TiDB and Amazon Aurora

Compare / Contrast / Combine

Ed Huang, CTO @ PingCAP
h@pingcap.com

PingCAP TiDB

TiDB Community Slack Channel
https://pingcap.com/tidbslack/

PingCAP

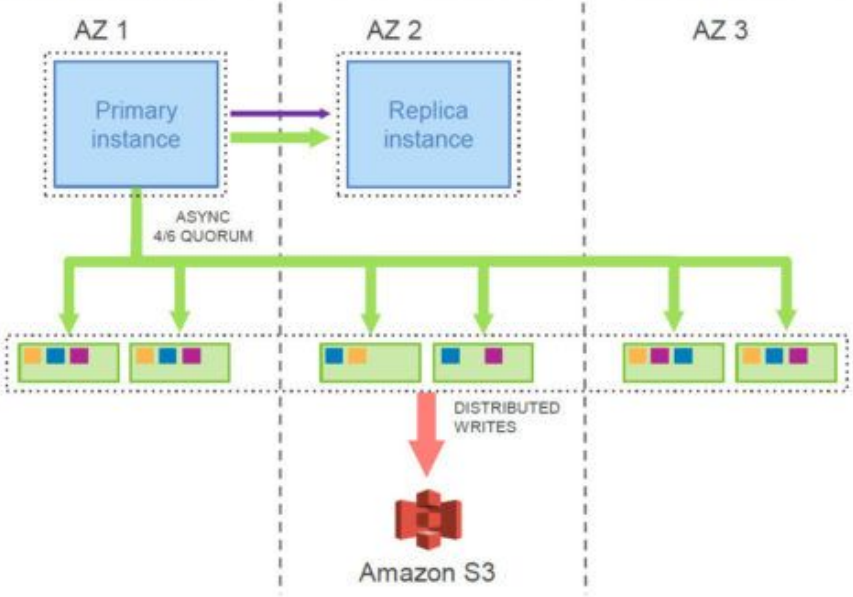
Compare

Why Aurora?

- Amazon Aurora is popular
- Amazon Aurora is designed for OLTP workload
- Amazon Aurora is still using the MySQL code base
- It would be cool to do some lightweight OLAP queries directly on the transactional database.
    - No need to involve data warehouse!
    - Example: a dashboard for each tenant in SaaS applications

IO traffic in Aurora (database)

AMAZON AURORA



IO FLOW

Boxcar redo log records – fully ordered by LSN
Shuffle to appropriate segments – partially ordered
Boxcar to storage nodes and issue writes

OBSERVATIONS

Only write redo log records; all steps asynchronous
No data block writes (checkpoint, cache replacement)
6X more log writes, but **9X** less network traffic
Tolerant of network and storage outlier latency

PERFORMANCE

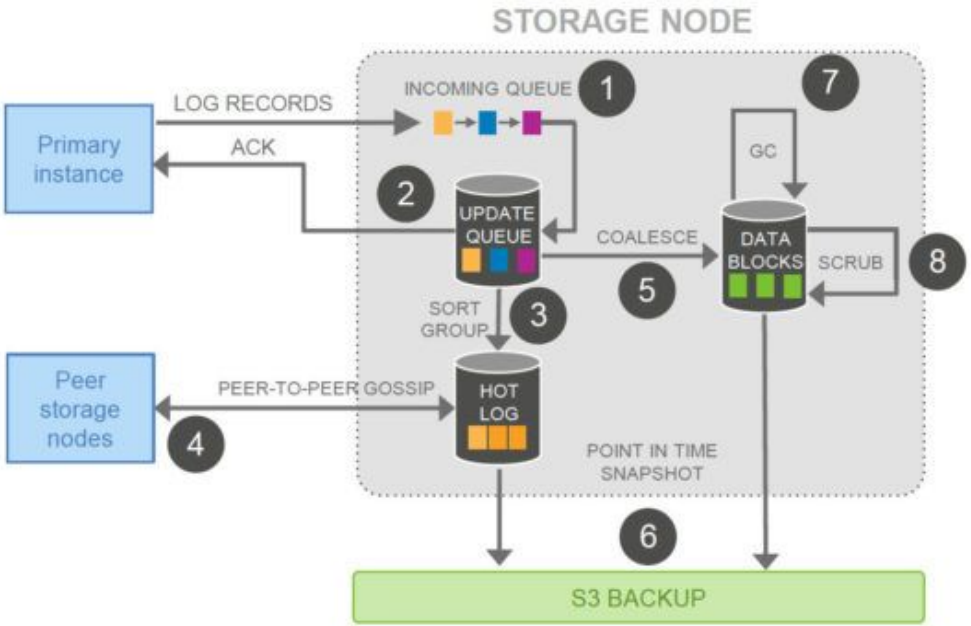
27,378K transactions	**35X** MORE
950K I/Os per 1M txns (6X amplification)	**7.7X** LESS

30 minute SysBench write-only workload, 100 GB data set

TYPE OF WRITE

LOG · BINLOG · DATA · DOUBLE-WRITE · FRM FILES

IO traffic in Aurora (storage node)



IO FLOW

1. Receive record and add to in-memory queue
2. Persist record and ACK
3. Organize records and identify gaps in log
4. Gossip with peers to fill in holes
5. Coalesce log records into new data block versions
6. Periodically stage log and new block versions to S3
7. Periodically garbage collect old versions
8. Periodically validate CRC codes on blocks

OBSERVATIONS

All steps are asynchronous

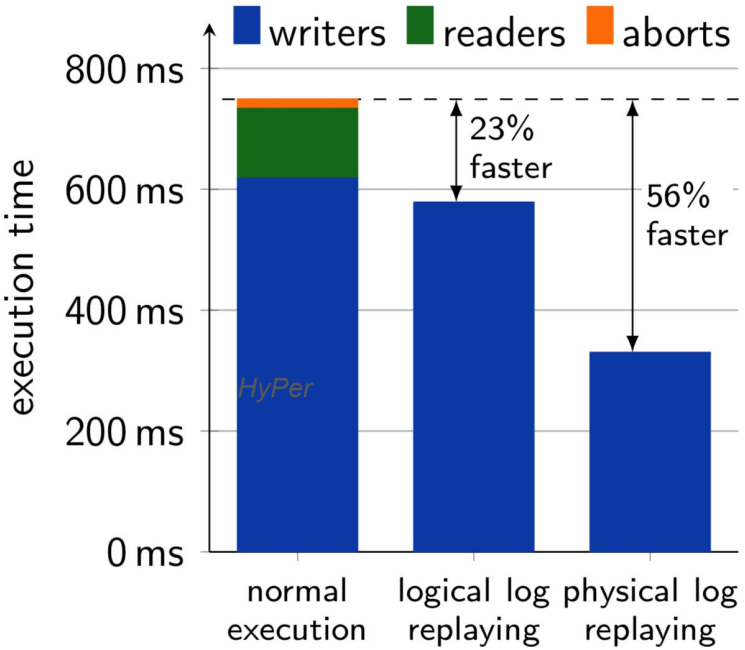
Only steps 1 and 2 are in foreground latency path

