (default "http://{{.GetTabletHostPort}}")
-topo_consul_watch_poll_duration	duration	time of the long poll for watch queries. (default 30s)
-topo_etcd_lease_ttl	int	Lease TTL for locks and master election. The client will use KeepAlive to keep the lease going. (default 30)
-topo_etcd_tls_ca	string	path to the ca to use to validate the server cert when connecting to the etcd topo server
-topo_etcd_tls_cert	string	path to the client cert to use to connect to the etcd topo server, requires topo_etcd_tls_key, enables TLS
-topo_etcd_tls_key	string	path to the client key to use to connect to the etcd topo server, enables TLS
-topo_global_root	string	the path of the global topology data in the global topology server
-topo_global_server_address	string	the address of the global topology server
-topo_implementation	string	the topology implementation to use
-topo_k8s_context	string	The kubeconfig context to use, overrides the 'current-context' from the config
-topo_k8s_kubeconfig	string	Path to a valid kubeconfig file.
-topo_k8s_namespace	string	The kubernetes namespace to use for all objects. Default comes from the context or in-cluster config
-topo_read_concurrency	int	concurrent topo reads (default 32)
-topo_zk_auth_file	string	auth to use when connecting to the zk topo server, file contents should be :, e.g., digest:user:pass
-topo_zk_base_timeout	duration	zk base timeout (see zk.Connect) (default 30s)
-topo_zk_max_concurrency	int	maximum number of pending requests to send to a Zookeeper server. (default 64)
-topo_zk_tls_ca	string	the server ca to use to validate servers when connecting to the zk topo server
-topo_zk_tls_cert	string	the cert to use to connect to the zk topo server, requires topo_zk_tls_key, enables TLS
-topo_zk_tls_key	string	the key to use to connect to the zk topo server, enables TLS
-tracer	string	tracing service to use (default "noop")
-tracing-sampling-rate	float	sampling rate for the probabilistic jaeger sampler (default 0.1)
-transaction_mode	string	SINGLE: disallow multi-db transactions, MULTI: allow multi-db transactions with best effort commit, TWOPC: allow multi-db transactions with 2pc commit (default "MULTI")
-v	value	log level for V logs
-version	boolean	print binary version
-vmodule	value	comma-separated list of pattern=N settings for file-filtered logging
-vschema_ddl_authorized_users	string	List of users authorized to execute vschema ddl operations, or '%' to allow all users.
-vtctld_addr	string	address of a vtctld instance
-vtgate-config-terse-errors	boolean	prevent bind vars from escaping in returned errors
-warn_memory_rows	int	Warning threshold for in-memory results. A row count higher than this amount will cause the VtGateWarnings.ResultsExceeded counter to be incremented. (default 30000)

vttablet

A VTTablet server *controls* a running MySQL server. VTTablet supports two primary types of deployments:

- Managed MySQL (most common)
- Unmanaged or Remote MySQL

In addition to these deployment types, a partially managed VTTablet is also possible by setting `-disable_active_reparents`.

Example Usage

Managed MySQL In this mode, Vitess actively manages MySQL:

```
export TOPOLOGY_FLAGS="-topo_implementation etcd2 -topo_global_server_address
   localhost:2379 -topo_global_root /vitess/global"
export VTDATAROOT="/tmp"

vttablet \
$TOPOLOGY_FLAGS
-tablet-path $alias
-init_keyspace $keyspace
-init_shard $shard
-init_tablet_type $tablet_type
-port $port
-grpc_port $grpc_port
-service_map 'grpc-queryservice,grpc-tabletmanager,grpc-updatestream'
```

`$alias` needs to be of the form: `<cell>-id`, and the cell should match one of the local cells that was created in the topology. The id can be left padded with zeroes: `cell-100` and `cell-000000100` are synonymous.

Unmanaged or Remote MySQL In this mode, an external MySQL can be used such as RDS, Aurora, CloudSQL:

```
mkdir -p $VTDATAROOT/vt_0000000401
vttablet \
 $TOPOLOGY_FLAGS \
 -logtostderr \
 -log_queries_to_file $VTDATAROOT/tmp/vttablet_0000000401_querylog.txt \
 -tablet-path "zone1-0000000401" \
 -init_keyspace legacy \
 -init_shard 0 \
 -init_tablet_type replica \
 -port 15401 \
 -grpc_port 16401 \
 -service_map 'grpc-queryservice,grpc-tabletmanager,grpc-updatestream' \
 -pid_file $VTDATAROOT/vt_0000000401/vttablet.pid \
 -vtctld_addr http://localhost:15000/ \
 -db_host 127.0.0.1 \
 -db_port 5726 \
 -db_app_user msandbox \
 -db_app_password msandbox \
 -db_dba_user msandbox \
 -db_dba_password msandbox \
 -db_repl_user msandbox \
 -db_repl_password msandbox \
 -db_filtered_user msandbox \
 -db_filtered_password msandbox \
 -db_allprivs_user msandbox \
 -db_allprivs_password msandbox \
 -init_db_name_override legacy \
 -init_populate_metadata &

sleep 10
vtctlclient TabletExternallyReparented zone1-401
```

See Unmanaged Tablet for the full guide.

Options

The following global options apply to `vttablet`:

Name	Type	Definition
-alsologtostderr	boolean	log to standard error as well as files
-app_idle_timeout	duration	Idle timeout for app connections (default 1m0s)
-app_pool_size	int	Size of the connection pool for app connections (default 40)
-azblob_backup_account_key_file	string	Path to a file containing the Azure Storage account key; if this flag is unset, the environment variable VT_AZBLOB_ACCOUNT_KEY will be used as the key itself (NOT a file path)
-azblob_backup_account_name	string	Azure Storage Account name for backups; if this flag is unset, the environment variable VT_AZBLOB_ACCOUNT_NAME will be used
-azblob_backup_container_name	string	Azure Blob Container Name
-azblob_backup_parallelism	int	Azure Blob operation parallelism (requires extra memory when increased) (default 1)
-azblob_backup_storage_root	string	Root prefix for all backup-related Azure Blobs; this should exclude both initial and trailing '/' (e.g. just 'a/b' not '/a/b/')
-backup_engine_implementation	string	Specifies which implementation to use for creating new backups (builtin or xtrabackup). Restores will always be done with whichever engine created a given backup. (default "builtin")
-backup_storage_block_size	int	if backup_storage_compress is true, backup_storage_block_size sets the byte size for each block while compressing (default is 250000). (default 250000)
-backup_storage_compress		if set, the backup files will be compressed (default is true). Set to false for instance if a backup_storage_hook is specified and it compresses the data. (default true)
-backup_storage_hook	string	if set, we send the contents of the backup files through this hook.
-backup_storage_implementation	string	which implementation to use for the backup storage feature
-backup_storage_number_blocks	int	if backup_storage_compress is true, backup_storage_number_blocks sets the number of blocks that can be processed, at once, before the writer blocks, during compression (default is 2). It should be equal to the number of CPUs available for compression (default 2)
-binlog_player_grpc_ca	string	the server ca to use to validate servers when connecting
-binlog_player_grpc_cert	string	the cert to use to connect
-binlog_player_grpc_key	string	the key to use to connect
-binlog_player_grpc_server_name	string	the server name to use to validate server certificate
-binlog_player_protocol	string	the protocol to download binlogs from a vttablet (default "grpc")
-binlog_use_v3_resharding_mode		True iff the binlog streamer should use V3-style sharding, which doesn't require a preset sharding key column. (default true)
-ceph_backup_storage_config	string	Path to JSON config file for ceph backup storage (default "ceph_backup_config.json")
-consul_auth_static_file	string	JSON File to read the topos/tokens from.
-cpu_profile	string	write cpu profile to file
-datadog-agent-host	string	host to send spans to. if empty, no tracing will be done
-datadog-agent-port	string	port to send spans to. if empty, no tracing will be done
-db-credentials-file	string	db credentials file; send SIGHUP to reload this file
-db-credentials-server	string	db credentials server type (use 'file' for the file implementation) (default "file")
-db_allprivs_password	string	db allprivs password

Name	Type	Definition
-db_allprivs_use_ssl		Set this flag to false to make the allprivs connection to not use ssl (default true)
-db_allprivs_user	string	db allprivs user userKey (default “vt_allprivs”)
-db_app_password	string	db app password
-db_app_use_ssl		Set this flag to false to make the app connection to not use ssl (default true)
-db_app_user	string	db app user userKey (default “vt_app”)
-db_appdebug_password	string	db appdebug password
-db_appdebug_use_ssl		Set this flag to false to make the appdebug connection to not use ssl (default true)
-db_appdebug_user	string	db appdebug user userKey (default “vt_appdebug”)
-db_charset	string	Character set. Only utf8 or latin1 based character sets are supported.
-db_connect_timeout_ms	int	connection timeout to mysqld in milliseconds (0 for no timeout)
-db_dba_password	string	db dba password
-db_dba_use_ssl		Set this flag to false to make the dba connection to not use ssl (default true)
-db_dba_user	string	db dba user userKey (default “vt_dba”)
-db_erepl_password	string	db erepl password
-db_erepl_use_ssl		Set this flag to false to make the erepl connection to not use ssl (default true)
-db_erepl_user	string	db erepl user userKey (default “vt_erepl”)
-db_filtered_password	string	db filtered password
-db_filtered_use_ssl		Set this flag to false to make the filtered connection to not use ssl (default true)
-db_filtered_user	string	db filtered user userKey (default “vt_filtered”)
-db_flags	uint	Flag values as defined by MySQL.
-db_flavor	string	Flavor overrid. Valid value is FilePos.
-db_host	string	The host name for the tcp connection.
-db_port	int	tcp port
-db_repl_password	string	db repl password
-db_repl_use_ssl		Set this flag to false to make the repl connection to not use ssl (default true)
-db_repl_user	string	db repl user userKey (default “vt_repl”)
-db_server_name	string	server name of the DB we are connecting to.
-db_socket	string	The unix socket to connect on. If this is specified, host and port will not be used.
-db_ssl_ca	string	connection ssl ca
-db_ssl_ca_path	string	connection ssl ca path
-db_ssl_cert	string	connection ssl certificate
-db_ssl_key	string	connection ssl key
-dba_idle_timeout	duration	Idle timeout for dba connections (default 1m0s)
-dba_pool_size	int	Size of the connection pool for dba connections (default 20)
-degraded_threshold	duration	replication lag after which a replica is considered degraded (only used in status UI) (default 30s)
-demote_master_type	string	the tablet type a demoted master will transition to (default “REPLICA”)
-disable_active_reparents		if set, do not allow active reparents. Use this to protect a cluster using external reparents.
-discovery_high_replication_lag_minimum_serving	duration	the replication lag that is considered too high when selecting the minimum num vttablets for serving (default 2h0m0s)
-discovery_low_replication_lag	duration	the replication lag that is considered low enough to be healthy (default 30s)
-emit_stats		true iff we should emit stats to push-based monitoring/stats backends
-enable-consolidator		This option enables the query consolidator. (default true)
-enable-consolidator-replicas		This option enables the query consolidator only on replicas.
-enable-query-plan-field-caching		This option fetches & caches fields (columns) when storing query plans (default true)
-enable-tx-throttler		If true replication-lag-based throttling on transactions will be enabled.

Name	Type	Definition
-enable_hot_row_protection		If true, incoming transactions for the same row (range) will be queued and cannot consume all txpool slots.
-enable_hot_row_protection_dry_run		If true, hot row protection is not enforced but logs if transactions would have been queued.
-enable_replication_reporter		Register the health check module that monitors MySQL replication
-enable_semi_sync		Enable semi-sync when configuring replication, on master and replica tablets only (rdonly tablets will not ack).
-enable_transaction_limit		If true, limit on number of transactions open at the same time will be enforced for all users. User trying to open a new transaction after exhausting their limit will receive an error immediately, regardless of whether there are available slots or not.
-enable_transaction_limit_dry_run		If true, limit on number of transactions open at the same time will be tracked for all users, but not enforced.
-enforce-tableacl-config		if this flag is true, vttablet will fail to start if a valid tableacl config does not exist
-enforce_strict_trans_tables		If true, vttablet requires MySQL to run with STRICT_TRANS_TABLES or STRICT_ALL_TABLES on. It is recommended to not turn this flag off. Otherwise MySQL may alter your supplied values before saving them to the database. (default true)
-file_backup_storage_root	string	root directory for the file backup storage
-filecustomrules	string	file based custom rule path
-finalize_external_reparent_timeout	duration	Timeout for the finalize stage of a fast external reparent reconciliation. (default 30s)
-gcs_backup_storage_bucket	string	Google Cloud Storage bucket to use for backups
-gcs_backup_storage_root	string	root prefix for all backup-related object names
-grpc_auth_mode	string	Which auth plugin implementation to use (eg: static)
-grpc_auth_mtls_allowed_substrings	string	List of substrings of at least one of the client certificate names (separated by colon).
-grpc_auth_static_client_creds	string	when using grpc_static_auth in the server, this file provides the credentials to use to authenticate with server
-grpc_auth_static_password_file	string	JSON File to read the users/passwords from.
-grpc_ca	string	ca to use, requires TLS, and enforces client cert check
-grpc_cert	string	certificate to use, requires grpc_key, enables TLS
-grpc_compression	string	how to compress gRPC, default: nothing, supported: snappy
-grpc_enable_tracing		Enable GRPC tracing
-grpc_initial_conn_window_size	int	grpc initial connection window size
-grpc_initial_window_size	int	grpc initial window size
-grpc_keepalive_time	duration	After a duration of this time if the client doesn't see any activity it pings the server to see if the transport is still alive. (default 10s)
-grpc_keepalive_timeout	duration	After having pinged for keepalive check, the client waits for a duration of Timeout and if no activity is seen even after that the connection is closed. (default 10s)
-grpc_key	string	key to use, requires grpc_cert, enables TLS
-grpc_max_connection_age	duration	Maximum age of a client connection before GoAway is sent. (default 2562047h47m16.854775807s)
-grpc_max_connection_age_grace	duration	Additional grace period after grpc_max_connection_age, after which connections are forcibly closed. (default 2562047h47m16.854775807s)
-grpc_max_message_size	int	Maximum allowed RPC message size. Larger messages will be rejected by gRPC with the error 'exceeding the max size'. (default 16777216)
-grpc_port	int	Port to listen on for gRPC calls
-grpc_prometheus		Enable gRPC monitoring with Prometheus
-grpc_server_initial_conn_window_size	int	grpc server initial connection window size

Name	Type	Definition
-grpc_server_initial_window_size	int	grpc server initial window size
-grpc_server_keepalive_enforcement_policy_min_time	duration	grpc server minimum keepalive time (default 5m0s)
-grpc_server_keepalive_enforcement_policy_permit_without_stream		grpc server permit client keepalive pings even when there are no active streams (RPCs)
-health_check_interval	duration	Interval between health checks (default 20s)
-heartbeat_enable		If true, vttablet records (if master) or checks (if replica) the current time of a replication heartbeat in the table _vt.heartbeat. The result is used to inform the serving state of the vttablet via healthchecks.
-heartbeat_interval	duration	How frequently to read and write replication heartbeat. (default 1s)
-hot_row_protection_concurrent_transactions	int	Number of concurrent transactions let through to the txpool/MySQL for the same hot row. Should be > 1 to have enough 'ready' transactions in MySQL and benefit from a pipelining effect. (default 5)
-hot_row_protection_max_global_queue_size	int	Global queue limit across all row (ranges). Useful to prevent that the queue can grow unbounded. (default 1000)
-hot_row_protection_max_queue_size	int	Maximum number of BeginExecute RPCs which will be queued for the same row (range). (default 20)
-init_db_name_override	string	(init parameter) override the name of the db used by vttablet. Without this flag, the db name defaults to vt_
-init_keyspace	string	(init parameter) keyspace to use for this tablet
-init_populate_metadata		(init parameter) populate metadata tables even if restore_from_backup is disabled. If restore_from_backup is enabled, metadata tables are always populated regardless of this flag.
-init_shard	string	(init parameter) shard to use for this tablet
-init_tablet_type	string	(init parameter) the tablet type to use for this tablet.
-init_tags	value	(init parameter) comma separated list of key:value pairs used to tag the tablet
-init_timeout	duration	(init parameter) timeout to use for the init phase. (default 1m0s)
-jaeger-agent-host	string	host and port to send spans to. if empty, no tracing will be done
-keep_logs	duration	keep logs for this long (using ctime) (zero to keep forever)
-keep_logs_by_mtime	duration	keep logs for this long (using mtime) (zero to keep forever)
-lameduck-period	duration	keep running at least this long after SIGTERM before stopping (default 50ms)
-legacy_replication_lag_algorithm		use the legacy algorithm when selecting the vttablets for serving (default true)
-lock_tables_timeout	duration	How long to keep the table locked before timing out (default 1m0s)
-log_backtrace_at	value	when logging hits line file:N, emit a stack trace
-log_dir	string	If non-empty, write log files in this directory
-log_err_stacks		log stack traces for errors
-log_queries		Enable query logging to syslog.
-log_queries_to_file	string	Enable query logging to the specified file
-log_rotate_max_size	uint	size in bytes at which logs are rotated (glog.MaxSize) (default 1887436800)
-logtostderr		log to standard error instead of files
-master_connect_retry	duration	how long to wait in between replica reconnect attempts. Only precise to the second. (default 10s)
-mem-profile-rate	int	profile every n bytes allocated (default 524288)
-min_number_serving_vttablets	int	the minimum number of vttablets that will be continue to be used even with low replication lag (default 2)
-mutex-profile-fraction	int	profile every n mutex contention events (see runtime.SetMutexProfileFraction)
-mycnf-file	string	path to my.cnf, if reading all config params from there
-mycnf_bin_log_path	string	mysql binlog path
-mycnf_data_dir	string	data directory for mysql
-mycnf_error_log_path	string	mysql error log path

Name	Type	Definition
-mycnf_general_log_path	string	mysql general log path
-mycnf_innodb_data_home_dir	string	Innodb data home directory
-mycnf_innodb_log_group_home_dir	string	Innodb log group home directory
-mycnf_master_info_file	string	mysql master.info file
-mycnf_mysql_port	int	port mysql is listening on
-mycnf_pid_file	string	mysql pid file
-mycnf_relay_log_index_path	string	mysql relay log index path
-mycnf_relay_log_info_path	string	mysql relay log info path
-mycnf_relay_log_path	string	mysql relay log path
-mycnf_server_id	int	mysql server id of the server (if specified, mycnf-file will be ignored)
-mycnf_slow_log_path	string	mysql slow query log path
-mycnf_socket_file	string	mysql socket file
-mycnf_tmp_dir	string	mysql tmp directory
-mysql_auth_server_static_file	string	JSON File to read the users/passwords from.
-mysql_auth_server_static_string	string	JSON representation of the users/passwords config.
-mysql_auth_static_reload_interval	duration	Ticker to reload credentials
-mysql_clientcert_auth_method	string	client-side authentication method to use. Supported values: mysql_clear_password, dialog. (default “mysql_clear_password”)
-mysql_server_flush_delay	duration	Delay after which buffered response will flushed to client. (default 100ms)
-mysqlctl_client_protocol	string	the protocol to use to talk to the mysqlctl server (default “grpc”)
-mysqlctl_mycnf_template	string	template file to use for generating the my.cnf file during server init
-mysqlctl_socket	string	socket file to use for remote mysqlctl actions (empty for local actions)
-onterm_timeout	duration	wait no more than this for OnTermSync handlers before stopping (default 10s)
-opentsdb_uri	string	URI of opentsdb /api/put method
-orc_api_password	string	(Optional) Basic auth password to authenticate with Orchestrator’s HTTP API.
-orc_api_url	string	Address of Orchestrator’s HTTP API (e.g. http://host:port/api/). Leave empty to disable Orchestrator integration.
-orc_api_user	string	(Optional) Basic auth username to authenticate with Orchestrator’s HTTP API. Leave empty to disable basic auth.
-orc_discover_interval	duration	How often to ping Orchestrator’s HTTP API endpoint to tell it we exist. 0 means never.
-orc_timeout	duration	Timeout for calls to Orchestrator’s HTTP API (default 30s)
-pid_file	string	If set, the process will write its pid to the named file, and delete it on graceful shutdown.
-pool_hostname_resolve_interval	duration	if set force an update to all hostnames and reconnect if changed, defaults to 0 (disabled)
-port	int	port for the server
-purge_logs_interval	duration	how often try to remove old logs (default 1h0m0s)
-query-log-stream-handler	string	URL handler for streaming queries log (default “/debug/querylog”)
-querylog-filter-tag	string	string that must be present in the query as a comment for the query to be logged, works for both vtgate and vttablet
-querylog-format	string	format for query logs (“text” or “json”) (default “text”)
-queryserver-config-acl-exempt-acl	string	an acl that exempt from table acl checking (this acl is free to access any vitess tables).
-queryserver-config-enable-table-acl-dry-run		If this flag is enabled, tabletserver will emit monitoring metrics and let the request pass regardless of table acl check results

Name	Type	Definition
-queryserver-config-idle-timeout	int	query server idle timeout (in seconds), vttablet manages various mysql connection pools. This config means if a connection has not been used in given idle timeout, this connection will be removed from pool. This effectively manages number of connection objects and optimize the pool performance. (default 1800)
-queryserver-config-max-dml-rows	int	query server max dml rows per statement, maximum number of rows allowed to return at a time for an update or delete with either 1) an equality where clauses on primary keys, or 2) a subselect statement. For update and delete statements in above two categories, vttablet will split the original query into multiple small queries based on this configuration value.
-queryserver-config-max-result-size	int	query server max result size, maximum number of rows allowed to return from vttablet for non-streaming queries. (default 10000)
-queryserver-config-message-postpone-cap	int	query server message postpone cap is the maximum number of messages that can be postponed at any given time. Set this number to substantially lower than transaction cap, so that the transaction pool isn't exhausted by the message subsystem. (default 4)
-queryserver-config-passthrough-dmls		query server pass through all dml statements without rewriting
-queryserver-config-pool-prefill-parallelism	int	query server read pool prefill parallelism, a non-zero value will prefill the pool using the specified parallism.
-queryserver-config-pool-size	int	query server read pool size, connection pool is used by regular queries (non streaming, not in a transaction) (default 16)
-queryserver-config-query-cache-size	int	query server query cache size, maximum number of queries to be cached. vttablet analyzes every incoming query and generate a query plan, these plans are being cached in a lru cache. This config controls the capacity of the lru cache. (default 5000)
-queryserver-config-query-pool-timeout	int	query server query pool timeout (in seconds), it is how long vttablet waits for a connection from the query pool. If set to 0 (default) then the overall query timeout is used instead.
-queryserver-config-query-pool-waiter-cap	int	query server query pool waiter limit, this is the maximum number of queries that can be queued waiting to get a connection (default 5000)
-queryserver-config-query-timeout	int	query server query timeout (in seconds), this is the query timeout in vttablet side. If a query takes more than this timeout, it will be killed. (default 30)
-queryserver-config-schema-reload-time	int	query server schema reload time, how often vttablet reloads schemas from underlying MySQL instance in seconds. vttablet keeps table schemas in its own memory and periodically refreshes it from MySQL. This config controls the reload time. (default 1800)
-queryserver-config-stream-buffer-size	int	query server stream buffer size, the maximum number of bytes sent from vttablet for each stream call. It's recommended to keep this value in sync with vtgate's stream_buffer_size. (default 32768)
-queryserver-config-stream-pool-prefill-parallelism	int	query server stream pool prefill parallelism, a non-zero value will prefill the pool using the specified parallelism
-queryserver-config-stream-pool-size	int	query server stream connection pool size, stream pool is used by stream queries: queries that return results to client in a streaming fashion (default 200)
-queryserver-config-strict-table-acl		only allow queries that pass table acl checks
-queryserver-config-terse-errors		prevent bind vars from escaping in returned errors
-queryserver-config-transaction-cap	int	query server transaction cap is the maximum number of transactions allowed to happen at any given point of a time for a single vttablet. E.g. by setting transaction cap to 100, there are at most 100 transactions will be processed by a vttablet and the 101th transaction will be blocked (and fail if it cannot get connection within specified timeout) (default 20)
-queryserver-config-transaction-prefill-parallelism	int	query server transaction prefill parallelism, a non-zero value will prefill the pool using the specified parallism.

Name	Type	Definition
-queryserver-config-transaction-timeout	int	query server transaction timeout (in seconds), a transaction will be killed if it takes longer than this value (default 30)
-queryserver-config-txpool-timeout	int	query server transaction pool timeout, it is how long vttablet waits if tx pool is full (default 1)
-queryserver-config-txpool-waiter-cap	int	query server transaction pool waiter limit, this is the maximum number of transactions that can be queued waiting to get a connection (default 5000)
-queryserver-config-warn-result-size	int	query server result size warning threshold, warn if number of rows returned from vttablet for non-streaming queries exceeds this
-redact-debug-ui-queries		redact full queries and bind variables from debug UI
-remote_operation_timeout	duration	time to wait for a remote operation (default 30s)
-restore_concurrency	int	(init restore parameter) how many concurrent files to restore at once (default 4)
-restore_from_backup		(init restore parameter) will check BackupStorage for a recent backup at startup and start there
-s3_backup_aws_endpoint	string	endpoint of the S3 backend (region must be provided)
-s3_backup_aws_region	string	AWS region to use (default “us-east-1”)
-s3_backup_aws_retries	int	AWS request retries (default -1)
-s3_backup_force_path_style		force the s3 path style
-s3_backup_log_level	string	determine the S3 loglevel to use from LogOff, LogDebug, LogDebugWithSigning, LogDebugWithHTTPBody, LogDebugWithRequestRetries, LogDebugWithRequestErrors (default “LogOff”)
-s3_backup_server_side_encryption	string	server-side encryption algorithm (e.g., AES256, aws:kms)
-s3_backup_storage_bucket	string	S3 bucket to use for backups
-s3_backup_storage_root	string	root prefix for all backup-related object names
-s3_backup_tls_skip_verify_cert		skip the ‘certificate is valid’ check for SSL connections
-security_policy	string	the name of a registered security policy to use for controlling access to URLs - empty means allow all for anyone (built-in policies: deny-all, read-only)
-service_map	value	comma separated list of services to enable (or disable if prefixed with ‘-’) Example: grpc-vtworker
-serving_state_grace_period	duration	how long to pause after broadcasting health to vtgate, before enforcing a new serving state
-shard_sync_retry_delay	duration	delay between retries of updates to keep the tablet and its shard record in sync (default 30s)
-sql-max-length-errors	int	truncate queries in error logs to the given length (default unlimited)
-sql-max-length-ui	int	truncate queries in debug UIs to the given length (default 512) (default 512)
-srv_topo_cache_refresh	duration	how frequently to refresh the topology for cached entries (default 1s)
-srv_topo_cache_ttl	duration	how long to use cached entries for topology (default 1s)
-stats_backend	string	The name of the registered push-based monitoring/stats backend to use
-stats_combine_dimensions	string	List of dimensions to be combined into a single “all” value in exported stats vars
-stats_drop_variables	string	Variables to be dropped from the list of exported variables.
-stats_emit_period	duration	Interval between emitting stats to all registered backends (default 1m0s)
-stderrthreshold	value	logs at or above this threshold go to stderr (default 1)
-table-acl-config	string	path to table access checker config file; send SIGHUP to reload this file
-table-acl-config-reload-interval	duration	Ticker to reload ACLs
-tablet-path	string	tablet alias
-tablet_config	string	YAML file config for tablet
-tablet_dir	string	The directory within the vtdataroot to store vttablet/mysql files. Defaults to being generated by the tablet uid.
-tablet_grpc_ca	string	the server ca to use to validate servers when connecting
-tablet_grpc_cert	string	the cert to use to connect
-tablet_grpc_key	string	the key to use to connect

Name	Type	Definition
-tablet_grpc_server_name	string	the server name to use to validate server certificate
-tablet_hostname	string	if not empty, this hostname will be assumed instead of trying to resolve it
-tablet_manager_grpc_ca	string	the server ca to use to validate servers when connecting
-tablet_manager_grpc_cert	string	the cert to use to connect
-tablet_manager_grpc_concurrency	int	concurrency to use to talk to a vttablet server for performance-sensitive RPCs (like ExecuteFetchAs{Dba,AllPrivs,App}) (default 8)
-tablet_manager_grpc_key	string	the key to use to connect
-tablet_manager_grpc_server_name	string	the server name to use to validate server certificate
-tablet_manager_protocol	string	the protocol to use to talk to vttablet (default “grpc”)
-tablet_protocol	string	how to talk to the vttablets (default “grpc”)
-tablet_url_template	string	format string describing debug tablet url formatting. See the Go code for getTabletDebugURL() how to customize this. (default “http://{{.GetTabletHostPort}}”)
-topo_consul_watch_poll_duration	duration	time of the long poll for watch queries. (default 30s)
-topo_etcd_lease_ttl	int	Lease TTL for locks and master election. The client will use KeepAlive to keep the lease going. (default 30)
-topo_etcd_tls_ca	string	path to the ca to use to validate the server cert when connecting to the etcd topo server
-topo_etcd_tls_cert	string	path to the client cert to use to connect to the etcd topo server, requires topo_etcd_tls_key, enables TLS
-topo_etcd_tls_key	string	path to the client key to use to connect to the etcd topo server, enables TLS
-topo_global_root	string	the path of the global topology data in the global topology server
-topo_global_server_address	string	the address of the global topology server
-topo_implementation	string	the topology implementation to use
-topo_k8s_context	string	The kubeconfig context to use, overrides the ‘current-context’ from the config
-topo_k8s_kubeconfig	string	Path to a valid kubeconfig file.
-topo_k8s_namespace	string	The kubernetes namespace to use for all objects. Default comes from the context or in-cluster config
-topo_zk_auth_file	string	auth to use when connecting to the zk topo server, file contents should be :, e.g., digest:user:pass
-topo_zk_base_timeout	duration	zk base timeout (see zk.Connect) (default 30s)
-topo_zk_max_concurrency	int	maximum number of pending requests to send to a Zookeeper server. (default 64)
-topo_zk_tls_ca	string	the server ca to use to validate servers when connecting to the zk topo server
-topo_zk_tls_cert	string	the cert to use to connect to the zk topo server, requires topo_zk_tls_key, enables TLS
-topo_zk_tls_key	string	the key to use to connect to the zk topo server, enables TLS
-topocustomrule_cell	string	topo cell for customrules file. (default “global”)
-topocustomrule_path	string	path for customrules file. Disabled if empty.
-tracer	string	tracing service to use (default “noop”)
-tracing-sampling-rate	float	sampling rate for the probabilistic jaeger sampler (default 0.1)
-transaction-log-stream-handler	string	URL handler for streaming transactions log (default “/debug/txlog”)
-transaction_limit_by_component		Include CallerID.component when considering who the user is for the purpose of transaction limit.
-transaction_limit_by_principal		Include CallerID.principal when considering who the user is for the purpose of transaction limit. (default true)
-transaction_limit_by_subcomponent		Include CallerID.subcomponent when considering who the user is for the purpose of transaction limit.
-transaction_limit_by_username		Include VTGateCallerID.username when considering who the user is for the purpose of transaction limit. (default true)
-transaction_limit_per_user	float	Maximum number of transactions a single user is allowed to use at any time, represented as fraction of -transaction_cap. (default 0.4)

Name	Type	Definition
-transaction_shutdown_grace_period	int	how long to wait (in seconds) for transactions to complete during graceful shutdown.
-twopc_abandon_age	float	time in seconds. Any unresolved transaction older than this time will be sent to the coordinator to be resolved.
-twopc_coordinator_address	string	address of the (VTGate) process(es) that will be used to notify of abandoned transactions.
-twopc_enable		if the flag is on, 2pc is enabled. Other 2pc flags must be supplied.
-tx-throttler-config	string	The configuration of the transaction throttler as a text formatted throttlerdata.Configuration protocol buffer message (default "target_replication_lag_sec: 2 max_replication_lag_sec: 10 initial_rate: 100 max_increase: 1 emergency_decrease: 0.5 min_duration_between_increases_sec: 40 max_duration_between_increases_sec: 62 min_duration_between_decreases_sec: 20 spread_backlog_across_sec: 20 age_bad_rate_after_sec: 180 bad_rate_increase: 0.1 max_rate_approach_threshold: 0.9")
-tx-throttler-healthcheck-cells	value	A comma-separated list of cells. Only tabletservers running in these cells will be monitored for replication lag by the transaction throttler.
-unhealthy_threshold	duration	replication lag after which a replica is considered unhealthy (default 2h0m0s)
-use_super_read_only		Set super_read_only flag when performing planned failover.
-v	value	log level for V logs
-version		print binary version
-vmodule	value	comma-separated list of pattern=N settings for file-filtered logging
-vreplication_healthcheck_retry_delay	duration	healthcheck retry delay (default 5s)
-vreplication_healthcheck_timeout	duration	healthcheck retry delay (default 1m0s)
-vreplication_healthcheck_topology_refresh	duration	refresh interval for re-reading the topology (default 30s)
-vreplication_retry_delay	duration	delay before retrying a failed binlog connection (default 5s)
-vreplication_tablet_type	string	comma separated list of tablet types used as a source (default "REPLICA")
-vstream_packet_size	int	Suggested packet size for VReplication streamer. This is used only as a recommendation. The actual packet size may be more or less than this amount. (default 30000)
-vtctld_addr	string	address of a vtctld instance
-vtgate_protocol	string	how to talk to vtgate (default "grpc")
-wait_for_backup_interval	duration	(init restore parameter) if this is greater than 0, instead of starting up empty when no backups are found, keep checking at this interval for a backup to appear
-watch_replication_stream		When enabled, vttablet will stream the MySQL replication stream from the local server, and use it to support the include_event_token ExecuteOptions.
-xbstream_restore_flags	string	flags to pass to xbstream command during restore. These should be space separated and will be added to the end of the command. These need to match the ones used for backup e.g. –compress / –decompress, –encrypt / –decrypt
-xtrabackup_backup_flags	string	flags to pass to backup command. These should be space separated and will be added to the end of the command
-xtrabackup_prepare_flags	string	flags to pass to prepare command. These should be space separated and will be added to the end of the command
-xtrabackup_root_path	string	directory location of the xtrabackup executable, e.g., /usr/bin
-xtrabackup_stream_mode	string	which mode to use if streaming, valid values are tar and xbstream (default "tar")
-xtrabackup_stripe_block_size	uint	Size in bytes of each block that gets sent to a given stripe before rotating to the next stripe (default 102400)

Name	Type	Definition
-xtrabackup_stripes	uint	If greater than 0, use data striping across this many destination files to parallelize data transfer and decompression
-xtrabackup_user	string	User that xtrabackup will use to connect to the database server. This user must have all necessary privileges. For details, please refer to xtrabackup documentation.

VReplication

description: Command references, architecture and design docs

DropSources

description: Cleans up after a MoveTables and Reshard workflow

```
DropSources  [-dry_run] [-rename_tables] <keyspace.workflow>
```

Description Once SwitchWrites has been run DropSources cleans up the source resources by deleting the source tables for a MoveTables workflow or source shards for a Reshard workflow. It also cleans up other artifacts of the workflow, deleting forward and reverse replication streams and blacklisted tables.

Warning: This command actually deletes data. We recommend that you run this with the -dry_run parameter first and reads its output so that you know which actions will be performed.

Parameters

-rename_tables optional
default all

Only applies for a MoveTables workflow. Instead of deleting the tables in the source it renames them by prefixing the tablename with an _ (underscore).

-dry-run optional
default false

You can do a dry run where no actual action is taken but the command logs all the actions that would be taken by SwitchReads.

keyspace.workflow mandatory

Name of target keyspace and the associated workflow to run VDiff on.

Life of a stream

Introduction The diagram above outlines how a VReplication workflow is performed. VReplication can be asked to start from a specific GTID or from the start. When starting from a GTID the *replication* mode is used where it streams events from the binlog.

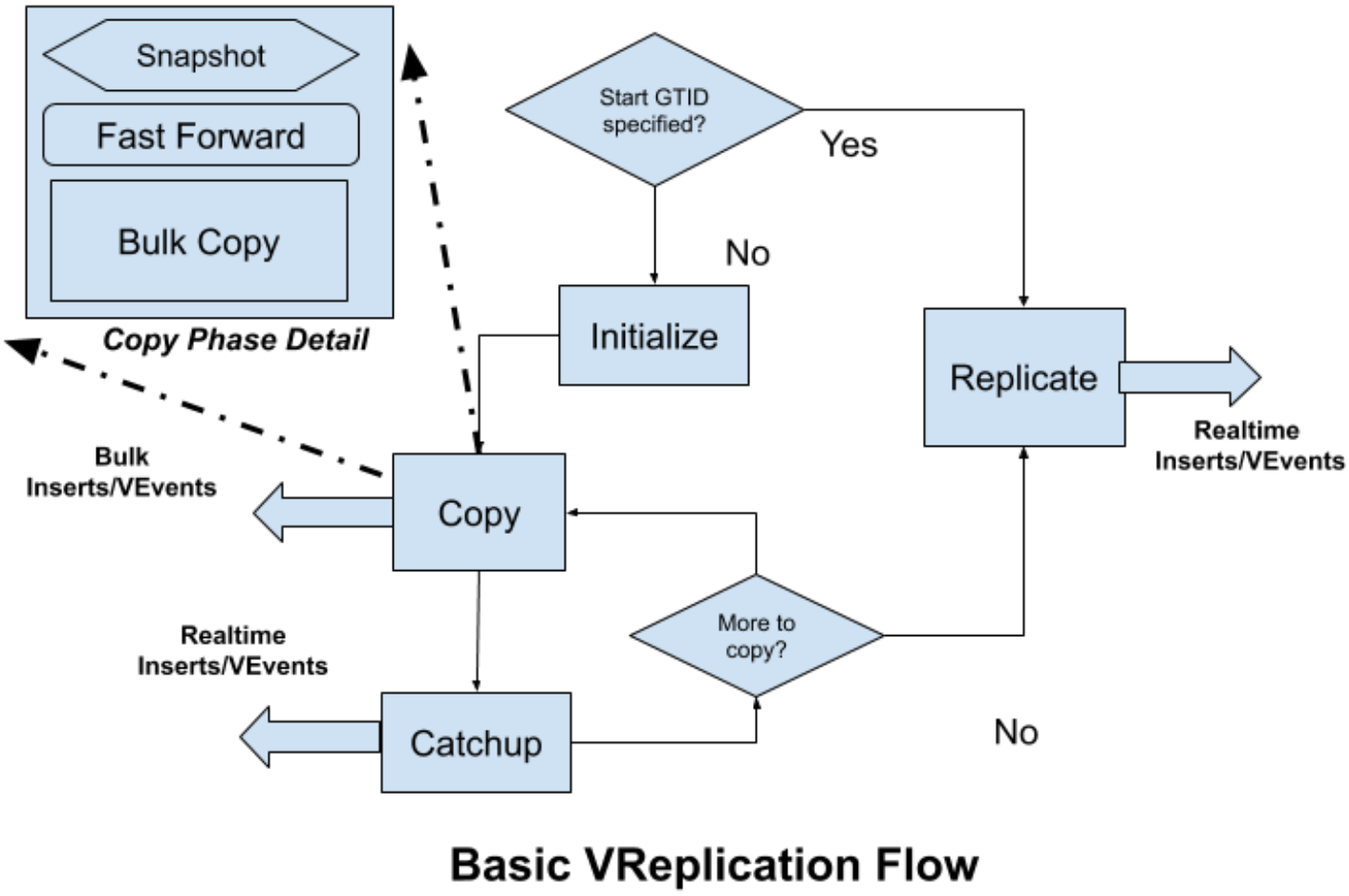

Figure 4: VReplication Flow

Full table copy When starting from the beginning the simple streaming done by *replication* can create an avalanche of events (think 10s of millions of rows). To speed things up a *copy/catchup* mode is initiated first: data in the tables are copied over in a consistent manner using bulk inserts. Once we have copied enough data so that we are close enough to the current position (when replication lag is low) it switches over (and stays in) the *replication* mode.

While we may have multiple database sources in a workflow each vstream has just one source and one target. The source is always a vttablet (and hence one mysql instance). The target could be another vttablet (resharding) or a streaming grpc response (vstream api clients).

Transformation and Filtering Note that for all steps the data selected from the source will only be from the list of tables specified (specified via Match). Furthermore if a Filter is specified for a table it will be applied before being sent to the target. Columns may also be transformed in the Filter's select clause.

Source and Sink Each stream has two parts. The target initiates streaming by making grpc calls to the source tablet. The source sources the data connecting to mysql as a slave or using sql queries and streams it to the target. The target takes appropriate action: in case of resharding it will convert the events into CRUDs and apply it to the target database. In case of vstream clients the events are forwarded by vtgate to the client.

Note that the target always pulls the data. This ensures that there is no problems of buffer overruns that can occur if the source is pushing the data since (especially in sharding) it is possible that the application of events can be substantially cpu intensive especially in the case of bulk inserts.

Modes, in detail

Replicate This is the easiest step to understand. The source stream just mimics a mysql slave and processes events as they are received. Events (after filtering and transformation) are sent to the target. Replication runs continuously with short sleeps when there are no more events to source.

