Making MySQL-8.0 XA transaction processing crash safe

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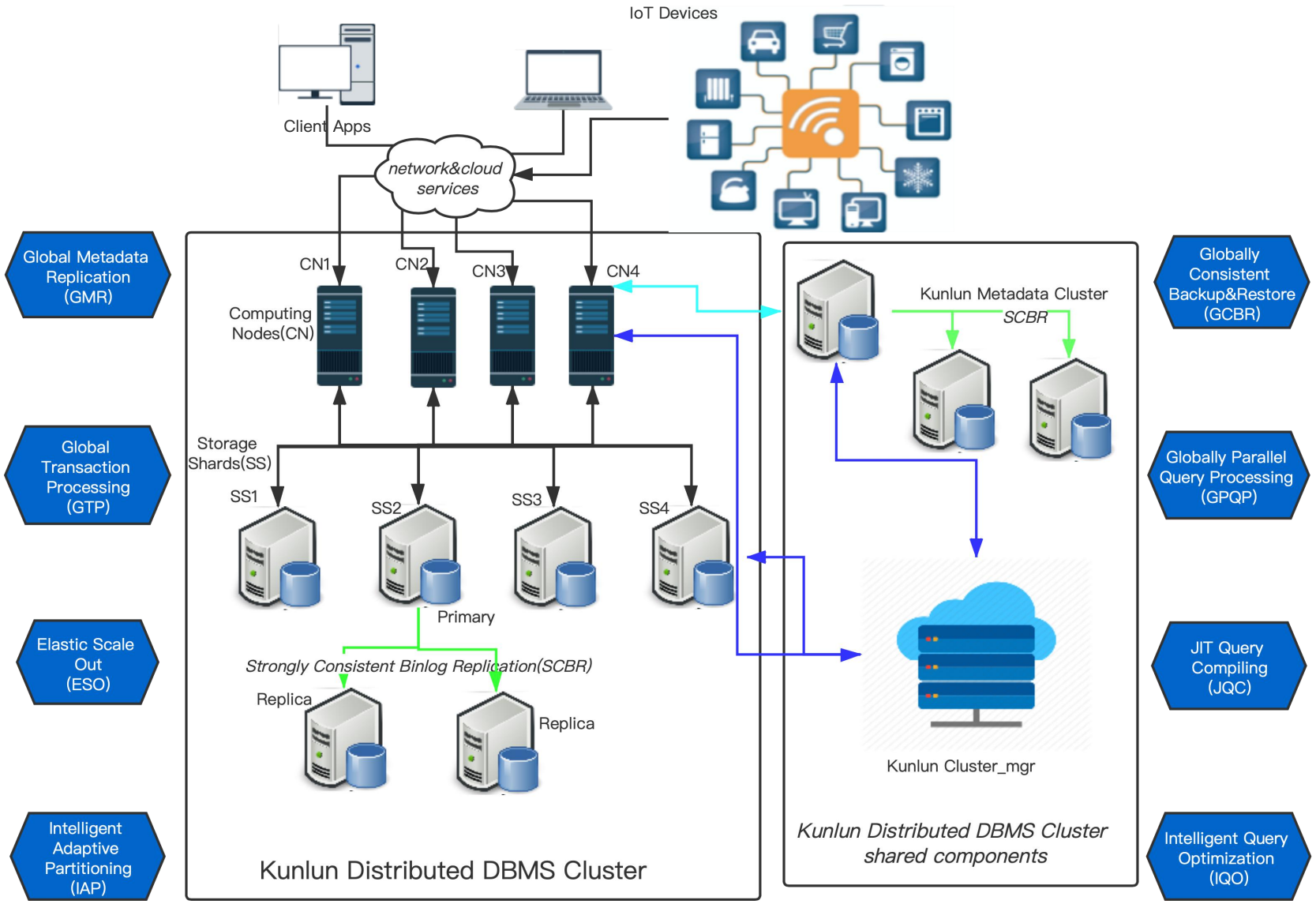
About the author