Input queue is **46X** less than MySQL (unamplified, per node)

Favor latency-sensitive operations

Use disk space to buffer against spikes in activity

Why Aurora is fast

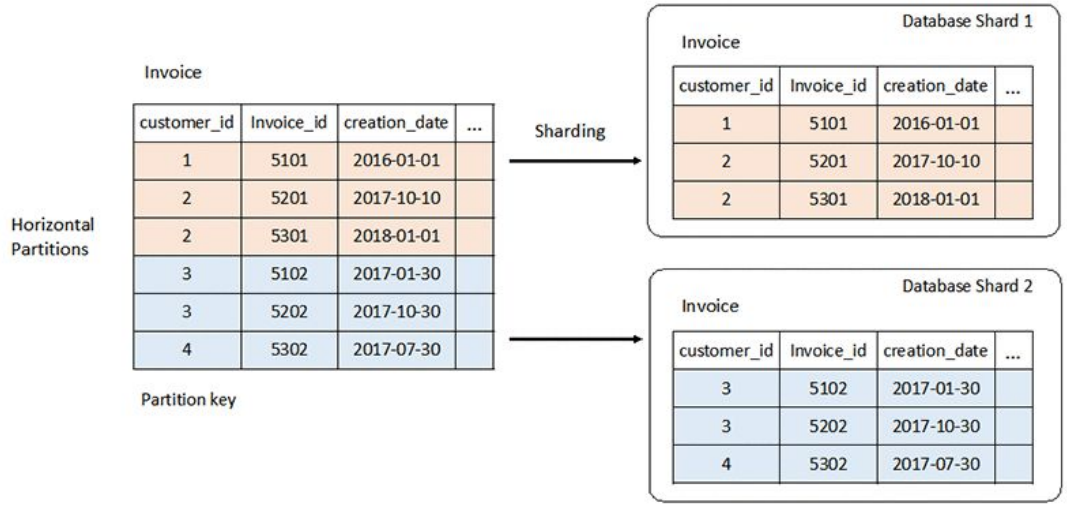


- Fewer I/O, fewer write amplification
- Smaller network packets
- Eventual consistency

Aurora Pros & Cons

Pros:

- 100% MySQL compatibility
- Fully-managed
- Scalable read



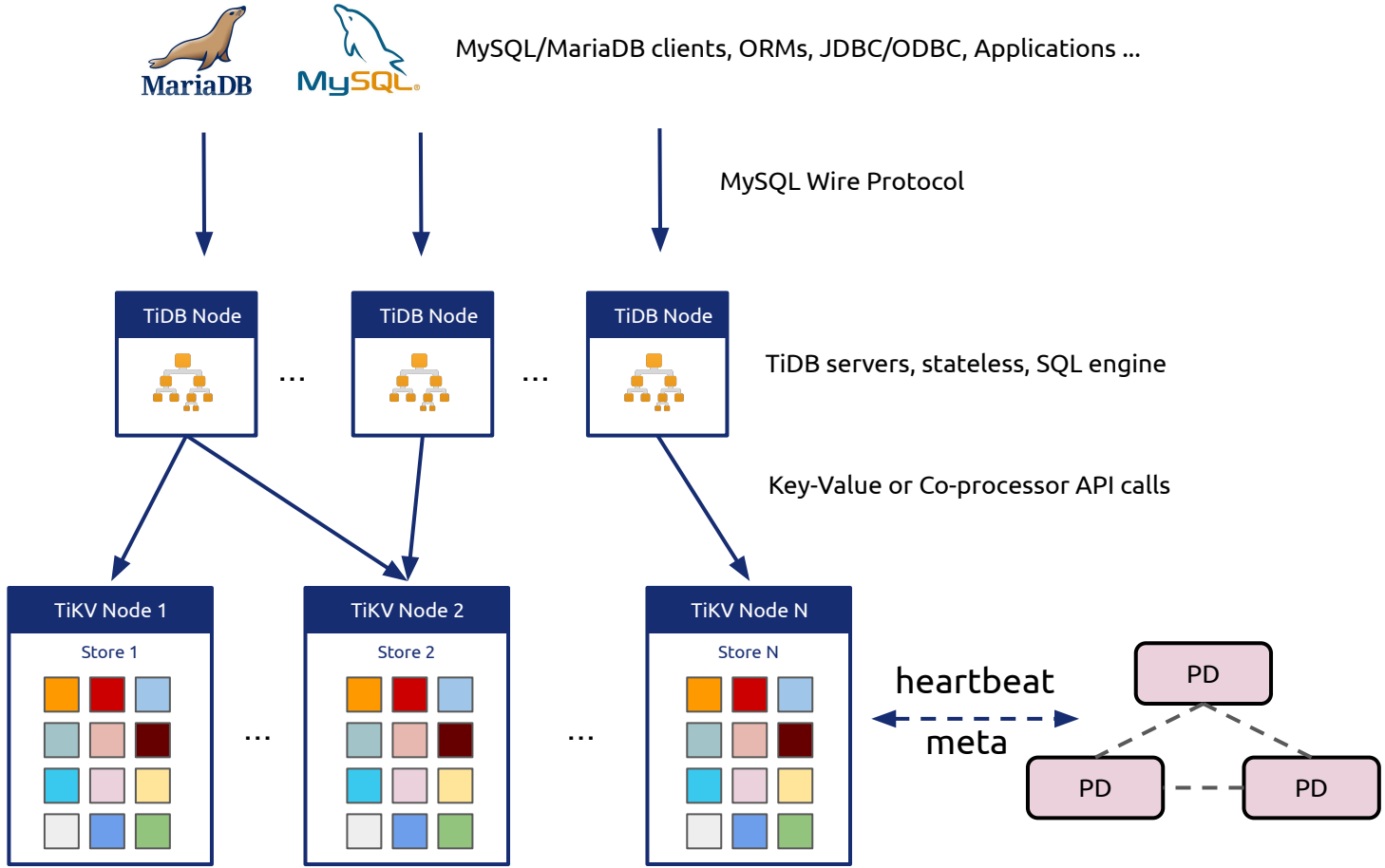
Cons:

- Single point write (if you want to scale out writer, you still need sharding)
- SQL layer is not designed for complex query
- Reader is eventual consistency
- Memory size and storage size is not proportional

Aurora typical scenarios

- Read >> Write, and all the writes can handle by one node
- Data size is not too large
    - Reason: Performance will have significant fluctuations, if the gap of memory and actual storage size is too large
- Reader doesn’t require stong consistency
- Migrate from legacy MySQL applications