Initialize Initialize is called at the start of the copy phase. For each table to be copied an entry is created in _vt.copy_state with a zero primary key. As each table copy is completed the related entry is deleted and when there are no more entries for this workflow the copy phase is considered complete and the workflow moves into the Replication mode.

Copy Copy works on one table at a time. The source selects a set of rows from the table with higher primary keys that the one copied so far using a consistent snapshot. This results in a stream of rows to be sent to the target which generates a bulk insert of these rows.

However there are a couple of factors which complicate our story::

- Each copy selects all rows until the current position of the binlog.
- Since transactions continue to be applied (presuming the database is online) the gtid positions are continuously moving forward

Consider this example.

We have two tables t1 and t2 and this is how the copy state proceeds: Each has 20 rows and we copy 10 rows at a time. (Queries are not exact but simplified for readability).

If we follow this we get:

```
T1: select * from t1 where pk > 0 limit 10. GTID: 100, Last PK 10

   send rows to target

T2: select * from t1 where pk > 10 limit 10  GTID: 110, Last PK 20

   send rows to target
```

Gotcha: however we see that 10 new txs have occurred since T1. Some of these can potentially modify the rows returned from the query at T1. Hence if we just return the rows from T2 (which have only rows from pk 11 to 20)
we will have an inconsistent state on the target: the updates to rows with PK between 1 and 10 will not be present.

This means that we need to first stream the events between 100 to 110 for PK between 1 and 10 first and then do the second select:

```
T1: select * from t1 where pk > 0 limit 10. GTID: 100, Last PK 10

   send rows to target

T2: replicate from 100 to current position (110 from previous example),

   only pass events for pks 1 to 10

T3: select * from t1 where pk > 10 limit 10  GTID: 112, Last PK 20

   send rows to target
```

Another gotcha!: Note that at T3 when we selected the pks from 11 to 20 the gtid position has moved further! This happened because of transactions that were applied between T2 and T3. So if we just applied the rows from T3 we would still have an inconsistent state, if transactions 111 and 112 affected the rows from pks 1 to 10.

This leads us to the following flow:

```
T1: select * from t1 where pk > 0 limit 10. GTID: 100, Last PK 10

   send rows to target

T2: replicate from 100 to current position (110 from previous example),

   only pass events for pks 1 to 10

T3: select * from t1 where pk > 10 limit 10  GTID: 112, Last PK 20

T4: replicate from 111 to 112

   only pass events for pks 1 to 10

T5: Send rows for pks 11 to 20 to target
```

This flow actually works!

T1 can take a long time (due to the bulk inserts). T3 (which is just a snapshot) is quick. So the position can diverge much more at T2 than at T4. Hence we call the step in T2 as Catchup and Step T4 is called Fast Forward.

Catchup As detailed above the catchup phase runs between two copy phases. During the copy phase the gtid position can move significantly ahead. So we run a replicate till we come close to the current position i.e.the replication lag is small. At this point we call Copy again.

Fast forward During the copy phase we first take a snapshot. Then we fast forward: we run another replicate from the gtid position where we stopped the Catchup to the position of the snapshot.

Finally once we have finished copying all the tables we proceed to replicate until our job is done: for example if we have resharded and switched over the reads and writes to the new shards or when the vstream client closes its connection.

Materialize

description:

```
Materialize <json_spec>
```

Description Materialize is a low level vreplication API that allows for generalized materialization of tables. The target tables can be copies, aggregations or views. The target tables are kept in sync in near-realtime.

You can specify multiple tables to materialize using the json_spec parameter.

Parameters

JSON spec details

- *workflow* name to refer to this materialization
- *source_keyspace* keyspace containing the source table
- *target_keyspace* keyspace to materialize to
- *table_settings* list of views to be materialized and the associated query
  - *target_table* name of table to which to materialize the data to
  - *source_expression* the materialization query

```
Materialize '{"workflow": "product_sales", "source_keyspace": "commerce",
   "target_keyspace": "customer",
    "table_settings": [{"target_table": "sales_by_sku",
    "source_expression": "select sku, count(*), sum(price) from corder group by
       order_id"}]}'
```

A Materialize Workflow Once you decide on your materialization requirements, you need to initiate a VReplication workflow as follows:

1. Initiate the migration using Materialize
2. Monitor the workflow using Workflow or VExec
3. Start accessing your views once the workflow has started Replicating

Notes There are special commands to perform common materialization tasks and you should prefer them to using Materialize directly. * If you just want to copy tables to a different keyspace use MoveTables. * If you want to change sharding strategies use Reshard instead

MoveTables

description: Move tables between keyspaces without downtime

```
MoveTables  [-cells=<cells>] [-tablet_types=<source_tablet_types>] -workflow=<workflow>
                                    <source_keyspace> <target_keyspace> <table_specs>
```

Description MoveTables is used to start a workflow to move one or more tables from an external database or an existing Vitess keyspace into a new Vitess keyspace. The target keyspace can be unsharded or sharded.

MoveTables is used typically for migrating data into Vitess or to implement vertical sharding. You might use the former when you first start using Vitess and the latter if you want to distribute your load across servers.

Parameters

-cells optional
default local cell

A comma separated list of cell names or cell aliases. This list is used by VReplication to determine which cells should be used to pick a tablet for selecting data from the source keyspace.

Uses

- Improve performance by using picking a tablet in cells in network proximity with the target
- To reduce bandwidth costs by skipping cells which are in different availability zones
- Select cells where replica lags are lower

-tablet_types optional
default replica

A comma separated list of tablet types that are used while picking a tablet for sourcing data. One or more from MASTER, REPLICA, RDONLY.

Uses

- To reduce load on master tablets by using REPLICAs or RDONLYs
- Reducing lags by pointing to MASTER

workflow mandatory

Unique name for the MoveTables-initiated workflow, used in later commands to refer back to this workflow

source_keyspace mandatory

Name of existing keyspace that contains the tables to be moved

target_keyspace mandatory

Name of existing keyspace to which the tables will be moved

table_specs mandatory

One of

- comma separated list of tables (if vschema has been already specified for all the tables)
- JSON table section of the vschema for associated tables in case vschema is not yet specified

A MoveTables Workflow Once you select the set of tables to move from one keyspace to another you need to initiate a VReplication workflow as follows:

1. Initiate the migration using MoveTables
2. Monitor the workflow using Workflow or VExec
3. Confirm that data has been copied over correctly using VDiff
4. Start the cutover by routing all reads from your application to those tables using SwitchReads
5. Complete the cutover by routing all writes using SwitchWrites
6. Optionally cleanup the source tables using DropSources

Common use cases for MoveTables

Adopting Vitess For those wanting to try out Vitess for the first time MoveTables provides an easy way to route part of their workload to Vitess with the ability of migrating back at any time without any risk. You point a vttablet to your existing MySQL installation, spin up a unsharded Vitess cluster and use a MoveTables workflow to start serving some tables from Vitess. You can also go further and use a Reshard workflow to experiment with a sharded version of a part of your database.

See user guide for detailed steps

Horizontal Sharding For existing Vitess users you can easily move one or more tables to another keyspace, either for balancing load or as a preparation to sharding your tables.

See user guide which describes how MoveTables works in the local example provided in the Vitess repo.

More Reading

- MoveTables in practice

Reshard

description: split or merge shards in a keyspace

```
Reshard  [-skip_schema_copy] <keyspace.workflow> <source_shards> <target_shards>
```

Description Reshard support horizontal sharding by letting you change the sharding ranges of your existing keyspace.

Parameters

-skip_schema_copy optional
default false

If true the source schema is copied to the target shards. If false, you need to create the tables before calling reshard.

keyspace.workflow mandatory

Name of keyspace being sharded and the associated workflow name, used in later commands to refer back to this reshard.

source_shards mandatory

Comma separated shard names to reshard from.

target_shards mandatory

Comma separated shard names to reshard to.

A Reshard Workflow Once you decide on the new resharding strategy for a keyspace, you need to initiate a VReplication workflow as follows:

1. Initiate the migration using Reshard
2. Monitor the workflow using Workflow or VExec
3. Confirm that data has been copied over correctly using VDiff
4. Start the cutover by routing all reads from your application to those tables using SwitchReads
5. Complete the cutover by routing all writes using SwitchWrites
6. Optionally cleanup the source tables using DropSources

SwitchReads

description: Route reads to target keyspace

```
SwitchReads  [-cells=<cells>] [-reverse] [-dry-run]
             -tablet_type={replica|rdonly} <keyspace.workflow>
```

Description SwitchReads is used to switch reads for tables in a MoveTables workflow or for entire keyspace to the target keyspace in a Reshard workflow.

Parameters

-cells optional
default all

Comma separated list of cells or cell aliases in which reads should be switched in the target keyspace

-reverse optional
default false

When a workflow is setup the routing rules are setup so that reads/writes to the target shards still go to the source shard since the target is not yet setup. If SwitchReads is called without -reverse then the routing rules for the target keyspace are setup to actually use it. It is assumed that the workflow was successful and user is ready to use the target keyspace now.

However if, for any reason, we want to abort this workflow using the -reverse flag deletes the rules that were setup and vtgate will route the queries to this table to the the source table. There is no way to reverse the use of the -reverse flag other than by recreating the routing rules again using the vtctl ApplyRoutingRules command.

-dry-run optional
default false

You can do a dry run where no actual action is taken but the command logs all the actions that would be taken by SwitchReads.

-tablet_type mandatory

On which type of tablets should be reads be switched to the target keyspace. One of replica or rdonly. rdonly tables should be switched first before replica tablets.

keyspace.workflow mandatory

Name of target keyspace and the associated workflow to SwitchReads for.

SwitchWrites

description: Route writes to target keyspace in a vreplication workflow

```
SwitchWrites  [-filtered_replication_wait_time=30s] [-cancel] [-reverse_replication=true]
              [-dry-run] <keyspace.workflow>
```

Description SwitchWrites is used to switch writes for tables in a MoveTables workflow or for entire keyspace in the Reshard workflow away from the master in the source keyspace to the master in the target keyspace

Parameters

-filtered_replication_wait_time optional
default 30s

SwitchWrites first stops writes on the source master and waits for the replication to the target to catchup with the point where the writes were stopped. If the wait time is longer than filtered_replication_wait_time the command will error out. For setups with high write qps you may need to increase this value.

-cancel optional
default false

If a previous SwitchWrites returned with an error you can restart it by running the command again (after fixing the issue that caused the failure) or the SwitchWrites can be canceled using this parameter. Only the SwitchWrites is cancelled: the workflow is set to Running so that replication continues.

-reverse_replication optional
default true

SwitchWrites, by default, starts a reverse replication stream with the current target as the source, replicating back to the original source. This enables a quick and simple rollback. This reverse workflow name is that of the original workflow concatenated with _reverse.

-dry-run optional
default false

You can do a dry run where no actual action is taken but the command logs all the actions that would be taken by SwitchReads.

keyspace.workflow mandatory

Name of target keyspace and the associated workflow to SwitchWrites for.

VDiff

description: Compare the source and target in a workflow to ensure integrity

```
VDiff  [-source_cell=<cell>] [-target_cell=<cell>] [-tablet_types=replica]
       [-filtered_replication_wait_time=30s] <keyspace.workflow>
```

Description VDiff does a row by row comparison of all tables associated with the workflow, diffing the source keyspace and the target keyspace and reporting counts of missing/extra/unmatched rows.

It is highly recommended that you do this before you finalize a workflow with SwitchWrites.

Parameters

-source_cell optional
default all

VDiff will choose a tablet from this cell to diff the source table(s) with the target tables

-target_cell optional
default all

VDiff will choose a tablet from this cell to diff the source table(s) with the target tables

-tablet_types optional
default replica

A comma separated list of tablet types that are used while picking a tablet for sourcing data. One or more from MASTER, REPLICA, RDONLY.

-filtered_replication_wait_time optional
default 30s

VDiff finds the current position of the source master and then waits for the target replication to reach that position for *filtered_replication_wait_time*. If the target is much behind the source or if there is a high write qps on the source then this time will need to be increased.

keyspace.workflow mandatory

Name of target keyspace and the associated workflow to run VDiff on.

```
$ vtctlclient VDiff customer.commerce2customer

Summary for corder: {ProcessedRows:10 MatchingRows:10 MismatchedRows:0 ExtraRowsSource:0
   ExtraRowsTarget:0}
Summary for customer: {ProcessedRows:11 MatchingRows:11 MismatchedRows:0 ExtraRowsSource:0
   ExtraRowsTarget:0}
```

Notes

- You can follow the progress of the command by tailing the vtctld logs
- VDiff can take very long (hours/days) for huge tables, so this needs to be taken into account. If VDiff takes more than an hour and you use vtctlclient then it will hit the grpc/http default timeout of 1 hour. In that case you can use vtctl (the bundled vctlclient + vtctld) instead.
- There is no throttling, so you might see an increased lag in the replica used as the source.

VReplication and VDiff performance improvements as well as freno-style throttling support are on the roadmap!

VExec

description: Wrapper on VReplicationExec to run query on all participating masters

```
VExec  [-dry_run] <keyspace.workflow> <query>
```

Description VExec is a wrapper over VReplicationExec. Given a workflow it executes the provided query on all masters in the target keyspace that participate in the workflow. Internally it calls VReplicationExec for running the query.

Parameters

-dry-run optional
default false

You can do a dry run where no actual action is taken but the command logs the queries and the tablets on which the query would be run. by VExec.

keyspace.workflow mandatory

Name of target keyspace and the associated workflow

sql query mandatory

SQL query to be run: validations are done to ensure that queries can be run only against vreplication tables. A limited set of queries are allowed.

```
vtctlclient VExec keyspace1.workflow1 'select * from _vt.vreplication'
```

Overview

description: VReplication features, design and options in a nutshell

VReplication is a core component of Vitess that can be used to compose many features. It can be used for the following use cases:

- **Resharding**: Legacy workflows of vertical and horizontal resharding. New workflows of resharding from an unsharded to a sharded keyspace and vice-versa. Resharding from an unsharded to an unsharded keyspace using a different vindex than the source keyspace.
- **Materialized Views**: You can specify a materialization rule that creates a view of the source table into a target keyspace. This materialization can use a different primary vindex than the source. It can also materialize a subset of the source columns, or add new expressions from the source. This view will be kept up-to-date in real time. One can also materialize reference tables onto all shards and have Vitess perform efficient local joins with those materialized tables.
- **Realtime rollups**: The materialization expression can include aggregation expressions in which case, Vitess will create a rolled up version of the source table which can be used for realtime analytics.
- **Backfilling lookup vindexes**: VReplication can be used to backfill a newly created lookup vindex. Workflows can be built to manage the switching from a backfill mode to the vindex itself keeping it up-to-date.
- **Schema deployment**: VReplication can be used to recreate the workflow performed by gh-ost and thereby support zero-downtime schema deployments in Vitess natively.
- **Data migration**: VReplication can be setup to migrate data from an existing system into Vitess. The replication could also be reversed after a cutover giving you the option to rollback a migration cutover if something went wrong, without losing the writes to the migration target.
- **Change notification**: The streamer component of VReplication can be used for the application or a systems operator to subscribe to change notification and use it to keep downstream systems up-to-date with the source.

The VReplication feature itself is a fairly low level one that is expected to be used as a building block for the above use cases. However, it is still possible to directly issue commands to perform some of the activities.

Feature description

VReplication works as a stream or set of streams. Each stream establishes a replication from a source keyspace/shard into a target keyspace/shard.

A given stream can replicate multiple tables. For each table, you can specify a `SELECT` statement that represents both the transformation rule and the filtering rule. The `SELECT` expressions specify the transformation, and the `WHERE` clause specifies the filtering.

The `SELECT` expressions can be any non-aggregate MySQL expression, or they can also be `COUNT` or `SUM` as aggregate expressions. Aggregate expressions combined with the corresponding `GROUP BY` clauses will allow you to materialize real-time rollups of the source table, which can be used for analytics. The target table can have a different name from the source.

For a sharded system like Vitess, multiple VReplication streams may be needed to achieve the objective. This is because there can be multiple source shards and multiple destination shards, and the relationship between them may not be one to one.

VReplication performs the following essential functions:

- Copy data from the source to the destination table in a consistent fashion. For a large table, this copy can be long-running. It can be interrupted and resumed. If interrupted, VReplication can keep the copied portion up-to-date with respect to the source, and it can resume the copy process at a point that is consistent with the current replication position.
- After copying is finished, it can continuously replicate the data from the source to destination.
- The copying rule can be expressed as a `SELECT` statement. The statement should be simple enough that the materialized table can be kept up-to-date from the data coming from the binlog. For example, joins in the `SELECT` statement are not supported.
- Correctness verification (to be implemented): VReplication can verify that the target table is an exact representation of the `SELECT` statement from the source by capturing consistent snapshots of the source and target and comparing them against each other. This step can be done without the need to create special snapshot replicas.
- Journaling: If there is any kind of traffic cut-over where we start writing to a different table than we used to before, VReplication will save the current binlog positions into a journal table. This can be used by other streams to resume replication from the new source.

- Routing rules: Although this feature is itself not a direct functionality of VReplication, it works hand in hand with it. It allows you to specify sophisticated rules about where to route queries depending on the type of workflow being performed. For example, it can be used to control the cut-over during resharding. In the case of materialized views, it can be used to establish equivalence of tables, which will allow VTGate to compute the most optimal plans given the available options.

VReplicationExec

The `VReplicationExec` command is a low-level command used to manage VReplication streams. The commands are issued as SQL statements. For example, a `SELECT` can be used to see the current list of streams. An `INSERT` can be used to create one, etc. By design, the metadata for vreplication streams are stored in a table called `vreplication` in the `_vt` sidecar database. VReplication uses a 'pull' model. This means that a stream is created on the target side, and the target pulls the data by finding the appropriate source. As a result, this metadata is stored on the target shard.

The table schema is as follows:

```
CREATE TABLE _vt.vreplication (
  id INT AUTO_INCREMENT,
  workflow VARBINARY(1000),
  source VARBINARY(10000) NOT NULL,
  pos VARBINARY(10000) NOT NULL,
  stop_pos VARBINARY(10000) DEFAULT NULL,
  max_tps BIGINT(20) NOT NULL,
  max_replication_lag BIGINT(20) NOT NULL,
  cell VARBINARY(1000) DEFAULT NULL,
  tablet_types VARBINARY(100) DEFAULT NULL,
  time_updated BIGINT(20) NOT NULL,
  transaction_timestamp BIGINT(20) NOT NULL,
  state VARBINARY(100) NOT NULL,
  message VARBINARY(1000) DEFAULT NULL,
  db_name VARBINARY(255) NOT NULL,
  PRIMARY KEY (id)
)
```

The fields are explained in the following section.

This is the syntax of the command:

```
VReplicationExec [-json] <tablet alias> <sql command>
```

Here's an example of the command to list all existing streams for a given tablet.

```
vtctlclient -server localhost:15999 VReplicationExec 'tablet-100' 'select * from
   _vt.vreplication'
```

Creating a stream It's generally easier to send the VReplication command programmatically instead of a bash script. This is because of the number of nested encodings involved:

- One of the arguments is an SQL statement, which can contain quoted strings as values.
- One of the strings in the SQL statement is a string encoded protobuf, which can contain quotes.
- One of the parameters within the protobuf is an SQL `SELECT` expression for the materialized view.

However, you can use vreplgen.go to generate a fully escaped bash command.

Alternately, you can use a python program. Here's an example:

```
cmd = [
  'vtctlclient',
  '-server',
  'localhost:15999',
  'VReplicationExec',
  'test-200',
  """insert into _vt.vreplication
  (db_name, source, pos, max_tps, max_replication_lag, tablet_types, time_updated,
     transaction_timestamp, state) values
  ('vt_keyspace', 'keyspace:"lookup" shard:"0" filter:<rules:<match:"uproduct"
     filter:"select * from product" > >', '', 99999, 99999, 'master', 0, 0, 'Running')""",
]
```

The first argument to the command is the master tablet id of the target keyspace/shard for the VReplication stream.

The second argument is the SQL command. To start a new stream, you need an insert statement. The parameters are as follows:

- `db_name`: This name must match the name of the MySQL database. In the future, this will not be required, and will be automatically filled in by the vttablet.
- `source`: The protobuf representation of the stream source, explained below.
- `pos`: For a brand new stream, this should be empty. To start from a specific position, a flavor-encoded position must be specified. A typical position would look like this `MySQL56/ac6c45eb-71c2-11e9-92ea-0a580a1c1026:1-1296`.
- `max_tps`: 99999, reserved.
- `max_replication_lag`: 99999, reserved.
- `tablet_types`: specifies a comma separated list of tablet types to replicate from. If empty, the default tablet type specified by the `-vreplication_tablet_type` command line flag is used, which in turn defaults to 'REPLICA'.
- `time_updated`: 0, reserved.
- `transaction_timestamp`: 0, reserved.
- `state`: 'Init', 'Copying', 'Running', 'Stopped', 'Error'.
- `cell`: is an optional parameter that specifies the cell from which the stream can be sourced. If no cell is specified, the default is the local/current cell.

The source field The source field is a proto-encoding of the following structure:

```
message BinlogSource {
  // the source keyspace
  string keyspace = 1;
  // the source shard
  string shard = 2;
  // list of filtering rules
  Filter filter = 6;
  // what to do if a DDL is encountered
  OnDDLAction on_ddl = 7;
}

message Filter {
  repeated Rule rules = 1;
}

message Rule {
  // match can be a table name or a regular expression
  // delineated by '/' and '/'.
  string match = 1;
  // filter can be an empty string or keyrange if the match
  // is a regular expression. Otherwise, it must be a select
  // query.
  string filter = 2;
```

```
}

enum OnDDLAction {
  IGNORE = 0;
  STOP = 1;
  EXEC = 2;
  EXEC_IGNORE = 3;
}
```

Here are some examples of proto encodings:

```
keyspace:"lookup" shard:"0" filter:<rules:<match:"uproduct" filter:"select * from product"
   > >
```

Meaning: copy and replicate all columns and rows of product from the source table `lookup/0.product` to the `uproduct` table in target keyspace.

```
keyspace:"user" shard:"-80" filter:<rules:<match:"morder" filter:"select * from uorder
   where in_keyrange(mname, \\'unicode_loose_md5\\', \\'-80\\')" > >
```

The double-backslash for the strings inside the select will first be escaped by the python script, which will cause the expression to internally be `\'unicode_loose_md5\'`. Since the entire source is surrounded by single quotes when being sent as a value inside the outer insert statement, the single `\` will escape the single quotes that follow. The final value in the source will therefore be:

```
keyspace:"user" shard:"-80" filter:<rules:<match:"morder" filter:"select * from uorder
   where in_keyrange(mname, 'unicode_loose_md5', '-80')" > >
```

Meaning: copy and replicate all columns of the source table `user/-80.uorder` where `unicode_loose_md5(mname)` is within `-80` keyrange, to the `morder` table in the the target keyspace.

This particular stream generally wouldn't make sense in isolation. This would typically be one of a set of four streams that combine to create a materialized view of `uorder` from the `user` keyspace into the target (`merchant`) keyspace, but sharded by using `mname` as the primary vindex. The vindex used would be `unicode_loose_md5` which should also match the primary vindex of other tables in the target keyspace.

```
keyspace:"user" shard:"-80" filter:<rules:<match:"sales" filter:"select pid, count(*) as
   kount, sum(price) as amount from uorder group by pid" > >
```

Meaning: create a materialized view of `user/-80.uorder` into `sales` of the target keyspace using the expression: `select pid, count(*)as kount, sum(price)as amount from uorder group by pid`.

This represents only one stream from source shard `-80`. Presumably, there will be one more for the other `-80` shard.

The 'SELECT' features The `SELECT` statement has the following features (and restrictions):

- The `SELECT` expressions can be any deterministic MySQL expression. Subqueries and joins are not supported. Among aggregate expressions, only `count(*)` and `sum(col)` are supported.
- The where clause can only contain the `in_keyrange` construct. It has two forms:
  - `in_keyrange('-80')`: The row's source keyrange matched against `-80`.
  - `in_keyrange(col, 'vindex_func', '-80')`: The keyrange is computed using the specified Vindex function as `vindex_func(col)` and matched against `-80`.
- `GROUP BY`: can be specified if using aggregations. The `GROUP BY` expressions are expected to cover the non-aggregated columns just like regular SQL requires.
- No other constructs like `ORDER BY`, `LIMIT`, etc. are allowed.

The pos field For starting a brand new vreplication stream, the `pos` field must be empty. The empty string signifies that there's no starting point for the vreplication. This causes VReplication to copy the contents of the source table first, and then start the replication.

For large tables, this is done in chunks. After each chunk is copied, replication is resumed until it's caught up. VReplication ensures that only changes that affect existing rows are applied. Following this another chunk is copied, and so on, until all tables are completed. After that, replication runs indefinitely until the VReplication stream is stopped or deleted.

It is a shared row The `vreplication` table row is shared between the operator and Vreplication itself. Once the row is created, the VReplication stream updates various fields of the row to save and report on its own status. For example, the `pos` field is continuously updated as it makes forward progress.

While copying, the `state` field will be `Init` or `Copying`.

Updating a stream You can change any field of the stream by issuing a `VReplicationExec` with an SQL `UPDATE` statement. You are required to specify the id of the row you intend to update. You can only update one row at a time.

Typically, you can update the row and change the state to `Stopped` to stop a stream, or to `Running` to restart a stopped stream.

You can also update the row to set a `stop_pos`, which will make the replication stop once it reaches the specified position.

Deleting a stream You can delete a stream by issuing a `DELETE` statement. This will stop the replication and delete the row. This statement is destructive. All data about the replication state will be permanently deleted. Note that the target table will be left as-is, potentially partially copied, and needs to be cleaned up separately, if desired.

Other properties of VReplication

Fast replay VReplication has the capability to batch transactions if the send rate of the source exceeds the replay rate of the destination. This allows it to catch up very quickly when there is a backlog. Load tests have shown a 3-20X improvement over traditional MySQL replication depending on the workload.

Accurate lag tracking The source vttablet sends its current time along with every event. This allows the target to correct for clock skew while estimating replication lag. Additionally, the source starts sending heartbeats if there is nothing to send. If the target receives no events from the source at all, it knows that it's definitely lagged and starts reporting itself accordingly.

Self-replication VReplication allows you to set the source keyspace/shard to be the same as the target. This is especially useful for performing schema rollouts: you can create the target table with the intended schema and vreplicate from the source table to the new target. Once caught up, you can cutover to write to the target table. In this situation, an apply on the target generates a binlog event that will be picked up by the source and sent to the target. Typically, it will be an empty transaction. In such cases, the target does not generally apply these transactions, because such an application will generate yet another event. However, there are situations where one needs to apply empty transactions, especially if it's a required stopping point. VReplication can differentiate between these situations and apply events only as needed.

Deadlocks and lock wait timeouts It is possible that multiple streams can conflict with each other and cause deadlocks or lock waits. When such things happen, VReplication silently retries such transactions without reporting an error. It does increment a counter so that the frequency of such occurrences can be tracked.

Automatic retries If any other error is encountered, the replication is retried after a short wait. Each time, the stream searches from the full list of available sources and picks one at random.

on_ddl The source specification allows you to specify a value for `on_ddl`. This allows you to specify what to do with DDL SQL statements when they are encountered in the replication stream from the source. The values can be as follows:

- `IGNORE`: Ignore all DDLs (this is also the default, if a value for `on_ddl` is not provided).
- `STOP`: Stop when DDL is encountered. This allows you to make any necessary changes to the target. Once changes are made, updating the state to `Running` will cause VReplication to continue from just after the point where it encountered the DDL.
- `EXEC`: Apply the DDL, but stop if an error is encountered while applying it.
- `EXEC_IGNORE`: Apply the DDL, but ignore any errors and continue replicating.

Failover continuation If a failover is performed on the target keyspace/shard, the new master will automatically resume VReplication from where the previous master left off.

Monitoring and troubleshooting

VTTablet /debug/status The first place to look at is the `/debug/status` page of the target master vttablet. The bottom of the page shows the status of all the VReplication streams.

Typically, if there is a problem, the `Last Message` column will display the error. Sometimes, it's possible that the stream cannot find a source. If so, the `Source Tablet` would be empty.

VTTablet logfile If the errors are not clear or if they keep disappearing, the VTTablet logfile will contain information about what it's been doing with each stream.

VReplicationExec select The current status of the streams can also be fetched by issuing a VReplicationExec command with `select * from _vt.vreplication`.

Monitoring variables VReplication also reports the following variables that can be scraped by monitoring tools like prometheus:

- VReplicationStreamCount: Number of VReplication streams.
- VReplicationSecondsBehindMasterMax: Max vreplication seconds behind master.
- VReplicationSecondsBehindMaster: vreplication seconds behind master per stream.
- VReplicationSource: The source for each VReplication stream.
- VReplicationSourceTablet: The source tablet for each VReplication stream.

Thresholds and alerts can be set to draw attention to potential problems.

VReplicationExec

description: Low level command to run a query on vreplication related tables

```
VReplicationExec [-json] <tablet alias> <sql command>
```

Description The VReplicationExec command is used to view or manage vreplication streams. More details are here. You would typically use one of the higher-level commands like the WorkFlow command accomplish the same task.

Parameters

-json optional

The output of the command is json formatted: to be readable by scripts.

tablet alias mandatory

Id of the target tablet on which to run the sql query, specified using the vitess tablet id format cell-uid (see example below).

sql query mandatory

SQL query which will be run: validations are done to ensure that queries can be run only against vreplication tables. A limited set of queries are allowed.

```
vtctlclient  VReplicationExec 'zone1-100' 'select * from _vt.vreplication'
```

Workflow

description: Wrapper on VExec to perform common actions on a workflow

```
Workflow  [-dry_run] <keyspace[.workflow]> <action>
```

Description Workflow is a convenience command for useful actions on a workflow that you can use instead of actually specifying a query to VExec.

Parameters

-dry-run optional
default false

You can do a dry run where no actual action is taken but the command logs all the actions that would be taken by SwitchReads.

keyspace.workflow mandatory

Name of target keyspace and the associated workflow to SwitchWrites for.

action mandatory

action is one of

- **stop**: sets the state of the workflow to Stopped: no further vreplication will happen until workflow is restarted
- **start**: restarts a Stopped workflows
- **delete**: removes the entries for this workflow in _vt.vreplication
- **show**: returns a JSON object with details about the associated shards and also with all the columns from the _vt.vreplication table
- **listall**: returns a comma separated list of all *running* workflows in a keyspace

```
vtctlclient  Workflow keyspace1.workflow1 stop
vtctlclient  Workflow keyspace1.workflow1 show
vtctlclient  Workflow keyspace1 listall
```

Resources

description: Additional resources including Presentations and Roadmap

Presentations and Videos

CNCF Webinar 2020

Lizz van Dijk demonstrates how to migrate from a regular MySQL release to Vitess.

{{< youtube id="W8VbiXo39Ik" autoplay="false" >}}

MySQL Pre-FOSDEM Day 2020

Lizz van Dijk presents an introduction to Vitess for MySQL users.

KubeCon San Diego 2019

KubeCon featured several Vitess talks, including:

- Scaling Resilient Systems: A Journey into Slack's Database Service - Rafael Chacon & Guido Iaquinti, Slack
- How to Migrate a MySQL Database to Vitess - Sugu Sougoumarane & Morgan Tocker, PlanetScale
- Building a Database as a Service on Kubernetes - Abhi Vaidyanatha & Lucy Burns, PlanetScale
- Vitess: Stateless Storage in the Cloud - Sugu Sougoumarane, PlanetScale
- Geo-partitioning with Vitess - Deepthi Sigireddi & Jitendra Vaidya, PlanetScale
- Gone in 60 Minutes: Migrating 20 TB from AKS to GKE in an Hour with Vitess - Derek Perkins, Nozzle

Vitess was also featured during the CNCF project updates keynote!

Highload 2019

Sugu Sougoumarane presents an overview of Vitess at Highload in Moscow.

{{< pdf src="/ViewerJS/#../files/2019-sugu-highload.pdf" >}}

Utah Kubernetes Meetup 2019

Jiten Vaidya shows how you can extend Vitess to create jurisdiction-aware database clusters.

{{< pdf src="/ViewerJS/#../files/2019-jiten-utah.pdf" >}}

CNCF Meetup Paris 2019

Sugu Sougoumarane and Morgan Tocker present a three hour Vitess workshop on Kubernetes.

{{< pdf src="/ViewerJS/#../files/2019-paris-cncf.pdf" >}}

Percona Live Europe 2019

My First 90 Days with Vitess

Morgan Tocker talks about his adventures in Vitess, after having come from a MySQL background.

{{< pdf src="/ViewerJS/#../files/2019-morgan-percona-eu.pdf" >}}

Sharded MySQL on Kubernetes

Sugu Sougoumarane presents an overview of running sharded MySQL on Kubernetes.

{{< pdf src="/ViewerJS/#../files/2019-sugu-percona-eu.pdf" >}}

Vitess Meetup 2019 @ Slack HQ

Vitess: New and Coming Soon!

Deepthi Sigireddi shares new features recently introduced in Vitess, and what's on the roadmap moving forward.

{{< pdf src="/ViewerJS/#../files/2019-deepthi-vitess-meetup.pdf" >}}

Deploying multi-cell Vitess

Rafael Chacon Vivas describes how Vitess is used in Slack.

{{< pdf src="/ViewerJS/#../files/2019-rafael-vitess-meetup.pdf" >}}

Vitess at Pinterest

David Weitzman provides an overview of how Vitess is used at Pinterest.

{{< youtube id="1cWWlaqlia8" autoplay="false" >}}

No more Regrets

Sugu Sougoumarane demonstrates new features coming to VReplication.

{{< youtube id="B1Nrtptjtcs" autoplay="false" >}}

Cloud Native Show 2019

Vitess at scale - how Nozzle.io runs MySQL on Kubernetes

Derek Perkins joins the Cloud Native show and explains how Nozzle uses Vitess.

Listen to Podcast

CNCF Webinar 2019

Vitess: Sharded MySQL on Kubernetes

Sugu Sougoumarane provides an overview of Vitess for Kubernetes users.

{{< youtube id="E6H4bgJ3Z6c" autoplay="false" >}}

Kubecon China 2019

How JD.Com runs the World's Largest Vitess

Xuhaihua and Jin Ke Xie present on their experience operating the largest known Vitess cluster, two years in.

{{< youtube id="qww4UVNG3Io" autoplay="false" >}}

RootConf 2019

OLTP or OLAP: why not both?

Jiten Vaidya from PlanetScale explains how you can use both OLTP and OLAP on Vitess.

{{< youtube id="bhzJJF82mFc" autoplay="false" >}}

Kubecon 19 Barcelona

Vitess Deep Dive

Jiten Vaidya and Dan Kozlowski from PlanetScale deep dive on Vitess.

{{< youtube id="OZl4HrB9p-8" autoplay="false" >}}

Percona Live Austin 2019

Vitess: Running Sharded MySQL on Kubernetes

Sugu Sougoumarane shows how you can run sharded MySQL on Kubernetes.

{{< youtube id="v7oxiVmGXp4" autoplay="false" >}}

MySQL, Kubernetes, Business & Enterprise

David Cohen (Intel), Steve Shaw (Intel) and Jiten Vaidya (PlanetScale) discuss Open Source cloud native databases.

View Talk Abstract and Slides

Velocity New York 2018

Smooth scaling: Slack's journey toward a new database

Slack has experienced tremendous growth for a young company, serving over nine million weekly active customers. But with great growth comes greater growth pains. Slack's rapid growth over the last few years outpaced the scaling capacity of its original sharded MySQL database, which negatively impacted the company's customers and engineers.

Ameet Kotian explains how a small team of engineers embarked on a journey for the right database solution, which eventually led them to Vitess, a powerful open source database cluster solution for MySQL. Vitess combines the features of MySQL with the scalability of a NoSQL database. It has been serving Youtube's traffic for numerous years and has a strong community.

Although Vitess meets a lot of Slack's needs, it's not an out-of-the-box solution. Ameet shares how the journey to Vitess was planned and executed, with little customer impact, in the face of piling operational challenges, such as AWS issues, MySQL replication, automatic failovers, deployments strategies, and so forth. Ameet also covers Vitess's architecture, trade-offs, and what the future of Vitess looks like at Slack.

Ameet Kotkian, senior storage operations engineer at Slack, shows us how Slack uses Vitess.

Percona Live Europe 2017

Migrating to Vitess at (Slack) Scale

Slack is embarking on a major migration of the MySQL infrastructure at the core of our service to use Vitess' flexible sharding and management instead of our simple application-based shard routing and manual administration. This effort is driven by the need for an architecture that scales to meet the growing demands of our largest customers and features under the pressure to maintain a stable and performant service that executes billions of MySQL transactions per hour. This talk will present the driving motivations behind the change, why Vitess won out as the best option, and how we went about laying the groundwork for the switch. Finally, we will discuss some challenges and surprises (both good and bad) found during our initial migration efforts, and suggest some ways in which the Vitess ecosystem can improve that will aid future migration efforts.

Michael Demmer shows us how, at Percona Live Europe 2017.

{{< pdf src="/ViewerJS/#../files/2017-demmer-percona.pdf" >}}

Vitess Deep Dive sessions

Start with session 1 and work your way through the playlist. This series focuses on the V3 engine of VTGate.

{{< youtube id="6yOjF7qhmyY" autoplay="false" >}}

Percona Live 2016

Sugu and Anthony showed what it looks like to use Vitess now that Keyspace IDs can be completely hidden from the application. They gave a live demo of resharding the Guestbook sample app, which now knows nothing about shards, and explained how new features in VTGate make all of this possible.

{{< pdf src="/ViewerJS/#../files/percona-2016.pdf" >}}

CoreOS Meetup, January 2016

Vitess team member Anthony Yeh's talk at the January 2016 CoreOS Meetup discussed challenges and techniques for running distributed databases within Kubernetes, followed by a deep dive into the design trade-offs of the Vitess on Kubernetes deployment templates.

{{< pdf src="/ViewerJS/#../files/coreos-meetup-2016-01-27.pdf" >}}

Oracle OpenWorld 2015

Vitess team member Anthony Yeh's talk at Oracle OpenWorld 2015 focused on what the Cloud Native Computing paradigm means when applied to MySQL in the cloud. The talk also included a deep dive into transparent, live resharding, one of the key features of Vitess that makes it well-adapted for a Cloud Native environment.

{{< pdf src="/ViewerJS/#../files/openworld-2015-vitess.pdf" >}}

Percona Live 2015

Vitess team member Anthony Yeh's talk at Percona Live 2015 provided an overview of Vitess as well as an explanation of how Vitess has evolved to live in a containerized world with Kubernetes and Docker.

{{< pdf src="/ViewerJS/#../files/percona-2015-vitess-and-kubernetes.pdf" >}}

Google I/O 2014 - Scaling with Go: YouTube's Vitess

In this talk, Sugu Sougoumarane from the Vitess team talks about how Vitess solved YouTube's scalability problems as well as about tips and techniques used to scale with Go.

{{< youtube id="midJ6b1LkA0" autoplay="false" >}}

Vitess Roadmap

description: Upcoming features planned for development

As an open source project, Vitess is developed by a community of contributors. Many of the contributors run Vitess in production, and add features to address their specific pain points. As a result of this, we can not guarantee features listed here will be implemented in any specific order.

{{< info >}} If you have a specific question about the Roadmap, we recommend posting in our Slack channel, click the Slack icon in the top right to join. This is a very active community forum and a great place to interact with other users. {{< /info >}}

Short Term

- Improve Documentation
- Improve Usability
- Support more MySQL Syntax (improve compatibility as a drop-in replacement)

  - Certify popular frameworks like Ruby on Rails, Hibernate etc.
- Vitess-native unplanned failovers
- Pluggable durability policies
- Nightly benchmarking (regression testing)
- Schema changes through vitess

  - gh-ost and pt-osc integration
- VReplication

  - VExec tool for management

Medium Term

- Vttablet to manage more than one MySQL schema
- Rewrite of vtctld UI including visualization of VReplication
- VReplication throttling
- Binlog server
- Topology Service: Reduce dependencies on the topology service. i.e. Vitess should be operable normally even if topology service is down for several hours. Topology service should be used only for passive discovery.
- Support for PostgreSQL: Vitess should be able to support PostgreSQL for both storing data, and speaking the protocol in VTGate.

Troubleshoot

description: Debug common issues with Vitess

If there is a problem in the system, one or many alerts would typically fire. If a problem was found through means other than an alert, then the alert system needs to be iterated upon.

When an alert fires, you have the following sources of information to perform your investigation:

- Alert values
- Graphs
- Diagnostic URLs
- Log files

Below are a few possible scenarios.

Elevated query latency on master

Diagnosis 1: Inspect the graphs to see if QPS has gone up. If yes, drill down on the more detailed QPS graphs to see which table, or user caused the increase. If a table is identified, look at /debug/queryz for queries on that table.

Action: Inform engineer about about toxic query. If it's a specific user, you can stop their job or throttle them to keep the load manageable. As a last resort, blacklist query to allow the rest of the system to stay healthy.

Diagnosis 2: QPS did not go up, only latency did. Inspect the per-table latency graphs. If it's a specific table, then it's most likely a long-running low QPS query that's skewing the numbers. Identify the culprit query and take necessary steps to get it optimized. Such queries usually do not cause outage. So, there may not be a need to take extreme measures.