- Zhao Wei (David Zhao) twitter/linkedin/wechat: david.zhao.cn@gmail.com
- Database kernel developer in Oracle 2007-2015
  - Berkeley DB
  - MySQL
- Database kernel developer in Tencent 2015-2019
  - TDSQL --- most popular distributed RDBMS inside Tencent and Tencent Public/Private Cloud
    - Lead the effort to evolve TDSQL from a table-sharding solution to a distributed RDBMS
- Left Tencent and started Kunlun project in Aug 2019
  - To build an epochal distributed RDBMS based on widely adopted technologies(MySQL & PostgreSQL).
  - For more info about kunlun project visit www.zettadb.com
  - Kunlun project is open source at https://github.com/zettadb/kunlun

About Kunlun Distributed RDBMS

- Goals&objectives
  - A distributed RDBMS for PostgreSQL and MySQL users
    - with knowledge&lessons learned from work on TDSQL
    - compatible with PostgreSQL in DML grammar and most DDL grammar
    - compatible with MySQL in client protocol and DML grammar
    - to manage multi-terabyte data for both OLTP and inplace OLAP workloads
  - Full-fledged NewSQL capabilities
    - highly available&fully consistent, crash safe&fault tolerant
    - highly scalable: table sharding & elastic horizontal scale-out
  - Cloud native & DBaaS
- Stands on the shoulders of giants
  - Kunlun computing node derived from PostgreSQL-11.5
  - Kunlun storage nodes derived from Percona-MySQL-8.0
  - keeps up with upper streams
  - Finished over 70% kernel development, released 0.7 in Sep. 2020

Kunlun Architecture



Kunlun Advantages & highlights

- Share nothing & adaptive sharding (IAP)
  - distribute tables/tablets intelligently to multiple storage shards
  - multiple nodes for read & write queries, premium scalability
- Distributed transaction mgmt & distributed query processing
  - works transparently, no burden for users, no client code changes needed
  - appears like a standalone DB server for apps and app developers
- Crash safety&fault tolerance, high availability&strong consistency (GTP)
  - any node/network fault at any time won't break transaction ACID guarantees
- Elastic horizontal scale-out (ESO) (*)
  - Automatic & elastic & continuous & on demand
  - unnoticible by application or end users
- Full-fledged distributed query processing (IQO) (on-going)
  - cross shard join, subqueries, prepared statement, jit
  - OLAP analysis, stored procedures and more
- Global parallel query processing (GPQP)
  - Inside computing nodes(CN)
  - CN send queries to target storage nodes(SN) asyncly so SS work in parallel
  - Inside a SN (*)