What's TiDB



PingCAP

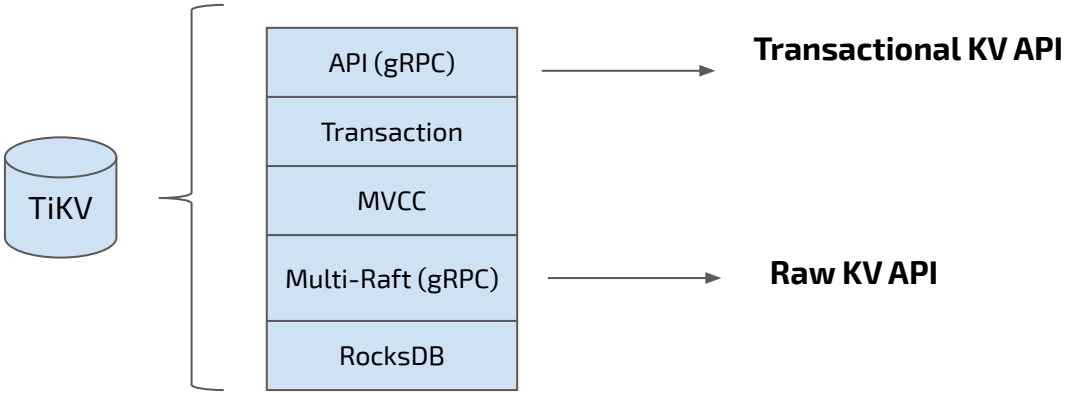
TiDB is not a database middleware

	Sharding middleware	TiDB
ACID Transaction Support	Mostly ✖	✓
Elastic Scaling	✖	✓
Complex Query (Join, Sub query, GROUP BY)	✖	✓
Failover	Manual	Auto
MySQL Compatibility	Low	High
Max Capacity (Good performance)	Few TBs	200 TB+

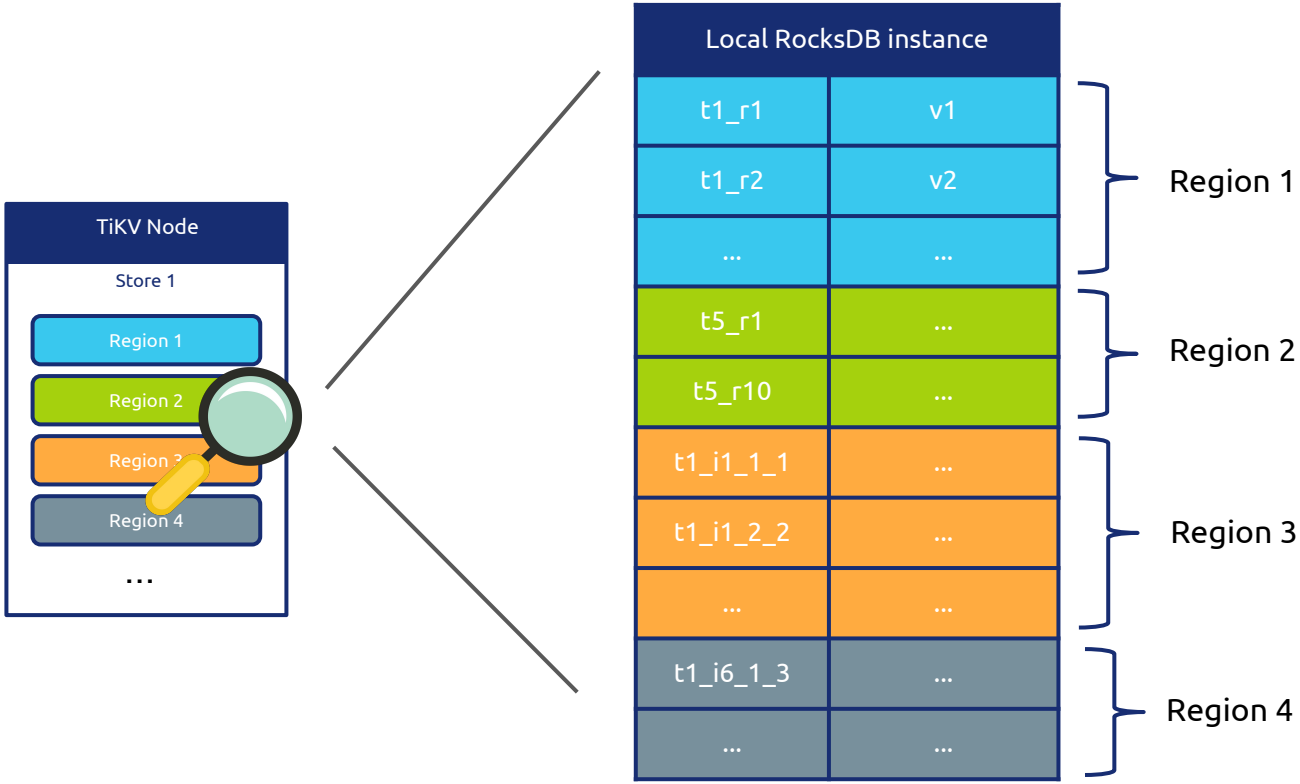
TiDB architecture

Storage Physical Stack

Highly layered

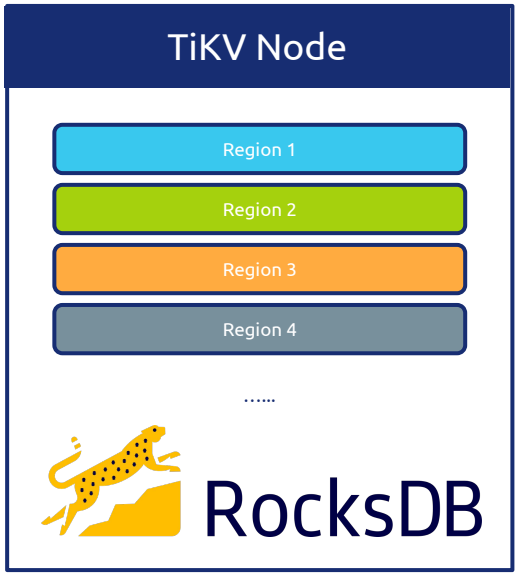


Data organization within TiDB

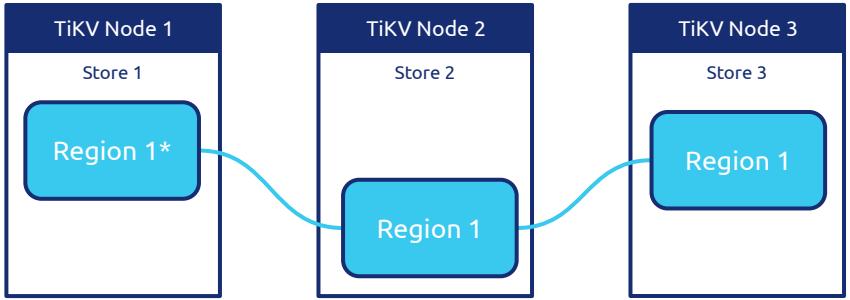


Data organization within TiDB

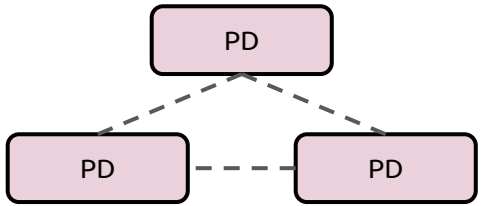
- Region (A bunch of key-value pairs, or Split)
  - Default total size of one Region: 96MB
    - You can change it in configuration
  - Ordered
- Region is a logical concept
  - Region meta : [Start key, End key)
  - All Regions within a TiKV node share the same **RocksDB** instance
- Each Region is a Raft group
  - Default: 3 replicas