Diagnosis 3: Latency seems to be up across the board. Inspect transaction latency. If this has gone up, then something is causing MySQL to run too many concurrent transactions which causes slow-down. See if there are any tx pool full errors. If there is an increase, the INFO logs will dump info about all transactions. From there, you should be able to if a specific sequence of statements is causing the problem. Once that is identified, find out the root cause. It could be network issues, or it could be a recent change in app behavior.

Diagnosis 4: No particular transaction seems to be the culprit. Nothing seems to have changed in any of the requests. Look at system variables to see if there are hardware faults. Is the disk latency too high? Are there memory parity errors? If so, you may have to failover to a new machine.

Master starts up read-only

To prevent accidentally accepting writes, our default my.cnf settings tell MySQL to always start up read-only. If the master MySQL gets restarted, it will thus come back read-only until you intervene to confirm that it should accept writes. You can use the `SetReadWrite` command to do that.

However, usually if something unexpected happens to the master, it's better to reparent to a different replica with `EmergencyReparentShard`. If you need to do planned maintenance on the master, it's best to first reparent to another replica with `PlannedReparentShard`.

Vitess sees the wrong tablet as master

If you do a failover manually (not through Vitess), you'll need to tell Vitess which tablet corresponds to the new master MySQL. Until then, writes will fail since they'll be routed to a read-only replica (the old master). Use the `TabletExternallyReparented` command to tell Vitess the new master tablet for a shard.

Tools like Orchestrator can be configured to call this automatically when a failover occurs. See our sample orchestrator.conf.json for an example of this.

User Guides

description: Task-based guides for common usage scenarios

We recommend running through a get started on your favorite platform before running through user guides.

Advanced Configuration

description: User guides covering advanced configuration concepts

Authorization

A common question is how to enforce fine-grained access control in Vitess. This question comes up because Vitess uses connection pooling with fixed MySQL users at the VTTablet level, and implements its own authentication at the VTGate level. As a result, you cannot use the normal MySQL GRANTs system to give certain application-level MySQL users more or less permissions than others.

The MySQL GRANT system is very extensive, and we have not reimplemented all of this functionality in Vitess. What we have done is to enable you to provide authorization via table-level ACLs, with a few basic characteristics:

- Individual users can be assigned 3 levels of permissions:
  - Read (corresponding to read DML, e.g. `SELECT`)
  - Write (corresponding to write DML, e.g. `INSERT`, `UPDATE`, `DELETE`)
  - Admin (corresponding to DDL, e.g. `ALTER TABLE`)
- Permissions are applied on a specified set of tables, which can be enumerated or specified by regex.

VTTablet parameters for table ACLs

Note that the Vitess authorization via ACLs are applied at the VTTablet level, as opposed to on VTGate, where authentication is enforced. There are a number of VTTablet command line parameters that control the behavior of ACLs. Let's review these:

- `-enforce-tableacl-config`: Set this to `true` to ensure VTTablet will not start unless there is a valid ACL configuration. This is used to catch misconfigurations resulting in blanket access to authenticated users.
- `-queryserver-config-enable-table-acl-dry-run`: Set to `true` to check the table ACL at runtime, and only emit the TableACLPseudoDenied metric if a request would have been blocked. The request is then allowed to pass, even if the ACL determined it should be blocked. This can be used for testing new or updated ACL policies. Default is `false`.
- `-queryserver-config-strict-table-acl`: Set to `true` to enforce table ACL checking. **This needs to be enabled for your ACLs to have any effect.** Any users that are not specified in an ACL policy will be denied. Default is `false`.
- `-queryserver-config-acl-exempt-acl`: Allows you to specify the name of an ACL (see below for format) that is exempt from enforcement. Allows you to separate the rollout and the subsequent enforcement of a specific ACL.
- `-table-acl-config`: Path to a file defining the table ACL config.
- `-table-acl-config-reload-interval`: How often the `table-acl-config` should be reloaded. Set this to allow you to update the ACL file on disk, and then have VTTablet automatically reload the file within this period. Default is not to reload the ACL file after VTTablet startup. Note that even if you do not set this parameter, you can always force VTTablet to reload the ACL config file from disk by sending a SIGHUP signal to your VTTablet process.

Format of the table ACL config file

The file specified in the `-table-acl-config` parameter above is a JSON file with the following example to explain the format:

```
{
    "table_groups": [
        {
            "name": "aclname",
            "table_names_or_prefixes": [
                "%"
            ],
```

```
            "readers": [
                "vtgate-user1"
            ],
            "writers": [
                "vtgate-user2"
            ],
            "admins": [
                "vtgate-user3"
            ]
        },
        { "... more ACLs here if necessary ..." }
    ]
}
```

Notes:

- `name`: This is the name of the ACL (`aclname` in the example above) and is what needs to be specified in `-queryserver-config-acl-exempt-acl`, if you need to exempt a specific ACL from enforcement.
- `table_names_or_prefixes`: A list of strings and/or regexes that allow a rule to target a specific table or set of tables. Use `%` as in the example to specify all tables. Note that only the SQL `%` "regex" wildcard is supported here at the moment.
- `readers`: A list of VTGate users, specified by their UserData field in the authentication specification, that are allowed to read the tables targeted by this ACL rule. Typically allows `SELECT`.
- `writers`: A list of VTGate users that are allowed to write to the tables targeted by this ACL rule. Typically allows `INSERT`, `UPDATE` and `DELETE`.
- `admins`: A list of VTGate users that are allowed admin privileges on the tables targeted by this ACL rule. Typically allows DDL privileges, e.g. `ALTER TABLE`. Note that this also includes some commands that might be thought of as DML, which are really DDL, like `TRUNCATE`)
- Note that `writers` privilege does not imply `readers` privilege, and `admins` privilege does not imply `readers` or `writers`. You need to therefore add your users to each list explicitly if you want them to have that level of access.
- You cannot use multiple ACL rules to target the same (sub)set of tables. Therefore the tablenames specified by `table_names_or_prefixes` (or expanded by regexes) need to be non-overlapping between ACL rules. Additionally, you cannot have duplicate tablenames or overlapping regexes in the `table_names_or_prefixes` list in a single ACL rule.

Example

Let's assume your Vitess cluster already has two keyspaces setup:

- `keyspace1` with a single table `t` that should only be accessed by `myuser1`
- `keyspace2` with a single table `t` that should only be accessed by `myuser2`

For the VTTablet configuration for `keyspace1`:

```
$ cat > acls_for_keyspace1.json << EOF
{
  "table_groups": [
    {
      "name": "keyspace1acls",
      "table_names_or_prefixes": ["%"],
      "readers": ["myuser1", "vitess"],
      "writers": ["myuser1", "vitess"],
      "admins": ["myuser1", "vitess"]
```

```
    }
  ]
}
EOF

$ vttablet -init_keyspace "keyspace1" -table-acl-config=acls_for_keyspace1.json
   -enforce-tableacl-config -queryserver-config-strict-table-acl ........
```

Note that the `%` specifier for `table_names_or_prefixes` translates to "all tables".

Do the same thing for `keyspace2`:

```
$ cat > acls_for_keyspace2.json << EOF
{
  "table_groups": [
    {
      "name": "keyspace2acls",
      "table_names_or_prefixes": ["%"],
      "readers": ["myuser2", "vitess"],
      "writers": ["myuser2", "vitess"],
      "admins": ["myuser2", "vitess"]
    }
  ]
}
EOF

$ vttablet -init_keyspace "keyspace2" -table-acl-config=acls_for_keyspace2.json
   -enforce-tableacl-config -queryserver-config-strict-table-acl ........
```

With this setup, the `myuser1` and `myuser2` users can only access their respective keyspaces, but the `vitess` user can access both.

```
# Attempt to access keyspace1 with myuser2 credentials through vtgate
$ mysql -h 127.0.0.1 -u myuser2 -ppassword2 -D keyspace1 -e "select * from t"
ERROR 1045 (HY000) at line 1: vtgate: http://vtgate-zone1-7fbfd8cc47-tchbz:15001/: target:
   keyspace1.-80.master, used tablet: zone1-476565201
   (zone1-keyspace1-x-80-replica-1.vttablet): vttablet: rpc error: code = PermissionDenied
   desc = table acl error: "myuser2" [] cannot run PASS_SELECT on table "t" (CallerID:
   myuser2)
target: keyspace1.80-.master, used tablet: zone1-1289569200
   (zone1-keyspace1-80-x-replica-0.vttablet): vttablet: rpc error: code = PermissionDenied
   desc = table acl error: "myuser2" [] cannot run PASS_SELECT on table "t" (CallerID:
   myuser2)
$
```

Whereas myuser1 is able to access its keyspace without error:

```
$ mysql -h 127.0.0.1 -u myuser1 -ppassword1 -D keyspace1 -e "select * from t"
$
```

CreateLookupVindex

{{< info >}} This guide follows on from the Get Started guides. Please make sure that you have an Operator, local or Helm installation ready. Make sure you are at the point where you have the sharded keyspace called `customer` setup. {{< /info >}}

CreateLookupVindex is a new VReplication workflow in Vitess 6. It is used to create **and** backfill a lookup Vindex automatically for a table that already exists, and may have a significant amount of data in it already.

Internally, the `CreateLookupVindex` process uses VReplication for the backfill process, until the lookup Vindex is "in sync". Then the normal process for adding/deleting/updating rows in the lookup Vindex via the usual transactional flow when updating the "owner" table for the Vindex takes over.

In this guide, we will walk through the process of using the `CreateLookupVindex` workflow, and give some insight into what happens underneath the covers.

`vtctlclient CreateLookupVindex` has the following syntax:

```
CreateLookupVindex [-cell=<cell>] [-tablet_types=<source_tablet_types>] <keyspace> <json_spec>
```

- `<json_spec>`: Use the lookup Vindex specified in `<json_spec>` along with VReplication to populate/backfill the lookup Vindex from the source table.
- `<keyspace>`: The Vitess keyspace we are creating the lookup Vindex in. The source table is expected to also be in this keyspace.
- `-tablet-types`: Provided to specify the shard tablet types (e.g. `MASTER`, `REPLICA`, `RDONLY`) that are acceptable as source tablets for the VReplication stream(s) that this command will create. If not specified, the tablet type used will default to the value of the vttablet `-vreplication_tablet_type` option, which defaults to `REPLICA`.
- `-cell`: By default VReplication streams, such as used by `CreateLookupVindex` will not cross cell boundaries. If you want the VReplication streams to source their data from tablets in a cell other than the local cell, you can use the `-cell` option to specify this.

The `<json_spec>` describes the lookup Vindex to be created, and details about the table it is to be created against (on which column, etc.). However, you do not have to specify details about the actual lookup table, Vitess will create that automatically based on the type of the column you are creating the Vindex column on, etc.

In the context of the regular `customer` database that is part of the Vitess examples we started earlier, let's add some rows into the `customer.corder` table, and then look at an example `<json_spec>`:

```
$ mysql -P 15306 -h 127.0.0.1 -u root --binary-as-hex=false -A
Welcome to the MySQL monitor.  Commands end with ; or \g.
.
.
.
mysql> use customer;
Database changed

mysql> show tables;
+------------------------+
| Tables_in_vt_customer |
+------------------------+
| corder                |
| customer              |
+------------------------+
2 rows in set (0.00 sec)

mysql> desc corder;
+-------------+----------------+------+-----+---------+-------+
| Field       | Type           | Null | Key | Default | Extra |
+-------------+----------------+------+-----+---------+-------+
| order_id    | bigint         | NO   | PRI | NULL    |       |
| customer_id | bigint         | YES  |     | NULL    |       |
| sku         | varbinary(128) | YES  |     | NULL    |       |
| price       | bigint         | YES  |     | NULL    |       |
+-------------+----------------+------+-----+---------+-------+
4 rows in set (0.01 sec)
```

```
mysql> insert into corder (order_id, customer_id, sku, price) values (1, 1, "Product_1",
   100);
Query OK, 1 row affected (0.01 sec)

mysql> insert into corder (order_id, customer_id, sku, price) values (2, 1, "Product_2",
   101);
Query OK, 1 row affected (0.01 sec)

mysql> insert into corder (order_id, customer_id, sku, price) values (3, 2, "Product_3",
   102);
Query OK, 1 row affected (0.01 sec)

mysql> insert into corder (order_id, customer_id, sku, price) values (4, 3, "Product_4",
   103);
Query OK, 1 row affected (0.01 sec)

mysql> insert into corder (order_id, customer_id, sku, price) values (5, 4, "Product_5",
   104);
Query OK, 1 row affected (0.03 sec)

mysql> select * from corder;
+----------+-------------+-----------+-------+
| order_id | customer_id | sku       | price |
+----------+-------------+-----------+-------+
|        1 |           1 | Product_1 |   100 |
|        2 |           1 | Product_2 |   101 |
|        3 |           2 | Product_3 |   102 |
|        4 |           3 | Product_4 |   103 |
|        5 |           4 | Product_5 |   104 |
+----------+-------------+-----------+-------+
5 rows in set (0.01 sec)
```

If we look at the VSchema for the `customer.corder` table, we will see there is a `hash` index on the `customer_id` table, and 4 of our 5 rows have ended up on the `-80` shard, and the 5th row on the `80-` shard:

```
mysql> use customer/-80
Database changed

mysql> select * from corder;
+----------+-------------+-----------+-------+
| order_id | customer_id | sku       | price |
+----------+-------------+-----------+-------+
|        1 |           1 | Product_1 |   100 |
|        2 |           1 | Product_2 |   101 |
|        3 |           2 | Product_3 |   102 |
|        4 |           3 | Product_4 |   103 |
+----------+-------------+-----------+-------+
4 rows in set (0.00 sec)

mysql> use customer/80-
Database changed

mysql> select * from corder;
+----------+-------------+-----------+-------+
| order_id | customer_id | sku       | price |
+----------+-------------+-----------+-------+
|        5 |           4 | Product_5 |   104 |
```

```
+----------+-------------+-----------+-------+
1 row in set (0.01 sec)
```

Note that this skewed distribution is completely coincidental, for larger numbers of rows, we would expect the distribution to be approximately even for a `hash` index.

Now let's say we want to add a lookup Vindex on the `sku` column. We can use a `consistent_lookup` or `consistent_lookup_unique` Vindex type. In our example we will use `consistent_lookup_unique`.

Here is our example `<json_spec>`:

```
$ cat lookup_vindex.json
{
    "sharded": true,
    "vindexes": {
        "corder_lookup": {
            "type": "consistent_lookup_unique",
            "params": {
                "table": "customer.corder_lookup",
                "from": "sku",
                "to": "keyspace_id"
            },
            "owner": "corder"
        }
    },
    "tables": {
        "corder": {
            "column_vindexes": [
                {
                    "column": "sku",
                    "name": "corder_lookup"
                }
            ]
        }
    }
}
```

Note that as mentioned above, we do not have to tell Vitess about how to shard the actual backing table for the lookup Vindex or any schema to create as it will do it automatically. Now, let us actually execute the `CreateLookupVindex` command:

```
$ vtctlclient -server localhost:15999 CreateLookupVindex -tablet_types=RDONLY customer
   "$(cat lookup_vindex.json)"
```

Note:

- We are specifying a tablet_type of `RDONLY`; meaning it is going to run the VReplication streams from tablets of the `RDONLY` type **only**. If tablets of this type cannot be found, in a shard, the lookup Vindex population will fail.

Now, in our case, the table is tiny, so the copy will be instant, but in a real-world case this might take hours. To monitor the process, we can use the usual VReplication commands. However, the VReplication status commands needs to operate on individual tablets. Let's check which tablets we have in our environment, so we know which tablets to issue commands against:

```
$ vtctlclient -server localhost:15999 ListAllTablets | grep customer
zone1-0000000300 customer -80 master localhost:15300 localhost:17300 [] 2020-08-13T01:23:15Z
zone1-0000000301 customer -80 replica localhost:15301 localhost:17301 [] <null>
zone1-0000000302 customer -80 rdonly localhost:15302 localhost:17302 [] <null>
zone1-0000000400 customer 80- master localhost:15400 localhost:17400 [] 2020-08-13T01:23:15Z
zone1-0000000401 customer 80- replica localhost:15401 localhost:17401 [] <null>
zone1-0000000402 customer 80- rdonly localhost:15402 localhost:17402 [] <null>
```

i.e. now we can see what will happen:

- VReplication streams will be setup from the master tablets `zone1-0000000300` and `zone1-0000000400`; pulling data from the `RDONLY` source tablets `zone1-0000000302` and `zone1-0000000402`.
- Note that each master tablet will start streams from each source tablet, for a total of 4 streams in this case.

Lets observe the VReplication streams that got created using the `vtctlclient VReplicationExec` command. First let's look at the streams to the first master tablet `zone1-0000000300`:

```
$ vtctlclient -server localhost:15999 VReplicationExec zone1-0000000300 "select * from
    _vt.vreplication"
+----+-------------------+----------------------------------------+--------------------------------
| id |     workflow      |                source                  |
   pos                        | stop_pos |       max_tps       | max_replication_lag | cell
   | tablet_types | time_updated | transaction_timestamp |  state  |       message       |
     db_name   |
+----+-------------------+----------------------------------------+--------------------------------
|  2 | corder_lookup_vdx | keyspace:"customer" shard:"-80"        |
   MySQL56/68da1cdd-dd03-11ea-95de-68a86d2718b0:1-43 |          | 9223372036854775807 |
   9223372036854775807 |      | RDONLY       |   1597282811 |                     0 |
   Stopped | Stopped after copy. | vt_customer |
|    |                   | filter:<rules:<match:"corder_lookup" |
                                                |          |                       |
                       |      |             |             |                         |
           |                     |             |
|    |                   | filter:"select sku as sku,             |
                                                |          |                       |
                       |      |             |             |                         |
           |                     |             |
|    |                   | keyspace_id() as keyspace_id from      |
                                                |          |                       |
                       |      |             |             |                         |
           |                     |             |
|    |                   | corder where in_keyrange(sku,          |
                                                |          |                       |
                       |      |             |             |                         |
           |                     |             |
|    |                   | 'customer.binary_md5', '-80')          |
                                                |          |                       |
                       |      |             |             |                         |
           |                     |             |
|    |                   | group by sku, keyspace_id" > >         |
                                                |          |                       |
                       |      |             |             |                         |
           |                     |             |
|    |                   | stop_after_copy:true                   |
                                                |          |                       |
                       |      |             |             |                         |
           |                     |             |
|  3 | corder_lookup_vdx | keyspace:"customer" shard:"80-"        |
   MySQL56/7d2c819e-dd03-11ea-92e4-68a86d2718b0:1-38 |          | 9223372036854775807 |
   9223372036854775807 |      | RDONLY       |   1597282811 |                     0 |
   Stopped | Stopped after copy. | vt_customer |
|    |                   | filter:<rules:<match:"corder_lookup" |
                                                |          |                       |
```

```
                        |      |              |              |                          |
           |                    |              |
|    |                    | filter:"select sku as sku,           |
                                                |          |                          |
                        |      |              |              |                          |
           |                    |              |
|    |                    | keyspace_id() as keyspace_id from    |
                                                |          |                          |
                        |      |              |              |                          |
           |                    |              |
|    |                    | corder where in_keyrange(sku,        |
                                                |          |                          |
                        |      |              |              |                          |
           |                    |              |
|    |                    | 'customer.binary_md5', '-80')        |
                                                |          |                          |
                        |      |              |              |                          |
           |                    |              |
|    |                    | group by sku, keyspace_id" > >       |
                                                |          |                          |
                        |      |              |              |                          |
           |                    |              |
|    |                    | stop_after_copy:true                 |
                                                |          |                          |
                        |      |              |              |                          |
           |                    |              |
+----+------------------+--------------------------------------+-------------------------------
```

And now the streams to the second master tablet zone1-0000000400:

```
$ vtctlclient -server localhost:15999 VReplicationExec zone1-0000000400 "select * from
   _vt.vreplication"
+----+------------------+--------------------------------------+-------------------------------
| id |     workflow     |                source                |
   pos                        | stop_pos |       max_tps       | max_replication_lag | cell
   | tablet_types | time_updated | transaction_timestamp |  state  |       message       |
     db_name   |
+----+------------------+--------------------------------------+-------------------------------
|  2 | corder_lookup_vdx | keyspace:"customer" shard:"-80"      |
   MySQL56/68da1cdd-dd03-11ea-95de-68a86d2718b0:1-43 |          | 9223372036854775807 |
   9223372036854775807 |      | RDONLY       |   1597282811 |                    0 |
   Stopped | Stopped after copy. | vt_customer |
|    |                    | filter:<rules:<match:"corder_lookup" |
                                                |          |                          |
                        |      |              |              |                          |
           |                    |              |
|    |                    | filter:"select sku as sku,           |
                                                |          |                          |
                        |      |              |              |                          |
           |                    |              |
|    |                    | keyspace_id() as keyspace_id from    |
                                                |          |                          |
                        |      |              |              |                          |
           |                    |              |
|    |                    | corder where in_keyrange(sku,        |
                                                |          |                          |
                        |      |              |              |                          |
```

```
           |                      |             |
|    |                  | 'customer.binary_md5', '80-')        |
                                                |          |                       |
                       |      |             |             |                       |
           |                      |             |
|    |                  | group by sku, keyspace_id" > >       |
                                                |          |                       |
                       |      |             |             |                       |
           |                      |             |
|    |                  | stop_after_copy:true                 |
                                                |          |                       |
                       |      |             |             |                       |
           |                      |             |
|  3 | corder_lookup_vdx | keyspace:"customer" shard:"80-"      |
   MySQL56/7d2c819e-dd03-11ea-92e4-68a86d2718b0:1-38 |          | 9223372036854775807 |
   9223372036854775807 |      | RDONLY       |   1597282811 |                     0 |
   Stopped | Stopped after copy. | vt_customer |
|    |                  | filter:<rules:<match:"corder_lookup" |
                                                |          |                       |
                       |      |             |             |                       |
           |                      |             |
|    |                  | filter:"select sku as sku,           |
                                                |          |                       |
                       |      |             |             |                       |
           |                      |             |
|    |                  | keyspace_id() as keyspace_id from    |
                                                |          |                       |
                       |      |             |             |                       |
           |                      |             |
|    |                  | corder where in_keyrange(sku,        |
                                                |          |                       |
                       |      |             |             |                       |
           |                      |             |
|    |                  | 'customer.binary_md5', '80-')        |
                                                |          |                       |
                       |      |             |             |                       |
           |                      |             |
|    |                  | group by sku, keyspace_id" > >       |
                                                |          |                       |
                       |      |             |             |                       |
           |                      |             |
|    |                  | stop_after_copy:true                 |
                                                |          |                       |
                       |      |             |             |                       |
           |                      |             |
+----+------------------+--------------------------------------+-------------------------------
```

There is a lot going on in this output, but the most important parts are the `state` and `message` fields which say `Stopped` and `Stopped after copy.` for all four the streams. This means that the VReplication streams finished their copying/backfill of the lookup table.

Note that if the tables were large and the copy was still in progress, the `state` field would say `Copying`, and you can see the state/progress of the copy by looking at the `_vt.copy_state` table, e.g.:

```
$ vtctlclient -server localhost:15999 VReplicationExec zone1-0000000300 "select * from
   _vt.copy_state"
+----------+------------+--------+
| vrepl_id | table_name | lastpk |
```

```
+----------+------------+--------+
+----------+------------+--------+
```

(In this case this table is empty, because the copy has finished already).

We can verify the result of the backfill by looking at the `customer` keyspace again in the MySQL client:

```
mysql> show tables;
+------------------------+
| Tables_in_vt_customer |
+------------------------+
| corder                |
| corder_lookup         |
| customer              |
+------------------------+
3 rows in set (0.01 sec)
```

Note there is now a new table, `corder_lookup`; which was created as the backing table for the lookup Vindex. Lets look at this table:

```
mysql> desc corder_lookup;
+-------------+----------------+------+-----+---------+-------+
| Field       | Type           | Null | Key | Default | Extra |
+-------------+----------------+------+-----+---------+-------+
| sku         | varbinary(128) | NO   | PRI | NULL    |       |
| keyspace_id | varbinary(128) | YES  |     | NULL    |       |
+-------------+----------------+------+-----+---------+-------+
2 rows in set (0.01 sec)

mysql> select sku, hex(keyspace_id) from corder_lookup;
+-----------+------------------+
| sku       | hex(keyspace_id) |
+-----------+------------------+
| Product_2 | 166B40B44ABA4BD6 |
| Product_3 | 06E7EA22CE92708F |
| Product_1 | 166B40B44ABA4BD6 |
| Product_4 | 4EB190C9A2FA169C |
| Product_5 | D2FD8867D50D2DFE |
+-----------+------------------+
```

Basically, this shows exactly what we expected. Now, we can clean up the VReplication streams. Note these commands will clean up all VReplication streams on these tablets. You may want to filter by `id` if there are other streams running:

```
$ vtctlclient -server localhost:15999 VReplicationExec zone1-0000000300 "delete from
   _vt.vreplication"
+
+
$ vtctlclient -server localhost:15999 VReplicationExec zone1-0000000400 "delete from
   _vt.vreplication"
+
+
```

Next, to confirm the lookup Vindex is doing what we think it should, we can use the Vitess MySQL explain format, e.g.:

```
mysql> explain format=vitess select * from corder where customer_id = 1;
+----------+-------------------+----------+-------------+------------+--------------------------
| operator | variant           | keyspace | destination | tabletType | query
                                    |
+----------+-------------------+----------+-------------+------------+--------------------------
```

```
| Route    | SelectEqualUnique | customer |             | UNKNOWN    | select * from corder
   where customer_id = 1 |
+----------+-------------------+----------+-------------+------------+-------------------------
1 row in set (0.00 sec)
```

Since the above `select` statement is doing a lookup using the primary Vindex on the `corder` table, this query does not Scatter (variant is `SelectEqualUnique`), as expected. Let's try a scatter query to see what that looks like:

```
mysql> explain format=vitess select * from corder;
+----------+---------------+----------+-------------+------------+----------------------+
| operator | variant       | keyspace | destination | tabletType | query                |
+----------+---------------+----------+-------------+------------+----------------------+
| Route    | SelectScatter | customer |             | UNKNOWN    | select * from corder |
+----------+---------------+----------+-------------+------------+----------------------+
1 row in set (0.00 sec)
```

OK, variant is `SelectScatter` for a scatter query. Let's try a lookup on a column that does not have a primary or secondary (lookup) Vindex, e.g. the `price` column:

```
mysql> explain format=vitess select * from corder where price = 103;
+----------+---------------+----------+-------------+------------+-------------------------
| operator | variant       | keyspace | destination | tabletType | query
                              |
+----------+---------------+----------+-------------+------------+-------------------------
| Route    | SelectScatter | customer |             | UNKNOWN    | select * from corder
   where price = 103 |
+----------+---------------+----------+-------------+------------+-------------------------
1 row in set (0.00 sec)
```

That also scatters, as expected.

Now, let's try a lookup on the `sku` column, which we have created our lookup Vindex on:

```
mysql> explain format=vitess select * from corder where sku = "Product_1";
+----------+-------------------+----------+-------------+------------+-------------------------
| operator | variant           | keyspace | destination | tabletType | query
                                 |
+----------+-------------------+----------+-------------+------------+-------------------------
| Route    | SelectEqualUnique | customer |             | UNKNOWN    | select * from corder
   where sku = 'Product_1' |
+----------+-------------------+----------+-------------+------------+-------------------------
1 row in set (0.00 sec)
```

As expected, we can see it is not scattering anymore, which it would have before we did `CreateLookupVindex`.

Lastly, let's ensure that the lookup Vindex is being updated appropriately when we insert and delete rows:

```
mysql> select * from corder;
+----------+-------------+-----------+-------+
| order_id | customer_id | sku       | price |
+----------+-------------+-----------+-------+
|        5 |           4 | Product_5 |   104 |
|        1 |           1 | Product_1 |   100 |
|        2 |           1 | Product_2 |   101 |
|        3 |           2 | Product_3 |   102 |
|        4 |           3 | Product_4 |   103 |
+----------+-------------+-----------+-------+
5 rows in set (0.00 sec)

mysql> delete from corder where customer_id = 1 and sku = "Product_1";
```

```
Query OK, 1 row affected (0.03 sec)

mysql> select * from corder;
+----------+-------------+-----------+-------+
| order_id | customer_id | sku       | price |
+----------+-------------+-----------+-------+
|        2 |           1 | Product_2 |   101 |
|        3 |           2 | Product_3 |   102 |
|        4 |           3 | Product_4 |   103 |
|        5 |           4 | Product_5 |   104 |
+----------+-------------+-----------+-------+
4 rows in set (0.01 sec)

mysql> select sku, hex(keyspace_id) from corder_lookup;
+-----------+------------------+
| sku       | hex(keyspace_id) |
+-----------+------------------+
| Product_4 | 4EB190C9A2FA169C |
| Product_5 | D2FD8867D50D2DFE |
| Product_2 | 166B40B44ABA4BD6 |
| Product_3 | 06E7EA22CE92708F |
+-----------+------------------+
4 rows in set (0.01 sec)
```

We deleted a row from the `corder` table, and the matching lookup Vindex row is gone.

```
mysql> insert into corder (order_id, customer_id, sku, price) values (6, 1, "Product_6",
   105);
Query OK, 1 row affected (0.02 sec)

mysql> select * from corder;
+----------+-------------+-----------+-------+
| order_id | customer_id | sku       | price |
+----------+-------------+-----------+-------+
|        2 |           1 | Product_2 |   101 |
|        3 |           2 | Product_3 |   102 |
|        4 |           3 | Product_4 |   103 |
|        6 |           1 | Product_6 |   105 |
|        5 |           4 | Product_5 |   104 |
+----------+-------------+-----------+-------+
5 rows in set (0.00 sec)

mysql> select sku, hex(keyspace_id) from corder_lookup;
+-----------+------------------+
| sku       | hex(keyspace_id) |
+-----------+------------------+
| Product_4 | 4EB190C9A2FA169C |
| Product_5 | D2FD8867D50D2DFE |
| Product_6 | 166B40B44ABA4BD6 |
| Product_2 | 166B40B44ABA4BD6 |
| Product_3 | 06E7EA22CE92708F |
+-----------+------------------+
5 rows in set (0.00 sec)
```

We added a new row to the `corder` table, and now we have a new row in the lookup table.

Integration with Orchestrator

Orchestrator is a tool for managing MySQL replication topologies, including automated failover. It can detect master failure and initiate a recovery in a matter of seconds.

For the most part, Vitess is agnostic to the actions of Orchestrator, which operates below Vitess at the MySQL level. That means you can pretty much set up Orchestrator in the normal way, with just a few additions as described below.

For the Kubernetes example, we provide a sample script to launch Orchestrator for you with these settings applied.

Orchestrator configuration

Orchestrator needs to know some things from the Vitess side, like the tablet aliases and whether semisync is enforced with async fallback disabled. We pass this information by telling Orchestrator to execute certain queries that return local metadata from a non-replicated table, as seen in our sample orchestrator.conf.json:

```
"DetectClusterAliasQuery": "SELECT value FROM _vt.local_metadata WHERE name='ClusterAlias'",
"DetectInstanceAliasQuery": "SELECT value FROM _vt.local_metadata WHERE name='Alias'",
"DetectPromotionRuleQuery": "SELECT value FROM _vt.local_metadata WHERE
   name='PromotionRule'",
"DetectSemiSyncEnforcedQuery": "SELECT @@global.rpl_semi_sync_master_wait_no_slave AND
   @@global.rpl_semi_sync_master_timeout > 1000000",
```

Vitess also needs to know the identity of the master for each shard. This is necessary in case of a failover.

It is important to ensure that orchestrator has access to `vtctlclient` so that orchestrator can trigger the change in topology via the `TabletExternallyReparented` command.

```
"PostMasterFailoverProcesses": [
"echo 'Recovered from {failureType} on {failureCluster}. Failed: {failedHost}:{failedPort};
   Promoted: {successorHost}:{successorPort}' >> /tmp/recovery.log",
"vtctlclient -server vtctld:15999 TabletExternallyReparented {successorAlias}"
  ],
```

VTTablet configuration

Normally, you need to seed Orchestrator by giving it the addresses of MySQL instances in each shard. If you have lots of shards, this could be tedious or error-prone.

Luckily, Vitess already knows everything about all the MySQL instances that comprise your cluster. So we provide a mechanism for tablets to self-register with the Orchestrator API, configured by the following vttablet parameters:

- `orc_api_url`: Address of Orchestrator's HTTP API (e.g. http://host:port/api/). Leave empty to disable Orchestrator integration.
- `orc_discover_interval`: How often (e.g. 60s) to ping Orchestrator's HTTP API endpoint to tell it we exist. 0 means never.

Not only does this relieve you from the initial seeding of addresses into Orchestrator, it also means new instances will be discovered immediately, and the topology will automatically repopulate even if Orchestrator's backing store is wiped out. Note that Orchestrator will forget stale instances after a configurable timeout.

LDAP authentication

Currently, Vitess supports two ways to authenticate to `vtgate` via the MySQL protocol:

- **Static** : You provide a static configuration file to `vtgate` with user names and plaintext passwords or `mysql_native_password` password hashes. This file can be reloaded without restarting `vtgate`. Further details can be found here.
- **LDAP** : You provide the necessary details of an upstream LDAP server, along with credentials and configuration, to query it. Using this information, the LDAP passwords for a user can then be used to authenticate the same user against `vtgate`. You can also integrate with LDAP groups to allow ACLs to be managed using information from the LDAP server.

In this guide, we will examine the capabilities of the `vtgate` LDAP integration and how to configure them.

Requirements

There are a few requirements that are necessary for the `vtgate` LDAP integration to work:

- The communication between `vtgate` and the LDAP server has to be encrypted.
- Encrypted communication to LDAP has to be via LDAP over TLS (STARTTLS) and not via LDAP over SSL (LDAPS). The latter is not a standardized protocol and is not supported by Vitess. Ensure that your LDAP server and the LDAP URI (hostname/port) that you provide supports STARTTLS.
- The application MySQL protocol connections to `vtgate` that use LDAP usernames/passwords need to use TLS. This is required because of the next point, but can be bypassed. We strongly **DO NOT** recommend doing this.
- The application needs to be able to, and configured to, pass its password authentication using the cleartext MySQL authentication protocol. This is why it is required that the MySQL connection to `vtgate` be encrypted first. This is required because LDAP servers do not standardize their password hashes and, as a result, a cleartext password is required by `vtgate` to bind (i.e. authenticate) against the LDAP server to verify the user's password. Note that some applications might not support passing cleartext MySQL passwords without alteration or configuration. An example is recent versions of the MySQL CLI client `mysql` need the additional `--enable-cleartext-plugin` option to allow the passing of cleartext passwords.

Configuration

To configure `vtgate` to integrate with LDAP you will have to perform various tasks:

- Generate/obtain TLS certificate(s) for the `vtgate` server(s), and configure `vtgate` to use them. Further details can be found here.
- Obtain or add the necessary LDAP user/groups for integration with `vtgate`. In general, you will need:
  - LDAP user entries for each of the MySQL users you want to use at the `vtgate` level. An example might be a readonly user, a readwrite user, and an admin/DBA user.
  - Ensure these users are part of one or more LDAP groups. This is not strictly required by Vitess, but is leveraged to obtain group membership that can then be used in Vitess (`vttablet`)ACLs. At the moment if you use an LDAP user that is not a member of an LDAP group, the MySQL client authentication to `vtgate` will fail, even if the password is correct.
- As mentioned above, you also need to have:

  - Your LDAP server setup for STARTTLS
  - Obtained the LDAP URI to connect to the LDAP server
  - The CA certificate, that your LDAP server TLS certificate is signed by, in PEM format
  - Make sure that you are accessing the LDAP server via a hostname or IP SAN that is defined in your LDAP server TLS certificate. If not, you will not be able to use your LDAP server as-is from `vtgate`.

Once you have your prerequisites above ready, you can now construct your JSON configuration file for `vtgate` using the command line parameter `-mysql_ldap_auth_config_file`. The content of this file is a JSON format object with string key/value members as follows:

```
{
    "LdapServer": "ldapserver.example.org:389",
    "LdapCert": "path/to/ldap-client-cert.pem",
    "LdapKey": "path/to/ldap-client-key.pem",
    "LdapCA": "path/to/ldap-server-ca.pem",
    "User": "cn=admin,dc=example,dc=org",
    "Password": "adminpassword!",
    "GroupQuery": "ou=groups,ou=people,dc=example,dc=org",
    "UserDnPattern": "uid=%s,ou=users,ou=people,dc=example,dc=org",
    "RefreshSeconds": 300
}
```

Not all these options are necessary in all configurations. Here are what each key/value option represents:

- **LdapServer** : Hostname/IP and port to access the LDAP server via using STARTTLS. Note that as mentioned above, this needs to match the server TLS certificate presented by the LDAP server. This is required.
- **LdapCert** : Path to the local file that contains the PEM format TLS client certificate that you want to present to the LDAP server. This is optional unless you use client-certificates with the LDAP server. If you are using this option, `LdapKey` is also required.
- **LdapKey** : Path to the local file that contains the PEM format TLS private key for the client certificate you want to present to the LDAP server. This is optional unless you use client-certificates with the LDAP server. If you are using this option, `LdapCert` is also required.
- **LdapCA** : Path to the local file that contains the PEM format TLS CA certificate to verify against the TLS server certificate presented by the LDAP server. This is required.
- **User** : DN of the LDAP user you will be authenticating to the LDAP server to read information such as group membership. Required, unless you are using LDAP client certificates to authenticate to the LDAP server. If you are using this option, `Password` option is also required.
- **Password** : Cleartext password for the LDAP user specified above in `User`. This is required, unless you are using LDAP client certificates to authenticate to the LDAP server. If you are using this option, `User` option is also required.
- **GroupQuery** : LDAP base DN from which to start the group membership query to establish the group of which the `User` specified (or implied via the client certificate) is a member. The group membership query itself is hardcoded to the LDAP query filter of `(memberUid=%s)` where `%s` is the authenticating username. This is required.
- **UserDnPattern** : LDAP DN pattern to autofill with MySQL username passed during MySQL client authentication to `vtgate`. This DN is then used, along with the password provided to `vtgate`, to attempt to bind with the LDAP server. If the bind is sucessful, you know that the password provided to `vtgate` was valid. This is required.
- **RefreshSeconds** : Number of seconds that you should cache individual LDAP credentials for in-memory at the `vtgate`. This is used to reduce load on the LDAP for high traffic MySQL servers. As well as to avoid short LDAP server outages from causing Vitess/`vtgate` authentication outages. Default value is 0, which means **do not cache**. For production it is recommended to set this value to something reasonably high, for example at least a few minutes. This is optional.

Note that `vtgate` only does very basic validation of the values passed here and that incorrect configurations may just fail at runtime. If you are lucky, relevant errors may be logged by `vtgate`, but in many cases incorrect configuration will just result in a `vtgate` instance that you cannot log into via the MySQL protocol.

For debugging this, it is useful to have access to the logs from your LDAP server that you are pointing to. The logs would preferably be at trace or debug level, so that you can see each LDAP bind and search operation against the LDAP server as you are testing.

Once you have constructed the above file, you will need to remove any options that references static authentication from your `vtgate` command line such as:

- `-mysql_auth_server_static_file`
- `-mysql_auth_server_static_string`
- `-mysql_auth_static_reload_interval`
- `-mysql_auth_server_impl static`

and add the following new options:

```
-mysql_auth_server_impl ldap -mysql_ldap_auth_config_file /path/to/ldapconfig.json
```

Region-based Sharding

{{< info >}} This guide follows on from the Get Started guides. Please make sure that you have a local installation ready. You should also have already gone through the MoveTables and Resharding tutorials. {{< /info >}}

Preparation

Having gone through the Resharding tutorial, you should be familiar with VSchema and Vindexes. In this tutorial, we will perform resharding on an existing keyspace using a location-based vindex. We will create 4 shards (-40, 40-80, 80-c0, c0-). The location will be denoted by a `country` column.

Schema

We will create one table in the unsharded keyspace to start with.

```
CREATE TABLE customer (
  id int NOT NULL,
  fullname varbinary(256),
  nationalid varbinary(256),
  country varbinary(256),
  primary key(id)
  );
```

The customer table is the main table we want to shard using country.

Region Vindex

We will use a `region_json` vindex to compute the keyspace_id for a customer row using the (id, country) fields. Here's what the vindex definition looks like:

```
    "region_vdx": {
        "type": "region_json",
        "params": {
            "region_map": "/home/user/my-vitess/examples/region_sharding/countries.json",
            "region_bytes": "1"
        }
    },
```

And we use it thus:

```
    "customer": {
      "column_vindexes": [
        {
            "columns": ["id", "country"],
            "name": "region_vdx"
        },
```

This vindex uses a byte mapping of countries provided in a JSON file and combines that with the id column in the customer table to compute the keyspace_id. This is what the JSON file contains:

```
{
    "United States": 1,
    "Canada": 2,
    "France": 64,
    "Germany": 65,
    "China": 128,
    "Japan": 129,
    "India": 192,
    "Indonesia": 193
}
```

The values for the countries have been chosen such that 2 countries fall into each shard.