Kunlun Basics

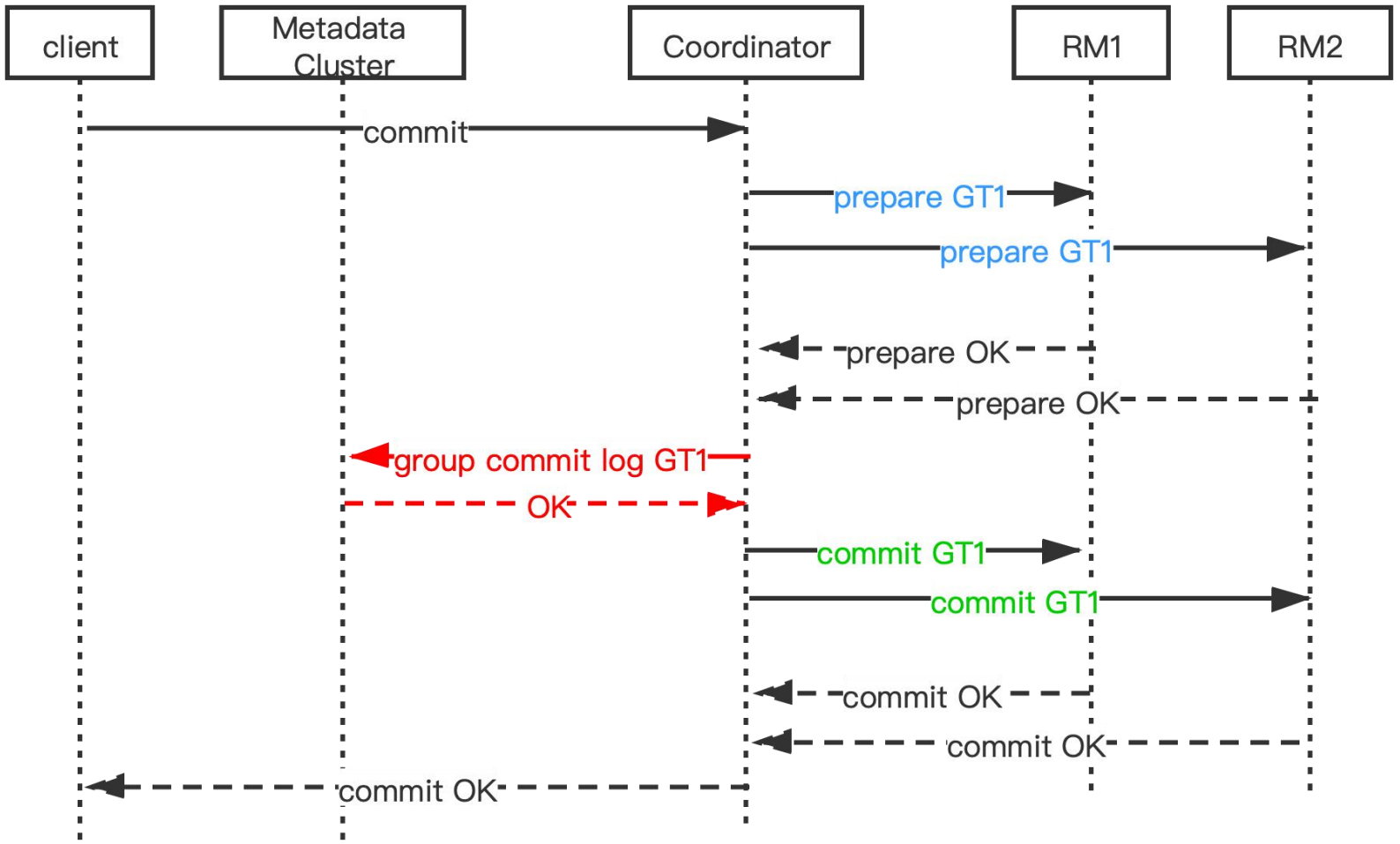
- Computing nodes
  - accept & validate user connections
  - accept & process user queries
    - parse -> optimize -> execute(send SQL -> receive & assemble)
    - executes DDLs and DMLs
  - doesn't store user data, only store metadata locally
    - takes trivial storage/memory space
    - stores user data in storage shards
    - can be built from metadata in metadata shard, equivalent to stateless proxies
      - needs no HA measures, no burden for DBAs
  - add/remove nodes on demand, nodes independent from each other
- Support most PostgreSQL query processing features
  - Most DDLs and DMLs grammars
  - indexes, views, materialized views, sequences; prepared statement, jit
  - cross shard join, subqueries, OLAP queries, stored procedures (on-going)
  - All basic data types (numeric, string/text, date/time/timestamp, enum), json&spatial in future
- Will support mysql client protocol and common MySQL private DML grammar(pending)

Kunlun Basics

- Storage shards
  - Stores application(user) data in standalone tables
    - PG single tables
    - PG table partitions
  - execute mostly single table queries
    - in a global transaction's local transaction branch
    - no table partitioning
  - Currently uses MySQL group replication(MGR) single primary mode for shard HA
    - primary election
    - robust consistency guarantees
  - Will support more types of HA (*) solutions
    - strongly consistent row based binlog replication
    - shared storage
  - Uses innodb only so far
    - never untransactional engines(myisam, etc)
    - maybe myrocks in future
  - Require kunlun-percona-MySQL-8.0.18-9
    - developed based on percona-MySQL-8.0.18-9
    - contains critical bug fixes & supporting features & performance enhancements
    - will keep up with upper stream