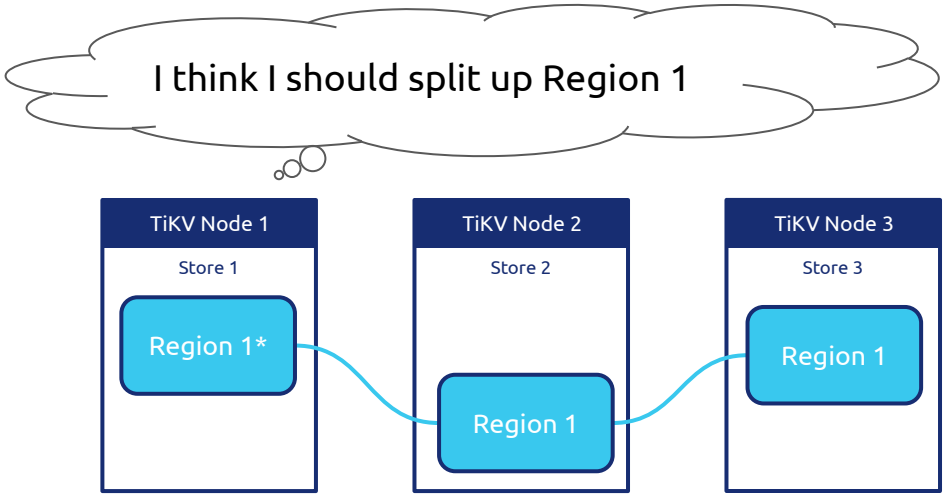
How scale-out works inside TiDB



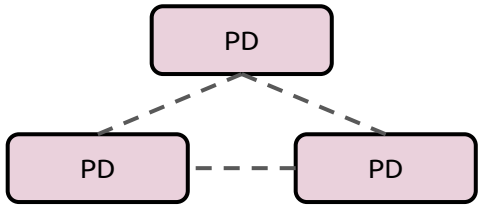
Let’s say, the amount of data within Region 1 exceeds the threshold (default: 96MB)



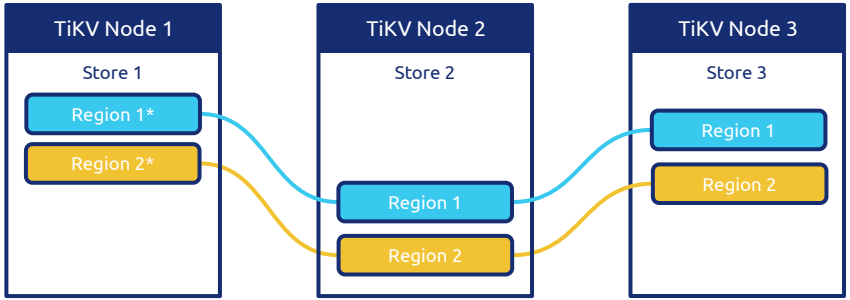
How scale-out works inside TiDB



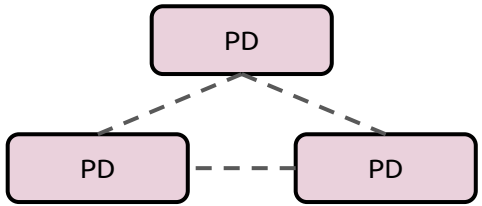
Let’s say, the amount of data within Region 1 exceeds the threshold (default: 96MB)