In this example, we are using 1 byte to represent a country code. You can use 1 or 2 bytes. With 2 bytes, 65536 distinct locations can be supported. The byte value of the country(or other location identifier) is prefixed to a hash value computed from the id to produce the keyspace_id. This will be primary vindex on the `customer` table. As such, it is sufficient for resharding, inserts and selects. However, we don't yet support updates and deletes using a multi-column vindex. In order for those to work, we need to create a lookup vindex that can used to find the correct rows by id. The lookup vindex also makes querying by id efficient. Without it, queries that provided id but not country will scatter to all shards.

To do this, we will use the new vreplication workflow `CreateLookupVindex`. This workflow will create the lookup table and a lookup vindex. It will also associate the lookup vindex with the `customer` table.

Start the Cluster

Start by copying the region_sharding example included with Vitess to your preferred location.

```
cp -r /usr/local/vitess/examples/region_sharding ~/my-vitess/examples/region_sharding
cd ~/my-vitess/examples/region_sharding
```

The VSchema for this tutorial uses a config file. You will need to edit the value of the `region_map` parameter in the vschema file `main_vschema_sharded.json`. For example:

```
"region_map": "/home/user/my-vitess/examples/region_sharding/countries.json",
```

Now start the cluster

```
./101_initial_cluster.sh
```

You should see output similar to the following:

```
~/my-vitess-example> ./101_initial_cluster.sh
add /vitess/global
add /vitess/zone1
add zone1 CellInfo
etcd start done...
Starting vtctld...
```

```
Starting MySQL for tablet zone1-0000000100...
Starting vttablet for zone1-0000000100...
HTTP/1.1 200 OK
Date: Mon, 17 Aug 2020 14:20:08 GMT
Content-Type: text/html; charset=utf-8

W0817 07:20:08.822742    7735 main.go:64] W0817 14:20:08.821985 reparent.go:185]
   master-elect tablet zone1-0000000100 is not the shard master, proceeding anyway as
   -force was used
W0817 07:20:08.823004    7735 main.go:64] W0817 14:20:08.822370 reparent.go:191]
   master-elect tablet zone1-0000000100 is not a master in the shard, proceeding anyway as
   -force was used
I0817 07:20:08.823239    7735 main.go:64] I0817 14:20:08.823075 reparent.go:222] resetting
   replication on tablet zone1-0000000100
I0817 07:20:08.833215    7735 main.go:64] I0817 14:20:08.833019 reparent.go:241]
   initializing master on zone1-0000000100
I0817 07:20:08.849955    7735 main.go:64] I0817 14:20:08.849736 reparent.go:274] populating
   reparent journal on new master zone1-0000000100
New VSchema object:
{
  "tables": {
    "customer": {

    }
  }
}
If this is not what you expected, check the input data (as JSON parsing will skip
   unexpected fields).
Waiting for vtgate to be up...
vtgate is up!
Access vtgate at http://localhost:15001/debug/status
```

You can also verify that the processes have started with `pgrep`:

```
~/my-vitess-example> pgrep -fl vtdataroot
9160 etcd
9222 vtctld
9280 mysqld_safe
9843 mysqld
9905 vttablet
10040 vtgate
10224 mysqld
```

The exact list of processes will vary. For example, you may not see `mysqld_safe` listed.

If you encounter any errors, such as ports already in use, you can kill the processes and start over:

```
pkill -9 -e -f '(vtdataroot|VTDATAROOT)' # kill Vitess processes
rm -rf vtdataroot
```

Aliases

For ease-of-use, Vitess provides aliases for `mysql` and `vtctlclient`. These are automatically created when you start the cluster.

```
source ./env.sh
```

Setting up aliases changes `mysql` to always connect to Vitess for your current session. To revert this, type `unalias mysql && unalias vtctlclient` or close your session.

Connect to your cluster

You should now be able to connect to the VTGate server that was started in `101_initial_cluster.sh`:

```
~/my-vitess-example> mysql
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 2
Server version: 5.7.9-Vitess (Ubuntu)

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affiliates. Other names may be trademarks of their respective
owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql> show tables;
+-------------------+
| Tables_in_vt_main |
+-------------------+
| customer          |
+-------------------+
1 row in set (0.01 sec)
```

Insert some data into the cluster

```
~/my-vitess-example> mysql < insert_customers.sql
```

Examine the data we just inserted

```
~/my-vitess-example> mysql --table < show_initial_data.sql
```

```
+----+------------------+-------------+---------------+
| id | fullname         | nationalid  | country       |
+----+------------------+-------------+---------------+
|  1 | Philip Roth      | 123-456-789 | United States |
|  2 | Gary Shteyngart  | 234-567-891 | United States |
|  3 | Margaret Atwood  | 345-678-912 | Canada        |
|  4 | Alice Munro      | 456-789-123 | Canada        |
|  5 | Albert Camus     | 912-345-678 | France        |
|  6 | Colette          | 102-345-678 | France        |
|  7 | Hermann Hesse    | 304-567-891 | Germany       |
|  8 | Cornelia Funke   | 203-456-789 | Germany       |
|  9 | Cixin Liu        | 789-123-456 | China         |
| 10 | Jian Ma          | 891-234-567 | China         |
| 11 | Haruki Murakami  | 405-678-912 | Japan         |
```

```
| 12 | Banana Yoshimoto | 506-789-123 | Japan         |
| 13 | Arundhati Roy    | 567-891-234 | India         |
| 14 | Shashi Tharoor   | 678-912-345 | India         |
| 15 | Andrea Hirata    | 607-891-234 | Indonesia     |
| 16 | Ayu Utami        | 708-912-345 | Indonesia     |
+----+------------------+-------------+---------------+
```

Prepare for resharding

Now that we have some data in our unsharded cluster, let us go ahead and perform the setup needed for resharding. The initial vschema is unsharded and simply lists the customer table (see script output above). We are going to first apply the sharding vschema to the cluster from `main_vschema_sharded.json`

```
{
  "sharded": true,
  "vindexes": {
    "region_vdx": {
      "type": "region_json",
      "params": {
        "region_map": "/home/user/my-vitess/examples/region_sharding/countries.json",
        "region_bytes": "1"
      }
    }
  },
  "tables": {
    "customer": {
      "column_vindexes": [
        {
          "columns": ["id", "country"],
              "name": "region_vdx"
        }
      ]
    }
  }
}
```

Then we will create a lookup vindex (`CreateLookupVindex`) using the definition in `lookup_vindex.json`

Here is the lookup vindex definition. Here we both define the lookup vindex, and associate it with the customer table.

```
{
  "sharded": true,
  "vindexes": {
    "customer_region_lookup": {
      "type": "consistent_lookup_unique",
      "params": {
        "table": "main.customer_lookup",
        "from": "id",
        "to": "keyspace_id"
      },
      "owner": "customer"
    }
  },
  "tables": {
    "customer": {
      "column_vindexes": [
```

```
        {
          "column": "id",
          "name": "customer_region_lookup"
        }
      ]
    }
  }
}
```

Once the vindex is available, we have to `Externalize` it for it to be usable. Putting this all together, we run the script that combines the above steps.

```
./201_main_sharded.sh
```

Once this is complete, we can view the new vschema. Note that it now includes both region_vdx and a lookup vindex.

```
~/my-vitess-example> vtctlclient GetVSchema main
{
  "sharded": true,
  "vindexes": {
    "customer_region_lookup": {
      "type": "consistent_lookup_unique",
      "params": {
        "from": "id",
        "table": "main.customer_lookup",
        "to": "keyspace_id"
      },
      "owner": "customer"
    },
    "hash": {
      "type": "hash"
    },
    "region_vdx": {
      "type": "region_json",
      "params": {
        "region_bytes": "1",
        "region_map": "/home/user/my-vitess/examples/region_sharding/countries.json"
      }
    }
  },
  "tables": {
    "customer": {
      "columnVindexes": [
        {
          "name": "region_vdx",
          "columns": [
            "id",
            "country"
          ]
        },
        {
          "column": "id",
          "name": "customer_region_lookup"
        }
      ]
    },
    "customer_lookup": {
      "columnVindexes": [
```

```
        {
          "column": "id",
          "name": "hash"
        }
      ]
    }
  }
}
```

Notice that the vschema shows a hash vindex on the lookup table. This is automatically created by the workflow. Creating a lookup vindex via `CreateLookupVindex` also creates the backing table needed to hold the vindex, and populates it with the correct rows. We can see that by checking the database.

```
mysql> show tables;
+--------------------+
| Tables_in_vt_main |
+--------------------+
| customer          |
| customer_lookup   |
+--------------------+
2 rows in set (0.00 sec)

mysql> describe customer_lookup;
+-------------+----------------+------+-----+---------+-------+
| Field       | Type           | Null | Key | Default | Extra |
+-------------+----------------+------+-----+---------+-------+
| id          | int(11)        | NO   | PRI | NULL    |       |
| keyspace_id | varbinary(128) | YES  |     | NULL    |       |
+-------------+----------------+------+-----+---------+-------+
2 rows in set (0.01 sec)

mysql> select id, hex(keyspace_id) from customer_lookup;
+----+--------------------+
| id | hex(keyspace_id)   |
+----+--------------------+
|  1 | 01166B40B44ABA4BD6 |
|  2 | 0106E7EA22CE92708F |
|  3 | 024EB190C9A2FA169C |
|  4 | 02D2FD8867D50D2DFE |
|  5 | 4070BB023C810CA87A |
|  6 | 40F098480AC4C4BE71 |
|  7 | 41FB8BAAAD918119B8 |
|  8 | 41CC083F1E6D9E85F6 |
|  9 | 80692BB9BF752B0F58 |
| 10 | 80594764E1A2B2D98E |
| 11 | 81AEFC44491CFE474C |
| 12 | 81D3748269B7058A0E |
| 13 | C062DCE203C602F358 |
| 14 | C0ACBFDA0D70613FC4 |
| 15 | C16A8B56ED414942B8 |
| 16 | C15B711BC4CEEBF2EE |
+----+--------------------+
16 rows in set (0.01 sec)
```

Once the sharding vschema and lookup vindex (+table) are ready, we can bring up the sharded cluster. Since we have 4 shards, we will bring up 4 sets of vttablets, 1 per shard. In this example, we are deploying only 1 tablet per shard and disabling semi-sync, but in general each shard will consist of at least 3 tablets.

```
./202_new_tablets.sh
```

```
Starting MySQL for tablet zone1-0000000200...
Starting vttablet for zone1-0000000200...
HTTP/1.1 200 OK
Date: Mon, 17 Aug 2020 15:07:41 GMT
Content-Type: text/html; charset=utf-8

Starting MySQL for tablet zone1-0000000300...
Starting vttablet for zone1-0000000300...
HTTP/1.1 200 OK
Date: Mon, 17 Aug 2020 15:07:46 GMT
Content-Type: text/html; charset=utf-8

Starting MySQL for tablet zone1-0000000400...
Starting vttablet for zone1-0000000400...
HTTP/1.1 200 OK
Date: Mon, 17 Aug 2020 15:07:50 GMT
Content-Type: text/html; charset=utf-8

Starting MySQL for tablet zone1-0000000500...
Starting vttablet for zone1-0000000500...
HTTP/1.1 200 OK
Date: Mon, 17 Aug 2020 15:07:55 GMT
Content-Type: text/html; charset=utf-8

W0817 08:07:55.217317   15230 main.go:64] W0817 15:07:55.215654 reparent.go:185]
   master-elect tablet zone1-0000000200 is not the shard master, proceeding anyway as
   -force was used
W0817 08:07:55.218083   15230 main.go:64] W0817 15:07:55.215771 reparent.go:191]
   master-elect tablet zone1-0000000200 is not a master in the shard, proceeding anyway as
   -force was used
I0817 08:07:55.218121   15230 main.go:64] I0817 15:07:55.215918 reparent.go:222] resetting
   replication on tablet zone1-0000000200
I0817 08:07:55.229794   15230 main.go:64] I0817 15:07:55.229416 reparent.go:241]
   initializing master on zone1-0000000200
I0817 08:07:55.249680   15230 main.go:64] I0817 15:07:55.249325 reparent.go:274] populating
   reparent journal on new master zone1-0000000200
W0817 08:07:55.286894   15247 main.go:64] W0817 15:07:55.286288 reparent.go:185]
   master-elect tablet zone1-0000000300 is not the shard master, proceeding anyway as
   -force was used
W0817 08:07:55.287392   15247 main.go:64] W0817 15:07:55.286354 reparent.go:191]
   master-elect tablet zone1-0000000300 is not a master in the shard, proceeding anyway as
   -force was used
I0817 08:07:55.287411   15247 main.go:64] I0817 15:07:55.286448 reparent.go:222] resetting
   replication on tablet zone1-0000000300
I0817 08:07:55.300499   15247 main.go:64] I0817 15:07:55.300276 reparent.go:241]
   initializing master on zone1-0000000300
I0817 08:07:55.324774   15247 main.go:64] I0817 15:07:55.324454 reparent.go:274] populating
   reparent journal on new master zone1-0000000300
W0817 08:07:55.363497   15264 main.go:64] W0817 15:07:55.362451 reparent.go:185]
   master-elect tablet zone1-0000000400 is not the shard master, proceeding anyway as
   -force was used
W0817 08:07:55.364061   15264 main.go:64] W0817 15:07:55.362569 reparent.go:191]
   master-elect tablet zone1-0000000400 is not a master in the shard, proceeding anyway as
   -force was used
I0817 08:07:55.364079   15264 main.go:64] I0817 15:07:55.362689 reparent.go:222] resetting
```

```
   replication on tablet zone1-0000000400
I0817 08:07:55.378370   15264 main.go:64] I0817 15:07:55.378201 reparent.go:241]
   initializing master on zone1-0000000400
I0817 08:07:55.401258   15264 main.go:64] I0817 15:07:55.400569 reparent.go:274] populating
   reparent journal on new master zone1-0000000400
W0817 08:07:55.437158   15280 main.go:64] W0817 15:07:55.435986 reparent.go:185]
   master-elect tablet zone1-0000000500 is not the shard master, proceeding anyway as
   -force was used
W0817 08:07:55.437953   15280 main.go:64] W0817 15:07:55.436038 reparent.go:191]
   master-elect tablet zone1-0000000500 is not a master in the shard, proceeding anyway as
   -force was used
I0817 08:07:55.437982   15280 main.go:64] I0817 15:07:55.436107 reparent.go:222] resetting
   replication on tablet zone1-0000000500
I0817 08:07:55.449958   15280 main.go:64] I0817 15:07:55.449725 reparent.go:241]
   initializing master on zone1-0000000500
I0817 08:07:55.467790   15280 main.go:64] I0817 15:07:55.466993 reparent.go:274] populating
   reparent journal on new master zone1-0000000500
```

Perform Resharding

Once the tablets are up, we can go ahead with the resharding.

```
./203_reshard.sh
```

This script has only one command: `Reshard`

```
vtctlclient Reshard -tablet_types=MASTER main.main2regions '0' '-40,40-80,80-c0,c0-'
```

Let us unpack this a bit. Since we are running only master tablets in this cluster, we have to tell the `Reshard` command to use them as the source for copying data into the target shards. The next argument is of the form `keyspace.workflow`. `keyspace` is the one we want to reshard. `workflow` is an identifier chosen by the user. It can be any arbitrary string and is used to tie the different steps of the resharding flow together. We will see it being used in subsequent steps. Then we have the source shard `0` and target shards `-40,40-80,80-c0,c0-`

This step copies all the data from source to target and sets up vreplication to keep the targets in sync with the source

We can check the correctness of the copy using `VDiff` and the `keyspace.workflow` we used for `Reshard`

```
vtctlclient VDiff main.main2regions
I0817 08:22:53.958578   16065 main.go:64] I0817 15:22:53.956743 traffic_switcher.go:389]
   Migration ID for workflow main2regions: 7369191857547657706
Summary for customer: {ProcessedRows:16 MatchingRows:16 MismatchedRows:0 ExtraRowsSource:0
   ExtraRowsTarget:0}
```

Let's take a look at the vreplication streams

```
vtctlclient VReplicationExec zone1-0000000200 'select * from _vt.vreplication'
+----+--------------+---------------------------------+-----------------------------------------
| id |   workflow   |             source              |                          pos
                         | stop_pos |       max_tps       | max_replication_lag | cell |
   tablet_types | time_updated | transaction_timestamp |  state  | message | db_name |
+----+--------------+---------------------------------+-----------------------------------------
|  1 | main2regions | keyspace:"main" shard:"0"       |
   MySQL56/cd3b495a-e096-11ea-9088-34e12d1e6711:1-44 |          | 9223372036854775807 |
   9223372036854775807 |      | MASTER       |   1597676983 |                      0 |
   Running |         | vt_main |
```

```
|    |              | filter:<rules:<match:"/.*"     |
                                                    |          |                        |
                        |      |              |              |                        |
            |         |         |
|    |              | filter:"-40" > >               |
                                                    |          |                        |
                        |      |              |              |                        |
            |         |         |
+----+--------------+---------------------------------+-----------------------------------------
```

We have a running stream on tablet 200 (shard `-40`) that will keep it up-to-date with the source shard (`0`)

Cutover

Once the copy process is complete, we can start cutting-over traffic. This is done in 2 steps, `SwitchReads` and `SwitchWrites`. Note that the commands are named for the tablet_types and not user operations. `Reads` is used for replica/rdonly, and `Writes` for master. Read operations on master will not be affected by a `SwitchReads`.

```
./204_switch_reads.sh
./205_switch_writes.sh
```

Let us take a look at the sharded data

```
mysql> use main/-40;
Database changed

mysql> select * from customer;
+----+-----------------+-------------+---------------+
| id | fullname        | nationalid  | country       |
+----+-----------------+-------------+---------------+
|  1 | Philip Roth     | 123-456-789 | United States |
|  2 | Gary Shteyngart | 234-567-891 | United States |
|  3 | Margaret Atwood | 345-678-912 | Canada        |
|  4 | Alice Munro     | 456-789-123 | Canada        |
+----+-----------------+-------------+---------------+
4 rows in set (0.01 sec)

mysql> select id,hex(keyspace_id) from customer_lookup;
+----+--------------------+
| id | hex(keyspace_id)   |
+----+--------------------+
|  1 | 01166B40B44ABA4BD6 |
|  2 | 0106E7EA22CE92708F |
+----+--------------------+
2 rows in set (0.00 sec)
```

You can see that only data from US and Canada exists in the customer table in this shard. Repeat this for the other shards (40-80, 80-c0 and c0-) and see that each shard contains 4 rows in customer table.

The lookup table, however, has a different number of rows. This is because we are using a `hash` vindex to shard the lookup table which means that it is distributed differently from the customer table. If we look at the next shard 40-80:

```
mysql> use main/40-80;

Database changed
mysql> select id, hex(keyspace_id) from customer_lookup;
+----+--------------------+
```

```
| id | hex(keyspace_id)   |
+----+--------------------+
|  3 | 024EB190C9A2FA169C |
|  5 | 4070BB023C810CA87A |
|  9 | 80692BB9BF752B0F58 |
| 10 | 80594764E1A2B2D98E |
| 13 | C062DCE203C602F358 |
| 15 | C16A8B56ED414942B8 |
| 16 | C15B711BC4CEEBF2EE |
+----+--------------------+
7 rows in set (0.00 sec)
```

Drop source

Once resharding is complete, we can teardown the source shard

```
./206_down_shard_0.sh
./207_delete_shard_0.sh
```

What we have now is a sharded keyspace. The original unsharded keyspace no longer exists.

Teardown

Once you are done playing with the example, you can tear it down completely.

```
./301_teardown.sh
rm -rf vtdataroot
```

Reparenting

Reparenting is the process of changing a shard's master tablet from one host to another or changing a replica tablet to have a different master. Reparenting can be initiated manually or it can occur automatically in response to particular database conditions. As examples, you might reparent a shard or tablet during a maintenance exercise or automatically trigger reparenting when a master tablet dies.

This document explains the types of reparenting that Vitess supports:

- Active reparenting occurs when Vitess manages the entire reparenting process.
- External reparenting occurs when another tool handles the reparenting process, and Vitess just updates its topology service, replication graph, and serving graph to accurately reflect master-replica relationships.

Note: The `InitShardMaster` command defines the initial parenting relationships within a shard. That command makes the specified tablet the master and makes the other tablets in the shard replicas that replicate from that master.

MySQL requirements

GTIDs Vitess requires the use of global transaction identifiers (GTIDs) for its operations:

- During active reparenting, Vitess uses GTIDs to initialize the replication process and then depends on the GTID stream to be correct when reparenting. (During external reparenting, Vitess assumes the external tool manages the replication process.)
- During resharding, Vitess uses GTIDs for VReplication, the process by which source tablet data is transferred to the proper destination tablets.

Semisynchronous replication Vitess does not depend on semisynchronous replication but does work if it is implemented. Larger Vitess deployments typically do implement semisynchronous replication.

Active Reparenting You can use the following `vtctl` commands to perform reparenting operations:

- `PlannedReparentShard`
- `EmergencyReparentShard`

Both commands lock the Shard record in the global topology service. The two commands cannot run in parallel, nor can either command run in parallel with the `InitShardMaster` command.

Both commands are both dependent on the global topology service being available, and they both insert rows in the topology service's `_vt.reparent_journal` table. As such, you can review your database's reparenting history by inspecting that table.

PlannedReparentShard: Planned reparenting The `PlannedReparentShard` command reparents a healthy master tablet to a new master. The current and new master must both be up and running.

This command performs the following actions:

1. Puts the current master tablet in read-only mode.
2. Shuts down the current master's query service, which is the part of the system that handles user SQL queries. At this point, Vitess does not handle any user SQL queries until the new master is configured and can be used a few seconds later.
3. Retrieves the current master's replication position.
4. Instructs the master-elect tablet to wait for replication data and then begin functioning as the new master after that data is fully transferred.
5. Ensures replication is functioning properly via the following steps:
    - On the master-elect tablet, insert an entry in a test table and then update the global Shard object's MasterAlias record.
    - In parallel on each replica, including the old master, set the new master and wait for the test entry to replicate to the replica tablet. Replica tablets that had not been replicating before the command was called are left in their current state and do not start replication after the reparenting process.
    - Start replication on the old master tablet so it catches up to the new master.

In this scenario, the old master's tablet type transitions to `spare`. If health checking is enabled on the old master, it will likely rejoin the cluster as a replica on the next health check. To enable health checking, set the `target_tablet_type` parameter when starting a tablet. That parameter indicates what type of tablet that tablet tries to be when healthy. When it is not healthy, the tablet type changes to spare.

EmergencyReparentShard: Emergency reparenting The `EmergencyReparentShard` command is used to force a reparent to a new master when the current master is unavailable. The command assumes that data cannot be retrieved from the current master because it is dead or not working properly.

As such, this command does not rely on the current master at all to replicate data to the new master. Instead, it makes sure that the master-elect is the most advanced in replication within all of the available replicas.

Important: Before calling this command, you must first identify the replica with the most advanced replication position as that replica must be designated as the new master. You can use the `vtctl ShardReplicationPositions` command to determine the current replication positions of a shard's replicas.

This command performs the following actions:

1. Determines the current replication position on all of the replica tablets and confirms that the master-elect tablet has the most advanced replication position.
2. Promotes the master-elect tablet to be the new master. In addition to changing its tablet type to master, the master-elect performs any other changes that might be required for its new state.
3. Ensures replication is functioning properly via the following steps:
    - On the master-elect tablet, Vitess inserts an entry in a test table and then updates the `MasterAlias` record of the global Shard object.
    - In parallel on each replica, excluding the old master, Vitess sets the master and waits for the test entry to replicate to the replica tablet. Replica tablets that had not been replicating before the command was called are left in their current state and do not start replication after the reparenting process.

External Reparenting

External reparenting occurs when another tool handles the process of changing a shard's master tablet. After that occurs, the tool needs to call the `vtctl TabletExternallyReparented` command to ensure that the topology service, replication graph, and serving graph are updated accordingly.

That command performs the following operations:

1. Reads the Tablet from the local topology service.
2. Reads the Shard object from the global topology service.
3. If the Tablet type is not already `MASTER`, sets the tablet type to `MASTER`.
4. The Shard record is updated asynchronously (if needed) with the current master alias.
5. Any other tablets that still have their tablet type to `MASTER` will demote themselves to `REPLICA`.

The `TabletExternallyReparented` command fails in the following cases:

- The global topology service is not available for locking and modification. In that case, the operation fails completely.

Active reparenting might be a dangerous practice in any system that depends on external reparents. You can disable active reparents by starting `vtctld` with the `--disable_active_reparents` flag set to true. (You cannot set the flag after `vtctld` is started.)

Fixing Replication

A tablet can be orphaned after a reparenting if it is unavailable when the reparent operation is running but then recovers later on. In that case, you can manually reset the tablet's master to the current shard master using the `vtctl ReparentTablet` command. You can then restart replication on the tablet if it was stopped by calling the `vtctl StartReplication` command.

Resharding

{{< info >}} This guide follows on from the Get Started guides. Please make sure that you have an Operator, local or Helm installation ready. {{< /info >}}

Preparation

Resharding enables you to both *initially shard* and reshard tables so that your keyspace is partitioned across several underlying tablets. A sharded keyspace has some additional restrictions on both query syntax and features such as `auto_increment`, so it is helpful to plan out a reshard operation diligently. However, you can always *reshard again* if your sharding scheme turns out to be suboptimal.

Using our example commerce and customer keyspaces, lets work through the two most common issues.

Sequences The first issue to address is the fact that customer and corder have auto-increment columns. This scheme does not work well in a sharded setup. Instead, Vitess provides an equivalent feature through sequences.

The sequence table is an unsharded single row table that Vitess can use to generate monotonically increasing IDs. The syntax to generate an id is: `select next :n values from customer_seq`. The vttablet that exposes this table is capable of serving a very large number of such IDs because values are cached and served out of memory. The cache value is configurable.

The VSchema allows you to associate a column of a table with the sequence table. Once this is done, an insert on that table transparently fetches an id from the sequence table, fills in the value, and routes the row to the appropriate shard. This makes the construct backward compatible to how MySQL's `auto_increment` property works.

Since sequences are unsharded tables, they will be stored in the commerce database. Here is the schema:

```
CREATE TABLE customer_seq (id int, next_id bigint, cache bigint, primary key(id)) comment
   'vitess_sequence';
INSERT INTO customer_seq (id, next_id, cache) VALUES (0, 1000, 100);
CREATE TABLE order_seq (id int, next_id bigint, cache bigint, primary key(id)) comment
   'vitess_sequence';
INSERT INTO order_seq (id, next_id, cache) VALUES (0, 1000, 100);
```

Note the `vitess_sequence` comment in the create table statement. VTTablet will use this metadata to treat this table as a sequence.

- `id` is always 0
- `next_id` is set to `1000`: the value should be comfortably greater than the `auto_increment` max value used so far.
- `cache` specifies the number of values to cache before vttablet updates `next_id`.

Larger cache values perform better, but will exhaust the values quicker, since during reparent operations the new master will start off at the `next_id` value.

The VTGate servers also need to know about the sequence tables. This is done by updating the VSchema for commerce as follows:

```
{
  "tables": {
    "customer_seq": {
      "type": "sequence"
    },
    "order_seq": {
      "type": "sequence"
    },
    "product": {}
  }
}
```

Vindexes The next decision is about the sharding keys, or Primary Vindexes. This is a complex decision that involves the following considerations:

- What are the highest QPS queries, and what are the `WHERE` clauses for them?

- Cardinality of the column; it must be high.
- Do we want some rows to live together to support in-shard joins?
- Do we want certain rows that will be in the same transaction to live together?

Using the above considerations, in our use case, we can determine that:

- For the customer table, the most common `WHERE` clause uses `customer_id`. So, it shall have a Primary Vindex.
- Given that it has lots of users, its cardinality is also high.
- For the corder table, we have a choice between `customer_id` and `order_id`. Given that our app joins `customer` with `corder` quite often on the `customer_id` column, it will be beneficial to choose `customer_id` as the Primary Vindex for the `corder` table as well.
- Coincidentally, transactions also update `corder` tables with their corresponding `customer` rows. This further reinforces the decision to use `customer_id` as Primary Vindex.

There are a couple of other considerations out of scope for now, but worth mentioning:

- It may also be worth creating a secondary lookup Vindex on `corder.order_id`.
- Sometimes the `customer_id` is really a `tenant_id`. For example, your application is a SaaS, which serves tenants that themselves have customers. One key consideration here is that the sharding by the `tenant_id` can lead to unbalanced shards. You may also need to consider sharding by the tenant's `customer_id`.

Putting it all together, we have the following VSchema for `customer`:

```
{
  "sharded": true,
  "vindexes": {
    "hash": {
      "type": "hash"
    }
  },
  "tables": {
    "customer": {
      "column_vindexes": [
        {
          "column": "customer_id",
          "name": "hash"
        }
      ],
      "auto_increment": {
        "column": "customer_id",
        "sequence": "customer_seq"
      }
    },
    "corder": {
      "column_vindexes": [
        {
          "column": "customer_id",
          "name": "hash"
        }
      ],
      "auto_increment": {
        "column": "order_id",
        "sequence": "order_seq"
      }
    }
  }
}
```

Since the primary vindex columns are `BIGINT`, we choose `hash` as the primary vindex, which is a pseudo-random way of distributing rows into various shards. For other data types:

- For `VARCHAR` columns, use `unicode_loose_md5` or `unicode_loose_xxhash`.
- For `VARBINARY`, use `binary_md5` or `xxhash`.
- Vitess uses a plugin system to define vindexes. If none of the predefined vindexes suit your needs, you can develop your own custom vindex.

Apply VSchema

Applying the new VSchema instructs Vitess that the keyspace is sharded, which may prevent some complex queries. It is a good idea to validate this before proceeding with this step. If you do notice that certain queries start failing, you can always revert temporarily by restoring the old VSchema. Make sure you fix all of the queries before proceeding to the Reshard process.

```
helm upgrade vitess ../../helm/vitess/ -f 301_customer_sharded.yaml
```

```
vtctlclient ApplySchema -sql="$(cat create_commerce_seq.sql)" commerce
vtctlclient ApplyVSchema -vschema="$(cat vschema_commerce_seq.json)" commerce
vtctlclient ApplySchema -sql="$(cat create_customer_sharded.sql)" customer
vtctlclient ApplyVSchema -vschema="$(cat vschema_customer_sharded.json)" customer
```

```
vtctlclient ApplySchema -sql-file create_commerce_seq.sql commerce
vtctlclient ApplyVSchema -vschema_file vschema_commerce_seq.json commerce
vtctlclient ApplySchema -sql-file create_customer_sharded.sql customer
vtctlclient ApplyVSchema -vschema_file vschema_customer_sharded.json customer
```

Create new shards

At this point, you have finalized your sharded VSchema and vetted all the queries to make sure they still work. Now, it's time to reshard.

The resharding process works by splitting existing shards into smaller shards. This type of resharding is the most appropriate for Vitess. There are some use cases where you may want to bring up a new shard and add new rows in the most recently created shard. This can be achieved in Vitess by splitting a shard in such a way that no rows end up in the 'new' shard. However, it's not natural for Vitess. We have to create the new target shards:

```
helm upgrade vitess ../../helm/vitess/ -f 302_new_shards.yaml
```

```
kubectl apply -f 302_new_shards.yaml
```

Make sure that you restart the port-forward after you have verified with `kubectl get pods` that this operation has completed:

```
killall kubectl
./pf.sh &
```

```
for i in 300 301 302; do
 CELL=zone1 TABLET_UID=$i ./scripts/mysqlctl-up.sh
 SHARD=-80 CELL=zone1 KEYSPACE=customer TABLET_UID=$i ./scripts/vttablet-up.sh
done

for i in 400 401 402; do
 CELL=zone1 TABLET_UID=$i ./scripts/mysqlctl-up.sh
 SHARD=80- CELL=zone1 KEYSPACE=customer TABLET_UID=$i ./scripts/vttablet-up.sh
done

vtctlclient InitShardMaster -force customer/-80 zone1-300
vtctlclient InitShardMaster -force customer/80- zone1-400
```

Start the Reshard

This process starts the reshard operation. It occurs online, and will not block any read or write operations to your database:

```
# With Helm and Local Installation
vtctlclient Reshard customer.cust2cust '0' '-80,80-'
# With Operator
vtctlclient Reshard customer.cust2cust '-' '-80,80-'
```

Validate Correctness

After the reshard is complete, we can use VDiff to check data integrity and ensure our source and target shards are consistent:

```
vtctlclient VDiff customer.cust2cust
```

You should see output similar to the following:

```
Summary for customer: {ProcessedRows:5 MatchingRows:5 MismatchedRows:0 ExtraRowsSource:0
   ExtraRowsTarget:0}
Summary for corder: {ProcessedRows:5 MatchingRows:5 MismatchedRows:0 ExtraRowsSource:0
   ExtraRowsTarget:0}
```

Switch Reads

After validating for correctness, the next step is to switch read operations to occur at the new location. By switching read operations first, we are able to verify that the new tablet servers are healthy and able to respond to requests:

```
vtctlclient SwitchReads -tablet_type=rdonly customer.cust2cust
vtctlclient SwitchReads -tablet_type=replica customer.cust2cust
```

Switch Writes

After reads have been switched, and the health of the system has been verified, it's time to switch writes. The usage is very similar to switching reads:

```
vtctlclient SwitchWrites customer.cust2cust
```

You should now be able to see the data that has been copied over to the new shards:

```
mysql --table < ../common/select_customer-80_data.sql
Using customer/-80
Customer
+-------------+--------------------+
| customer_id | email              |
+-------------+--------------------+
|           1 | alice@domain.com   |
|           2 | bob@domain.com     |
|           3 | charlie@domain.com |
|           5 | eve@domain.com     |
+-------------+--------------------+
COrder
+----------+-------------+----------+-------+
| order_id | customer_id | sku      | price |
+----------+-------------+----------+-------+
|        1 |           1 | SKU-1001 |   100 |
|        2 |           2 | SKU-1002 |    30 |
|        3 |           3 | SKU-1002 |    30 |
|        5 |           5 | SKU-1002 |    30 |
+----------+-------------+----------+-------+

mysql --table < ../common/select_customer80-_data.sql
Using customer/80-
Customer
+-------------+----------------+
| customer_id | email          |
+-------------+----------------+
|           4 | dan@domain.com |
+-------------+----------------+
COrder
+----------+-------------+----------+-------+
| order_id | customer_id | sku      | price |
+----------+-------------+----------+-------+
|        4 |           4 | SKU-1002 |    30 |
+----------+-------------+----------+-------+
```

Cleanup

After celebrating your second successful resharding, you are now ready to clean up the leftover artifacts:

```
helm upgrade vitess ../../helm/vitess/ -f 306_down_shard_0.yaml
```

```
kubectl apply -f 306_down_shard_0.yaml
```

```
for i in 200 201 202; do
 CELL=zone1 TABLET_UID=$i ./scripts/vttablet-down.sh
 CELL=zone1 TABLET_UID=$i ./scripts/mysqlctl-down.sh
done
```

In this script, we just stopped all tablet instances for shard 0. This will cause all those vttablet and `mysqld` processes to be stopped. But the shard metadata is still present. After Vitess brings down all vttablets, we can clean that up with this command:

```
vtctlclient DeleteShard -recursive customer/0
```

Beyond this, you will also need to manually delete the disk associated with this shard.

Tracing

Vitess tracing

Vitess allows you to generate Jaeger / OpenTracing compatible trace events from the Vitess major server components: `vtgate`, `vttablet`, and `vtctld`. To sync these trace events you need an OpenTracing compatible server (e.g. Jaeger). Vitess can send tracing events to this server in the Jaeger compact Thrift protocol wire format which is usually UDP on port 6381.

Configuring tracing

The first step of configuring tracing is to make sure you have tracing collectors properly setup. The tracing collectors must be located where they can be reached from the various Vitess components on which you want to configure tracing. We will not cover the entire setup process in this guide. The guide will cover the minimal config for testing/running locally, using the Jaeger docker container running on `localhost`. You can read more about Jaeger here.

Running Jaeger in docker You can follow the Jaeger getting started documentation here. In essence you need to run the Jaeger docker container:

```
$ docker run -d --name jaeger \
  -e COLLECTOR_ZIPKIN_HTTP_PORT=9411 \
  -p 5775:5775/udp \
  -p 6831:6831/udp \
  -p 6832:6832/udp \
  -p 5778:5778 \
  -p 16686:16686 \
  -p 14268:14268 \
  -p 14250:14250 \
  -p 9411:9411 \
  jaegertracing/all-in-one:1.20
```

Note that you don't need to expose all these ports, Vitess only cares about port 6831 (the UDP compact Thrift Jaeger protocol listener). You will also need port 16686 for the Jaeger web UI to browse the spans reported.

Configuring tracing for vtgate, vttablet and vtctld Now that you have the Jaeger server running, you can add the necessary startup options to `vtgate`, `vttablet` and `vtctld`. This will enable you to send trace spans to the server. The command line options for doing this are the same across `vtgate`, `vttablet` and `vtctld`. Add the following options for a tracing agent running on the `localhost`:

```
-tracer opentracing-jaeger -jaeger-agent-host 127.0.0.1:6831 -tracing-sampling-rate 0.0
```

There are a few things to note:

- There are other tracing plugins and the `-tracer` option allows you to select them. Currently we have `opentracing-jaeger` and `opentracing-datadog`. Only `opentracing-jaeger` is covered in this document.
- `-jaeger-agent-host` should point to the `hostname:port` or `ip:port` of the tracing collector running the Jaeger compact Thrift protocol.
- The tracing sample rate (`-tracing-sampling-rate`) is expressed as a fraction from 0.0 (no sampling) to 1.0 (100% of all events are sent to the server). In the example, this option is set to zero, because we will be passing custom span contexts to the queries we want to trace. In this way, we only instrument the queries we want. This is recommended for large installations because it is typically very hard to organize and consume the volume of tracing events generated by even a small fraction of events from a non-trivial production Vitess system. However, if you just want events to flow automatically without you having to instrument queries, you can set this to a value other than `0.0` and skip the following section on instrumenting queries.

After adding these options, you must restart the Vitess components in question.

Instrumenting queries Now that you have the Vitess components setup, you can start instrumenting your queries to choose which queries (or application actions) for which you want to generate trace events. This is obviously an application-specific process, but there are a few things to note:

- The `SpanContext` id you have to instrument your Vitess queries with, in order for them to generate trace events, has a very specific format. It is recommended to use one of the Jaeger / OpenTracing client libraries to generate these for you. They take the format of a base64 string of a JSON object that, at it simplest, looks something like this:

  ```
  {"uber-trace-id":"{trace-id}:{span-id}:{parent-span-id}:{flags}"}
  ```

  Note the very specific format requirements in the documentation. Because of these requirements, it can be tiresome to generate them yourself, and it is more convenient to use the client libraries instead.

- Once you have the `SpanContext` string in its encoded base64 format, you can then generate your SQL query/queries related to this span to send them to Vitess. To inform Vitess of the `SpanContext`, you need to use a special SQL comment style, e.g.:

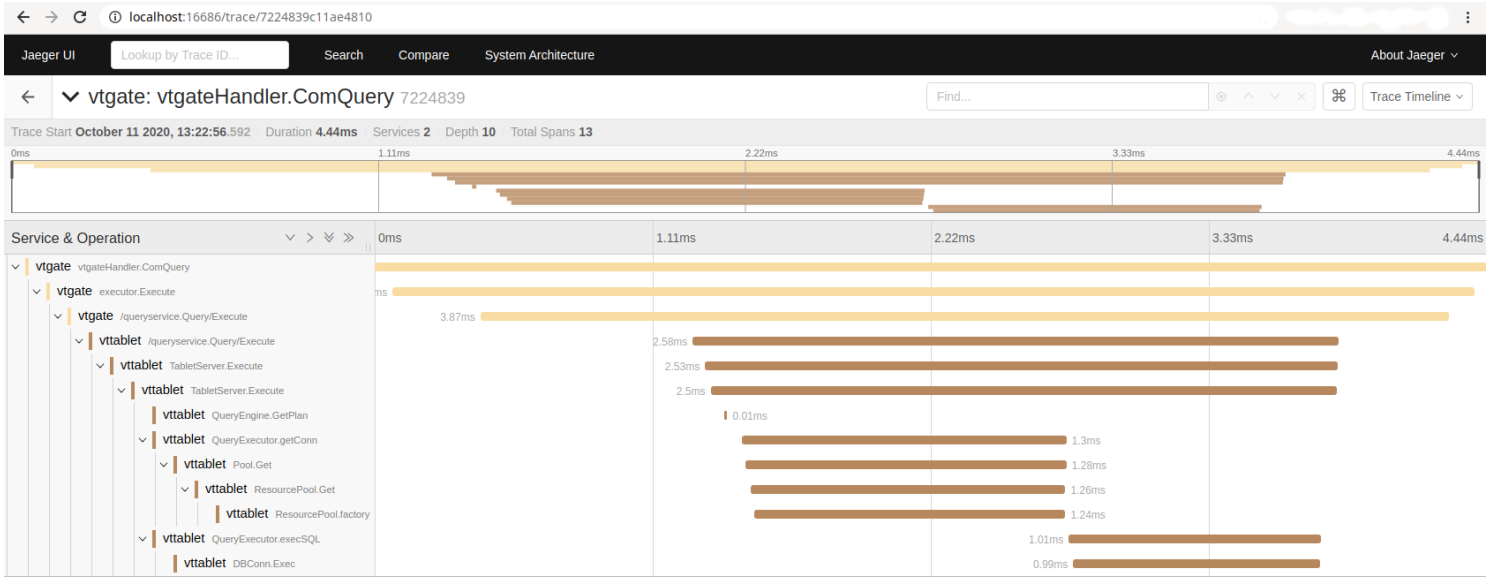
  ```
  /*VT_SPAN_CONTEXT=<base64 value>*/ SELECT * from product;
  ```

  There are additional notes here:

  - The underlying tracing libraries are very particular about the base64 value, so if you have any formatting problems (including trailing spaces between the base64 value and the closing of the comment); you will get many warnings in your `vtgate` logs.
  - When testing with, for example, the `mysql` CLI tool, make sure you are using the `-c` (or `--comments` flag), since the default is `--skip-comments`, which will never send your comments to the server (`vtgate`).