Kunlun Distributed Transaction Processing

- Global Transaction Coordinator
  - component of a computing node
  - Tracks txn branch states
  - 2PC for multi-shard writers
  - 1PC for single shard writers
  - 1PC for read-only txn branches
  - before 2nd phase, group log commit decisions in commit-log
  - Abort txn on error during txn commit



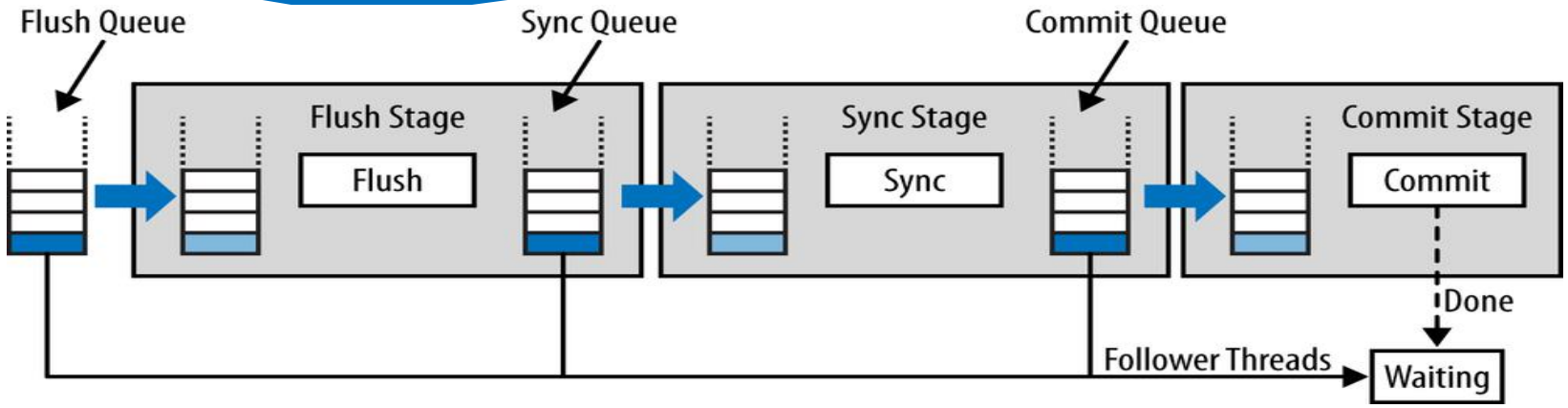
Potential Failures

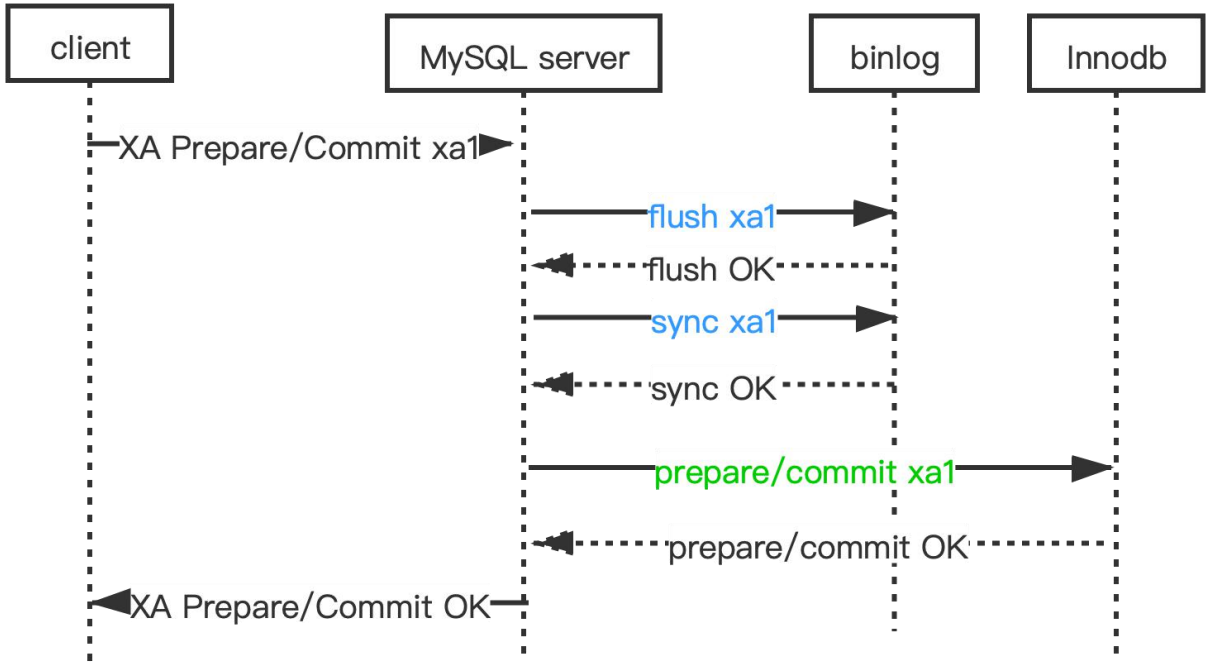
- Node failures
  - Computing nodes (CNs)
  - Primary nodes of storage shards
  - Replica nodes of storage shards
  - Primary nodes of metadata shards
- Network failures between
  - CNs & Meta shard primary
  - CNs & Storage shard primary
  - A primary MySQL node and its replicas
- Fail while many global txns are in 2PC commit phases
  - partial commits
- Fail during binlog group commit
  - many regular txns doing internal 2PC (prepare->commit)
  - many XA txns doing prepare
  - many prepared XA txns doing commit

Requirement for crash-safety & consistency in MySQL

- Keep consistency between
  - a primary and its replicas
    - replica local sync
    - same binlog event groups
  - innodb and binlog
    - for any txn T, T in innodb <=> T in binlog
    - key: no extra event groups in binlog
    - challenge: binlog is passive and inflexible
  - gtid set in innodb undo log, binlog and mysql.gtid_executed (MGE)
    - New requirement for MySQL-8.0 for clone
    - txn.gtid -> undo log -> mysql.gtid_executed (MGE)

MySQL Binlog Group Commit (BGC)