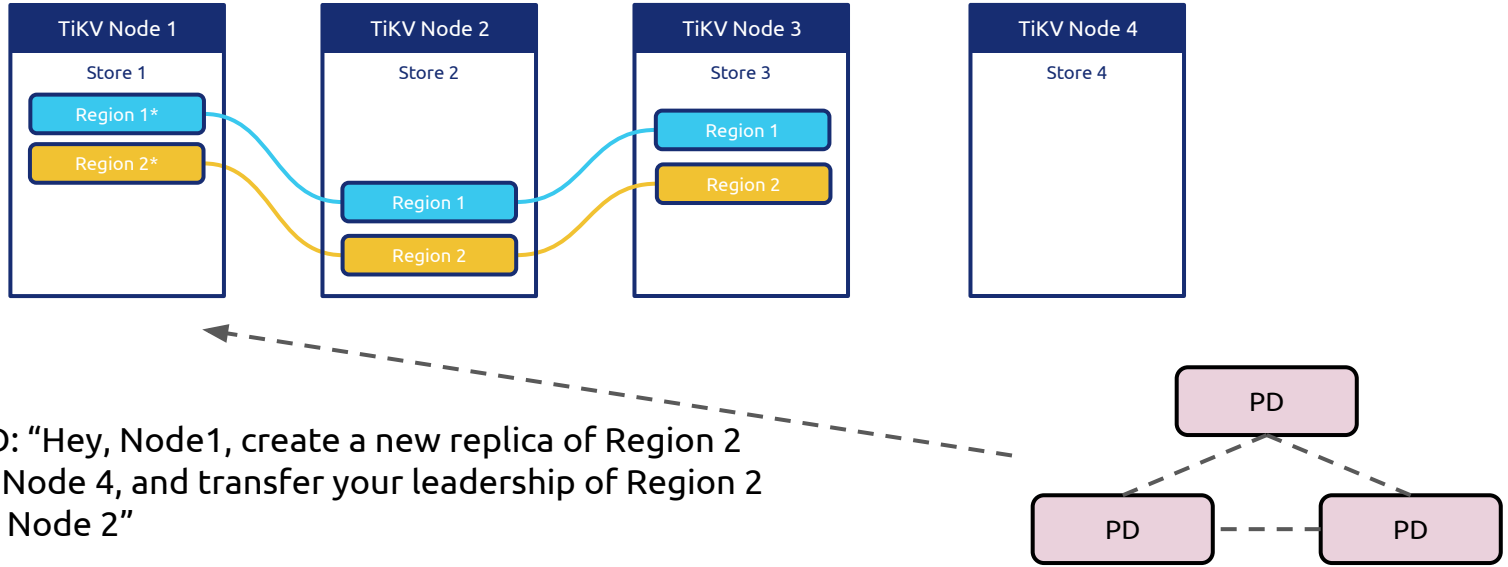
How scale-out works inside TiDB



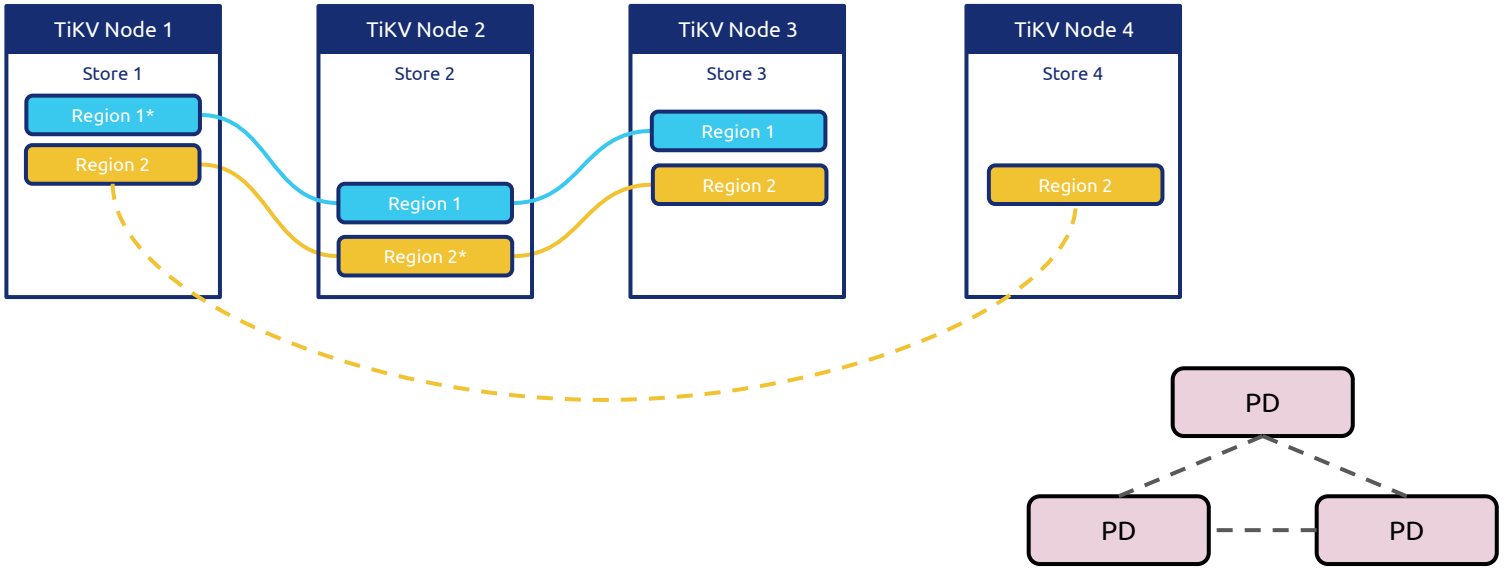
Region 1 will be split into two smaller Regions.
(the leader of Region 1 sends a Split command as a special log to its replicas via the Raft protocol.
Once the Split command is successfully committed by Raft, that means the Region has been successfully split.)