Inspecting trace spans in the Jaeger web UI This is beyond the scope of this guide. However, in general, if you have set everything above up correctly and you have instrumented and executed some queries appropriately, you can now access the Jager web UI to look at the spans recorded. If you are using the local docker container version of Jaeger, you can access the web UI in your browser at http://localhost:16686/.

You should be able to search for and find spans based on the `trace-id` or `span-id` with which your query/queries were instrumented. Once you find a query, you will be able to see the trace events emitted by different parts of the code as the query moves through `vtgate` and the `vttablet(s)` involved in the query. An example would look something like this:



Unmanaged Tablet

{{< info >}} This guide follows on from the local installation guide. {{< /info >}}

This guide uses the Vitess components vtctld, Topology Service and VTGate which have already been started in the local installation guide. It assumes that you have an existing MySQL Server setup that you would like to add to Vitess as a new keyspace, which we will call `legacy`. The same set of steps can be used to create a tablet that uses Amazon RDS, Aurora, or Google CloudSQL.

Ensure all components are up

You should have previously executed `./101_initial_cluster.sh` in the get-started guide. This will ensure that you have a Topology Service, vtgate, vtctld. For the unmanaged MySQL instance, I will be using an instance running on `127.0.0.1:5726`:

```
source env.sh

# verify vtgate/vitess is up and running
mysql commerce -e 'show tables'

# verify my unmanaged mysql is running
mysql -h 127.0.0.1 -P 5726 -umsandbox -pmsandbox legacy -e 'show tables'
```

Output:

```
~/vitess/examples/local$ source env.sh
~/vitess/examples/local$
~/vitess/examples/local$ # verify vtgate/vitess is up and running
~/vitess/examples/local$ mysql commerce -e 'show tables'
+------------------------+
| Tables_in_vt_commerce  |
+------------------------+
| corder                 |
| customer               |
| product                |
+------------------------+
~/vitess/examples/local$ # verify my unmanaged mysql is running
```

```
~/vitess/examples/local$ mysql -h 127.0.0.1 -P 5726 -umsandbox -pmsandbox legacy -e 'show
   tables'
mysql: [Warning] Using a password on the command line interface can be insecure.
+------------------+
| Tables_in_legacy |
+------------------+
| legacytable      |
+------------------+
```

Start a tablet to correspond to legacy

The variables `TOPOLOGY_FLAGS` and `VTDATAROOT` should already be in the environment from sourcing env.sh earlier. We will call the new tablet UID 401.

```
mkdir -p $VTDATAROOT/vt_0000000401
vttablet \
 $TOPOLOGY_FLAGS \
 -logtostderr \
 -log_queries_to_file $VTDATAROOT/tmp/vttablet_0000000401_querylog.txt \
 -tablet-path "zone1-0000000401" \
 -init_keyspace legacy \
 -init_shard 0 \
 -init_tablet_type replica \
 -port 15401 \
 -grpc_port 16401 \
 -service_map 'grpc-queryservice,grpc-tabletmanager,grpc-updatestream' \
 -pid_file $VTDATAROOT/vt_0000000401/vttablet.pid \
 -vtctld_addr http://localhost:15000/ \
 -db_host 127.0.0.1 \
 -db_port 5726 \
 -db_app_user msandbox \
 -db_app_password msandbox \
 -db_dba_user msandbox \
 -db_dba_password msandbox \
 -db_repl_user msandbox \
 -db_repl_password msandbox \
 -db_filtered_user msandbox \
 -db_filtered_password msandbox \
 -db_allprivs_user msandbox \
 -db_allprivs_password msandbox \
 -init_db_name_override legacy \
 -init_populate_metadata &
```

You should be able to see debug information written to screen confirming Vitess can reach the unmanaged server. A common problem is that you may need to change the authentication plugin to `mysql_native_password` (MySQL 8.0).

Assuming that there are no errors, after a few seconds you can mark the server as externally promoted to master:

```
vtctlclient TabletExternallyReparented zone1-401
```

Connect via VTGate

VTGate should now be able to route queries to your unmanaged MySQL server:

```
~/vitess/examples/local$ mysql legacy -e 'show tables'
+------------------+
```

```
| Tables_in_legacy |
+------------------+
| legacytable      |
+------------------+
```

You can even join between the unmanaged tablet and the managed tablets. Vitess will execute the query as a scatter-gather:

```
mysql> use commerce;
Database changed

mysql> select corder.order_id from corder inner join legacy.legacytable on
   corder.order_id=legacy.legacytable.id;
Empty set (0.01 sec)
```

Move legacytable to the commerce keyspace

Move the table:

```
vtctlclient MoveTables -tablet_types=master -workflow=legacy2commerce legacy commerce
   '{"legacytable": {}}'
```

Switch reads:

```
vtctlclient SwitchReads -tablet_type=rdonly commerce.legacy2commerce
vtctlclient SwitchReads -tablet_type=replica commerce.legacy2commerce
```

Switch writes:

```
vtctlclient SwitchWrites commerce.legacy2commerce
```

Drop source table:

```
vtctlclient DropSources commerce.legacy2commerce
```

Verify that the table was moved:

```
source env.sh

# verify vtgate/vitess is up and running
mysql commerce -e 'show tables'

# verify my unmanaged mysql is running
mysql -h 127.0.0.1 -P 5726 -umsandbox -pmsandbox legacy -e 'show tables'
```

Output:

```
~/vitess/examples/local$ source env.sh
~/vitess/examples/local$
~/vitess/examples/local$ # verify vtgate/vitess is up and running
~/vitess/examples/local$ mysql commerce -e 'show tables'
+------------------------+
| Tables_in_vt_commerce  |
+------------------------+
| corder                 |
| customer               |
| legacytable            |
| product                |
+------------------------+
~/vitess/examples/local$ # verify my unmanaged mysql is running
```

```
~/vitess/examples/local$ mysql -h 127.0.0.1 -P 5726 -umsandbox -pmsandbox legacy -e 'show
   tables'
mysql: [Warning] Using a password on the command line interface can be insecure.
```

User Management and Authentication

Vitess uses its own mechanism for managing users and their permissions through VTGate. As a result, the `CREATE USER...` and `GRANT...` statements will not work if sent through VTGate.

Authentication

The Vitess VTGate component takes care of authentication for requests so we will need to add any users that should have access to the Keyspaces via the command-line options to VTGate.

The simplest way to configure users is using a `static` auth method and we can define the users in a JSON formatted file or string.

```
$ cat > users.json << EOF
{
  "vitess": [
    {
      "UserData": "vitess",
      "Password": "supersecretpassword"
    }
  ],
  "myuser1": [
    {
      "UserData": "myuser1",
      "Password": "password1"
    }
  ],
  "myuser2": [
    {
      "UserData": "myuser2",
      "Password": "password2"
    }
  ]
}
EOF
```

Then we can load this into VTGate with the additional commandline parameters:

```
vtgate $(cat <<END_OF_COMMAND
    -mysql_auth_server_impl=static
    -mysql_auth_server_static_file=users.json
    ...
    ...
    ...
END_OF_COMMAND
)
```

Now we can test our new users:

```
$ mysql -h 127.0.0.1 -u myuser1 -ppassword1 -e "select 1"
+---+
| 1 |
+---+
```

```
| 1 |
+---+

$ mysql -h 127.0.0.1 -u myuser1 -pincorrect_password -e "select 1"
ERROR 1045 (28000): Access denied for user 'myuser1'
```

Password format

In the above example we used plaintext passwords. Vitess supports the MySQL mysql_native_password hash format, and you should always specify your passwords using this in a non-test or external environment. Vitess does not yet support the caching_sha2_password format that became the default for MySQL in 8.0.

To use a `mysql_native_password` hash, your user section in your static JSON authentication file would look something like this instead:

```
{
  "vitess": [
    {
      "UserData": "vitess",
      "MysqlNativePassword": "*9E128DA0C64A6FCCCDCFBDD0FC0A2C967C6DB36F"
    }
  ]
}
```

You can extract a `mysql_native_password` hash from an existing MySQL install by looking at the `authentication_string` column of the relevant user's row in the `mysql.user` table. An alternate way to generate this hash is to SHA1 the cleartext password string twice, e.g. doing it in MySQL for the cleartext password `password`:

```
mysql> SELECT UPPER(SHA1(UNHEX(SHA1("password")))) as hash;
+-------------------------------------------+
| hash                                      |
+-------------------------------------------+
| 2470C0C06DEE42FD1618BB99005ADCA2EC9D1E19 |
+-------------------------------------------+
1 row in set (0.01 sec)
```

So, you would use `*2470C0C06DEE42FD1618BB99005ADCA2EC9D1E19` as the `MysqlNativePassword` hash value for the cleartext password `password`.

UserData

In the static authentication JSON file, the `UserData` string is **not** the username; the username is the string key for the list. The `UserData` string does **not** need to correspond to the username, and is used by the authorization mechanism when referring to a user. It is usually however simpler if you make the `UserData` string and the username the same.

The `UserData` feature can be leveraged to create multiple users that are equivalent to the authorization layer (i.e. multiple users having the same `UserData` strings), but are different in the authentication layer (i.e. have different usernames and passwords).

Multiple passwords

A very convenient feature of the VTGate authorization is that, as can be seen in the example JSON authentication files, you have a **list** of `UserData` and `Password`/`MysqlNativePassword` pairs associated with a user. You can optionally leverage this to assign multiple different passwords to a single user, and VTGate will allow a user to authenticate with any of the defined passwords. This makes password rotation much easier; and less likely to require or cause downtime.

An example could be:

```
{
  "vitess": [
    {
      "UserData": "vitess_old",
      "MysqlNativePassword": "*9E128DA0C64A6FCCCDCFBDD0FC0A2C967C6DB36F"
    },
    {
      "UserData": "vitess_new",
      "MysqlNativePassword": "*B3AD996B12F211BEA47A7C666CC136FB26DC96AF"
    }
  ]
}
```

This feature also allows different `UserData` strings to be associated with a user depending on the password used. This can be used in concert with the authorization mechanism to migrate an application gracefully from one set of ACLs (or no ACLs) to another set of ACLs, by just changing the password used by the application.

In the example above, the username `vitess` has **two different** passwords that would be allowed, each resulting in different `UserData` strings (`vitess_old` or `vitess_new`) being passed to the VTTablet layer that can be used for authorization/ACL enforcement.

Other authentication methods

Other than the static authentication file method above, other authentication mechanisms are also provided: * LDAP-based authentication * TLS client certificate-based authentication

Configuration

description: User guides covering basic configuration concepts

Configuring Components

Managed MySQL

The following describes the requirements for Vitess when fully managing MySQL with `mysqlctl` (see VTTablet Modes).

When using Unmanaged or Remote MySQL instead, the requirement is only that the server speak the MySQL protocol.

Version and Flavor `mysqlctl` supports MySQL/Percona Server 5.6 to 8.0, and MariaDB 10.0 to 10.3. MariaDB 10.4 is currently known to have installation issues (#5362).

Base Configuration Starting with Vitess 4.0, `mysqlctl` will auto-detect the version and flavor of MySQL you are using, and automatically-include a base configuration file in `config/mycnf/*`.

Auto-dection works by searching for `mysqld` in the `$PATH`, as well as in the environment variable `$VT_MYSQL_ROOT`. If auto-detection fails, `mysqlctl` will apply version detection based on the `$MYSQL_FLAVOR` environment variable. Auto-detection will always take precedence over `$MYSQL_FLAVOR`.

Specifying Additional Configuration The automatically-included base configuration makes only the required settings changes for Vitess to operate correctly. It is recommended to configure InnoDB settings such as `innodb_buffer_pool_size` and `innodb_log_file_size` according to your available system resources.

`mysqlctl` **will not** read configuration files from common locations such as `/etc/my.cnf` or `/etc/mysql/my.cnf`. To include a custom `my.cnf` file as part of the initialization of tablets, set the `$EXTRA_MY_CNF` environment variable to a list of colon-separated files. Each file must be an absolute path.

In Kubernetes, you can use a ConfigMap to overwrite the entire `$VTROOT/config/mycnf` directory with your custom versions, rather than baking them into a custom container image.

Unsupported Configuration Changes When specifying additional configuration changes to Vitess, please keep in mind that changing the following settings is unsupported:

Setting	Reason
`auto_commit`	MySQL autocommit needs to be turned on. VTTablet uses connection pools to MySQL. If autocommit is turned off, MySQL will start an implicit transaction (with a point in time snapshot) for each connection and will work very hard at keeping the current view unchanged, which would be counter-productive.
`log-bin`	Several Vitess features rely on the binary log being enabled.
`binlog-format`	Vitess only supports row-based replication. Do not change this setting from the included configuration files.
`binlog-row-image`	Vitess only supports the default value (`FULL`)
`log-slave-updates`	Vitess requires this setting enabled, as it is in the included configuration files.
`character-set\*`	Vitess only supports `utf8` (and variants such as `utf8mb4`)
`gtid-mode`	Vitess relies on GTIDs to track changes to topology.
`gtid-strict-mode/enforce-gtid-consistency`	Vitess requires this setting to be unchanged.
`sql-mode`	Vitess can operate with non-default SQL modes, but VTGate will not allow you to change the sql-mode on a per-session basis. This can create compatibility issues for applications that require changes to this setting.

init_db.sql When a new instance is initialized with mysqlctl init (as opposed to restarting in a previously initialized data dir with mysqlctl start), the `init_db.sql` file is applied to the server immediately after running the bootstrap procedure (either `mysqld --initialize-insecure` or `mysql_install_db`, depending on the MySQL version). This file is also responsible for removing unprivileged users, as well as adding the necessary tables and grants for Vitess.

Note that changes to this file will not be reflected in shards that have already been initialized and had at least one backup taken. New instances in such shards will automatically restore the latest backup upon vttablet startup, overwriting the data dir created by `mysqlctl`.

Vitess Servers

Logging Vitess servers write to log files, and they are rotated when they reach a maximum size. It's recommended that you run at INFO level logging. The information printed in the log files come in handy for troubleshooting. You can limit the disk usage by running cron jobs that periodically purge or archive them.

Vitess supports both MySQL protocol and gRPC for communication between client and Vitess and uses gRPC for communication between Vitess servers. By default, Vitess does not use SSL.

Also, even without using SSL, we allow the use of an application-provided CallerID object. It allows unsecured but easy to use authorization using Table ACLs.

See the TLS example for more information on how to set up both of these features, and what command line parameters exist.

Topology Service configuration Vttablet, vtgate and vtctld need the right command line parameters to find the topology service. First the `topo_implementation` flag needs to be set to one of zk2, etcd2, or consul. Then they're all configured as follows:

- The `topo_global_server_address` contains the server address / addresses of the global topology service.
- The `topo_global_root` contains the directory / path to use.

Note that the local cell for the tablet must exist and be configured properly in the Topology Service for vttablet to start. Local cells are configured inside the topology service, by using the `vtctl AddCellInfo` command. See the Topology Service documentation for more information.

VTTablet

VTTablet has a large number of command line options. Some important ones will be covered here. In terms of provisioning these are the recommended values

- 2-4 cores (in proportion to MySQL cores)
- 2-4 GB RAM

Directory Configuration vttablet supports a number of command line options and environment variables to facilitate its setup.

The VTDATAROOT environment variable specifies the toplevel directory for all data files. If not set, it defaults to /vt.

By default, a vttablet will use a subdirectory in VTDATAROOT named vt_NNNNNNNNNN where NNNNNNNNNN is the tablet id. The tablet_dir command-line parameter allows overriding this relative path. This is useful in containers where the filesystem only contains one vttablet, in order to have a fixed root directory.

When starting up and using mysqlctl to manage MySQL, the MySQL files will be in subdirectories of the tablet root. For instance, bin-logs for the binary logs, data for the data files, and relay-logs for the relay logs.

It is possible to host different parts of a MySQL server files on different partitions. For instance, the data file may reside in flash, while the bin logs and relay logs are on spindle. To achieve this, create a symlink from $VTDATAROOT/<dir name> to the proper location on disk. When MySQL is configured by mysqlctl, it will realize this directory exists, and use it for the files it would otherwise have put in the tablet directory. For instance, to host the binlogs in /mnt/bin-logs:

- Create a symlink from $VTDATAROOT/bin-logs to /mnt/bin-logs.
- When starting up a tablet: * /mnt/bin-logs/vt_NNNNNNNNNN will be created. * $VTDATAROOT/vt_NNNNNNNNNN/bin-logs will be a symlink to /mnt/bin-logs/vt_NNNNNNNNNN

Initialization

- Init_keyspace, init_shard, init_tablet_type: These parameters should be set at startup with the keyspace / shard / tablet type to start the tablet as. Note 'master' is not allowed here, instead use 'replica', as the tablet when starting will figure out if it is the master (this way, all replica tablets start with the same command line parameters, independently of which one is the master).

Query server parameters

- **queryserver-config-pool-size**: This value should typically be set to the max number of simultaneous queries you want MySQL to run. This should typically be around 2-3x the number of allocated CPUs. Around 4-16. There is not much harm in going higher with this value, but you may see no additional benefits.
- **queryserver-config-stream-pool-size**: This value is relevant only if you plan to run streaming queries against the database. It's recommended that you use rdonly instances for such streaming queries. This value depends on how many simultaneous streaming queries you plan to run. Typical values are in the low 100s.

- **queryserver-config-transaction-cap**: This value should be set to how many concurrent transactions you wish to allow. This should be a function of transaction QPS and transaction length. Typical values are in the low 100s.
- **queryserver-config-query-timeout**: This value should be set to the upper limit you're willing to allow a query to run before it's deemed too expensive or detrimental to the rest of the system. VTTablet will kill any query that exceeds this timeout. This value is usually around 15-30s.
- **queryserver-config-transaction-timeout**: This value is meant to protect the situation where a client has crashed without completing a transaction. Typical value for this timeout is 30s.
- **queryserver-config-max-result-size**: This parameter prevents the OLTP application from accidentally requesting too many rows. If the result exceeds the specified number of rows, VTTablet returns an error. The default value is 10,000.

DB config parameters VTTablet requires multiple user credentials to perform its tasks. Since it's required to run on the same machine as MySQL, it's most beneficial to use the more efficient unix socket connections.

connection parameters

- `db_socket`: The unix socket to connect on. If this is specified, host and port will not be used.
- `db_host`: The host name for the tcp connection.
- `db_port`: The tcp port to be used with the `db_host`.
- `db_charset`: Character set. Only utf8 or latin1 based character sets are supported.
- `db_flags`: Flag values as defined by MySQL.
- `db_ssl_ca`, `db_ssl_ca_path`, `db_ssl_cert`, `db_ssl_key`: SSL flags.

app credentials are for serving app queries:

- `db_app_user`: App username.
- `db_app_password`: Password for the app username. If you need a more secure way of managing and supplying passwords, VTTablet does allow you to plug into a "password server" that can securely supply and refresh usernames and passwords. Please contact the Vitess team for help if you'd like to write such a custom plugin.
- `db_app_use_ssl`: Set this flag to false if you don't want to use SSL for this connection. This will allow you to turn off SSL for all users except for `repl`, which may have to be turned on for replication that goes over open networks.

appdebug credentials are for the appdebug user:

- `db_appdebug_user`
- `db_appdebug_password`
- `db_appdebug_use_ssl`

dba credentials will be used for housekeeping work like loading the schema or killing runaway queries:

- `db_dba_user`
- `db_dba_password`
- `db_dba_use_ssl`

repl credentials are for managing replication.

- `db_repl_user`
- `db_repl_password`
- `db_repl_use_ssl`

filtered credentials are for performing resharding:

- `db_filtered_user`
- `db_filtered_password`
- `db_filtered_use_ssl`

Monitoring VTTablet exports a wealth of real-time information about itself. This section will explain the essential ones:

/debug/status This page has a variety of human-readable information about the current VTTablet. You can look at this page to get a general overview of what's going on. It also has links to various other diagnostic URLs below.

/debug/vars This is the most important source of information for monitoring. There are other URLs below that can be used to further drill down.

Queries (as described in /debug/vars section) Vitess has a structured way of exporting certain performance stats. The most common one is the Histogram structure, which is used by Queries:

```
"Queries": {
  "Histograms": {
    "PASS\_SELECT": {
      "1000000": 1138196,
      "10000000": 1138313,
      "100000000": 1138342,
      "1000000000": 1138342,
      "10000000000": 1138342,
      "500000": 1133195,
      "5000000": 1138277,
      "50000000": 1138342,
      "500000000": 1138342,
      "5000000000": 1138342,
      "Count": 1138342,
      "Time": 387710449887,
      "inf": 1138342
    }
  },
  "TotalCount": 1138342,
  "TotalTime": 387710449887
},
```

The histograms are broken out into query categories. In the above case, "`PASS\_SELECT`" is the only category. An entry like `"500000": 1133195` means that `1133195` queries took under `500000` nanoseconds to execute.

`Queries.Histograms.PASS\_SELECT.Count` is the total count in the `PASS\_SELECT` category.

`Queries.Histograms.PASS\_SELECT.Time` is the total time in the `PASS\_SELECT` category.

`Queries.TotalCount` is the total count across all categories.

`Queries.TotalTime` is the total time across all categories.

There are other Histogram variables described below, and they will always have the same structure.

Use this variable to track:

- QPS
- Latency
- Per-category QPS. For replicas, the only category will be PASS_SELECT, but there will be more for masters.
- Per-category latency
- Per-category tail latency

```
"Results": {
  "0": 0,
  "1": 0,
```

```
    "10": 1138326,
    "100": 1138326,
    "1000": 1138342,
    "10000": 1138342,
    "5": 1138326,
    "50": 1138326,
    "500": 1138342,
    "5000": 1138342,
    "Count": 1138342,
    "Total": 1140438,
    "inf": 1138342
  }
```

Results is a simple histogram with no timing info. It gives you a histogram view of the number of rows returned per query.

Mysql Mysql is a histogram variable like Queries, except that it reports MySQL execution times. The categories are "Exec" and "ExecStream".

In the past, the exec time difference between VTTablet and MySQL used to be substantial. With the newer versions of Go, the VTTablet exec time has been predominantly been equal to the mysql exec time, conn pool wait time and consolidations waits. In other words, this variable has not shown much value recently. However, it's good to track this variable initially, until it's determined that there are no other factors causing a big difference between MySQL performance and VTTablet performance.

Transactions Transactions is a histogram variable that tracks transactions. The categories are "Completed" and "Aborted".

Waits Waits is a histogram variable that tracks various waits in the system. Right now, the only category is "Consolidations". A consolidation happens when one query waits for the results of an identical query already executing, thereby saving the database from performing duplicate work.

This variable used to report connection pool waits, but a refactor moved those variables out into the pool related vars.

```
  "Errors": {
    "Deadlock": 0,
    "Fail": 1,
    "NotInTx": 0,
    "TxPoolFull": 0
  },
```

Errors are reported under different categories. It's beneficial to track each category separately as it will be more helpful for troubleshooting. Right now, there are four categories. The category list may vary as Vitess evolves.

Plotting errors/query can sometimes be useful for troubleshooting.

VTTablet also exports an InfoErrors variable that tracks inconsequential errors that don't signify any kind of problem with the system. For example, a dup key on insert is considered normal because apps tend to use that error to instead update an existing row. So, no monitoring is needed for that variable.

```
  "InternalErrors": {
    "HungQuery": 0,
    "Invalidation": 0,
    "MemcacheStats": 0,
    "Mismatch": 0,
```

```
    "Panic": 0,
    "Schema": 0,
    "StrayTransactions": 0,
    "Task": 0
  },
```

An internal error is an unexpected situation in code that may possibly point to a bug. Such errors may not cause outages, but even a single error needs be escalated for root cause analysis.

```
  "Kills": {
    "Queries": 2,
    "Transactions": 0
  },
```

Kills reports the queries and transactions killed by VTTablet due to timeout. It's a very important variable to look at during outages.

TransactionPool* There are a few variables with the above prefix:

```
  "TransactionPoolAvailable": 300,
  "TransactionPoolCapacity": 300,
  "TransactionPoolIdleTimeout": 600000000000,
  "TransactionPoolMaxCap": 300,
  "TransactionPoolTimeout": 30000000000,
  "TransactionPoolWaitCount": 0,
  "TransactionPoolWaitTime": 0,
```

- `WaitCount` will give you how often the transaction pool gets full that causes new transactions to wait.
- `WaitTime/WaitCount` will tell you the average wait time.
- `Available` is a gauge that tells you the number of available connections in the pool in real-time. `Capacity-Available` is the number of connections in use. Note that this number could be misleading if the traffic is spiky.

Other Pool variables Just like `TransactionPool`, there are variables for other pools:

- `ConnPool`: This is the pool used for read traffic.
- `StreamConnPool`: This is the pool used for streaming queries.

There are other internal pools used by VTTablet that are not very consequential.

`TableACLAllowed, TableACLDenied, TableACLPseudoDenied` The above three variables table acl stats broken out by table, plan and user.

`QueryPlanCacheSize` If the application does not make good use of bind variables, this value would reach the QueryCacheCapacity. If so, inspecting the current query cache will give you a clue about where the misuse is happening.

`QueryCounts, QueryErrorCounts, QueryRowCounts, QueryTimesNs` These variables are another multi-dimensional view of Queries. They have a lot more data than Queries because they're broken out into tables as well as plan. This is a priceless source of information when it comes to troubleshooting. If an outage is related to rogue queries, the graphs plotted from these vars will immediately show the table on which such queries are run. After that, a quick look at the detailed query stats will most likely identify the culprit.

`UserTableQueryCount`, `UserTableQueryTimesNs`, `UserTransactionCount`, `UserTransactionTimesNs` These variables are yet another view of Queries, but broken out by user, table and plan. If you have well-compartmentalized app users, this is another priceless way of identifying a rogue "user app" that could be misbehaving.

`DataFree`, `DataLength`, `IndexLength`, `TableRows` These variables are updated periodically from information_schema.tables. They represent statistical information as reported by MySQL about each table. They can be used for planning purposes, or to track unusual changes in table stats.

- `DataFree` represents `data_free`
- `DataLength` represents `data_length`
- `IndexLength` represents `index_length`
- `TableRows` represents `table_rows`

/debug/health This URL prints out a simple "ok" or "not ok" string that can be used to check if the server is healthy. The health check makes sure mysqld connections work, and replication is configured (though not necessarily running) if not master.

/queryz, /debug/query_stats, /debug/query_plans, /streamqueryz

- /debug/query_stats is a JSON view of the per-query stats. This information is pulled in real-time from the query cache. The per-table stats in /debug/vars are a roll-up of this information.
- /queryz is a human-readable version of /debug/query_stats. If a graph shows a table as a possible source of problems, this is the next place to look at to see if a specific query is the root cause.
- /debug/query_plans is a more static view of the query cache. It just shows how VTTablet will process or rewrite the input query.
- /streamqueryz lists the currently running streaming queries. You have the option to kill any of them from this page.

/querylogz, /debug/querylog, /txlogz, /debug/txlog

- /debug/querylog is a never-ending stream of currently executing queries with verbose information about each query. This URL can generate a lot of data because it streams every query processed by VTTablet. The details are as per this function: https://github.com/vitessio/vitess/blob/master/go/vt/tabletserver/logstats.go#L202
- /querylogz is a limited human readable version of /debug/querylog. It prints the next 300 queries by default. The limit can be specified with a limit=N parameter on the URL.
- /txlogz is like /querylogz, but for transactions.
- /debug/txlog is the JSON counterpart to /txlogz.

/consolidations This URL has an MRU list of consolidations. This is a way of identifying if multiple clients are spamming the same query to a server.

/schemaz, /debug/schema

- /schemaz shows the schema info loaded by VTTablet.
- /debug/schema is the JSON version of /schemaz.

/debug/query_rules This URL displays the currently active query blacklist rules.

Alerting Alerting is built on top of the variables you monitor. Before setting up alerts, you should get some baseline stats and variance, and then you can build meaningful alerting rules. You can use the following list as a guideline to build your own:

- Query latency among all vttablets
- Per keyspace latency
- Errors/query
- Memory usage
- Unhealthy for too long
- Too many vttablets down
- Health has been flapping
- Transaction pool full error rate
- Any internal error
- Traffic out of balance among replicas
- Qps/core too high

VTGate

A typical VTGate should be provisioned as follows.

- 2-4 cores
- 2-4 GB RAM

Since VTGate is stateless, you can scale it linearly by just adding more servers as needed. Beyond the recommended values, it's better to add more VTGates than giving more resources to existing servers, as recommended in the philosophy section.

Load-balancer in front of vtgate to scale up (not covered by Vitess). Stateless, can use the health URL for health check.

Parameters Some of the important VTGate and VTTablet flags for modifying query serving behavior:

VTGate: * `cells_to_watch`: which cell vtgate is in and will monitor tablets from. Cross-cell master access needs multiple cells here. * `tablet_types_to_wait`: VTGate waits for at least one serving tablet per tablet type specified here during startup, before listening to the serving port, so that VTGate does not start up serving errors. It should match a subset of the available tablet types VTGate connects to (master, replica, rdonly). The default is empty, i.e. VTGate will not wait for any serving tablets to start listening. * `discovery_low_replication_lag (default: 30s)`: when replication lags of all VTTablet instances in a particular shard and of a specific tablet type are less than or equal this value, VTGate does not filter the tablets by replication lag and uses all to balance traffic. * `discovery_high_replication_lag_minimum_serving (default: 2h)`: the replication lag that is considered too high when applying the `min_number_serving_vttablets` threshold * `min_number_serving_vttablets (default: 2)`: when replication lag exceeds `discovery_low_replication_lag`, but not `discovery_high_replication_lag_minimum_serving`, keep serving from at least this many replica tablets per shard. This threshold also applies separately to the minimum number of serving rdonly tablets per shard. * `transaction_mode (default: multi)`: default write transaction mode to allow: * `single`: disallow multi-db transactions * `multi`: allow multi-db transactions with best effort commit * `twopc`: allow multi-db transactions with 2pc commit.

Note that `transaction_mode` does not affect read-only transactions. * `normalize_queries (default: true)`: Turning this flag on will cause vtgate to rewrite queries with bind vars. This is beneficial if the app doesn't itself send normalized queries.

VTTablet: * `unhealthy_threshold (default: 2h)`: a replicating tablet (e.g. tablet type replica or rdonly) will publish itself as unhealthy if replication lag exceeds this threshold. * `degraded_threshold (30s)`: a replicating tablet (e.g. tablet type replica or rdonly) will publish itself as degraded if replication lag exceeds this threshold. This will cause VTGates to choose more up-to-date servers over this one. If all servers are degraded, VTGate resorts to serving from all of them. Also note the potential impact of the `-min_number_serving_vttablets` above.

Monitoring

/debug/status This is the landing page for a VTGate, which gives you the status of how a particular server is doing. Of particular interest there is the list of tablets this vtgate process is connected to, as this is the list of tablets that can potentially serve queries.

/debug/vars VTGateApi

This is the main histogram variable to track for vtgates. It gives you a break up of all queries by command, keyspace, and type.

HealthcheckConnections

It shows the number of tablet connections for query/healthcheck per keyspace, shard, and tablet type.

/debug/query_plans

This URL gives you all the query plans for queries going through VTGate.

/debug/vschema

This URL shows the vschema as loaded by VTGate.

Alerting For VTGate, here's a list of possible variables to alert on:

- Error rate
- Error/query rate
- Error/query/tablet-type rate
- VTGate serving graph is stale by x minutes (topology service is down)
- Qps/core
- Latency

Exporting data from Vitess

Since VTGate supports the MySQL protocol, in many cases it is possible to use existing client utilities when connecting to Vitess. This includes using logical dump tools such as `mysqldump`, in certain cases.

This guide provides instructions on the required options when using these tools against a VTGate server for the purposes of exporting data from Vitess. It is recommended to follow the Backup and Restore guide for regular backups, since this method is performed directly on the tablet servers and is more efficient and safer for databases of any significant size. The dump methods that follow are typically not suitable for production backups, because Vitess does not implement all the locking constructs across a sharded database that are necessary to do a consistent logical backup while writing to the database. As a result, you will only be guaranteed to get a 100% consistent dump using these tools if you are sure that you are not writing to the database while running the dump.

mysqldump The default invocation of `mysqldump` attempts to execute statements which are not supported by Vitess, such as attempting to lock tables and dump GTID coordinates. The following options are required when using the `mysqldump` binary from MySQL 5.7 to export data from the `commerce` keyspace:

- `--lock-tables=off`: VTGate currently prohibits the syntax `LOCK TABLES` and `UNLOCK TABLES`.
- `--set-gtid-purged=OFF`: `mysqldump` attemps to dump GTID coordinates of a server, but in the case of VTGate this does not make sense since it could be routing to multiple servers.
- `--no-tablespaces`: This option disables dumping InnoDB tables by tablespace. This functionality is not yet supported by Vitess.
- `--skip-network-timeout`: This option is required when using `mysqldump` from MySQL 8.0 (#5401) with Vitess versions before 7.0.

For example to export the `commerce` keyspace using the `mysqldump` binary from MySQL 5.7:

```
$ mysqldump  --lock-tables=off --set-gtid-purged=OFF --no-tablespaces commerce >
   commerce.sql
```

NOTE: You will be limited by the Vitess row limits in the size of the tables that you can dump using this method. The default Vitess row limit is determined by the VTTablet option `-queryserver-config-max-result-size` and defaults to 10000 rows. So for an unsharded database, you will not be able to dump tables with more than 10000 rows, or N x 10000 rows if the table

is fully sharded across N shards. Note that you should not blindly raise your row limits just because of this, it is an important Vitess operability and reliability feature. If you have large tables to dump, look into using go-mydumper instead.

To restore dump files created by `mysqldump`, replay it against a Vitess server or other MySQL server using the `mysql` command line client.

go-mydumper Alternatively, you can use a slight modification of the `go-mydumper` tool to export logical dumps of a Vitess keyspace. `go-mydumper` has the advantage of being multi-threaded, and so can run faster on a database that has many tables. For a database with just one or a handful of large tables, `go-mydumper` may not be that much faster than `mysqldump`.

For information on the Vitess-compatible fork of `go-mydumper`, see https://github.com/aquarapid/go-mydumper . Examples and instructions are available in the README.md in that repo. You will need to be able to compile golang binaries to use this tool.

`go-mydumper` creates multiple files for each backup. To restore a backup, you can use the `mysql` commandline client, but using the `myloader` tool as described in the `go-mydumper` repo above is easier and can be faster, since the loader is also multithreaded.

Production Planning

Provisioning

Minimum Topology A highly available Vitess cluster requires the following components:

- 2 VTGate Servers
- A redundant Topology Service (e.g. 3 etcd servers)
- 3 MySQL Servers with semi-sync replication enabled
- 3 VTTablet processes
- A Vtctld process

It is common practice to locate the VTTablet process and MySQL Servers on the same host, and Vitess uses the terminology *tablet* to refer to both. The topology service in Vitess is pluggable, and you can use an existing etcd, ZooKeeper or Consul cluster to reduce the footprint required to deploy Vitess.

For development environments, it is possible to deploy with a lower number of these components. See `101_initial_cluster.sh` from the Run Vitess Locally guide for an example.

General Recommendations Vitess components (excluding the `mysqld` server) tend to be CPU-bound processes. They use disk space for storing their logs, but do not store any intermediate results on disk, and tend not to be disk IO bound. It is recommended to allocate 2-4 CPU cores for each VTGate server, and the same number of cores for VTTablet as with `mysqld`. If you are provisioning for a new workload, we recommend projecting that `mysqld` will require 1 core per 1500 QPS. Workloads with well optimized queries should be able to achieve greater than this.

The memory requirements for VTGate and VTTablet servers will depend on QPS and result set sizes, but a typical rule of thumb is to provision a baseline of 1GB per core.

The impact of network latency can be a factor when migrating from MySQL to Vitess. A simple rule of thumb is to estimate 2ms of round trip latency added to each query. Application code paths that make large numbers of database round-trips in a sequential code path will be most affected. To compensate, you may have to optimize or parallelize some code paths; or run additional threads or workers, which may result in additional memory requirements.

Planning Shard Size Vitess recommends provisioning shard sizes to approximately 250GB. This is not a hard-limit, and is driven primarily by the recovery time should an instance fail. With 250GB a full-recovery from backup is expected within less than 15 minutes. For most workloads this results in shards instances with relatively few CPU cores and lighter memory requirements, which tend to be more economical than running large instance sizes.

Running Multiple Tablets Per Server If you are using physical servers, Vitess encourages running multiple tablets (shards) per server. Typically the best way to do this is with Kubernetes, but `mysqlctl` also supports launching and managing multiple tablet servers if required.

Assuming tablets are kept to the recommended size of 250GB, they can start with a baseline CPU requirement of 2-4 cores for `mysqld` plus 2-4 cores for the VTTablet process, but this is obviously very workload-dependent.

Topology Service Provisioning By design, Vitess tries to contact the topology service as little as possible, and stores very little data in the topology server. For estimating CPU/memory/disk requirements, you can use the minimum requirements recommended by your preferred Topology Service.

Production testing

Before running Vitess in production, you should become comfortable with the different administrative operations. We recommend to go through the following scenarios on a non-production system.

Here is a short list of all the basic workflows Vitess supports:

- Reparenting
- Backup/Restore
- Schema Management
- Resharding / Horizontal Sharding Tutorial
- Upgrading

Legacy

description: User guides for features in older version of Vitess

Horizontal Sharding

{{< warning >}} In Vitess 6, Horizontal Sharding became obsolete with the introduction of Resharding! It is recommended to skip this guide, and continue on with the resharding user guide instead. {{< /warning >}}

{{< info >}} This guide follows on from Vertical Split and Get Started with a Local deployment. It assumes that several scripts have been executed, and that you have a running Vitess cluster. {{< /info >}}

The DBAs you hired with massive troves of hipster cash are pinging you on Slack and are freaking out. With the amount of data that you're loading up in your keyspaces, MySQL performance is starting to tank - it's okay, you're prepared for this! Although the query guardrails and connection pooling are cool features that Vitess can offer to a single unsharded keyspace, the real value comes into play with horizontal sharding.

Preparation

Before starting the resharding process, you need to make some decisions and prepare the system for horizontal resharding. Important note, this is something that should have been done before starting the vertical split. However, this is a good time to explain what normally would have been decided upon earlier the process.

Sequences The first issue to address is the fact that customer and corder have auto-increment columns. This scheme does not work well in a sharded setup. Instead, Vitess provides an equivalent feature through sequences.

The sequence table is an unsharded single row table that Vitess can use to generate monotonically increasing ids. The syntax to generate an id is: `select next :n values from customer_seq`. The vttablet that exposes this table is capable of serving a very large number of such ids because values are cached and served out of memory. The cache value is configurable.

The VSchema allows you to associate a column of a table with the sequence table. Once this is done, an insert on that table transparently fetches an id from the sequence table, fills in the value, and routes the row to the appropriate shard. This makes the construct backward compatible to how MySQL's `auto_increment` property works.

Since sequences are unsharded tables, they will be stored in the commerce database. The schema:

```
CREATE TABLE customer_seq (id int, next_id bigint, cache bigint, primary key(id)) comment
   'vitess_sequence';
INSERT INTO customer_seq (id, next_id, cache) VALUES (0, 1000, 100);
CREATE TABLE order_seq (id int, next_id bigint, cache bigint, primary key(id)) comment
   'vitess_sequence';
INSERT INTO order_seq (id, next_id, cache) VALUES (0, 1000, 100);
```

Note the `vitess_sequence` comment in the create table statement. VTTablet will use this metadata to treat this table as a sequence.

- `id` is always 0
- `next_id` is set to 1000: the value should be comfortably greater than the `auto_increment` max value used so far.
- `cache` specifies the number of values to cache before vttablet updates `next_id`.

Larger cache values perform better, but will exhaust the values quicker since during reparent operations the new master will start off at the `next_id` value.

The VTGate servers also need to know about the sequence tables. This is done by updating the VSchema for commerce as follows:

```
{
  "tables": {
    "customer_seq": {
      "type": "sequence"
    },
    "order_seq": {
      "type": "sequence"
    },
    "product": {}
  }
}
```

Vindexes The next decision is about the sharding keys, aka Primary Vindexes. This is a complex decision that involves the following considerations:

- What are the highest QPS queries, and what are the where clauses for them?
- Cardinality of the column; it must be high.
- Do we want some rows to live together to support in-shard joins?
- Do we want certain rows that will be in the same transaction to live together?