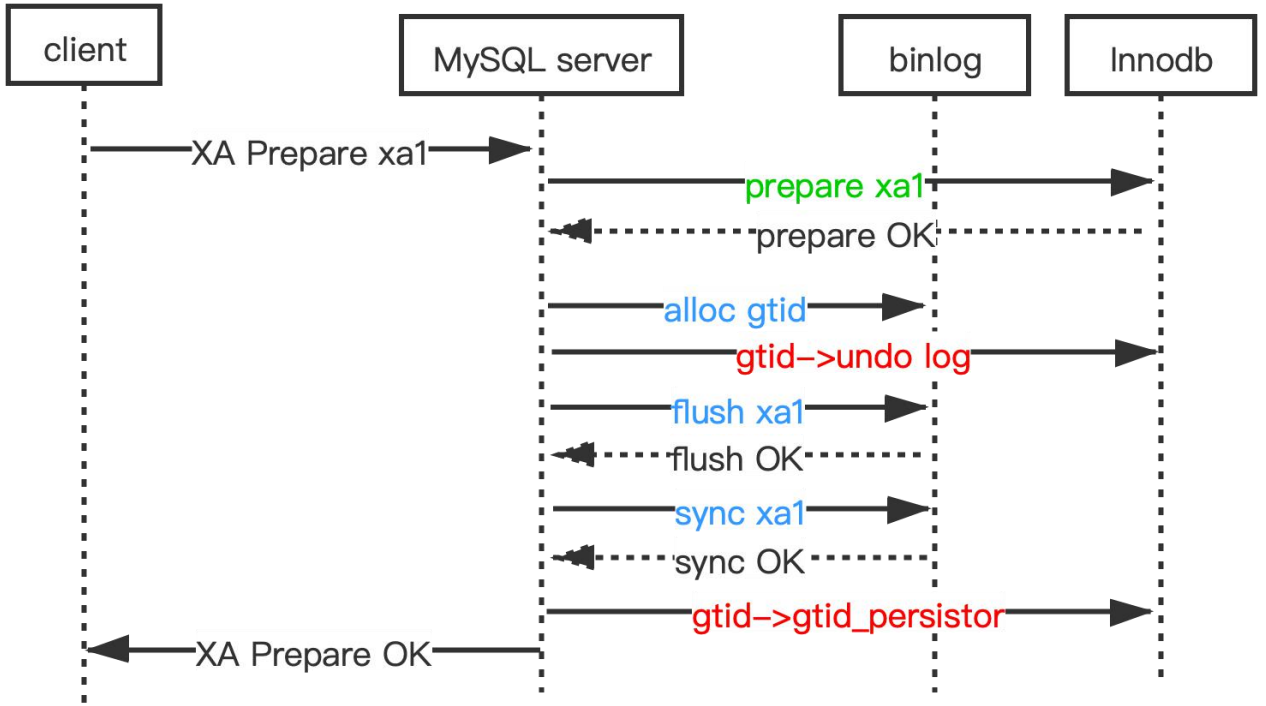


MySQL-8.0 XA Transaction Processing Issues

- XA Prepare handling in community mysql
  - step1: binlog prepare GT
    - binlog group commit flush&sync phases
    - wait for its reception by replicas before flush(MGR) or after sync (semisync)
  - step 2: engine(innodb, myrocks, etc) prepare GT
- Issue 1: primary may crash between steps #1 and #2
  - Some replicas may have replicated binlogs of GT and replayed it, so GT is prepared in replica(s)
  - Crashed primary node has inconsistent binlogs&innodb
  - after primary switch, old primary(now replica) can't do 'XA COMMIT GT', replication blocks
- Solution: do binlog prepare after all engine prepare, so the new procedure is:
  - step1: engine(innodb, myrocks, etc) prepare GT
  - step2: binlog prepare GT
  - the solution causes issue 2

MySQL-8.0 XA Transaction Processing Issues

- XA Prepare Issue 2: dilemma caused by MySQL-8.0 clone
  - no gtid at step #1, only has gtid at beginning of step #2
- Solution: interleave operations
  - engine prepare -> generate gtid -> write gtid to undo log -> flush binlog
  - innodb recovery: abort prepared txns without gtid in its undo log
  - gtid -> gtid_persistor -> MGE after binlog sync



MySQL-8.0 XA Transaction Processing Issues

- Binlog Recovery
  - engine recovery first
  - scans last binlog file to form internal XA txn ids S
    - why only last binlog ?
  - commit/abort each recovered prepared innodb txn if it is/isn't in S
  - Issue 3: external XA txns are ignored in binlog recovery
  - Solution: for each prepared external XA txn xi in every storage engine
    - commit xi if 'XA COMMIT xi' is found in last binlog file
    - otherwise abort xi if 'XA ROLLBACK xi' is found in last binlog file
    - otherwise leave xi prepared if 'XA PREAPRE xi' is found in S
    - otherwise abort xi if 'XA PREPARE xi' isn't found in S
    - special handling for 'XA COMMIT ONE PHASE'