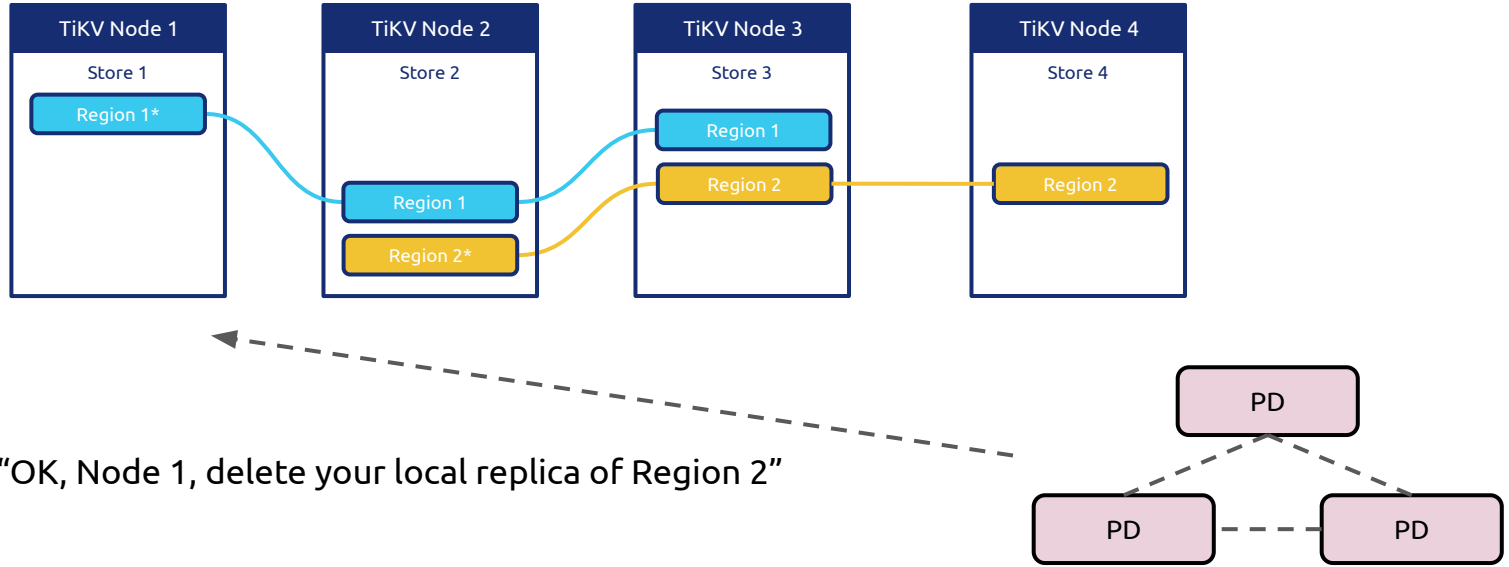
How scale-out works inside TiDB



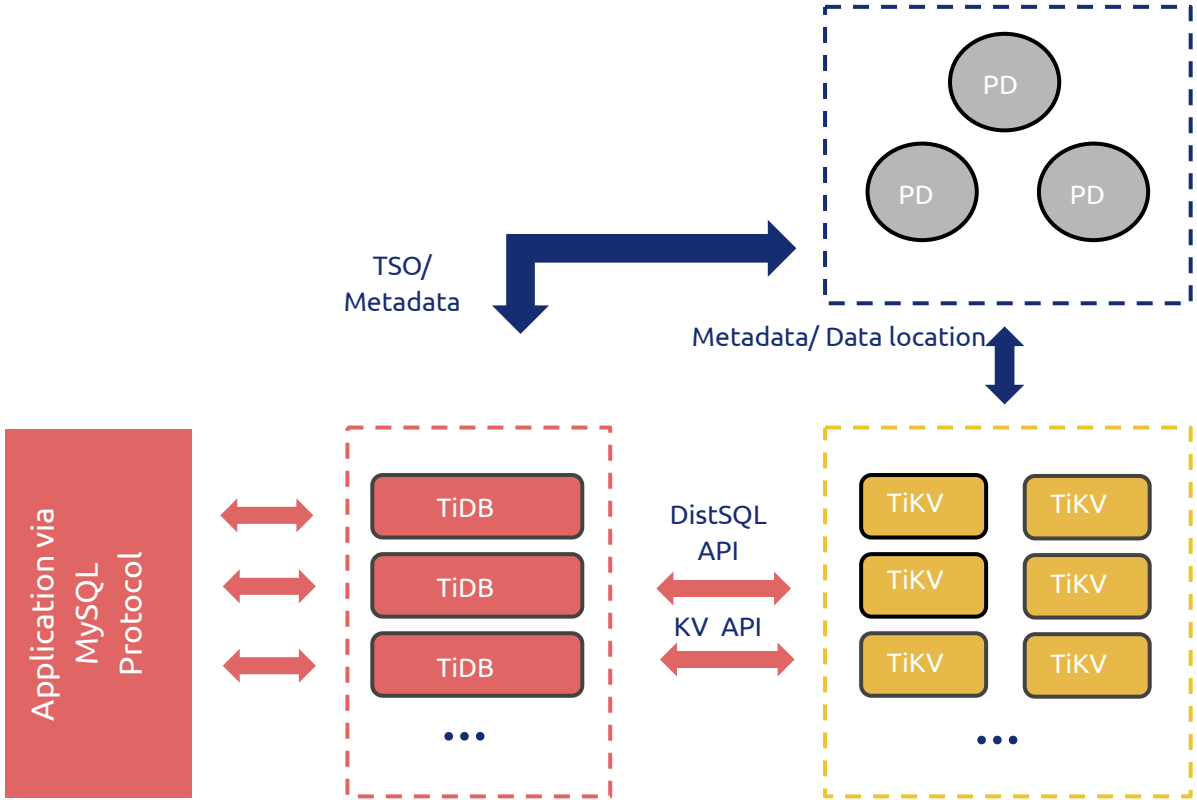
How scale-out works inside TiDB



How scale-out works inside TiDB



TiDB architecture



TiDB Pros & Cons

Pros:

- Scale-out well on both read and write, without manual sharding or specifying sharding rules
- Full-featured SQL layer which is designed for distributed computing
- ACID sementics, transaparent to application layer
- MySQL compatiblity

Cons:

- Not 100% MySQL compatibility (full list here)
- Less economical when data is small
- Extra latency introduced by 2PC
- Relatively complex to deploy than standalone MySQL

TiDB typical scenarios

- High concurrent / large data volume / OLTP application
  - Data volume is growing rapidly and is soon to exceed the capacity of a single machine
  - Typical size: 1 TB ~ 200 TB
- Migration from MySQL for your existing applications
- No obvious access hotspot
  - SaaS applications
- No obvious sharding key, application needs to support multi-dimensional SQL query
- Synchronize multiple MySQL masters in real time via binlog, and using SQL for real-time data analysis in TiDB

PingCAP

Contrast

Benchmark environment

All tests are done in AWS

TiDB environment:

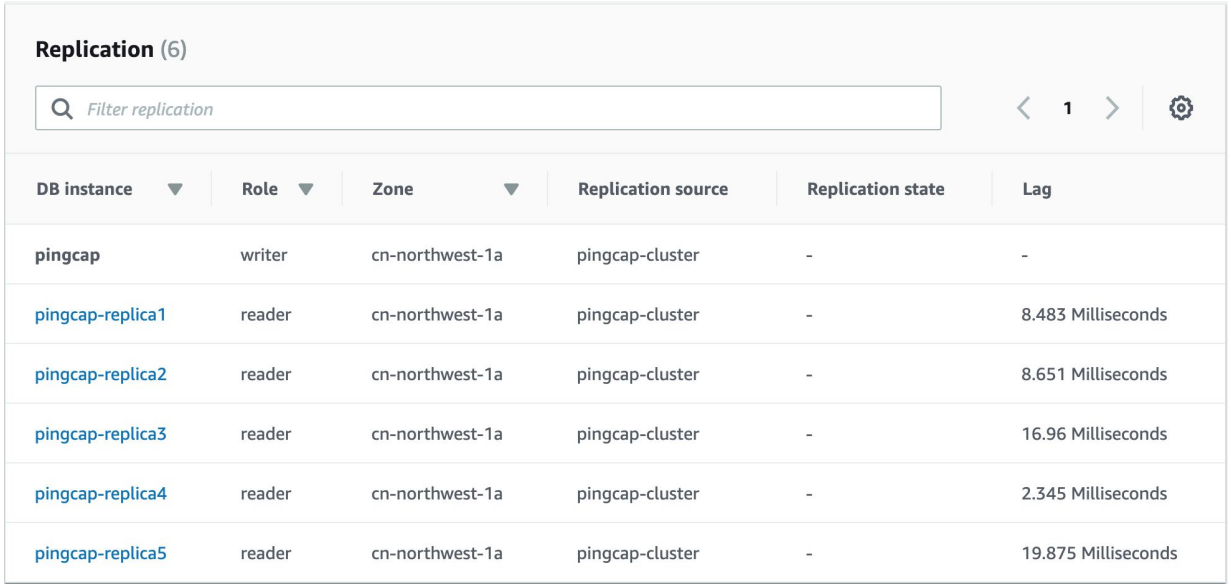
type	remarks	usage
m4.2xlarge		monitoring
c5.4xlarge		launched 3 sysbench processes in this node
r5d.xlarge		pd x3
c5d.4xlarge	16 vCPU 32 GB mem 400GB SSD	tikv-server x3
c5d.4xlarge	16 vCPU 32 GB mem 400GB SSD	tidb-server x3

TiKV configuration modifications: https://gist.github.com/c4pt0r/b0c39f9da9360af2fb2c41ace274b30e

Benchmark environment

Aurora environment:

type	remarks	usage
db.r4.4xlarge	16 vCPU 122 GB mem	1 writer + 5 replicas



Replication (6)

Filter replication

1

DB instance	Role	Zone	Replication source	Replication state	Lag
pingcap	writer	cn-northwest-1a	pingcap-cluster	-	-
pingcap-replica1	reader	cn-northwest-1a	pingcap-cluster	-	8.483 Milliseconds
pingcap-replica2	reader	cn-northwest-1a	pingcap-cluster	-	8.651 Milliseconds
pingcap-replica3	reader	cn-northwest-1a	pingcap-cluster	-	16.96 Milliseconds
pingcap-replica4	reader	cn-northwest-1a	pingcap-cluster	-	2.345 Milliseconds
pingcap-replica5	reader	cn-northwest-1a	pingcap-cluster	-	19.875 Milliseconds