Using the above considerations, in our use case, we can determine that:

- For the customer table, the most common where clause uses `customer_id`. So, it shall have a Primary Vindex.
- Given that it has lots of users, its cardinality is also high.
- For the corder table, we have a choice between `customer_id` and `order_id`. Given that our app joins `customer` with `corder` quite often on the `customer_id` column, it will be beneficial to choose `customer_id` as the Primary Vindex for the `corder` table as well.
- Coincidentally, transactions also update `corder` tables with their corresponding `customer` rows. This further reinforces the decision to use `customer_id` as Primary Vindex.

NOTE: It may be worth creating a secondary lookup Vindex on `corder.order_id`. This is not part of the example. We will discuss this in the advanced section.

NOTE: For some use cases, `customer_id` may actually map to a tenant_id. In such cases, the cardinality of a tenant id may be too low. It's also common that such systems have queries that use other high cardinality columns in their where clauses. Those should then be taken into consideration when deciding on a good Primary Vindex.

Putting it all together, we have the following VSchema for `customer`:

```
{
  "sharded": true,
  "vindexes": {
    "hash": {
      "type": "hash"
    }
  },
  "tables": {
    "customer": {
      "column_vindexes": [
        {
          "column": "customer_id",
          "name": "hash"
        }
      ],
      "auto_increment": {
        "column": "customer_id",
        "sequence": "customer_seq"
      }
    },
    "corder": {
      "column_vindexes": [
        {
          "column": "customer_id",
          "name": "hash"
        }
      ],
      "auto_increment": {
        "column": "order_id",
        "sequence": "order_seq"
      }
    }
  }
}
```

Note that we have now marked the keyspace as sharded. Making this change will also change how Vitess treats this keyspace. Some complex queries that previously worked may not work anymore. This is a good time to conduct thorough testing to ensure that all the queries work. If any queries fail, you can temporarily revert the keyspace as unsharded. You can go back and forth until you have got all the queries working again.

Since the primary vindex columns are `BIGINT`, we choose `hash` as the primary vindex, which is a pseudo-random way of distributing rows into various shards.

NOTE: For `VARCHAR` columns, use `unicode_loose_md5` or `unicode_loose_xxhash`. For `VARBINARY`, use `binary_md5` or `xxhash`.

NOTE: All vindexes in Vitess are plugins. If none of the predefined vindexes suit your needs, you can develop your own custom vindex.

Now that we have made all the important decisions, it's time to apply these changes:

```
./301_customer_sharded.sh
```

Create new shards

At this point, you have finalized your sharded VSchema and vetted all the queries to make sure they still work. Now, it's time to reshard.

The resharding process works by splitting existing shards into smaller shards. This type of resharding is the most appropriate for Vitess. There are some use cases where you may want to spin up a new shard and add new rows in the most recently created shard. This can be achieved in Vitess by splitting a shard in such a way that no rows end up in the 'new' shard. However, it's not natural for Vitess.

We have to create the new target shards:

```
./302_new_shards.sh
```

Shard 0 was already there. We have now added shards `-80` and `80-`. We've also added the `CopySchema` directive which requests that the schema from shard 0 be copied into the new shards.

Shard naming What is the meaning of `-80` and `80-`? The shard names have the following characteristics:

- They represent a range, where the left number is included, but the right is not.
- Their notation is hexadecimal.
- They are left justified.
- A `-` prefix means: anything less than the RHS value.
- A `-` postfix means: anything greater than or equal to the LHS value.
- A plain `-` denotes the full keyrange.

What does this mean: `-80` == `00-80` == `0000-8000` == `000000-800000`

`80-` is not the same as `80-FF`. This is why:

`80-FF` == `8000-FF00`. Therefore `FFFF` will be out of the `80-FF` range.

`80-` means: 'anything greater than or equal to `0x80`

A `hash` vindex produces an 8-byte number. This means that all numbers less than `0x8000000000000000` will fall in shard `-80`. Any number with the highest bit set will be >= `0x8000000000000000`, and will therefore belong to shard `80-`.

This left-justified approach allows you to have keyspace ids of arbitrary length. However, the most significant bits are the ones on the left.

For example an `md5` hash produces 16 bytes. That can also be used as a keyspace id.

A `varbinary` of arbitrary length can also be mapped as is to a keyspace id. This is what the `binary` vindex does.

In the above case, we are essentially creating two shards: any keyspace id that does not have its leftmost bit set will go to `-80`. All others will go to `80-`.

Applying the above change should result in the creation of six more vttablet instances.

At this point, the tables have been created in the new shards but have no data yet.

```
mysql --table < ../common/select_customer-80_data.sql
Using customer/-80
Customer
COrder
mysql --table < ../common/select_customer80-_data.sql
Using customer/80-
Customer
COrder
```

SplitClone

The process for SplitClone is similar to VerticalSplitClone. It starts the horizontal resharding process:

```
./303_horizontal_split.sh
```

This starts the following job "SplitClone -min_healthy_rdonly_tablets=1 customer/0":

For large tables, this job could potentially run for many days, and can be restarted if failed. This job performs the following tasks:

- Dirty copy data from customer/0 into the two new shards. But rows are split based on their target shards.
- Stop replication on customer/0 rdonly tablet and perform a final sync.
- Start a filtered replication process from customer/0 into the two shards by sending changes to one or the other shard depending on which shard the rows belong to.

Once `SplitClone` has completed, you should see this:

The horizontal counterpart to `VerticalSplitDiff` is `SplitDiff`. It can be used to validate the data integrity of the resharding process "SplitDiff -min_healthy_rdonly_tablets=1 customer/-80":

NOTE: This example does not actually run this command.

Note that the last argument of SplitDiff is the target (smaller) shard. You will need to run one job for each target shard. Also, you cannot run them in parallel because they need to take an `rdonly` instance offline to perform the comparison.

NOTE: SplitDiff can be used to split shards as well as to merge them.

Cut over

Now that you have verified that the tables are being continuously updated from the source shard, you can cutover the traffic. This is typically performed in three steps: `rdonly`, `replica` and `master`:

For rdonly and replica:

```
./304_migrate_replicas.sh
```

For master:

```
./305_migrate_master.sh
```

During the *master* migration, the original shard master will first stop accepting updates. Then the process will wait for the new shard masters to fully catch up on filtered replication before allowing them to begin serving. Since filtered replication has been following along with live updates, there should only be a few seconds of master unavailability.

The replica and rdonly cutovers are freely reversible. Unlike the Vertical Split, a horizontal split is also reversible. You just have to add a `-reverse_replication` flag while cutting over the master. This flag causes the entire resharding process to run in the opposite direction, allowing you to Migrate in the other direction if the need arises.

You should now be able to see the data that has been copied over to the new shards.

```
mysql --table < ../common/select_customer-80_data.sql
Using customer/-80
Customer
+-------------+--------------------+
| customer_id | email              |
+-------------+--------------------+
|           1 | alice@domain.com   |
|           2 | bob@domain.com     |
|           3 | charlie@domain.com |
|           5 | eve@domain.com     |
+-------------+--------------------+
```

```
COrder
+----------+-------------+----------+-------+
| order_id | customer_id | sku      | price |
+----------+-------------+----------+-------+
|        1 |           1 | SKU-1001 |   100 |
|        2 |           2 | SKU-1002 |    30 |
|        3 |           3 | SKU-1002 |    30 |
|        5 |           5 | SKU-1002 |    30 |
+----------+-------------+----------+-------+

mysql --table < ../common/select_customer80-_data.sql
Using customer/80-
Customer
+-------------+----------------+
| customer_id | email          |
+-------------+----------------+
|           4 | dan@domain.com |
+-------------+----------------+
COrder
+----------+-------------+----------+-------+
| order_id | customer_id | sku      | price |
+----------+-------------+----------+-------+
|        4 |           4 | SKU-1002 |    30 |
+----------+-------------+----------+-------+
```

Clean up

After celebrating your second successful resharding, you are now ready to clean up the leftover artifacts:

```
./306_down_shard_0.sh
```

In this script, we just stopped all tablet instances for shard 0. This will cause all those vttablet and `mysqld` processes to be stopped. But the shard metadata is still present. We can clean that up with this command (after all vttablets have been brought down):

```
./307_delete_shard_0.sh
```

This command runs the following "`DeleteShard -recursive customer/0`".

Beyond this, you will also need to manually delete the disk associated with this shard.

Next Steps

Feel free to experiment with your Vitess cluster! Execute the following when you are ready to teardown your example:

```
./401_teardown.sh
```

Vertical Split

{{< warning >}} In Vitess 6, Vertical Split became obsolete with the introduction of MoveTables! It is recommended to skip this guide, and continue on with the MoveTables user guide instead. {{< /warning >}}

{{< info >}} This guide follows on from get started with a local deployment. It assumes that the `./101_initial_cluster.sh` script has been executed, and that you have a running Vitess cluster. {{< /info >}}

Vertical Split enables you to move a subset of tables to their own keyspace. Continuing on from the ecommerce example started in the get started guide, as your database continues to grow, you may decide to separate the `customer` and `corder` tables from the `product` table. Let us add some data into our tables to illustrate how the vertical split works. Paste the following:

```
mysql < ../common/insert_commerce_data.sql
```

We can look at what we just inserted:

```
mysql --table < ../common/select_commerce_data.sql
Using commerce/0
Customer
+-------------+--------------------+
| customer_id | email              |
+-------------+--------------------+
|           1 | alice@domain.com   |
|           2 | bob@domain.com     |
|           3 | charlie@domain.com |
|           4 | dan@domain.com     |
|           5 | eve@domain.com     |
+-------------+--------------------+
Product
+----------+-------------+-------+
| sku      | description | price |
+----------+-------------+-------+
| SKU-1001 | Monitor     |   100 |
| SKU-1002 | Keyboard    |    30 |
+----------+-------------+-------+
COrder
+----------+-------------+----------+-------+
| order_id | customer_id | sku      | price |
+----------+-------------+----------+-------+
|        1 |           1 | SKU-1001 |   100 |
|        2 |           2 | SKU-1002 |    30 |
|        3 |           3 | SKU-1002 |    30 |
|        4 |           4 | SKU-1002 |    30 |
|        5 |           5 | SKU-1002 |    30 |
+----------+-------------+----------+-------+
```

Notice that we are using keyspace `commerce/0` to select data from our tables.

Create Keyspace

For a vertical split, we first need to create a special `served_from` keyspace. This keyspace starts off as an alias for the `commerce` keyspace. Any queries sent to this keyspace will be redirected to `commerce`. Once this is created, we can vertically split tables into the new keyspace without having to make the app aware of this change:

```
./201_customer_keyspace.sh
```

This creates an entry into the topology indicating that any requests to master, replica, or rdonly sent to `customer` must be redirected to (served from) `commerce`. These tablet type specific redirects will be used to control how we transition the cutover from `commerce` to `customer`.

Customer Tablets

Now you have to create vttablet instances to back this new keyspace onto which you'll move the necessary tables:

```
./202_customer_tablets.sh
```

The most significant change, this script makes is the instantiation of vttablets for the new keyspace. Additionally:

- You moved customer and corder from the commerce's VSchema to customer's VSchema. Note that the physical tables are still in commerce.

- You requested that the schema for customer and corder be copied to customer using the `copySchema` directive.

The move in the VSchema should not make a difference yet because any queries sent to customer are still redirected to commerce, where all the data is still present.

VerticalSplitClone

The next step:

```
./203_vertical_split.sh
```

starts the process of migrating the data from commerce to customer.

For large tables, this job could potentially run for many days, and may be restarted if failed. This job performs the following tasks:

- Dirty copy data from commerce's customer and corder tables to customer's tables.
- Stop replication on commerce's rdonly tablet and perform a final sync.
- Start a filtered replication process from commerce->customer that keeps the customer's tables in sync with those in commerce.

NOTE: In production, you would want to run multiple sanity checks on the replication by running `SplitDiff` jobs multiple times before starting the cutover.

We can look at the results of VerticalSplitClone by examining the data in the customer keyspace. Notice that all data in the `customer` and `corder` tables has been copied over.

```
mysql --table < ../common/select_customer0_data.sql
Using customer/0
Customer
+-------------+--------------------+
| customer_id | email              |
+-------------+--------------------+
|           1 | alice@domain.com   |
|           2 | bob@domain.com     |
|           3 | charlie@domain.com |
|           4 | dan@domain.com     |
|           5 | eve@domain.com     |
+-------------+--------------------+
COrder
+----------+-------------+----------+-------+
| order_id | customer_id | sku      | price |
+----------+-------------+----------+-------+
|        1 |           1 | SKU-1001 |   100 |
|        2 |           2 | SKU-1002 |    30 |
|        3 |           3 | SKU-1002 |    30 |
|        4 |           4 | SKU-1002 |    30 |
|        5 |           5 | SKU-1002 |    30 |
+----------+-------------+----------+-------+
```

Cut over

Once you have verified that the `customer` and `corder` tables are being continuously updated from commerce, you can cutover the traffic. This is typically performed in three steps: `rdonly`, `replica` and `master`:

For rdonly and replica:

```
./204_vertical_migrate_replicas.sh
```

For master:

```
./205_vertical_migrate_master.sh
```

Once this is done, the `customer` and `corder` tables are no longer accessible in the `commerce` keyspace. You can verify this by trying to read from them.

```
mysql --table < ../common/select_commerce_data.sql
Using commerce/0
Customer
ERROR 1105 (HY000) at line 4: vtgate: http://vtgate-zone1-5ff9c47db6-7rmld:15001/: target:
   commerce.0.master, used tablet: zone1-1564760600 (zone1-commerce-0-replica-0.vttablet),
   vttablet: rpc error: code = FailedPrecondition desc = disallowed due to rule: enforce
   blacklisted tables (CallerID: userData1)
```

The replica and rdonly cutovers are freely reversible. However, the master cutover is one-way and cannot be reversed. This is a limitation of vertical resharding, which will be resolved in the near future. For now, care should be taken so that no loss of data or availability occurs after the cutover completes.

Clean up

After celebrating your first successful 'vertical resharding', you will need to clean up the leftover artifacts:

```
./206_clean_commerce.sh
```

Those tables are now being served from customer. So, they can be dropped from commerce.

The 'control' records were added by the `MigrateServedFrom` command during the cutover to prevent the commerce tables from accidentally accepting writes. They can now be removed.

After this step, the `customer` and `corder` tables no longer exist in the `commerce` keyspace.

```
mysql --table < ../common/select_commerce_data.sql
Using commerce/0
Customer
ERROR 1105 (HY000) at line 4: vtgate: http://vtgate-zone1-5ff9c47db6-7rmld:15001/: target:
   commerce.0.master, used tablet: zone1-1564760600 (zone1-commerce-0-replica-0.vttablet),
   vttablet: rpc error: code = InvalidArgument desc = table customer not found in schema
   (CallerID: userData1)
```

Next Steps

You can now proceed with Horizontal Sharding.

Or alternatively, if you would like to teardown your example:

```
./401_teardown.sh
```

Migration

description: User guides covering migration to Vitess

Materialize

{{< info >}} This guide follows on from the Get Started guides. Please make sure that you have an Operator, local or Helm installation ready. Make sure you have only run the "101" step of the examples, for example `101_initial_cluster.sh` in the

local example. The commands in this guide also assumes you have setup the shell aliases from the example, e.g. `env.sh` in the local example. {{< /info >}}

Materialize is a new VReplication workflow in Vitess 6. It can be used as a more general way to achieve something similar to MoveTables, or as a way to generate materialized views of a table (or set of tables) in the same or different keyspace from the source table (or set of tables). In general, it can be used to create and maintain continually updated materialized views in Vitess, without having to resort to manual or trigger-based population of the view content.

Since `Materialize` uses VReplication, the view can be kept up-to-date very close to real-time, which enables use-cases like creating copies of the same table sharded different ways for the purposes of certain types of queries that would otherwise be prohibitively expensive on the original table. `Materialize` is also flexible enough to allow for you to pre-create the schema and vschema for the copied table, allowing you to, for example, maintain a copy of a table without some of the source table's MySQL indexes. Alternatively, you could use `Materialize` to do certain schema changes (e.g. change the type of a table column) without having to use other tools like gh-ost.

In our example, we will be using `Materialize` to perform something similar to the MoveTables user guide, which will cover just the basics of what is possible using `Materialize`.

Let's start by simulating this situation by loading sample data:

```
mysql < ../common/insert_commerce_data.sql
```

We can look at what we just inserted:

```
# On helm and local installs:
mysql --table < ../common/select_commerce_data.sql
# With operator:
mysql --table < select_commerce_data.sql

Using commerce/0
Customer
+-------------+--------------------+
| customer_id | email              |
+-------------+--------------------+
|           1 | alice@domain.com   |
|           2 | bob@domain.com     |
|           3 | charlie@domain.com |
|           4 | dan@domain.com     |
|           5 | eve@domain.com     |
+-------------+--------------------+
Product
+----------+-------------+-------+
| sku      | description | price |
+----------+-------------+-------+
| SKU-1001 | Monitor     |   100 |
| SKU-1002 | Keyboard    |    30 |
+----------+-------------+-------+
COrder
+----------+-------------+----------+-------+
| order_id | customer_id | sku      | price |
+----------+-------------+----------+-------+
|        1 |           1 | SKU-1001 |   100 |
|        2 |           2 | SKU-1002 |    30 |
|        3 |           3 | SKU-1002 |    30 |
|        4 |           4 | SKU-1002 |    30 |
|        5 |           5 | SKU-1002 |    30 |
+----------+-------------+----------+-------+
```

Note that we are using keyspace `commerce/0` to select data from our tables.

Planning to use Materialize

In this scenario, we are going to make two copies of the `corder` table **in the same keyspace** using a different tablenames of `corder_view` and `corder_view_redacted`. The first copy will be identical to the source table, but for the `corder_view_redacted` copy, we will use the opportunity to drop the `price` column from the copy. Since we are doing the `Materialize` to the same keyspace, we do not need to create a new keyspace or tablets as we did for the MoveTables user guide.

Create the destination tables

In the case where we using `Materialize` to copy tables between keyspaces, we can use the `"create_ddl": "copy"` option in the `Materialize` `json_spec` `table_settings` to create the target table for us (similar to what `MoveTables` does). However, in our case where we are using `Materialize` with a target table name different from the source table name, we need to manually create the target tables. Let's go ahead and do that:

```
$ mysql -A
Welcome to the MySQL monitor.  Commands end with ; or \g.
.
.

mysql> CREATE TABLE `corder_view` (
  `order_id` bigint NOT NULL,
  `customer_id` bigint DEFAULT NULL,
  `sku` varbinary(128) DEFAULT NULL,
  `price` bigint DEFAULT NULL,
  PRIMARY KEY (`order_id`)
) ENGINE=InnoDB;
Query OK, 0 rows affected (0.13 sec)

mysql> CREATE TABLE `corder_view_redacted` (
  `order_id` bigint NOT NULL,
  `customer_id` bigint DEFAULT NULL,
  `sku` varbinary(128) DEFAULT NULL,
  PRIMARY KEY (`order_id`)
) ENGINE=InnoDB;
Query OK, 0 rows affected (0.09 sec)
```

Now we need to make sure Vitess' view of our schema is up-to-date:

```
$ vtctlclient ReloadSchemaKeyspace commerce
```

And now we can proceed to the `Materialize` step(s).

Start the Materialize (first copy)

We will run two `Materialize` operations, one for each copy/view of the `corder` table we will be creating. We could combine these two operations into a single `Materialize` operation, but we will keep them separate for clarity.

```
$ vtctlclient Materialize '{"workflow": "copy_corder_1", "source_keyspace": "commerce",
   "target_keyspace": "commerce", "table_settings": [{"target_table": "corder_view",
   "source_expression": "select * from corder"}]}'
```

Now, we should see the materialized view table `corder_view`:

```
$ echo "select * from corder_view;" | mysql --table commerce
+----------+-------------+----------+-------+
| order_id | customer_id | sku      | price |
+----------+-------------+----------+-------+
```

```
|        1 |           1 | SKU-1001 |   100 |
|        2 |           2 | SKU-1002 |    30 |
|        3 |           3 | SKU-1002 |    30 |
|        4 |           4 | SKU-1002 |    30 |
|        5 |           5 | SKU-1002 |    30 |
+----------+-------------+----------+-------+
```

And if we insert a row into the source table, it will be replicated to the materialized view:

```
$ echo "insert into corder (order_id, customer_id, sku, price) values (6, 6, 'SKU-1002',
   30);" | mysql commerce
$ echo "select * from corder_view;" | mysql --table commerce
+----------+-------------+----------+-------+
| order_id | customer_id | sku      | price |
+----------+-------------+----------+-------+
|        1 |           1 | SKU-1001 |   100 |
|        2 |           2 | SKU-1002 |    30 |
|        3 |           3 | SKU-1002 |    30 |
|        4 |           4 | SKU-1002 |    30 |
|        5 |           5 | SKU-1002 |    30 |
|        6 |           6 | SKU-1002 |    30 |
+----------+-------------+----------+-------+
```

Note that the target table is just a normal table, there is nothing that prevents you from writing to it directly. While you might not want to do that in this "view" use-case, in certain other use-cases, it might be completely acceptable to write to the table, as long as you don't end up altering or removing rows in a fashion that would break the "replication" part of VReplication (e.g. removing a row in the target table directly that is later updated in the source table).

Viewing the workflow while in progress

While we can also see and manipulate the underlying VReplication streams created by `Materialize`; there are commands to show, stop, start and delete the operations associated with a Materialize workflow. For example, once we have started the `Materialize` command above, we can observe the status of the VReplication stream doing the materialization via the `vtctlclient Workflow` command:

```
$ vtctlclient Workflow commerce.copy_corder_1 show
{
    "Workflow": "copy_corder_1",
    "SourceLocation": {
        "Keyspace": "commerce",
        "Shards": [
            "0"
        ]
    },
    "TargetLocation": {
        "Keyspace": "commerce",
        "Shards": [
            "0"
        ]
    },
    "MaxVReplicationLag": 1599019410,
    "ShardStatuses": {
        "0/zone1-0000000100": {
            "MasterReplicationStatuses": [
                {
                    "Shard": "0",
                    "Tablet": "zone1-0000000100",
```

```
                    "ID": 4,
                    "Bls": {
                        "keyspace": "commerce",
                        "shard": "0",
                        "filter": {
                            "rules": [
                                {
                                    "match": "corder_view",
                                    "filter": "select * from corder"
                                }
                            ]
                        }
                    },
                    "Pos": "MySQL56/c0d82d27-ecd0-11ea-9840-001e677affd5:1-97978",
                    "StopPos": "",
                    "State": "Copying",
                    "MaxReplicationLag": 9223372036854775807,
                    "DBName": "vt_commerce",
                    "TransactionTimestamp": 0,
                    "TimeUpdated": 1599019408,
                    "Message": "",
                    "CopyState": [
                        {
                            "Table": "corder_view",
                            "LastPK": "fields:<name:\"order_id\" type:INT64 >
                               rows:<lengths:5 values:\"37014\" >"
                        }
                    ]
                }
            ],
            "TabletControls": null,
            "MasterIsServing": true
        }
    }
}
```

Note the state of `Copying`, this will transition to `Running` when the bulk copying of rows is complete.

We can now also use the stop/start commands to temporarily stop the materialization workflow. E.g. `stop`:

```
$ vtctlclient Workflow commerce.copy_corder_1 stop
+------------------+--------------+
|      Tablet      | RowsAffected |
+------------------+--------------+
| zone1-0000000100 |            1 |
+------------------+--------------+
```

And `start` to start the workflow again and continue the materialization:

```
$ vtctlclient Workflow commerce.copy_corder_1 start
+------------------+--------------+
|      Tablet      | RowsAffected |
+------------------+--------------+
| zone1-0000000100 |            1 |
+------------------+--------------+
```

Eventually, when the copy is done, or we have materialized the data, and do not want to continue the copy of new source rows, we can delete the workflow via:

```
$ vtctlclient Workflow commerce.copy_corder_1 delete
+------------------+--------------+
|      Tablet      | RowsAffected |
+------------------+--------------+
| zone1-0000000100 |            1 |
+------------------+--------------+
```

Note that deleting the workflow will not drop the target table for the `Materialize` workflow, or any of the data already copied. The data in the target table will remain as it was at the moment the workflow was deleted (or previously stopped).

Start the Materialize (redacted copy)

Now, we can perform the copy to the `corder_view_redacted` table we created earlier. Note that we created this table without a price column; we will not be copying that column.

```
$ vtctlclient Materialize '{"workflow": "copy_corder_2", "source_keyspace": "commerce",
   "target_keyspace": "commerce", "table_settings": [{"target_table":
   "corder_view_redacted", "source_expression": "select order_id, customer_id, sku from
   corder"}]}'
```

Again, looking the target table will show all the source table rows, this time without the `sku` column:

```
$ echo "select * from corder_view_redacted;" | mysql --table commerce
+----------+-------------+----------+
| order_id | customer_id | sku      |
+----------+-------------+----------+
|        1 |           1 | SKU-1001 |
|        2 |           2 | SKU-1002 |
|        3 |           3 | SKU-1002 |
|        4 |           4 | SKU-1002 |
|        5 |           5 | SKU-1002 |
|        6 |           6 | SKU-1002 |
+----------+-------------+----------+
```

Again, we can add a row to the source table, and see it replicated into the target table:

```
$ echo "insert into corder (order_id, customer_id, sku, price) values (7, 7, 'SKU-1002',
   30);" | mysql commerce
$ echo "select * from corder_view_redacted;" | mysql --table commerce
+----------+-------------+----------+
| order_id | customer_id | sku      |
+----------+-------------+----------+
|        1 |           1 | SKU-1001 |
|        2 |           2 | SKU-1002 |
|        3 |           3 | SKU-1002 |
|        4 |           4 | SKU-1002 |
|        5 |           5 | SKU-1002 |
|        6 |           6 | SKU-1002 |
|        7 |           7 | SKU-1002 |
+----------+-------------+----------+
```

What happened under the covers

As with `MoveTables`, a VReplication stream was formed for each of the `Materialize` workflows we executed. We can see these by inspecting the VReplication table on the target keyspace master tablet, e.g. in this case:

```
$ vtctlclient VReplicationExec zone1-0000000100 'select * from _vt.vreplication'
+----+---------------+----------------------------------------------+----------------------------
| id |   workflow    |                    source                    |
   pos                          | stop_pos |       max_tps       | max_replication_lag |
   cell | tablet_types | time_updated | transaction_timestamp |  state  | message |
   db_name   |
+----+---------------+----------------------------------------------+----------------------------
|  1 | copy_corder_1 | keyspace:"commerce" shard:"0"                |
   MySQL56/00a04e3a-e74d-11ea-a8c9-001e677affd5:1-926 |          | 9223372036854775807 |
   9223372036854775807 |      |              |   1598416592 |            1598416591 |
   Running |         | vt_commerce |
|    |               | filter:<rules:<match:"corder_view"           |
                                                 |          |                      |
                       |      |              |              |                      |
           |         |             |
|    |               | filter:"select * from corder" > >            |
                                                 |          |                      |
                       |      |              |              |                      |
           |         |             |
|  2 | copy_corder_2 | keyspace:"commerce" shard:"0"                |
   MySQL56/00a04e3a-e74d-11ea-a8c9-001e677affd5:1-926 |          | 9223372036854775807 |
   9223372036854775807 |      |              |   1598416592 |            1598416591 |
   Running |         | vt_commerce |
|    |               | filter:<rules:<match:"corder_view_redacted" |
                                                 |          |                      |
                       |      |              |              |                      |
           |         |             |
|    |               | filter:"select order_id, customer_id, sku    |
                                                 |          |                      |
                       |      |              |              |                      |
           |         |             |
|    |               | from corder" > >                             |
                                                 |          |                      |
                       |      |              |              |                      |
           |         |             |
+----+---------------+----------------------------------------------+----------------------------
```

It is important to use the `vtctlclient VReplicationExec` command to inspect this table, since some of the fields are binary and might not render properly in a MySQL client (at least with default options). In the above output, you can see a summary of the VReplication streams that were setup (and are still `Running`) to copy and then do continuous replication of the source table (`corder`) to the two different target tables.

Cleanup

As seen earlier, you can easily use the `vtctlclient Workflow ... delete` command to clean up a materialize operation. If you like, you can also instead use the `VReplicationExec` command to temporarily stop the replication streams for the VReplication streams that make up the `Materialize` process. For example, to stop both streams, you can do:

```
$ vtctlclient VReplicationExec zone1-0000000100 'update _vt.vreplication set state =
   "Stopped" where id in (1,2)'
+
+
$ vtctlclient VReplicationExec zone1-0000000100 'select * from _vt.vreplication'
+----+---------------+----------------------------------------------+----------------------------
| id |   workflow    |                    source                    |
                           pos                          | stop_pos |       max_tps       |
```

```
   max_replication_lag | cell | tablet_types | time_updated | transaction_timestamp |
   state  | message |   db_name   |
+----+---------------+-------------------------------------------------+-----------------------------
|  1 | copy_corder_1 | keyspace:"commerce" shard:"0"                   |
   MySQL56/00a04e3a-e74d-11ea-a8c9-001e677affd5:1-1218 |          | 9223372036854775807 |
   9223372036854775807 |      |              |   1598416861 |            1598416859 |
   Stopped |         | vt_commerce |
|    |               | filter:<rules:<match:"corder_view"          |
                                                 |          |                     |
                       |      |              |              |                     |
           |         |             |
|    |               | filter:"select * from corder" > >           |
                                                 |          |                     |
                       |      |              |              |                     |
           |         |             |
|  2 | copy_corder_2 | keyspace:"commerce" shard:"0"                   |
   MySQL56/00a04e3a-e74d-11ea-a8c9-001e677affd5:1-1218 |          | 9223372036854775807 |
   9223372036854775807 |      |              |   1598416861 |            1598416859 |
   Stopped |         | vt_commerce |
|    |               | filter:<rules:<match:"corder_view_redacted" |
                                                 |          |                     |
                       |      |              |              |                     |
           |         |             |
|    |               | filter:"select order_id, customer_id, sku   |
                                                 |          |                     |
                       |      |              |              |                     |
           |         |             |
|    |               | from corder" > >                            |
                                                 |          |                     |
                       |      |              |              |                     |
           |         |             |
+----+---------------+-------------------------------------------------+-----------------------------
```

Any changes to the source tables will now not be applied to the target tables until you update the `state` column back to `Running`.

Lastly, you can clean up the `Materialize` process by just using `VReplicationExec` to delete the rows in the `_vt.vreplication` table. This will do the necessary runtime cleanup as well. E.g.:

```
$ vtctlclient VReplicationExec zone1-0000000100 'delete from  _vt.vreplication where id in
   (1,2)'
+
+
$ vtctlclient VReplicationExec zone1-0000000100 'select * from _vt.vreplication'
+----+----------+--------+-----+----------+---------+---------------------+------+--------------+-
| id | workflow | source | pos | stop_pos | max_tps | max_replication_lag | cell |
   tablet_types | time_updated | transaction_timestamp | state | message | db_name |
+----+----------+--------+-----+----------+---------+---------------------+------+--------------+-
+----+----------+--------+-----+----------+---------+---------------------+------+--------------+-
```

Note that this just cleans up the VReplication streams; the actual source and target tables are left untouched and in the same state they were at the moment the VReplication streams were stopped or deleted.

Recap

As mentioned at the beginning, `Materialize` gives you finer control over the VReplication process without having to form VReplication rules completely by hand. For the ultimate flexibility, that is still possible, but you should be able to use `Materialize` together with other Vitess features like routing rules to cover a large set of potential migration and data maintenance use-cases without resorting to creating VReplication rules directly.

Migrating data into Vitess

Introduction

There are two main parts to migrating your data to Vitess: migrating the actual data and repointing the application. The answer here will focus primarily on the methods that can be used to migrate your data into Vitess.

Overview

There are three different methods to migrate your data into Vitess. Choosing the appropriate option depends on several factors. 1. The nature of the application accessing the MySQL database 1. The size of the MySQL database to be migrated 1. The load, especially the write load, on the MySQL database 1. Your tolerance for downtime during the migration of data 1. Whether you require the ability to reverse the migration if needed 1. The network level configuration of your components

The three different methods are:

- 'Stop-the-world'
- VReplication from Vitess setup in front of the existing external MySQL database
- Application-level migration

Method 1: "Stop-the-world":

The simplest method to migrate data is to do a 'dump and restore' or 'stop-the-world'. We recommend using 'go-mydumper'. To execute this method you would follow these steps: 1. Stop writing to the source MySQL database 1. Take a logical dump of the database using go-mydumper or possibly mysqldump 1. Apply some simple transformations on the output 1. Import the data into Vitess via the frontend 1. Repoint your application to the new database
1. Resume writing to the new database in Vitess

This method is only suitable for migrating small or non-critical databases that can tolerate downtime. The database will be unavailable for writes between the time the dump is started and the time the restore of the dump is completed. For databases of 10's of GB and up this process could take hours or even days. The amount of downtime scales with the amount of data being migrated.

Please note the 'dump and restore' method likely isn't viable for most production applications, unless the applicable downtime can be handled.

Method 2: VReplication from Vitess setup in front of the existing external MySQL database

A set of Vitess components will be created, on a temporary basis, to run in front of the source MySQL database in order to migrate the data. These components should reference at least one of the replicas, in addition to the master, of the MySQL database. The Vitess components can be run on bare metal, in a VM, or potentially even in Kubernetes.

It is important to note that the Vitess components must be reachable over a network by Vitess's backend systems. Your topology must be set up such that the source database is reachable from your vitess cluster. Similarly, all the VTTablets being configured for migration must be set up to run against your database within the same Vitess cluster.

Vitess offers a choice of two VReplication commands to perform the data migration process described above: *MoveTables* or *Materialize*.

Both methods use a combination of transactional SELECTs and filtered MySQL replication to copy each of the tables in the source database to Vitess. Once all the data is copied, the two databases are kept in sync using the replication stream from the source database. While in this synchronized state, you can verify the source and destination are in sync, and testing on the copy of the data in Vitess can commence.

Once the testing has completed, application traffic can be removed from the source MySQL database and switched to the Vitess database. For this switch, a small amount of downtime will be necessary. This downtime could be seconds or minutes, depending on the application and application automation.

There are some differences between *MoveTables* and *Materialize* that you will need to evaluate to determine which process to use:

Materialize: This process works well if you want to get data out as purely a copy or you want to transform the data during the copying process

- Has more flexibility because you can transform the data while you are migrating it. E.g. you can choose not to migrate specific columns from a table
- It isn't directly reversible. E.g. changes to the downstream Vitess copy of the data after the application cutover will not flow back to the original source MySQL database
- Switching over application traffic is not integrated. You have to manually configure the commands in order to do the switch over

MoveTables: This process works well if you want to have minimum downtime during the switch over and to be able to reverse the switch over

- Switch reads and switch writes are integrated
- Allows the switch over to be reversible due to reverse replication. Writes to Vitess can be propagated back to the source MySQL database after the copy
- Cannot transform the data during the migration. The assumption is that the entire dataset is being copied as is

Choosing the Right Method The first and most important point to consider when choosing the right method is whether you can or cannot interconnect between components on your network. If you cannot, or do not wish to, perform extra steps to ensure interconnectivity then you will need to use the 'Stop-the-world' method.

If you can ensure interconnectivity and that the target VTTablets are in the same Vitess cluster, then for cases when larger amounts of downtime are not an option you will want to use VReplication with either *MoveTables* or *Materialize*.

Method 3: Application-level migration

In some cases it might be necessary to perform the data migration on an application level. Reasons for this might be things like:

- The source data is spread across a large set of MySQL databases, and is being consolidated as part of the migration process. Thus it's not possible to migrate data using only normal MySQL replication
- The source database systems are not running MySQL Row-Based Replication and it's not possible, feasible, or practical to convert them
- The source database system might not be MySQL, in which case a custom application-level migration will be necessary

In these cases custom tools must first be written on the application side to start writing data to both the legacy database and Vitess. Secondly, the source data must be moved over in bulk to the Vitess database and then the switch over can be performed.

There are multiple options to do those steps, however we won't go into detail as each situation for these cases is unique. A summary of some potential options are:

"Stop the world":

- Write application-level tools to export, import, and verify data between the source and destination systems.

Dual writes:

- Modify the application to start doing dual writes between the source and destination databases, while the application is still pointing to the source database as the primary datastore.
- Create custom tools to backfill old data from the source to destination system. VReplication could be used to form a part of this solution.
- Cut-over by having the application start to read, as well as write, from the destination Vitess database as the primary data source. This option can be reversible, assuming the dual writes continue after the read cutover.

MoveTables

{{< info >}} This guide follows on from the Get Started guides. Please make sure that you have an Operator, local or Helm installation ready after the `101_initial_cluster` step, and making sure you have setup aliases and port-forwarding (if necessary). {{< /info >}}

MoveTables is a new VReplication workflow in Vitess 6 and later, and obsoletes Vertical Split from earlier releases.

This feature enables you to move a subset of tables between keyspaces without downtime. For example, after Initially deploying Vitess, your single commerce schema may grow so large that it needs to be split into multiple keyspaces.

As a stepping stone towards splitting a single table across multiple servers (sharding), it usually makes sense to first split from having a single monolithic keyspace (`commerce`) to having multiple keyspaces (`commerce` and `customer`). For example, in our hypothetical ecommerce system we may know that `customer` and `corder` tables are closely related and both growing quickly.

Let's start by simulating this situation by loading sample data:

```
mysql < ../common/insert_commerce_data.sql
```

We can look at what we just inserted:

```
# On helm and local installs:
mysql --table < ../common/select_commerce_data.sql
# With operator:
mysql --table < select_commerce_data.sql

Using commerce/0
customer
+-------------+--------------------+
| customer_id | email              |
+-------------+--------------------+
|           1 | alice@domain.com   |
|           2 | bob@domain.com     |
|           3 | charlie@domain.com |
|           4 | dan@domain.com     |
|           5 | eve@domain.com     |
+-------------+--------------------+
product
+----------+-------------+-------+
| sku      | description | price |
+----------+-------------+-------+
| SKU-1001 | Monitor     |   100 |
| SKU-1002 | Keyboard    |    30 |
+----------+-------------+-------+
corder
+----------+-------------+----------+-------+
| order_id | customer_id | sku      | price |
+----------+-------------+----------+-------+
|        1 |           1 | SKU-1001 |   100 |
|        2 |           2 | SKU-1002 |    30 |
|        3 |           3 | SKU-1002 |    30 |
|        4 |           4 | SKU-1002 |    30 |
|        5 |           5 | SKU-1002 |    30 |
+----------+-------------+----------+-------+
```

Notice that we are using keyspace `commerce/0` to select data from our tables.

Planning to Move Tables

In this scenario, we are going to add the `customer` keyspace to the `commerce` keyspace we already have. This new keyspace will be backed by its own set of mysqld instances. We will then move the tables `customer` and `corder` from the `commerce` keyspace into the newly created `customer`. The `product` table will remain in the `commerce` keyspace. This operation happens online, which means that it does not block either read or write operations to the tables, **except** for a small window during the final cut-over.

Show our current tablets

```
$ echo "show vitess_tablets;" | mysql --table
+-------+----------+-------+------------+---------+------------------+-----------+----------------
| Cell  | Keyspace | Shard | TabletType | State   | Alias            | Hostname  |
   MasterTermStartTime  |
+-------+----------+-------+------------+---------+------------------+-----------+----------------
| zone1 | commerce | 0     | MASTER     | SERVING | zone1-0000000100 | localhost |
   2020-08-26T00:37:21Z |
| zone1 | commerce | 0     | REPLICA    | SERVING | zone1-0000000101 | localhost |
                        |
| zone1 | commerce | 0     | RDONLY     | SERVING | zone1-0000000102 | localhost |
                        |
+-------+----------+-------+------------+---------+------------------+-----------+----------------
```

As can be seen, we have 3 tablets running, with tablet ids 100, 101 and 102; which we use in the examples to form the tablet alias/names like `zone1-0000000100`, etc.