MySQL-8.0 XA Transaction Processing Issues

- Where are prepared txns?
  - prepared XA txns can live across binlog file rotations
  - Issue 4: not sufficient to scan last binlog file for prepared external XA txns
    - XA PREPARE & XA COMMIT seperated apart
- Solution: record all current prepared external XA txns at creation of each new binlog file
  - kunlun-percona: pack into Previous_gtids event
  - loss: ecosystem compatibility
  - gains: distributed txn crash safety

```
mysql> xa start 'xa2';
Query OK, 0 rows affected (0.00 sec)

mysql> insert into t1 values(7,8);
ERROR 1046 (3D000): No database selected
mysql> use test
Database changed
mysql> insert into t1 values(7,8);
Query OK, 1 row affected (0.01 sec)

mysql> xa end 'xa2';
Query OK, 0 rows affected (0.01 sec)

mysql> xa prepare 'xa2';
Query OK, 0 rows affected (0.01 sec)
```

```
mysql> show binlog events in 'binlog.000011';
+---------------+-----+----------------+-----------+-------------+-----------------------------------------------------------------------------------------------+
| Log_name      | Pos | Event_type     | Server_id | End_log_pos | Info                                                                                          |
+---------------+-----+----------------+-----------+-------------+-----------------------------------------------------------------------------------------------+
| binlog.000011 |   4 | Format_desc    |     29511 |         124 | Server ver: 8.0.18-9-kunlun-percona-mysql-debug, Binlog ver: 4                                |
| binlog.000011 | 124 | Previous_gtids |     29511 |         223 | 51078c3a-547e-11ea-9780-981fd1bd410d:1-9252:1000608-1000667  XA-PREPARED: xa1 |
+---------------+-----+----------------+-----------+-------------+-----------------------------------------------------------------------------------------------+
2 rows in set (0.00 sec)
```

```
mysql> show binlog events in 'binlog.000012';
+---------------+-----+----------------+-----------+-------------+-----------------------------------------------------------------------------------------------+
| Log_name      | Pos | Event_type     | Server_id | End_log_pos | Info                                                                                          |
+---------------+-----+----------------+-----------+-------------+-----------------------------------------------------------------------------------------------+
| binlog.000012 |   4 | Format_desc    |     29511 |         124 | Server ver: 8.0.18-9-kunlun-percona-mysql-debug, Binlog ver: 4                                |
| binlog.000012 | 124 | Previous_gtids |     29511 |         227 | 51078c3a-547e-11ea-9780-981fd1bd410d:1-9253:1000608-1000667  XA-PREPARED: xa1|xa2 |
+---------------+-----+----------------+-----------+-------------+-----------------------------------------------------------------------------------------------+
2 rows in set (0.00 sec)

mysql> flush logs;
Query OK, 0 rows affected (0.04 sec)

mysql> show binlog events in 'binlog.000013';
+---------------+-----+----------------+-----------+-------------+-----------------------------------------------------------------------------------------------+
| Log_name      | Pos | Event_type     | Server_id | End_log_pos | Info                                                                                          |
+---------------+-----+----------------+-----------+-------------+-----------------------------------------------------------------------------------------------+
| binlog.000013 |   4 | Format_desc    |     29511 |         124 | Server ver: 8.0.18-9-kunlun-percona-mysql-debug, Binlog ver: 4                                |
| binlog.000013 | 124 | Previous_gtids |     29511 |         231 | 51078c3a-547e-11ea-9780-981fd1bd410d:1-9254:1000608-1000667  XA-PREPARED: xa3|xa1|xa2 |
+---------------+-----+----------------+-----------+-------------+-----------------------------------------------------------------------------------------------+
2 rows in set (0.00 sec)
```

```
mysql> xa start 'xa3';
Query OK, 0 rows affected (0.01 sec)

mysql> insert into t1 values(9,10);
Query OK, 1 row affected (0.00 sec)

mysql> xa end 'xa3';
Query OK, 0 rows affected (0.00 sec)

mysql> xa prepare 'xa3';
Query OK, 0 rows affected (0.00 sec)
```

Thank you!