Benchmark - Sysbench

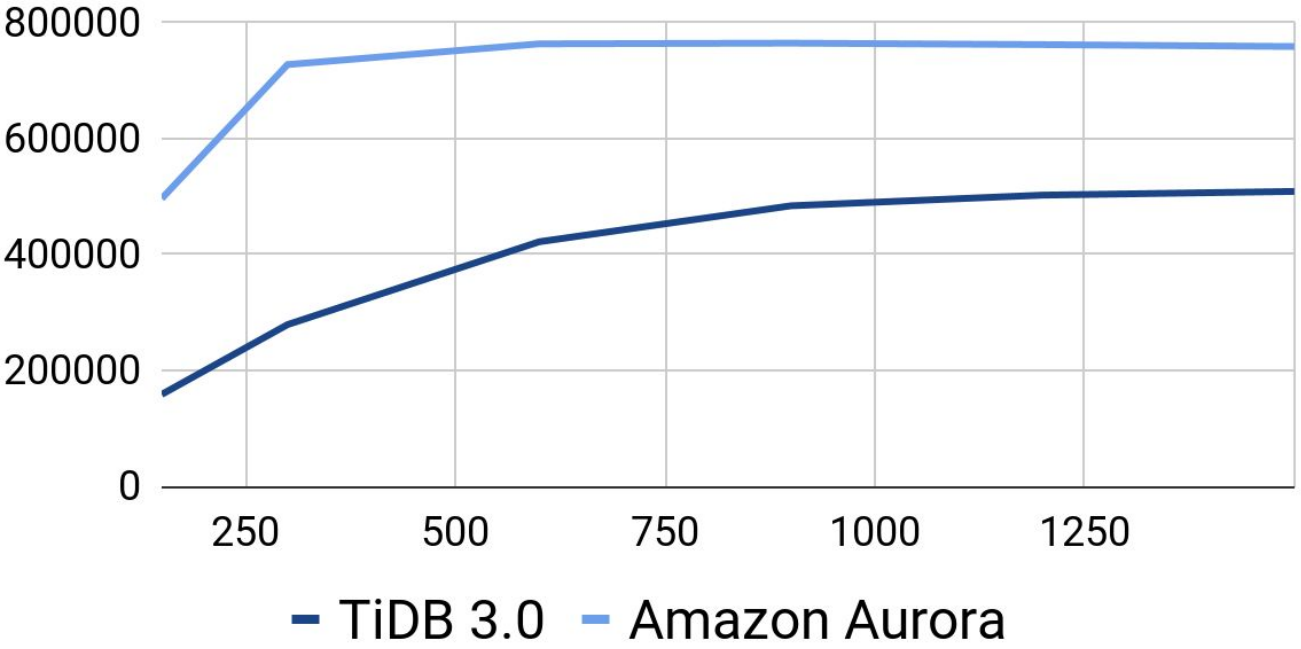
16 tables, 10m rows/table

```
sysbench    --threads=16
            --rand-type=uniform
            --mysql-host=123.123.123.123  --mysql-user=root --mysql-port=4000
            --mysql-db=sbtest --db-driver=mysql
            oltp_common prepare
            --tables=16
            --table-size=10000000
            --auto-inc=false
```

Benchmark - Sysbench - Point Select (QPS)

Thread	TiDB 3.0	Amazon Aurora
150	158,908.53	496,746.62
300	279,335.92	727,939.27
600	422,278.72	763,700.65
900	484,304.54	764,880.91
1200	502,705.22	762,363.69
1500	509,098.83	759,074.87

Sysbench - Point Select



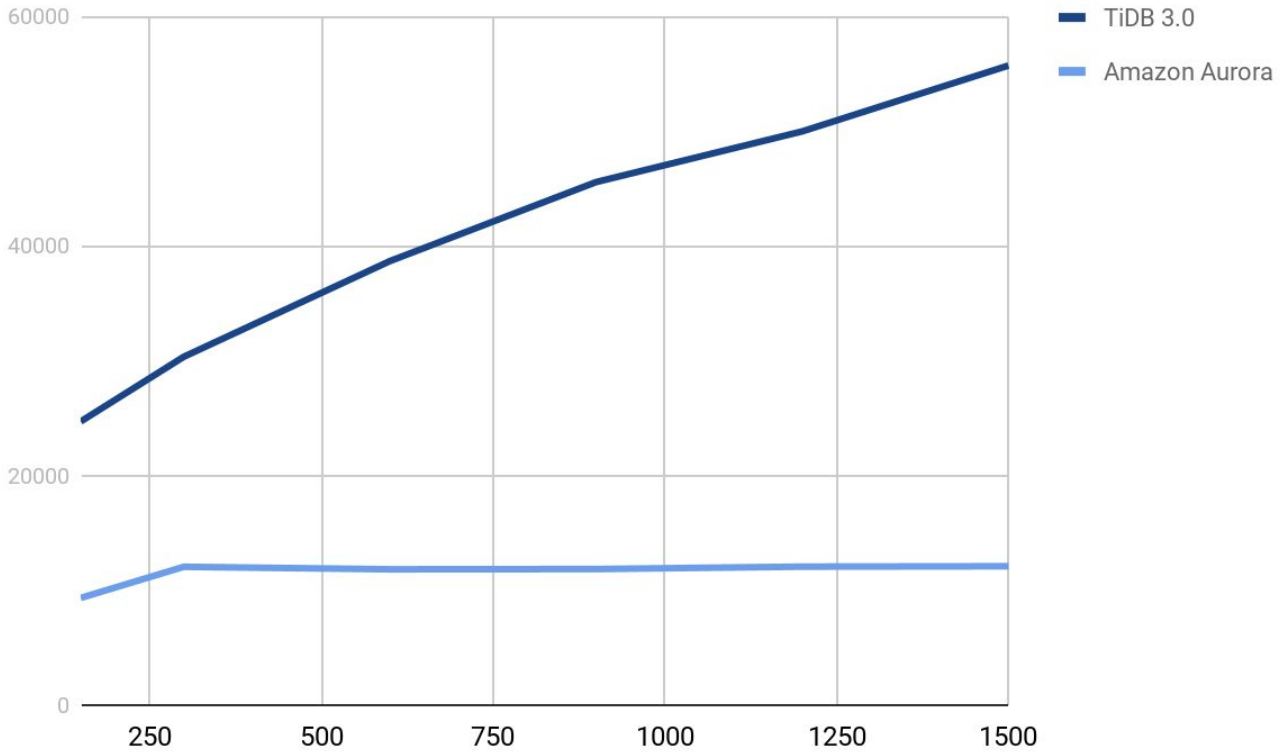
Sysbench - Point Select (.95 Latency in ms)

Thread	TiDB 3.0	Amazon Aurora
150	1.04	0.40
300	1.30	0.58
600	2.11	0.96
900	3.07	1.37
1200	4.10	1.84
1500	5.18	2.30

Sysbench - Update Non-index (TPS)

Thread	TiDB 3.0	Amazon Aurora
150	24,710.55	9341.03
300	30,347.88	12,052.74
600	38,685.87	11,834.75
900	45,567.08	11,855.36
1200	49,982.75	12,065.85
1500	55,717.09	12,100.72

Sysbench - Update Non-index (TPS)