Create new tablets

The first step in our MoveTables operation is to deploy new tablets for our `customer` keyspace. By the convention used in our examples, we are going to use the tablet ids 200-202 as the `commerce` keyspace previously used `100-102`. Once the tablets have started, we can force the first tablet to be the master using the `InitShardMaster -force` flag:

```
helm upgrade vitess ../../helm/vitess/ -f 201_customer_tablets.yaml
```

After a few minutes the pods should appear running:

```
$ kubectl get pods,jobs
NAME                                            READY   STATUS      RESTARTS   AGE
pod/vtctld-58bd955948-pgz7k                     1/1     Running     0          5m36s
pod/vtgate-zone1-c7444bbf6-t5xc6                1/1     Running     3          5m36s
pod/zone1-commerce-0-init-shard-master-gshz9    0/1     Completed   0          5m35s
pod/zone1-commerce-0-replica-0                  2/2     Running     0          5m35s
pod/zone1-commerce-0-replica-1                  2/2     Running     0          5m35s
pod/zone1-commerce-0-replica-2                  2/2     Running     0          5m35s
pod/zone1-customer-0-init-shard-master-7w7rm    0/1     Completed   0          84s
pod/zone1-customer-0-replica-0                  2/2     Running     0          84s
pod/zone1-customer-0-replica-1                  2/2     Running     0          84s
pod/zone1-customer-0-replica-2                  2/2     Running     0          84s

NAME                                            COMPLETIONS   DURATION   AGE
job.batch/zone1-commerce-0-init-shard-master    1/1           90s        5m36s
job.batch/zone1-customer-0-init-shard-master    1/1           23s        84s
```

`InitShardMaster` is performed implicitly by Helm for you.

```
kubectl apply -f 201_customer_tablets.yaml
```

After a few minutes the pods should appear running:

```
$ kubectl get pods
NAME                                          READY   STATUS    RESTARTS   AGE
example-etcd-faf13de3-1                       1/1     Running   0          8m11s
example-etcd-faf13de3-2                       1/1     Running   0          8m11s
example-etcd-faf13de3-3                       1/1     Running   0          8m11s
example-vttablet-zone1-1250593518-17c58396    3/3     Running   1          2m20s
example-vttablet-zone1-2469782763-bfadd780    3/3     Running   1          7m57s
example-vttablet-zone1-2548885007-46a852d0    3/3     Running   1          7m47s
example-vttablet-zone1-3778123133-6f4ed5fc    3/3     Running   1          2m20s
example-zone1-vtctld-1d4dcad0-59d8498459-kdml8   1/1     Running   1          8m11s
example-zone1-vtgate-bc6cde92-6bd99c6888-csnkj   1/1     Running   2          8m11s
vitess-operator-8454d86687-4wfnc              1/1     Running   0          22m
```

Again, the operator will perform `InitShardMaster` implicitly for you.

Make sure that you restart the port-forward after launching the pods has completed:

```
killall kubectl
./pf.sh &
```

```
for i in 200 201 202; do
 CELL=zone1 TABLET_UID=$i ./scripts/mysqlctl-up.sh
 CELL=zone1 KEYSPACE=customer TABLET_UID=$i ./scripts/vttablet-up.sh
done

vtctlclient InitShardMaster -force customer/0 zone1-200
vtctlclient ReloadSchemaKeyspace customer
```

Show our old and new tablets

```
$ echo "show vitess_tablets;" | mysql --table
+-------+----------+-------+------------+---------+------------------+-----------+----------------
| Cell  | Keyspace | Shard | TabletType | State   | Alias            | Hostname  |
   MasterTermStartTime  |
+-------+----------+-------+------------+---------+------------------+-----------+----------------
| zone1 | commerce | 0     | MASTER     | SERVING | zone1-0000000100 | localhost |
   2020-08-26T00:37:21Z |
| zone1 | commerce | 0     | REPLICA    | SERVING | zone1-0000000101 | localhost |
                        |
| zone1 | commerce | 0     | RDONLY     | SERVING | zone1-0000000102 | localhost |
                        |
| zone1 | customer | 0     | MASTER     | SERVING | zone1-0000000200 | localhost |
   2020-08-26T00:52:39Z |
| zone1 | customer | 0     | REPLICA    | SERVING | zone1-0000000201 | localhost |
                        |
| zone1 | customer | 0     | RDONLY     | SERVING | zone1-0000000202 | localhost |
                        |
+-------+----------+-------+------------+---------+------------------+-----------+----------------
```

Note: The following change does not change actual routing yet. We will use a *switch* directive to achieve that shortly.

Start the Move

In this step we will initiate the MoveTables, which copies tables from the commerce keyspace into customer. This operation does not block any database activity; the MoveTables operation is performed online:

```
$ vtctlclient MoveTables -workflow=commerce2customer commerce customer '{"customer":{},
   "corder":{}}'
```

You can read this command as: "Start copying the tables called **customer** and **corder** from the **commerce** keyspace to the **customer** keyspace."

A few things to note:

- In a real-world situation this process might take hours/days to complete if the table has millions or billions of rows.
- The workflow name (`commerce2customer` in this case) is arbitrary, you can name it whatever you want. You will use this handle/alias for the other `MoveTables` related commands like `SwitchReads` and `SwitchWrites` in the next steps.

Check routing rules (optional)

To see what happens under the covers, let's look at the **routing rules** that the `MoveTables` operation created. These are instructions used by VTGate to determine which backend keyspace to send requests for a given table or schema/table combo:

```
$ vtctlclient GetRoutingRules commerce
{
  "rules": [
    {
      "fromTable": "customer",
      "toTables": [
        "commerce.customer"
      ]
    },
    {
      "fromTable": "customer.customer",
      "toTables": [
        "commerce.customer"
      ]
    },
    {
      "fromTable": "corder",
      "toTables": [
        "commerce.corder"
      ]
    },
    {
      "fromTable": "customer.corder",
      "toTables": [
        "commerce.corder"
      ]
    }
  ]
}
```

Basically what the `MoveTables` operation has done is to create routing rules to explicitly route queries to the tables `customer` and `corder`, as well as the schema/table combos of `customer.customer` and `customer.corder` to the respective tables in the `commerce` keyspace. This is done so that when `MoveTables` creates the new copy of the tables in the `customer` keyspace, there is no ambiguity about where to route requests for the `customer` and `corder` tables. All requests for those tables will keep going to the original instance of those tables in `commerce` keyspace. Any changes to the tables after the `MoveTables` is executed will be copied faithfully to the new copy of these tables in the `customer` keyspace.

Monitoring Progress (optional)

In this example there are only a few rows in the tables, so the `MoveTables` operation only takes seconds. If the tables were large, you may need to monitor the progress of the operation. There is no simple way to get a percentage complete status, but you can estimate the progress by running the following against the master tablet of the target keyspace:

```
$ vtctlclient VReplicationExec zone1-0000000200 "select * from _vt.copy_state"
+----------+------------+--------+
| vrepl_id | table_name | lastpk |
+----------+------------+--------+
+----------+------------+--------+
```

In the above case the copy is already complete, but if it was still ongoing, there would be details about the last PK (primary key) copied by the VReplication copy process. You could use information about the last copied PK along with the max PK and data distribution of the source table to estimate progress.

Validate Correctness (optional)

We can use VDiff to checksum the two sources and confirm they are in sync:

```
$ vtctlclient VDiff customer.commerce2customer
```

You should see output similar to the following:

```
Summary for corder: {ProcessedRows:5 MatchingRows:5 MismatchedRows:0 ExtraRowsSource:0
   ExtraRowsTarget:0}
Summary for customer: {ProcessedRows:5 MatchingRows:5 MismatchedRows:0 ExtraRowsSource:0
   ExtraRowsTarget:0}
```

This can obviously take a long time on very large tables.

Phase 1: Switch Reads

Once the MoveTables operation is complete, the first step in making the changes live is to *switch* `SELECT` statements to read from the new keyspace. Other statements will continue to route to the `commerce` keyspace. By staging this as two operations, Vitess allows you to test the changes and reduce the associated risks. For example, you may have a different configuration of hardware or software on the new keyspace.

```
vtctlclient SwitchReads -tablet_type=rdonly customer.commerce2customer
vtctlclient SwitchReads -tablet_type=replica customer.commerce2customer
```

Interlude: check the routing rules (optional)

Lets look at what has happened to the routing rules since we checked the last time. The two `SwitchReads` commands above added a number of new routing rules for the tables involved in the `MoveTables` operation/workflow, e.g.:

```
$ vtctlclient GetRoutingRules commerce
{
  "rules": [
    {
      "fromTable": "commerce.corder@rdonly",
      "toTables": [
        "customer.corder"
      ]
    },
    {
      "fromTable": "commerce.corder@replica",
      "toTables": [
        "customer.corder"
      ]
    },
    {
      "fromTable": "customer.customer@rdonly",
      "toTables": [
        "customer.customer"
      ]
    },
    {
      "fromTable": "customer@rdonly",
      "toTables": [
        "customer.customer"
      ]
    },
    {
      "fromTable": "commerce.customer@replica",
      "toTables": [
        "customer.customer"
      ]
    },
    {
      "fromTable": "corder",
      "toTables": [
        "commerce.corder"
      ]
    },
    {
      "fromTable": "customer.corder@replica",
      "toTables": [
        "customer.corder"
      ]
    },
    {
      "fromTable": "customer.customer@replica",
      "toTables": [
        "customer.customer"
      ]
    },
    {
```

```
      "fromTable": "customer.corder",
      "toTables": [
        "commerce.corder"
      ]
    },
    {
      "fromTable": "corder@rdonly",
      "toTables": [
        "customer.corder"
      ]
    },
    {
      "fromTable": "customer.corder@rdonly",
      "toTables": [
        "customer.corder"
      ]
    },
    {
      "fromTable": "customer",
      "toTables": [
        "commerce.customer"
      ]
    },
    {
      "fromTable": "customer.customer",
      "toTables": [
        "commerce.customer"
      ]
    },
    {
      "fromTable": "commerce.customer@rdonly",
      "toTables": [
        "customer.customer"
      ]
    },
    {
      "fromTable": "corder@replica",
      "toTables": [
        "customer.corder"
      ]
    },
    {
      "fromTable": "customer@replica",
      "toTables": [
        "customer.customer"
      ]
    }
  ]
}
```

As you can see, we now have requests to the `rdonly` and `replica` tablets for the source `commerce` keyspace being redirected to the in-sync copy of the table in the target `customer` keyspace.

Phase 2: Switch Writes

After the reads have been *switched*, and you have verified that the system is operating as expected, it is time to *switch* the *write* operations. The command to execute the switch is very similar to switching reads:

```
$ vtctlclient SwitchWrites customer.commerce2customer
```

Interlude: check the routing rules (optional)

Again, if we look at the routing rules after the `SwitchWrites` process, we will find that it has been cleaned up, and replaced with a blanket redirect for the moved tables (`customer` and `corder`) from the source keyspace (`commerce`) to the target keyspace (`customer`), e.g.:

```
$ vtctlclient GetRoutingRules commerce
{
  "rules": [
    {
      "fromTable": "commerce.customer",
      "toTables": [
        "customer.customer"
      ]
    },
    {
      "fromTable": "customer",
      "toTables": [
        "customer.customer"
      ]
    },
    {
      "fromTable": "commerce.corder",
      "toTables": [
        "customer.corder"
      ]
    },
    {
      "fromTable": "corder",
      "toTables": [
        "customer.corder"
      ]
    }
  ]
}
```

Reverse workflow

As part of the `SwitchWrites` operation above, Vitess will automatically (unless you supply the `-reverse_replication false` flag) setup a reverse VReplication workflow to copy changes now applied to the moved tables in the target keyspace (i.e. tables `customer` and `corder` in the `customer` keyspace) back to the original source tables in the source keyspace (`customer`). This allows us to reverse the process using additional `SwitchReads` and `SwitchWrites` commands without data loss, even after we have started writing to the new copy of the table in the new keyspace. Note that the workflow for this reverse process is given the name of the original workflow with `_reverse` appended. So in our example where the MoveTables workflow was called `commerce2customer`; the reverse workflow would be `commerce2customer_reverse`.

Drop Sources

The final step is to remove the data from the original keyspace. As well as freeing space on the original tablets, this is an important step to eliminate potential future confusions. If you have a misconfiguration down the line and accidentally route queries for the `customer` and `corder` tables to `commerce`, it is much better to return a "table not found" error, rather than return stale data:

```
$ vtctlclient DropSources customer.commerce2customer
```

After this step is complete, you should see an error similar to:

```
# Expected to fail!
mysql --table < ../common/select_commerce_data.sql
Using commerce/0
Customer
ERROR 1146 (42S02) at line 4: vtgate: http://localhost:15001/: target: commerce.0.master,
   used tablet: zone1-100
(localhost): vttablet: rpc error: code = NotFound desc = Table 'vt_commerce.customer'
   doesn't exist (errno 1146)
(sqlstate 42S02) (CallerID: userData1): Sql: "select * from customer", BindVars: {}
```

This confirms that the data has been correctly cleaned up. Note that the `DropSources` process also cleans up the reverse VReplication workflow mentioned above. Finally, the only thing that is not cleaned up is the explicit routing rules from the source keyspace to the target keyspace. The assumption is that you might still have applications that refer to the tables by their explicit `schema.table` designation, and you want these applications to (still) transparently be forwarded to the new location of the data. When you are absolutely sure that no applications are using this access pattern, you can clean up the routing rules by manually adjusting the routing rules via the `vtctlclient ApplyRoutingRules` command.

Next Steps

Congratulations! You've successfully moved tables between keyspaces. The next step to try out is to shard one of your keyspaces in Resharding.

Operational

description: User guides for covering operational aspects of Vitess description: User guides covering operational aspects of Vitess — — ## Backup and Restore

Backup and Restore are integrated features provided by tablets managed by Vitess. As well as using *backups* for data integrity, Vitess will also create and restore backups for provisioning new tablets in an existing shard.

Concepts

Vitess supports pluggable interfaces for both Backup Storage Services and Backup Engines.

Before backing up or restoring a tablet, you need to ensure that the tablet is aware of the Backup Storage system and Backup engine that you are using. To do so, use the following command-line flags when starting a vttablet that has access to the location where you are storing backups.

Backup Storage Services Currently, Vitess has plugins for:

- A network-mounted path (e.g. NFS)
- Google Cloud Storage
- Amazon S3
- Ceph

Backup Engines The engine is the techology used for generating the backup. Currently Vitess has plugins for:

- Builtin: Shutdown an instance and copy all the database files (default)
- XtraBackup: An online backup using Percona's XtraBackup

VTTablet Configuration

The following options can be used to configure VTTablet for backups:

Flags

backup_storage_implementation

Specifies the implementation of the Backup Storage interface to use. Current plugin options available are:

file: NFS or any other filesystem-mounted network drive.

gcs: Google Cloud Storage.

s3: Amazon S3.

ceph: Ceph Object Gateway S3 API.

```
  </td>
</tr>
<tr>
  <td><code>backup_engine_implementation</code></td>
  <td>Specifies the implementation of the Backup Engine to
    use.<br><br>
    Current options available are:
    <ul>
      <li><code>builtin</code>: Copy all the database files into specified storage. This is
         the default.</li>
      <li><code>xtrabackup</code>: Percona Xtrabackup.</li>
    </ul>
  </td>
</tr>
<tr>
  <td><code>backup_storage_hook</code></td>
  <td>If set, the content of every file to backup is sent to a hook. The
    hook receives the data for each file on stdin. It should echo the
    transformed data to stdout. Anything the hook prints to stderr will
    be printed in the vttablet logs.<br>
    Hooks should be located in the <code>vthook</code> subdirectory of the
    <code>VTROOT</code> directory.<br>
    The hook receives a <code>-operation write</code> or a
    <code>-operation read</code> parameter depending on the direction
    of the data processing. For instance, <code>write</code> would be for
    encryption, and <code>read</code> would be for decryption.</br>
  </td>
</tr>
<tr>
```

```
  <td><code>backup_storage_compress</code></td>
  <td>This flag controls if the backups are compressed by the Vitess code.
    By default it is set to true. Use
    <code>-backup_storage_compress=false</code> to disable.</br>
    This is meant to be used with a <code>-backup_storage_hook</code>
    hook that already compresses the data, to avoid compressing the data
    twice.
  </td>
</tr>
<tr>
  <td><code>file_backup_storage_root</code></td>
  <td>For the <code>file</code> plugin, this identifies the root directory
    for backups.
  </td>
</tr>
<tr>
  <td><code>gcs_backup_storage_bucket</code></td>
  <td>For the <code>gcs</code> plugin, this identifies the
    <a href="https://cloud.google.com/storage/docs/concepts-techniques#concepts">bucket</a>
    to use.</td>
</tr>
<tr>
  <td><code>s3_backup_aws_region</code></td>
  <td>For the <code>s3</code> plugin, this identifies the AWS region.</td>
</tr>
<tr>
  <td><code>s3_backup_storage_bucket</code></td>
  <td>For the <code>s3</code> plugin, this identifies the AWS S3
    bucket.</td>
</tr>
<tr>
  <td><code>ceph_backup_storage_config</code></td>
  <td>For the <code>ceph</code> plugin, this identifies the path to a text
    file with a JSON object as configuration. The JSON object requires the
    following keys: <code>accessKey</code>, <code>secretKey</code>,
    <code>endPoint</code> and <code>useSSL</code>. Bucket name is computed
    from keyspace name and shard name is separated for different
    keyspaces / shards.</td>
</tr>
<tr>
  <td><code>restore_from_backup</code></td>
  <td>Indicates that, when started with an empty MySQL instance, the
    tablet should restore the most recent backup from the specified
    storage plugin.</td>
</tr>
<tr>
  <td><code>xtrabackup_root_path</code></td>
  <td>For the <code>xtrabackup</code> backup engine, directory location of the xtrabackup
     executable, e.g., /usr/bin</td>
</tr>
<tr>
  <td><code>xtrabackup_backup_flags</code></td>
  <td>For the <code>xtrabackup</code> backup engine, flags to pass to backup command. These
     should be space separated and will be added to the end of the command</td>
</tr>
<tr>
```

```
  <td><code>xbstream_restore_flags</code></td>
  <td>For the <code>xtrabackup</code> backup engine, flags to pass to xbstream command
     during restore. These should be space separated and will be added to the end of the
     command. These need to match the ones used for backup e.g. --compress / --decompress,
     --encrypt / --decrypt</td>
</tr>
<tr>
  <td><code>xtrabackup_stream_mode</code></td>
  <td>For the <code>xtrabackup</code> backup engine, which mode to use if streaming, valid
     values are <code>tar</code> and <code>xbstream</code>. Defaults to
     <code>tar</code></td>
</tr>
<tr>
  <td><code>xtrabackup_user</code></td>
  <td>For the <code>xtrabackup</code> backup engine, required user that xtrabackup will use
     to connect to the database server. This user must have all necessary privileges. For
     details, please refer to xtrabackup documentation.</td>
</tr>
<tr>
  <td><code>xtrabackup_stripes</code></td>
  <td>For the <code>xtrabackup</code> backup engine, if greater than 0, use data striping
     across this many destination files to parallelize data transfer and decompression</td>
</tr>
<tr>
  <td><code>xtrabackup_stripe_block_size</code></td>
  <td>For the <code>xtrabackup</code> backup engine, size in bytes of each block that gets
     sent to a given stripe before rotating to the next stripe</td>
</tr>
```

Authentication Note that for the Google Cloud Storage plugin, we currently only support Application Default Credentials. It means that access to Cloud Storage is automatically granted by virtue of the fact that you're already running within Google Compute Engine or Container Engine.

For this to work, the GCE instances must have been created with the scope that grants read-write access to Cloud Storage. When using Container Engine, you can do this for all the instances it creates by adding `--scopes storage-rw` to the `gcloud container clusters create` command.

Backup Frequency We recommend to take backups regularly e.g. you should set up a cron job for it.

To determine the proper frequency for creating backups, consider the amount of time that you keep replication logs and allow enough time to investigate and fix problems in the event that a backup operation fails.

For example, suppose you typically keep four days of replication logs and you create daily backups. In that case, even if a backup fails, you have at least a couple of days from the time of the failure to investigate and fix the problem.

Concurrency The backup and restore processes simultaneously copy and either compress or decompress multiple files to increase throughput. You can control the concurrency using command-line flags:

- The vtctl Backup command uses the `-concurrency` flag.
- vttablet uses the `-restore_concurrency` flag.

If the network link is fast enough, the concurrency matches the CPU usage of the process during the backup or restore process.

Creating a backup

Run the following vtctl command to create a backup:

```
vtctl Backup <tablet-alias>
```

If the engine is `builtin`, in response to this command, the designated tablet performs the following sequence of actions:

1. Switches its type to `BACKUP`. After this step, the tablet is no longer used by VTGate to serve any query.
2. Stops replication, gets the current replication position (to be saved in the backup along with the data).
3. Shuts down its mysqld process.
4. Copies the necessary files to the Backup Storage implementation that was specified when the tablet was started. Note if this fails, we still keep going, so the tablet is not left in an unstable state because of a storage failure.
5. Restarts mysqld.
6. Restarts replication (with the right semi-sync flags corresponding to its original type, if applicable).
7. Switches its type back to its original type. After this, it will most likely be behind on replication, and not used by VTGate for serving until it catches up.

If the engine is `xtrabackup`, we do not do any of the above. The tablet can continue to serve traffic while the backup is running.

Restoring a backup

When a tablet starts, Vitess checks the value of the `-restore_from_backup` command-line flag to determine whether to restore a backup to that tablet.

- If the flag is present, Vitess tries to restore the most recent backup from the Backup Storage system when starting the tablet.
- If the flag is absent, Vitess does not try to restore a backup to the tablet. This is the equivalent of starting a new tablet in a new shard.

As noted in the Configuration section, the flag is generally enabled all of the time for all of the tablets in a shard. By default, if Vitess cannot find a backup in the Backup Storage system, the tablet will start up empty. This behavior allows you to bootstrap a new shard before any backups exist.

If the `-wait_for_backup_interval` flag is set to a value greater than zero, the tablet will instead keep checking for a backup to appear at that interval. This can be used to ensure tablets launched concurrently while an initial backup is being seeded for the shard (e.g. uploaded from cold storage or created by another tablet) will wait until the proper time and then pull the new backup when it's ready.

```
vttablet ... -backup_storage_implementation=file \
             -file_backup_storage_root=/nfs/XXX \
             -restore_from_backup
```

Managing backups

vtctl provides two commands for managing backups:

- ListBackups displays the existing backups for a keyspace/shard in chronological order.

  ```
  vtctl ListBackups <keyspace/shard>
  ```

- RemoveBackup deletes a specified backup for a keyspace/shard.

  ```
  RemoveBackup <keyspace/shard> <backup name>
  ```

Bootstrapping a new tablet

Bootstrapping a new tablet is almost identical to restoring an existing tablet. The only thing you need to be cautious about is that the tablet specifies its keyspace, shard and tablet type when it registers itself at the topology. Specifically, make sure that the following additional vttablet parameters are set:

```
    -init_keyspace <keyspace>
    -init_shard <shard>
    -init_tablet_type replica|rdonly
```

The bootstrapped tablet will restore the data from the backup and then apply changes, which occurred after the backup, by restarting replication.

Backing up Topology Server

The Topology Server stores metadata (and not tablet data). It is recommended to create a backup using the method described by the underlying plugin:

- etcd
- ZooKeeper
- Consul

Making Schema Changes

For applying schema changes for MySQL instances managed by Vitess, there are a few options.

ApplySchema

`ApplySchema` is a `vtctlclient` command that can be used to apply a schema to a keyspace. The main advantage of using this tool is that it performs some sanity checks about the schema before applying it. For example, if the schema change affects too many rows of a table, it will reject it.

However, the downside is that it is a little too strict, and may not work for all use cases.

VTGate

You can send a DDL statement directly to a VTGate just like you would send to a MySQL instance. If the target is a sharded keyspace, then the DDL would be scattered to all shards.

If a specific shard fails you can target it directly using the `keyspace/shard` syntax to retry the apply just to that shard.

If VTGate does not recognize a DDL syntax, the statement will get rejected.

This approach is not recommended for changing large tables.

Directly to MySQL

You can apply schema changes directly to the underlying MySQL shard master instances. VTTablet will eventually notice the change and update itself (this is controlled by the `-queryserver-config-schema-reload-time` parameter and defaults to 1800 seconds). You can also explicitly issue the `vtctlclient ReloadSchema` command to make it reload immediately.

This approach can be extended to use schema deployment tools like `gh-ost` or `pt-online-schema-change`. Using these schema deployment tools is the recommended approach for large tables, because they incur no downtime.

Upgrading Vitess

This document highlights things to be aware of when upgrading a Vitess production installation to a newer Vitess release.

Generally speaking, upgrading Vitess is a safe and easy process because it is explicitly designed for it. This is because at YouTube we followed the practice of releasing new versions often (usually from the tip of the Git master branch).

Compatibility

Our versioning strategy is based on Semantic Versioning.

Vitess version numbers follow the format `MAJOR.MINOR.PATCH`. We guarantee compatibility when upgrading to a newer **patch** or **minor** version. Upgrades to a higher **major** version may require manual configuration changes.

In general, always **read the 'Upgrading' section of the release notes**. It will mention any incompatible changes and necessary manual steps.

Upgrade Order

We recommend to upgrade components in a bottom-to-top order such that "old" clients will talk to "new" servers during the transition.

Please use this upgrade order (unless otherwise noted in the release notes):

- vttablet
- vtctld
- vtgate
- application code which links client libraries

Canary Testing

Within the vtgate and vttablet components, we recommend to canary single instances, keyspaces and cells. Upgraded canary instances can "bake" for several hours or days to verify that the upgrade did not introduce a regression. Eventually, you can upgrade the remaining instances.

Rolling Upgrades

We recommend to automate the upgrade process with a configuration management software. It will reduce the possibility of human errors and simplify the process of managing all instances.

As of June 2016 we do not have templates for any major open-source configuration management software because our internal upgrade process is based on a proprietary software. Therefore, we invite open-source users to contribute such templates.

Any upgrade should be a rolling release i.e. usually one tablet at a time within a shard. This ensures that the remaining tablets continue serving live traffic and there is no interruption.

Upgrading the Master Tablet

The *master* tablet of each shard should always be updated last in the following manner:

- verify that all *replica* tablets in the shard have been upgraded
- reparent away from the current *master* to a *replica* tablet
- upgrade old *master* tablet

Making Schema Changes

description:

This user guide describes the problem space of schema changes and the various approaches you may use with Vitess.

Quick links:

- Vitess supports EXPERIMENTAL managed, online schema changes via `gh-ost` or `pt-online-schema-change`, and with visibility and control over the migration process
- Multiple approaches to unmanaged schema changes, either blocking, or owned by the user/DBA.

Some background on schema changes follows.

The schema change problem

Schema change is one of the oldest problems in MySQL. With accelerated development and deployment flows, engineers find they need to deploy schema changes sometimes on a daily basis. With the growth of data this task becomes more and more difficult. A direct MySQL `ALTER TABLE` statement is a blocking (no reads nor writes are possible on the migrated table) and resource heavy operation; variants of `ALTER TABLE` include `InnoDB` Online DDL, which allows for some concurrency on a `primary` (aka `master`) server, but still blocking on replicas, leading to unacceptable replication lags once the statement hits the replicas.

`ALTER TABLE` operations are greedy, consume as much CPU/Disk IO as needed, are uninterruptible and uncontrollable. Once the operation has begun, it must run to completion; aborting an `ALTER TABLE` may be more expensive than letting it run through, depending on the progress the migration has made.

Direct `ALTER TABLE` is fine in development or possibly staging environments, where datasets are either small, or where table locking is acceptable.

ALTER TABLE solutions

Busy production systems tend to use either of these two approaches, to make schema changes less disruptive to ongoing production traffic:

- Using online schema change tools, such as gh-ost and pt-online-schema-change. These tools *emulate* an `ALTER TABLE` statement by creating a *ghost* table in the new desired format, and slowly working through copying data from the existing table, while also applying ongoing changes throughout the migration. Online schema change tools can be throttled on high load, and can be interrupted at will.
- Run the migration independently on replicas; when all replicas have the new schema, demote the `primary` and promote a `replica` as the new `primary`; then, at leisure, run the migration on the demoted server. Two considerations if using this approach are:
  - Each migration requires a failover (aka successover, aka planned reparent).
  - Total wall clock time is higher since we run the same migration in sequence on different servers.

Schema change cycle and operation

The cycle of schema changes, from idea to production, is complex, involves multiple environments and possibly multiple teams. Below is one possible breakdown common in production. Notice how even interacting with the database itself takes multiple steps:

1. Design: the developer designs a change, tests locally
2. Publish: the developer calls for review of their changes (e.g. on a Pull Request)
3. Review: developer's colleagues and database engineers to check the changes and their impact
4. Formalize: what is the precise `ALTER TABLE` statement to be executed? If running with `gh-ost` or `pt-online-schema-change`, what are the precise command line flags?

5. Locate: where does this change need to go? Which keyspace/cluster? Is this cluster sharded? What are the shards? Having located the affected MySQL clusters, which is the `primary` server per cluster?
6. Schedule: is there an already running migration on the relevant keyspace/cluster(s)?
7. Execute: invoke the command. In the time we waited, did the identity of `primary` servers change?
8. Audit/control: is the migration in progress? Do we need to abort for some reason?
9. Cut-over/complete: a potential manual step to complete the migration process
10. Cleanup: what do you do with the old tables? An immediate `DROP` is likely not advisable. What's the alternative?
11. Notify user: let the developer know their changes are now in production.
12. Deploy & merge: the developer completes their process.

Steps `4 - 10` are tightly coupled with the database or with the infrastrcture around the database.

Schema change and Vitess

Vitess solves or automates multiple parts of the flow:

Formalize In managed, online schema changes the user supplies a valid SQL `ALTER TABLE` statement, and Vitess generates the `gh-ost` or `pt-online-schema-change` command line invocation. It will also auto generate config files and set up the environment for those tools. This is hidden from the user.

Locate For a given table in a given keyspace, Vitess knows at all times:

- In which shards (MySQL clusters) the table is found
- Which is the `primary` server per shard.

When using either managed schema changes, or direct schema changes via `vtctl` or `vtgate`, Vitess resolves the discovery of the affected servers automatically, and this is hidden from the user.

Schedule In managed, online schema changes, Vitess owns and tracks all pending and active migrations. As a rule of thumb, it is generally advisable to only run one online schema change at a time on a given server. Following that rule of thumb, Vitess will queue incoming schema change requests and schedule them to run sequentially.

Execute In managed, online schema changes, Vitess owns the execution of `gh-ost` or `pt-online-schema-change`. While these run in the background, Vitess keeps track of the migratoin state.

In direct schema changes via `vtctl` or `vtgate`, Vitess issues a synchronous `ALTER TABLE` statement on the relevant shards.

Audit/control In managed, online schema changes, Vitess keeps track of the state of the migration. It automatically detects when the migration is complete or has failed. It will detect failure even if the tablet itself, which is running the migration, fails. Vitess allows the user to cancel a migration. If such a migration is queued by the scheduler, then it is unqueued. If it's already running, it is interrupted and aborted. Vitess allows the user to check on a migration status across the relevant shards.

Cut-over/complete Vitess runs automated cut-overs. The migration will complete as soon as it's able to.

Cleanup In the case of managed, online schema changes via `pt-online-schema-change`, Vitess will ensure to drop the triggers in case the tool failed to do so for whatever reason.

Vitess automatically garbage-collects the "old" tables, artifacts of `gh-ost` and `pt-online-schema-change`. It drops those tables in an incremental, non blocking method.

The various approaches

Vitess allows a variety of approaches to schema changes, from fully automated to fully owned by the user.

- Managed, online schema changes are *experimental* at this time, but are Vitess's way forward
- Direct, blocking ALTERs are generally impractical in production given that they can block writes for substantial lengths of time.
- User controlled migrations are allowed, and under the user's responsibility.

See breakdown in managed, online schema changes and in unmanaged schema changes.

Managed, Online Schema Changes

Note: this feature is **EXPERIMENTAL**. Also, the syntax for online-DDL is **subject to change**.

Vitess offers managed, online schema migrations, via gh-ost and pt-online-schema-change. As a quick breakdown:

- Vitess recognizes a special `ALTER TABLE` syntax that indicates an online schema change request.
- Vitess responds to an online schema change request with a job ID
- Vitess resolves affected shards
- A shard's `primary` tablet schedules the migration to run when possible
- The tablets run migrations via `gh-ost` or `pt-online-schema-change`
- Vitess provides the user a mechanism to view migration status, cancel or retry migrations, based on the job ID

Syntax

Note: while this feature is experimental the syntax is subject to change.

We assume we have a keyspace (schema) called `commerce`, with a table called `demo`, that has the following definition:

```
CREATE TABLE `demo` (
  `id` int NOT NULL,
  `status` varchar(32) DEFAULT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB
```

The following syntax is valid and is interpreted by Vitess as an online schema change request:

```
ALTER WITH 'gh-ost' TABLE demo modify id bigint unsigned;
ALTER WITH 'gh-ost' '--max-load="Threads_running=200"' TABLE demo modify id bigint unsigned;
ALTER WITH 'pt-osc' TABLE demo ADD COLUMN created_timestamp TIMESTAMP NOT NULL;
ALTER WITH 'pt-osc' '--null-to-not-null' TABLE demo ADD COLUMN created_timestamp TIMESTAMP
   NOT NULL;
```

`gh-ost` and `pt-osc` are the only supported values. Any other value is a syntax error. Specifics about `gh-ost` and `pt-online-schema-change` follow later on.

You may use this syntax either with `vtctlclient` or via `vtgate`

ApplySchema

Invocation is similar to direct DDL statements. However, the response is different:

```
$ vtctlclient ApplySchema -sql "ALTER WITH 'gh-ost' TABLE demo modify id bigint unsigned"
   commerce
a2994c92_f1d4_11ea_afa3_f875a4d24e90
```

When the user indicates online schema change (aka online DDL), `vtctl` registers an online-DDL request with global `topo`. This generates a job ID for tracking. `vtctl` does not try to resolve the shards nor the `primary` tablets. The command returns immediately, without waiting for the migration(s) to start. It prints out the job ID (`a2994c92_f1d4_11ea_afa3_f875a4d24e90` in the above)

If we immediately run `SHOW CREATE TABLE`, we are likely to still see the old schema:

```
SHOW CREATE TABLE demo;

CREATE TABLE `demo` (
  `id` int NOT NULL,
  `status` varchar(32) DEFAULT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB
```

We discuss how the migration jobs get scheduled and executed shortly. We will use the job ID for tracking.

`ApplySchema` will have vitess run some validations:

```
$ vtctlclient ApplySchema -sql "ALTER WITH 'gh-ost' TABLE demo add column status int"
   commerce
E0908 16:17:07.651284 3739130 main.go:67] remote error: rpc error: code = Unknown desc =
   schema change failed, ExecuteResult: {
  "FailedShards": null,
  "SuccessShards": null,
  "CurSQLIndex": 0,
  "Sqls": [
    "ALTER WITH 'gh-ost' TABLE demo add column status int"
  ],
  "ExecutorErr": "rpc error: code = Unknown desc = TabletManager.PreflightSchema on
     zone1-0000000100 error: /usr/bin/mysql: exit status 1, output: ERROR 1060 (42S21) at
     line 3: Duplicate column name 'status' : /usr/bin/mysql: exit status 1, output: ERROR
     1060 (42S21) at line 3: Duplicate column name 'status' ",
  "TotalTimeSpent": 144283260
}
```

Vitess was able to determine that the migration is invalid because a column named `status` already exists. `vtctld` generates no job ID, and does not persist any migration request.

VTGate

You may run online DDL directly from VTGate. For example:

```
$ mysql -h 127.0.0.1 -P 15306 commerce
Welcome to the MySQL monitor.  Commands end with ; or \g.

mysql> ALTER WITH 'pt-osc' TABLE demo ADD COLUMN sample INT;
+--------------------------------------+
| uuid                                 |
+--------------------------------------+
| fa2fb689_f1d5_11ea_859e_f875a4d24e90 |
+--------------------------------------+
1 row in set (0.00 sec)
```

Just like in the previous example, `VTGate` identifies that this is an online schema change request, and persists it in global `topo`, returning a job ID for tracking. Migration does not start immediately.

Migration flow and states

We highlight how Vitess manages migrations internally, and explain what states a migration goes through.

- Whether via `vtctlclient ApplySchema` or via `VTGate` as described above, a migration request entry is persisted in global `topo` (e.g. the global `etcd` cluster).
- `vtctld` periodically checks on new migration requests.
- `vtctld` resolves the relevant shards, and the `primary` tablet for each shard.
- `vtctld` pushes the request to all relevant `primary` tablets.
- If not all shards confirm receipt, `vtctld` periodically keeps retrying pushing the request to the shards until all approve.
- Internally, tablets persist the request in a designated table in the `_vt` schema. **Do not** manipulate that table directly as that can cause inconsistencies.
- A shard's `primary` tablet owns running the migration. It is independent of other shards. It will schedule the migration to run when possible. A tablet will not run two migrations at the same time.
- A migration is first created in `queued` state.
- If the tablet sees queued migration, and assuming there's no reason to wait, it picks the oldest requested migration in `queued` state, and moves it to `ready` state.
- Tablet then prepares for the migration. It creates a MySQL account with a random password, to be used by this migration only. It creates the command line invocation, and extra scripts if possible.
- The tablet then runs the migration. Whether `gh-ost` or `pt-online-schema-change`, it first runs in *dry run* mode, and, if successful, in actual *execute* mode. The migration is then in `running` state.
- The migration will either run to completion, fail, or be interrupted. If successful, it transitions into `complete` state, which is the end of the road for that migration. If failed or interrupted, it transitions to `failed` state. The user may choose to *retry* failed migrations (see below).
- The user is able to *cancel* a migration (details below). If the migration hasn't started yet, it transitions to `cancelled` state. If the migration is `running`, then it is interrupted, and is expected to transition into `failed` state.

By way of illustration, suppose a migration is now in `running` state, and is expected to keep on running for the next few hours. The user may initiate a new `ALTER WITH 'gh-ost' TABLE...` statement. It will persist in global `topo`. `vtctld` will pick it up and advertise it to the relevant tablets. Each will persist the migration request in `queued` state. None will run the migration yet, since another migration is already in progress. In due time, and when the executing migration completes (whether successfully or not), and assuming no other migrations are `queued`, the `primary` tablets, each in its own good time, will execute the new migration.

At this time, the user is responsible to track the state of all migrations. VTTablet does not report back to `vtctld`. This may change in the future.

At this time, there are no automated retries. For example, a failover on a shard causes the migration to fail, and Vitess will not try to re-run the migration on the new `primary`. It is the user's responsibility to issue a `retry`. This may change in the future.

Tracking migrations

You may track the status of a single migration, of all or recent migrations, or of migrations in a specific state. Examples:

```
$ vtctlclient OnlineDDL commerce show ab3ffdd5_f25c_11ea_bab4_0242c0a8b007
+-----------------+-------+--------------+-------------+--------------------------------------+---
|     Tablet      | shard | mysql_schema | mysql_table |            migration_uuid
              | strategy |  started_timestamp  | completed_timestamp | migration_status |
+-----------------+-------+--------------+-------------+--------------------------------------+---
| test-0000000201 | 40-80 | vt_commerce  | demo        |
   ab3ffdd5_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:24:33 | 2020-09-09
   05:24:34 | complete         |
| test-0000000301 | 80-c0 | vt_commerce  | demo        |
   ab3ffdd5_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:25:13 | 2020-09-09
   05:25:14 | complete         |
| test-0000000401 | c0-   | vt_commerce  | demo        |
   ab3ffdd5_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:25:13 | 2020-09-09
   05:25:14 | complete         |
```

```
| test-0000000101 |   -40 | vt_commerce  | demo        |
   ab3ffdd5_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:25:13 | 2020-09-09
   05:25:14 | complete         |
+-----------------+-------+--------------+-------------+--------------------------------------+---

$ vtctlclient OnlineDDL commerce show 8a797518_f25c_11ea_bab4_0242c0a8b007
+-----------------+-------+--------------+-------------+--------------------------------------+---
|     Tablet      | shard | mysql_schema | mysql_table |            migration_uuid
              | strategy |  started_timestamp  | completed_timestamp | migration_status |
+-----------------+-------+--------------+-------------+--------------------------------------+---
| test-0000000401 | c0-   | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 |
                     | running          |
| test-0000000201 | 40-80 | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 | 2020-09-09
   05:23:33 | complete         |
| test-0000000301 | 80-c0 | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 |
                     | running          |
| test-0000000101 |   -40 | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 |
                     | running          |
+-----------------+-------+--------------+-------------+--------------------------------------+---

$ vtctlclient OnlineDDL commerce show 8a797518_f25c_11ea_bab4_0242c0a8b007
+-----------------+-------+--------------+-------------+--------------------------------------+---
|     Tablet      | shard | mysql_schema | mysql_table |            migration_uuid
              | strategy |  started_timestamp  | completed_timestamp | migration_status |
+-----------------+-------+--------------+-------------+--------------------------------------+---
| test-0000000401 | c0-   | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 |
                     | failed           |
| test-0000000101 |   -40 | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 |
                     | failed           |
| test-0000000301 | 80-c0 | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 |
                     | failed           |
| test-0000000201 | 40-80 | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 | 2020-09-09
   05:23:33 | complete         |
+-----------------+-------+--------------+-------------+--------------------------------------+---

$ vtctlclient OnlineDDL commerce show recent
+-----------------+-------+--------------+-------------+--------------------------------------+---
|     Tablet      | shard | mysql_schema | mysql_table |            migration_uuid
              | strategy |  started_timestamp  | completed_timestamp | migration_status |
+-----------------+-------+--------------+-------------+--------------------------------------+---
| test-0000000201 | 40-80 | vt_commerce  | demo        |
   63b5db0c_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:22:41 | 2020-09-09
   05:22:42 | complete         |
| test-0000000201 | 40-80 | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 | 2020-09-09
   05:23:33 | complete         |
| test-0000000201 | 40-80 | vt_commerce  | demo        |
   ab3ffdd5_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:24:33 | 2020-09-09
```

```
   05:24:34 | complete         |
| test-0000000301 | 80-c0 | vt_commerce  | demo        |
   63b5db0c_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:22:41 | 2020-09-09
   05:22:42 | complete         |
| test-0000000301 | 80-c0 | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 |
                      | failed           |
| test-0000000301 | 80-c0 | vt_commerce  | demo        |
   ab3ffdd5_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:25:13 | 2020-09-09
   05:25:14 | complete         |
| test-0000000401 | c0-   | vt_commerce  | demo        |
   63b5db0c_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:22:41 | 2020-09-09
   05:22:42 | complete         |
| test-0000000401 | c0-   | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 |
                      | failed           |
| test-0000000401 | c0-   | vt_commerce  | demo        |
   ab3ffdd5_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:25:13 | 2020-09-09
   05:25:14 | complete         |
| test-0000000101 |   -40 | vt_commerce  | demo        |
   63b5db0c_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:22:41 | 2020-09-09
   05:22:42 | complete         |
| test-0000000101 |   -40 | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 |
                      | failed           |
| test-0000000101 |   -40 | vt_commerce  | demo        |
   ab3ffdd5_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:25:13 | 2020-09-09
   05:25:14 | complete         |
+-----------------+-------+--------------+-------------+--------------------------------------+---

$ vtctlclient OnlineDDL commerce show failed
+-----------------+-------+--------------+-------------+--------------------------------------+---
|     Tablet      | shard | mysql_schema | mysql_table |            migration_uuid
              | strategy |  started_timestamp  | completed_timestamp | migration_status |
+-----------------+-------+--------------+-------------+--------------------------------------+---
| test-0000000301 | 80-c0 | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 |
                      | failed           |
| test-0000000401 | c0-   | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 |
                      | failed           |
| test-0000000101 |   -40 | vt_commerce  | demo        |
   8a797518_f25c_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 05:23:32 |
                      | failed           |
+-----------------+-------+--------------+-------------+--------------------------------------+---
```

The syntax for tracking migrations is:

```
vtctlclient OnlineDDL <keyspace> show
   <migration_id|all|recent|queued|ready|running|complete|failed|cancelled>
```

Cancelling a migration

The user may cancel a migration, as follows:

- If the migration hasn't started yet (it is `queued` or `ready`), then it is removed from queue and will not be executed.

- If the migration is `running`, then it is forcibly interrupted. The migration is expected to transition to `failed` state.
- In all other cases, cancelling a migration has no effect.

The syntax to cancelling a migration is:

```
vtctlclient OnlineDDL cancel <migration_id>
```

Example:

```
$ vtctlclient OnlineDDL commerce show 2201058f_f266_11ea_bab4_0242c0a8b007
+-----------------+-------+--------------+-------------+--------------------------------------+---
|     Tablet      | shard | mysql_schema | mysql_table |            migration_uuid
              | strategy |  started_timestamp  | completed_timestamp | migration_status |
+-----------------+-------+--------------+-------------+--------------------------------------+---
| test-0000000301 | 80-c0 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:32:31 |
                      | running          |
| test-0000000101 |   -40 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:32:31 |
                      | running          |
| test-0000000401 | c0-   | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:32:31 |
                      | running          |
| test-0000000201 | 40-80 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:32:31 |
                      | running          |
+-----------------+-------+--------------+-------------+--------------------------------------+---

$ vtctlclient OnlineDDL commerce cancel 2201058f_f266_11ea_bab4_0242c0a8b007
+-----------------+--------------+
|     Tablet      | RowsAffected |
+-----------------+--------------+
| test-0000000401 |            1 |
| test-0000000101 |            1 |
| test-0000000201 |            1 |
| test-0000000301 |            1 |
+-----------------+--------------+

$ vtctlclient OnlineDDL commerce show 2201058f_f266_11ea_bab4_0242c0a8b007
+-----------------+-------+--------------+-------------+--------------------------------------+---
|     Tablet      | shard | mysql_schema | mysql_table |            migration_uuid
              | strategy |  started_timestamp  | completed_timestamp | migration_status |
+-----------------+-------+--------------+-------------+--------------------------------------+---
| test-0000000401 | c0-   | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:32:31 |
                      | failed           |
| test-0000000301 | 80-c0 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:32:31 |
                      | failed           |
| test-0000000201 | 40-80 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:32:31 |
                      | failed           |
| test-0000000101 |   -40 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:32:31 |
                      | failed           |
+-----------------+-------+--------------+-------------+--------------------------------------+---
```

Retrying a migration

The user may retry running a migration. If the migration is in `failed` or in `cancelled` state, Vitess will re-run the migration, with exact same arguments as previously intended. If the migration is in any other state, `retry` does nothing.

It is not possible to retry a migration with different options. e.g. if the user initially runs `ALTER WITH 'gh-ost' '--max-load Threads_running=200' TABLE demo MODIFY id BIGINT` and the migration failed, it is not possible to retry with `'--max-load Threads_running=500'`.

Continuing the above example, where we cancelled a migration while running, we now retry it:

```
$ vtctlclient OnlineDDL commerce show 2201058f_f266_11ea_bab4_0242c0a8b007
+-----------------+-------+--------------+-------------+--------------------------------------+---
|     Tablet      | shard | mysql_schema | mysql_table |            migration_uuid
              | strategy |  started_timestamp  | completed_timestamp | migration_status |
+-----------------+-------+--------------+-------------+--------------------------------------+---
| test-0000000401 | c0-   | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:32:31 |
                       | failed           |
| test-0000000301 | 80-c0 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:32:31 |
                       | failed           |
| test-0000000201 | 40-80 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:32:31 |
                       | failed           |
| test-0000000101 |   -40 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:32:31 |
                       | failed           |
+-----------------+-------+--------------+-------------+--------------------------------------+---

$ vtctlclient OnlineDDL commerce retry 2201058f_f266_11ea_bab4_0242c0a8b007
+-----------------+--------------+
|     Tablet      | RowsAffected |
+-----------------+--------------+
| test-0000000101 |            1 |
| test-0000000201 |            1 |
| test-0000000301 |            1 |
| test-0000000401 |            1 |
+-----------------+--------------+

$ vtctlclient OnlineDDL commerce show 2201058f_f266_11ea_bab4_0242c0a8b007
+-----------------+-------+--------------+-------------+--------------------------------------+---
|     Tablet      | shard | mysql_schema | mysql_table |            migration_uuid
              | strategy | started_timestamp | completed_timestamp | migration_status |
+-----------------+-------+--------------+-------------+--------------------------------------+---
| test-0000000201 | 40-80 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   |                     |
                       | queued           |
| test-0000000101 |   -40 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   |                     |
                       | queued           |
| test-0000000301 | 80-c0 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   |                     |
                       | queued           |
| test-0000000401 | c0-   | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   |                     |
                       | queued           |
+-----------------+-------+--------------+-------------+--------------------------------------+---
```

```
$ vtctlclient OnlineDDL commerce show 2201058f_f266_11ea_bab4_0242c0a8b007
+-----------------+-------+--------------+-------------+--------------------------------------+---
|     Tablet      | shard | mysql_schema | mysql_table |            migration_uuid
              | strategy |  started_timestamp  | completed_timestamp | migration_status |
+-----------------+-------+--------------+-------------+--------------------------------------+---
| test-0000000101 |   -40 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:37:33 |
                      | running          |
| test-0000000401 | c0-   | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:37:33 |
                      | running          |
| test-0000000201 | 40-80 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:37:33 |
                      | running          |
| test-0000000301 | 80-c0 | vt_commerce  | demo        |
   2201058f_f266_11ea_bab4_0242c0a8b007 | gh-ost   | 2020-09-09 06:37:33 |
                      | running          |
+-----------------+-------+--------------+-------------+--------------------------------------+---
```

gh-ost and pt-online-schema-change

The user must pick one of these migration tools. The tools differ in features, operation, load, and more.

Using gh-ost

gh-ost was developed by GitHub as a lightweight and safe schema migration tool.

To be able to run online schema migrations via `gh-ost`:

- If you're on Linux/amd64 architecture, and on `glibc 2.3` or similar, there are no further dependencies. Vitess comes with a built-in `gh-ost` binary, that is compatible with your system.
- On other architectures:
  - Have `gh-ost` executable installed
  - Run `vttablet` with `-gh-ost-path=/full/path/to/gh-ost` flag

Vitess automatically creates a MySQL account for the migration, with a randomly generated password. The account is destroyed at the end of the migration.

Vitess takes care of setting up the necessary command line flags. It automatically creates a hooks directory and populates it with hooks that report `gh-ost`'s progress back to Vitess. You may supply additional flags for your migration as part of the `ALTER` statement. Examples:

- `ALTER WITH 'gh-ost' '--max-load Threads_running=200' TABLE demo MODIFY id BIGINT`
- `ALTER WITH 'gh-ost' '--critical-load Threads_running=500 --critical-load-hibernate-seconds=60' --default-retries=512 TABLE demo MODIFY id BIGINT`
- `ALTER WITH 'gh-ost' '--allow-nullable-unique-key --chunk-size 200' TABLE demo MODIFY id BIGINT`

Do not override the following flags: `alter, database, table, execute, max-lag, force-table-names, serve-socket-file, hooks-path, hooks-hint-token, panic-flag-file`.

`gh-ost` throttling is done via Vitess's own tablet throttler, based on replication lag.

Using pt-online-schema-change

pt-online-schema-change is part of Percona Toolkit, a set of Perl scripts. To be able to use `pt-online-schema-change`, you must have the following setup on all your tablet servers (normally tablets are co-located with MySQL on same host and so this implies setting up on all MySQL servers):

- `pt-online-schema-change` tool installed and is executable
- Perl `libdbi` and `libdbd-mysql` modules installed. e.g. on Debian/Ubuntu, `sudo apt-get install libdbi-perl libdbd-mysql-perl`
- Run `vttablet` with `-pt-osc-path=/full/path/to/pt-online-schema-change` flag.

Vitess automatically creates a MySQL account for the migration, with a randomly generated password. The account is destroyed at the end of the migration.

Vitess takes care of supplying the command line flags, the DSN, the username & password. It also sets up `PLUGINS` used to communicate migration progress back to the tablet. You may supply additional flags for your migration as part of the `ALTER` statement. Examples:

- `ALTER WITH 'pt-osc' '--null-to-not-null' TABLE demo MODIFY id BIGINT`
- `ALTER WITH 'pt-osc' '--max-load Threads_running=200' TABLE demo MODIFY id BIGINT`
- `ALTER WITH 'pt-osc' '--alter-foreign-keys-method auto --chunk-size 200' TABLE demo MODIFY id BIGINT`

Vitess tracks the state of the `pt-osc` migration. If it fails, Vitess makes sure to drop the migration triggers. Vitess keeps track of the migration even if the tablet itself restarts for any reason. Normally that would terminate the migration; vitess will cleanup the triggers if so, or will happily let the migration run to completion if not.

Do not override the following flags: `alter, pid, plugin, dry-run, execute, new-table-name, [no-]drop-new-table, [no-]drop-old-table`.

`pt-osc` throttling is done via Vitess's own tablet throttler, based on replication lag, and via a `pt-online-schema-change` plugin.

Throttling

Schema migrations use the tablet throttler, which is a cooperative throttler service based on replication lag. The tablet throttler automatically detectes topology `REPLICA` tablets and adapts to changes in the topology. See Tablet throttler.

NOTE that at this time the tablet throttler is an experimental feature and is opt in. Enable it with `vttablet`'s `-enable-lag-throttler` flag. If the tablet throttler is disabled, schema migrations will not throttle on replication lag.

Table cleanup

Both `gh-ost` and `pt-online-schema-change` leave artifacts behind. Whether successful or failed, either the original table or the *ghost* table are left still populated at the end of the migration. Vitess explicitly configures both tools to not drop those tables. The reason is that in MySQL, a `DROP TABLE` operation can be dangerous in production as it commonly locks the buffer pool for a substantial period.

Artifact tables are identifiable via `SELECT artifacts FROM _vt.schema_migrations` in a `VExec` command, see below.

Vitess automatically cleans up those tables as soon as a migration completes (either successful or failed). You will normally not need to do anything.

VExec commands for greater control and visibility

`vtctlclient OnlineDDL` command should provide with most needs. However, Vitess gives the user greater control through the `VExec` command and via SQL queries.

For schema migrations, Vitess allows operations on the virtual table `_vt.schema_migrations`. Queries on this virtual table scatter to the underlying tablets and gather or manipulate data on their own, private backend tables (which incidentally are called by the same name). `VExec` only allows specific types of queries on that table.

- `SELECT`: you may SELECT any column, or `SELECT *`. `vtctlclient OnlineDDL show` commands only present with a subset of columns, and so running `VExec SELECT` provides greater visibility. Some columns that are not shown are:
  - `log_path`: tablet server and path where migration logs are.
  - `artifacts`: tables created by the migration. This can be used to determine which tables need cleanup.
  - `alter`: the exact `alter` statement used by the migration
  - `options`: any options passed by the user (e.g. `--max-load=Threads_running=200`)
  - Various timestamps indicating the migratoin progress Aggregate functions do not work as expected and should be avoided. `LIMIT` and `OFFSET` are not supported.
- `UPDATE`: you may directly update the status of a migration. You may only change status into `cancel` or `retry`, which Vitess interprets similarly to a `vtctlclient OnlineDDL cancel/retry` command. However, you get greater control as you may filter on a specific `shard`.
- `DELETE`: unsupported
- `INSERT`: unsupported, used internally only to advertise new migration requests to the tablets.

The syntax to run `VExec` queries is:

```
vtctlclient VExec <keyspace>.<migration_id> "<sql query>"
```

Examples:

```
$ vtctlclient VExec commerce.2201058f_f266_11ea_bab4_0242c0a8b007 "select * from
   _vt.schema_migrations"

$ vtctlclient VExec commerce.91b5c953-e1e2-11ea-a097-f875a4d24e90 "update
   _vt.schema_migrations set migration_status='retry'

$ vtctlclient VExec commerce.91b5c953-e1e2-11ea-a097-f875a4d24e90 "update
   _vt.schema_migrations set migration_status='retry' where shard='40-80'
```

```
$ vtctlclient VExec commerce.2201058f_f266_11ea_bab4_0242c0a8b007 "select shard,
   mysql_table, migration_uuid, started_timestamp, completed_timestamp, migration_status
   from _vt.schema_migrations"
+-----------------+-------+-------------+--------------------------------------+-----------------
|     Tablet      | shard | mysql_table |            migration_uuid            |
   started_timestamp  | completed_timestamp | migration_status |
+-----------------+-------+-------------+--------------------------------------+-----------------
| test-0000000301 | 80-c0 | demo        | 2201058f_f266_11ea_bab4_0242c0a8b007 | 2020-09-09
   06:37:33 |                     | failed           |
| test-0000000101 |   -40 | demo        | 2201058f_f266_11ea_bab4_0242c0a8b007 | 2020-09-09
   06:37:33 |                     | failed           |
| test-0000000201 | 40-80 | demo        | 2201058f_f266_11ea_bab4_0242c0a8b007 | 2020-09-09
   08:31:47 |                     | failed           |
| test-0000000401 | c0-   | demo        | 2201058f_f266_11ea_bab4_0242c0a8b007 | 2020-09-09
   06:37:33 |                     | failed           |
+-----------------+-------+-------------+--------------------------------------+-----------------

$ vtctlclient VExec commerce.2201058f_f266_11ea_bab4_0242c0a8b007 "update
   _vt.schema_migrations set migration_status='retry' where
   migration_uuid='2201058f_f266_11ea_bab4_0242c0a8b007' and shard='40-80'"
+-----------------+--------------+
|     Tablet      | RowsAffected |
+-----------------+--------------+
| test-0000000201 |            1 |
+-----------------+--------------+

$ vtctlclient VExec commerce.2201058f_f266_11ea_bab4_0242c0a8b007 "select shard,
   mysql_table, migration_uuid, started_timestamp, completed_timestamp, migration_status
   from _vt.schema_migrations"
```

```
+----------------+-------+-------------+--------------------------------------+----------------
|     Tablet     | shard | mysql_table |            migration_uuid            |
   started_timestamp  | completed_timestamp | migration_status |
+----------------+-------+-------------+--------------------------------------+----------------
| test-0000000301 | 80-c0 | demo        | 2201058f_f266_11ea_bab4_0242c0a8b007 | 2020-09-09
   06:37:33 |                     | failed           |
| test-0000000201 | 40-80 | demo        | 2201058f_f266_11ea_bab4_0242c0a8b007 | 2020-09-09
   08:34:59 |                     | running          |
| test-0000000101 |   -40 | demo        | 2201058f_f266_11ea_bab4_0242c0a8b007 | 2020-09-09
   06:37:33 |                     | failed           |
| test-0000000401 | c0-   | demo        | 2201058f_f266_11ea_bab4_0242c0a8b007 | 2020-09-09
   06:37:33 |                     | failed           |
+----------------+-------+-------------+--------------------------------------+----------------

$ vtctlclient VExec commerce.2201058f_f266_11ea_bab4_0242c0a8b007 "update
   _vt.schema_migrations set migration_status='cancel' where
   migration_uuid='2201058f_f266_11ea_bab4_0242c0a8b007' and shard='40-80'"
+----------------+--------------+
|     Tablet     | RowsAffected |
+----------------+--------------+
| test-0000000201 |            1 |
+----------------+--------------+

$ vtctlclient VExec commerce.2201058f_f266_11ea_bab4_0242c0a8b007 "select shard,
   mysql_table, migration_uuid, started_timestamp, completed_timestamp, migration_status
   from _vt.schema_migrations"
+----------------+-------+-------------+--------------------------------------+----------------
|     Tablet     | shard | mysql_table |            migration_uuid            |
   started_timestamp  | completed_timestamp | migration_status |
+----------------+-------+-------------+--------------------------------------+----------------
| test-0000000401 | c0-   | demo        | 2201058f_f266_11ea_bab4_0242c0a8b007 | 2020-09-09
   06:37:33 |                     | failed           |
| test-0000000101 |   -40 | demo        | 2201058f_f266_11ea_bab4_0242c0a8b007 | 2020-09-09
   06:37:33 |                     | failed           |
| test-0000000201 | 40-80 | demo        | 2201058f_f266_11ea_bab4_0242c0a8b007 | 2020-09-09
   08:34:59 |                     | failed           |
| test-0000000301 | 80-c0 | demo        | 2201058f_f266_11ea_bab4_0242c0a8b007 | 2020-09-09
   06:37:33 |                     | failed           |
+----------------+-------+-------------+--------------------------------------+----------------

$ vtctlclient VExec commerce.2201058f_f266_11ea_bab4_0242c0a8b007 "update
   _vt.schema_migrations set migration_status='cancel' where
   migration_uuid='2201058f_f266_11ea_bab4_0242c0a8b007' and shard='40-80'"
<no result>

$ vtctlclient VExec commerce.2201058f_f266_11ea_bab4_0242c0a8b007 "select shard, log_path
   from _vt.schema_migrations"
+----------------+-------+-------------------------------------------------------------------------
|     Tablet     | shard |                                    log_path
                                |
+----------------+-------+-------------------------------------------------------------------------
| test-0000000201 | 40-80 |
   11ac2af6e63e:/tmp/online-ddl-2201058f_f266_11ea_bab4_0242c0a8b007-657478384 |
| test-0000000101 |   -40 |
   e779a82d35d7:/tmp/online-ddl-2201058f_f266_11ea_bab4_0242c0a8b007-901629215 |
| test-0000000401 | c0-   |
```

```
   5aad1249ab91:/tmp/online-ddl-2201058f_f266_11ea_bab4_0242c0a8b007-039568897 |
| test-0000000301 | 80-c0 |
   5e7c662679d3:/tmp/online-ddl-2201058f_f266_11ea_bab4_0242c0a8b007-532703073 |
+-----------------+-------+--------------------------------------------------------------------------
```

Unmanaged Schema Changes

Vitess offers multiple approaches to running unmanaged schema changes. Below, we review each of these approaches.

We assume we have a keyspace (schema) called `commerce`, with a table called `demo`, that has the following definition:

```
CREATE TABLE `demo` (
  `id` int NOT NULL,
  `status` varchar(32) DEFAULT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB
```

ApplySchema

`ApplySchema` is a `vtctlclient` command that can be used to apply a schema change to a keyspace. The main advantage of using this tool is that it performs some sanity checks about the schema before applying it.

Consider the following examples:

```
$ vtctlclient ApplySchema -sql "ALTER TABLE demo modify id bigint unsigned" commerce
```

```
SHOW CREATE TABLE demo;


CREATE TABLE `demo` (
  `id` bigint unsigned NOT NULL,
  `status` varchar(32) DEFAULT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB
```

In the above, we run a direct, synchronous, blocking `ALTER TABLE` statement. Knowing the table is in `commerce` keyspace, Vitess autodetects the relevant shards, and then autodetects which is the `primary` server in each shard. It then directly invokes the `ALTER TABLE` statement on all shards (concurrently), and the `vtctlclient` command only returns when all are complete.

Vitess will run some validations:

```
$ vtctlclient ApplySchema -sql "ALTER TABLE demo add column status int" commerce
E0908 10:35:53.478462 3711762 main.go:67] remote error: rpc error: code = Unknown desc =
   schema change failed, ExecuteResult: {
  "FailedShards": null,
  "SuccessShards": null,
  "CurSQLIndex": 0,
  "Sqls": [
    "ALTER TABLE demo add column status int"
  ],
  "ExecutorErr": "rpc error: code = Unknown desc = TabletManager.PreflightSchema on
     zone1-0000000100 error: /usr/bin/mysql: exit status 1, output: ERROR 1060 (42S21) at
     line 3: Duplicate column name 'status' : /usr/bin/mysql: exit status 1, output: ERROR
     1060 (42S21) at line 3: Duplicate column name 'status' ",
  "TotalTimeSpent": 87104194
}
```

Vitess was able to determine that the migration is invalid because a column named `status` already exists. The statement never made it to the MySQL servers. These checks are not thorough, though they cover common scenarios.

If the table is large, then `ApplySchema` will reject the statement, try to protect the user from blocking their production servers. You may override that by supplying `-allow_long_unavailability` as follows:

```
$ vtctlclient ApplySchema -allow_long_unavailability -sql "ALTER TABLE demo modify id
   bigint unsigned" commerce
```

VTGate

You may run DDL directly from VTGate. For example:

```
$ mysql -h 127.0.0.1 -P 15306 commerce
Welcome to the MySQL monitor.  Commands end with ; or \g.

mysql> ALTER TABLE demo ADD COLUMN sample INT;
Query OK, 0 rows affected (0.04 sec)
```

Just like in the previous example, Vitess will find out what the affected shards are, what the identity is of each shard's `primary`, then invoke the statement on all shards.

You may apply the change to specific shards by connecting directly to those shards:

```
$ mysql -h 127.0.0.1 -P 15306 commerce/-80
Welcome to the MySQL monitor.  Commands end with ; or \g.

mysql> ALTER TABLE demo ADD COLUMN sample INT;
Query OK, 0 rows affected (0.04 sec)
```

In the above we connect to VTGate via the `mysql` command line client, but of course you may connect with any standard MySQL client or from your applicaiton.

This approach is not recommended for changing large tables.

Directly to MySQL

You can apply schema changes directly to the underlying MySQL shard master instances.

VTTablet will eventually notice the change and update itself. This is controlled by the `-queryserver-config-schema-reload-time` parameter which defaults to 1800 seconds.

You can also explicitly issue the `vtctlclient ReloadSchema` command to make it reload immediately. Specify a tablet to reload the schema from, as in:

```
$ vtctlclient ReloadSchema zone1-0000000100
```

Users will likely want to deploy schema changes via `gh-ost` or `pt-online-schema-change`, which do not block the table. Vitess offers managed, online schema changes where it automates the invocation and execution of these tools.

SQL Statement Analysis

description: User guides covering analyzing SQL statements

Analyzing SQL statements in bulk

Introduction

This document covers the way the VTexplain tool can be used to evaluate if Vitess is compatible with a list of SQL statements. Enabling the evaluation of if queries from an existing application that accesses a MySQL database are generally Vitess-compatible.

If there are any issues identified they can be used to target any necessary application changes needed for a successful migration from MySQL to Vitess.

Prerequisites

You can find a prebuilt binary version of the VTexplain tool in the most recent release of Vitess.

You can also build the `vtexplain` binary in your environment. To build this binary, refer to the Build From Source guide.

Overview

To analyze multiple SQL queries and determine how, or if, Vitess executes each statement, follow these steps:

1. Gather the queries from your current MySQL database environment
2. Filter out specific queries
3. Populate fake values for your queries
4. Run the VTexplain tool via a script
5. Add your SQL schema
6. Add your VSchema to the output file
7. Run the VTexplain tool and capture the output
8. Check your output for errors

1. Gather the queries from your current MySQL database environment

These queries should be most, if not all, of the queries that are sent to your current MySQL database over an extended period of time. You may need to record your queries for days or weeks depending on the nature of your application(s) and workload. You will need to normalize the queries you will be analyzing. Depending on the scope and complexity of your applications you may have a few hundred to thousands of distinct normalized queries. To obtain normalized queries you can use common MySQL monitoring tools like VividCortex, Monyog or PMM.

It is also possible to use the MySQL general query log feature to capture raw queries and then normalize it using post-processing.

2. Filter out specific queries

Remove from your list any unsupported queries or queries from non-application sources. The following are examples of queries to remove are:

- `LOCK/UNLOCK TABLES` - These likely come from schema management tools, which VTGate obviates.
- `FLUSH/PURGE LOGS` - Vitess performs its own log management.
- `performance_schema queries` - These queries are not supported by Vitess.
- `BEGIN/COMMIT` - Vitess supports these statements, but VTexplain does not.

The following is an example pipeline to filter out these specific queries:

```
cat queries.txt \
 | grep -v performance_schema \
 | grep -v information_schema \
 | grep -v @@ \
 | grep -v "SELECT ? $" \
 | grep -v "PURGE BINARY" \
 | grep -v "^SET" \
 | grep -v "^EXPLAIN" \
 | grep -v ^query \
 | grep -v ^BEGIN \
 | grep -v ^COMMIT \
```

```
 | grep -v ^FLUSH \
 | grep -v ^LOCK \
 | grep -v ^UNLOCK \
 | grep -v mysql > queries_for_vtexplain.txt
```

3. Populate fake values for your queries

Once the queries are normalized in prepared statement style, populate fake values to allow VTexplain to run properly. This is because `vtexplain` operates only on concrete (or un-normalized) queries. Doing this by textual substitution is shown below and typically requires some trial and error. An alternative is to use a MySQL monitoring tool. This tool sometimes has a feature where it can provide one concrete query example for every normalized query form, which is ideal for this purpose.

If you need to use textual substitution to obtain your concrete queries, the following is an example pipeline you can run:

```
cat queries.txt \
 | perl -p -e 's#\? = \?#1 = 1#g' \
 | perl -p -e 's#= \?#="1"#g' \
 | perl -p -e 's#LIMIT \?#LIMIT 1#g' \
 | perl -p -e 's#\> \?#> "1"#g' \
 | perl -p -e 's#IN \(\?\)#IN (1)#g' \
 | perl -p -e 's#\? AS ONE#1 AS ONE#g' \
 | perl -p -e 's#BINARY \?#BINARY \"1\"#g' \
 | perl -p -e 's#\< \?#< "2"#g' \
 | perl -p -e 's#, \?#, "1"#g' \
 | perl -p -e 's#VALUES \(...\)#VALUES \(1,2\)#g' \
 | perl -p -e 's#IN \(\.\.\.\)#IN \(1,2\)#g' \
 | perl -p -e 's#\- \? #\- 50 #g' \
 | perl -p -e 's#BETWEEN \? AND \?#BETWEEN 1 AND 10#g' \
 | perl -p -e 's#LIKE \? #LIKE \"1\" #g' \
 | perl -p -e 's#OFFSET \?#OFFSET 1#g' \
 | perl -p -e 's#\?, \.\.\.#\"1\", \"2\"#g' \
 | perl -p -e 's#\/ \? #\/ \"1\" #g' \
 | perl -p -e 's#THEN \? ELSE \?#THEN \"2\" ELSE \"3\"#g' \
 | perl -p -e 's#THEN \? WHEN#THEN \"4\" WHEN#g' \
 | perl -p -e 's#SELECT \? FROM#SELECT \"6\" FROM#g' \
 | perl -p -e 's#SELECT \?  AS#SELECT id AS#g' \
 | perl -p -e 's#\`DAYOFYEAR\` \(\?\)#DAYOFYEAR \("2020-01-20"\)#g' \
 | perl -p -e 's#YEAR \(\?\)#YEAR \("2020-01-01"\)#g' \
 | grep -v mysql > queries_for_vtexplain.txt
```

4. Run the VTexplain tool via a script

In order to analyze every query in your list, create and run a script. The following is an example Python script that assumes a sharded database with 4 shards. You can adjust this script to match your individual requirements.

```
$ cat testfull.py
for line in open("queries_for_vtexplain.txt", "r").readlines():
    sql = line.strip()
    print("vtexplain -schema-file schema.sql -vschema-file vschema.json -shards 4 -sql
       '%s'" % sql)
x
$ python testfull.py > run_vtexplain.sh
```

An alternative method is to use the `-sql-file` option for `vtexplain` to pass the whole file to a single vtexplain invocation. This is much more efficient, but we have found that it can be easier to find errors if you perform one `vtexplain` invocation per SQL query.

If you choose to use the single invocation, it would look something like:

```
$ vtexplain -schema-file schema.sql -vschema-file vschema.json -shards 4 -sql-file
   queries_for_vtexplain.txt
```

5. Add your SQL schema to the output file

Add your proposed SQL schema to the file created by the script (e.g. schema.sql). The following is an example SQL schema:

```
$ cat schema.sql
CREATE TABLE `user` (
  `user_id` bigint(20) NOT NULL,
  `name` varchar(128) DEFAULT NULL,
  `balance` decimal(13,4) DEFAULT NULL,
  PRIMARY KEY (`user_id`),
  KEY `balance` (`balance`)
) ENGINE=InnoDB DEFAULT CHARSET=utf8;
```

6. Add your VSchema

Add your VSchema to the file created by the script: in this example, the file is named `schema.json`. The following is an example VSchema to match the example SQL schema above.

```
$ cat vschema.json
{
    "ks1": {
        "sharded": true,
        "vindexes": {
            "hash": {
                "type": "hash"
            }
        },
        "tables": {
            "user": {
                "column_vindexes": [
                    {
                        "column": "user_id",
                        "name": "hash"
                    }
                ]
            }
        }
    }
}
```

Note that unlike the VSchema used in Vitess, e.g. in `vtctlclient GetVSchema` and `vtctlclient ApplyVSchema`, the format required by `vtexplain` differs slightly. There is an extra level of JSON objects at the top-level of the JSON format to allow you to have a single file that represents the VSchema for multiple Vitess keyspaces. In the above example, there is just a single keyspace called `ks1`.

7. Run the VTexplain tool and capture the output

This step will generate the output you need to analyze to determine what queries may have issues with your proposed VSchema. It may take a long time to finish if you have a number of queries.

```
$ sh -x run_vtexplain.sh 2> vtexplain.output
```

8. Check your output

Once you have your full output in vtexplain.output, use `grep` to search for the string "ERROR" to review any issues that VTExplain found.

Example: Scatted across shards In the following example, VTGate scatters the example query across both shards, and then aggregates the query results.

```
$ vtexplain -schema-file schema.sql -vschema-file vschema.json -shards 2 -sql 'SELECT *
   FROM user;'
----------------------------------------------------------------------
SELECT * FROM user

1 ks1/-40: SELECT * FROM user limit 10001
1 ks1/40-80: SELECT * FROM user limit 10001
1 ks1/80-c0: SELECT * FROM user limit 10001
1 ks1/c0-: SELECT * FROM user limit 10001
----------------------------------------------------------------------
```

This is not an error, but illustrates a few things about the query:

- The query of this type will be scattered across all 4 the shards, given the schema and VSchema.
- The phases of the scatter operation will occur in parallel. This is because the number `1` on the left-hand-side of the output indicates the ordering of the operations in time. The same number indicates parallel processing.
- The implicit Vitess row limit of 10000 rows is also seen, even though that was not present in the original query.

Example: Query returns an error The following query produces an error because Vitess does not support the `AVG` function for scatter queries across multiple shards.

```
$ vtexplain -schema-file schema.sql -vschema-file vschema.json -shards 4 -sql 'SELECT
   AVG(balance) FROM user;'
ERROR: vtexplain execute error in 'SELECT AVG(balance) FROM user': unsupported: in scatter
   query: complex aggregate expression
```

Example: Targeting a single shard The following query only targets a single shard because the query supplies the sharding key.

```
$ vtexplain -schema-file schema.sql -vschema-file vschema.json -shards 2 -sql 'SELECT *
   FROM user WHERE user_id = 100;'
----------------------------------------------------------------------
SELECT * FROM user WHERE user_id = 100

1 ks1/80-c0: SELECT * FROM user WHERE user_id = 100 limit 10001
----------------------------------------------------------------------
```~~~
Analyzing a SQL statement

Introduction

This document covers the way Vitess executes a particular SQL statement using the
   [VTExplain tool](../../../reference/vtexplain). This tool works similarly to the MySQL
   `EXPLAIN` statement.

Prerequisites
```
```

```
You can find a prebuilt binary version of the VTExplain tool in [the most recent release of
   Vitess](https://github.com/vitessio/vitess/releases/).

You can also build the `vtexplain` binary in your environment. To build this binary, refer
   to the [Build From Source](../../../contributing/build-from-source) guide.

### Overview

To successfully analyze your SQL queries and determine how Vitess executes each statement,
   follow these steps:

1. Identify a SQL schema for the statement's source tables
1. Identify a VSchema for the statement's source tables
1. Run the VTExplain tool

If you have a large number of queries you want to analyze for issues, based on a Vschema
   'youve created for your database, you can read through a detailed scripted example
   [here](../vtexplain-in-bulk).

### 1. Identify a SQL schema for tables in the statement

In order to explain a statement, first identify the SQL schema for the tables that the
   statement uses. This includes tables that a query targets and tables that a DML
   statement modifies.

#### Example SQL Schema

The following example SQL schema creates two tables, `users` and `users_name_idx`, each of
   which contain the columns `user_id` and `name`, and define both columns as a composite
   primary key. The example statements in step 3 include these tables.
```

CREATE TABLE users(user_id bigint, name varchar(128), primary key(user_id));

CREATE TABLE users_name_idx(user_id bigint, name varchar(128), primary key(name, user_id));

```
### 2. Identify a VSchema for the statement's source tables

Next, identify a [VSchema](../../../concepts/vschema) that contains the
   [Vindexes](../../../reference/vindexes) for the tables in the statement.

#### The VSchema must use a keyspace name.

VTExplain requires a keyspace name for each keyspace in an input VSchema:
```

“keyspace_name”: { ”_comment“:”Keyspace definition goes here.” }

```
If no keyspace name is present, VTExplain will return the following error:
```

ERROR: initVtgateExecutor: json: cannot unmarshal bool into Go value of type map[string]json.RawMessage

```
#### Example VSchema

The following example VSchema defines a single keyspace `mainkeyspace` and three Vindexes,
   and specifies vindexes for each column in the two tables `users` and `users_name_idx`.
   The keyspace name `"mainkeyspace"` precedes the keyspace definition object.
```

{ “mainkeyspace”: { “sharded”: true, “vindexes”: { “hash”: { “type”: “hash” }, “md5”: { “type”: “unicode_loose_md5”, “params”: {}, “owner”: ”” }, “users_name_idx”: { “type”: “lookup_hash”, “params”: { “from”: “name”, “table”: “users_name_idx”, “to”: “user_id” }, “owner”: “users” } }, “tables”: { “users”: { “column_vindexes”: [{ “column”: “user_id”,

“name”: “hash” }, { “column”: “name”, “name”: “users_name_idx” }], “auto_increment”: null }, “users_name_idx”: { “type”: ””,”column_vindexes“: [{ ”column”: ”name”, ”name”: ”md5” }],”auto_increment”: null } } } }

```
### 3. Run the VTExplain tool

To explain a query, pass the SQL schema and VSchema files as arguments to the `VTExplain`
   command.

#### Example: Explaining a SELECT query

In the following example, the `VTExplain` command takes a `SELECT` query and returns the
   sequence of queries that Vitess runs in order to execute the query:
```

vtexplain -shards 8 -vschema-file vschema.json -schema-file schema.sql -replication-mode “ROW” -output-mode text -sql “SELECT * from users”

SELECT * from users

1 mainkeyspace/-20: select * from users limit 10001 1 mainkeyspace/20-40: select * from users limit 10001 1 mainkeyspace/40-60: select * from users limit 10001 1 mainkeyspace/60-80: select * from users limit 10001 1 mainkeyspace/80-a0: select * from users limit 10001 1 mainkeyspace/a0-c0: select * from users limit 10001 1 mainkeyspace/c0-e0: select * from users limit 10001 1 mainkeyspace/e0-: select * from users limit 10001

“‘

In the example above, the output of `VTExplain` shows the sequence of queries that Vitess runs in order to execute the query. Each line shows the logical sequence of the query, the keyspace where the query executes, the shard where the query executes, and the query that executes, in the following format:
`[Sequence number] [keyspace]/[shard]: [query]`
In this example, each query has sequence number `1`, which shows that Vitess executes these in parallel. Vitess automatically adds the `LIMIT 10001` clause to protect against large results.
Example: Explaining an INSERT query
In the following example, the `VTExplain` command takes an `INSERT` query and returns the sequence of queries that Vitess runs in order to execute the query:
“‘ vtexplain -shards 128 -vschema-file vschema.json -schema-file schema.sql -replication-mode “ROW” -output-mode text -sql “INSERT INTO users (user_id, name) VALUES(1, ‘john’)”

INSERT INTO users (user_id, name) VALUES(1, ‘john’)

1 mainkeyspace/22-24: begin 1 mainkeyspace/22-24: insert into users_name_idx(name, user_id) values (‘john’, 1) /* vtgate:: keyspace_id:22c0c31d7a0b489a16332a5b32b028bc */ 2 mainkeyspace/16-18: begin 2 mainkeyspace/16-18: insert into users(user_id, name) values (1, ‘john’) */ vtgate:: keyspace_id:166b40b44aba4bd6 */ 3 mainkeyspace/22-24: commit 4 mainkeyspace/16-18: commit

---

“‘

The example above shows how Vitess handles an insert into a table with a secondary lookup Vindex:
* At sequence number `1`, Vitess opens a transaction on shard `22-24` to insert the row into the `users_name_idx` table. * At sequence number `2`, Vitess opens a second transaction on shard `16-18` to perform the actual insert into the `users` table. * At sequence number `3`, the first transaction commits. * At sequence number `4`, the second transaction commits.
Example: Explaining an uneven keyspace
In previous examples, we used the `-shards` flag to set up an evenly-sharded keyspace, where each shard covers the same fraction of the keyrange. `VTExplain` also supports receiving a JSON mapping of shard ranges to see how Vitess would handle a query against an arbitrarly-sharded keyspace.
To do this, we first create a JSON file containing a mapping of keyspace names to shardrange maps. The shardrange map has the same structure as the output of running `vtctl FindAllShardsInKeyspace <keyspace>`.

```
{ "mainkeyspace": { "-80": { "master_alias": { "cell": "test", "uid": 00000000100 },
"master_term_start_time": { "seconds": 1599828375, "nanoseconds": 664404881 }, "key_range": { "end":
"gA==" }, "is_master_serving": true }, "80-90": { "master_alias": { "cell": "test", "uid":
00000000200 }, "master_term_start_time": { "seconds": 1599828344, "nanoseconds": 868327074 },
"key_range": { "start": "gA==", "end": "kA==" }, "is_master_serving": true }, "90-a0": {
"master_alias": { "cell": "test", "uid": 00000000300 }, "master_term_start_time": { "seconds":
1599828405, "nanoseconds": 152120945 }, "key_range": { "start": "kA==", "end": "oA==" },
"is_master_serving": true }, "a0-e8": { "master_alias": { "cell": "test", "uid": 00000000400 },
"master_term_start_time": { "seconds": 1599828183, "nanoseconds": 911677983 }, "key_range": {
"start": "oA==", "end": "6A==" }, "is_master_serving": true }, "e8-": { "master_alias": { "cell":
"test", "uid": 00000000500 }, "master_term_start_time": { "seconds": 1599827865, "nanoseconds":
770606551 }, "key_range": { "start": "6A==" }, "is_master_serving": true } }
```

After having saved that to a file called `shardmaps.json`:

“‘ vtexplain -vschema-file vschema.json -schema-file schema.sql -ks-shard-map shardmaps.json -replication-mode “ROW” -output-mode text -sql “SELECT * FROM users; SELECT * FROM users WHERE id IN (10, 17, 42, 1000);”

SELECT * FROM users

1 mainkeyspace/-80: select * from users limit 10001 1 mainkeyspace/80-90: select * from users limit 10001 1 mainkeyspace/90-a0: select * from users limit 10001 1 mainkeyspace/a0-e8: select * from users limit 10001 1 mainkeyspace/e8-: select * from users limit 10001

SELECT * FROM users WHERE id IN (10, 17, 42, 100000)
1 mainkeyspace/-80: select * from users where id in (10, 17, 42) limit 10001 1 mainkeyspace/80-90: select * from users where id in (100000) limit 10001

“‘

See also

- For detailed configuration options for VTExplain, see the VTExplain syntax reference.