PingCAP

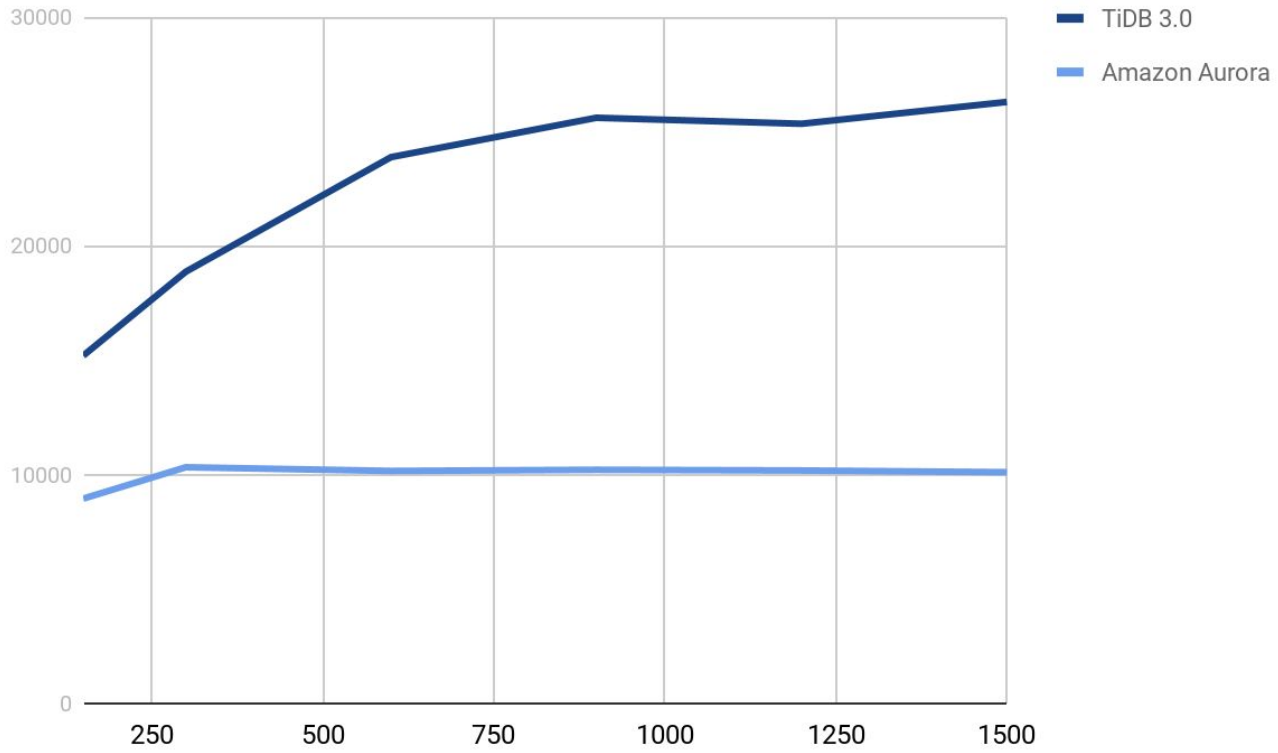
Sysbench - Update Non-index (.95 Latency)

Thread	TiDB 3.0	Amazon Aurora
150	8.43	20.00
300	13.95	38.25
600	23.52	71.83
900	30.81	104.84
1200	39.65	137.35
1500	51.02	155.80

Sysbench - Update Index (TPS)

Thread	TiDB 3.0	Amazon Aurora
150	15,202.94	8953.53
300	18,874.35	10,326.72
600	23,882.45	10,164.60
900	25,602.60	10,215.11
1200	25,340.77	10,184.25
1500	26,294.65	10,109.65

Sysbench - Update Index (TPS)



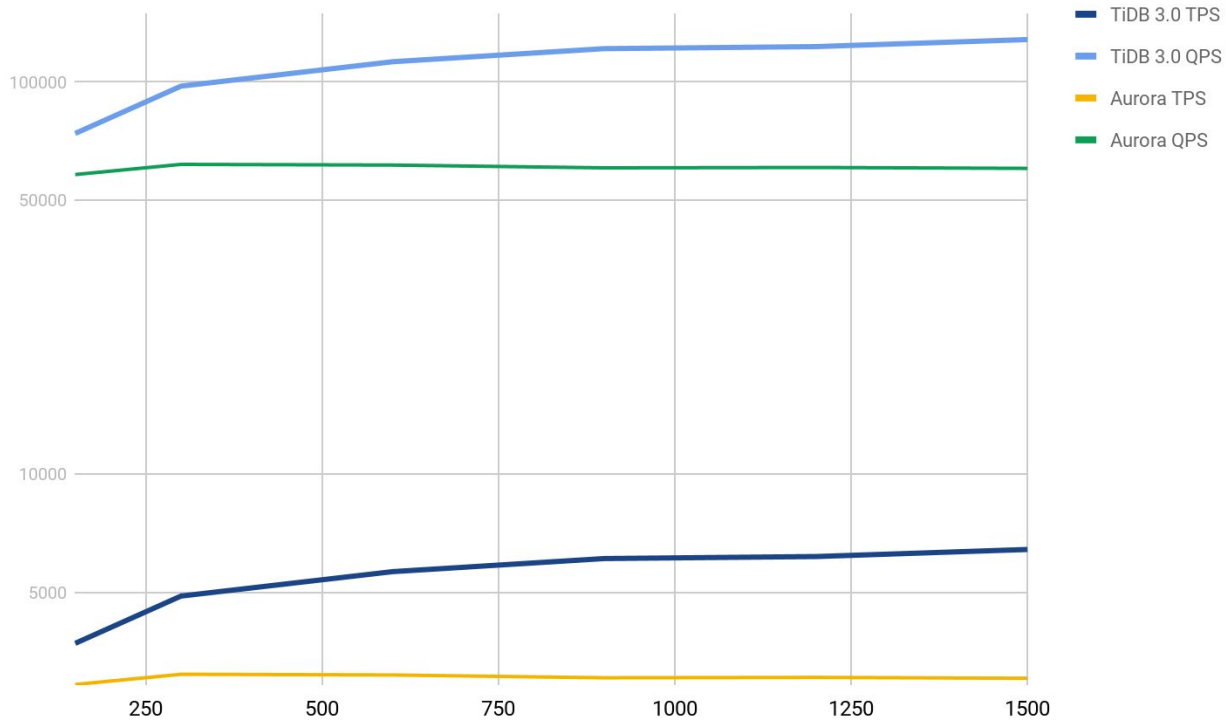
Sysbench - Update Index (.95 Latency)

Thread	TiDB 3.0	Amazon Aurora
150	13.46	25.74
300	23.52	50.11
600	40.37	95.81
900	63.32	137.35
1200	104.84	179.94
1500	155.80	219.36

Sysbench - Read-Write (TPS & QPS)

Thread	TiDB 3.0 TPS	TiDB 3.0 QPS	Aurora TPS	Aurora QPS
150	3703.97	74,079.43	2909.01	58,180.29
300	4890.35	97,806.84	3088.33	61,766.69
600	5644.47	112,889.45	3075.74	61,514.71
900	6095.21	121,904.23	3025.59	60,511.92
1200	6168.28	123,365.48	3032.45	60,649.02
1500	6429.45	128,589.10	3016.63	60,332.61

Sysbench - Read-Write (TPS & QPS)



Benchmark - TPC-C

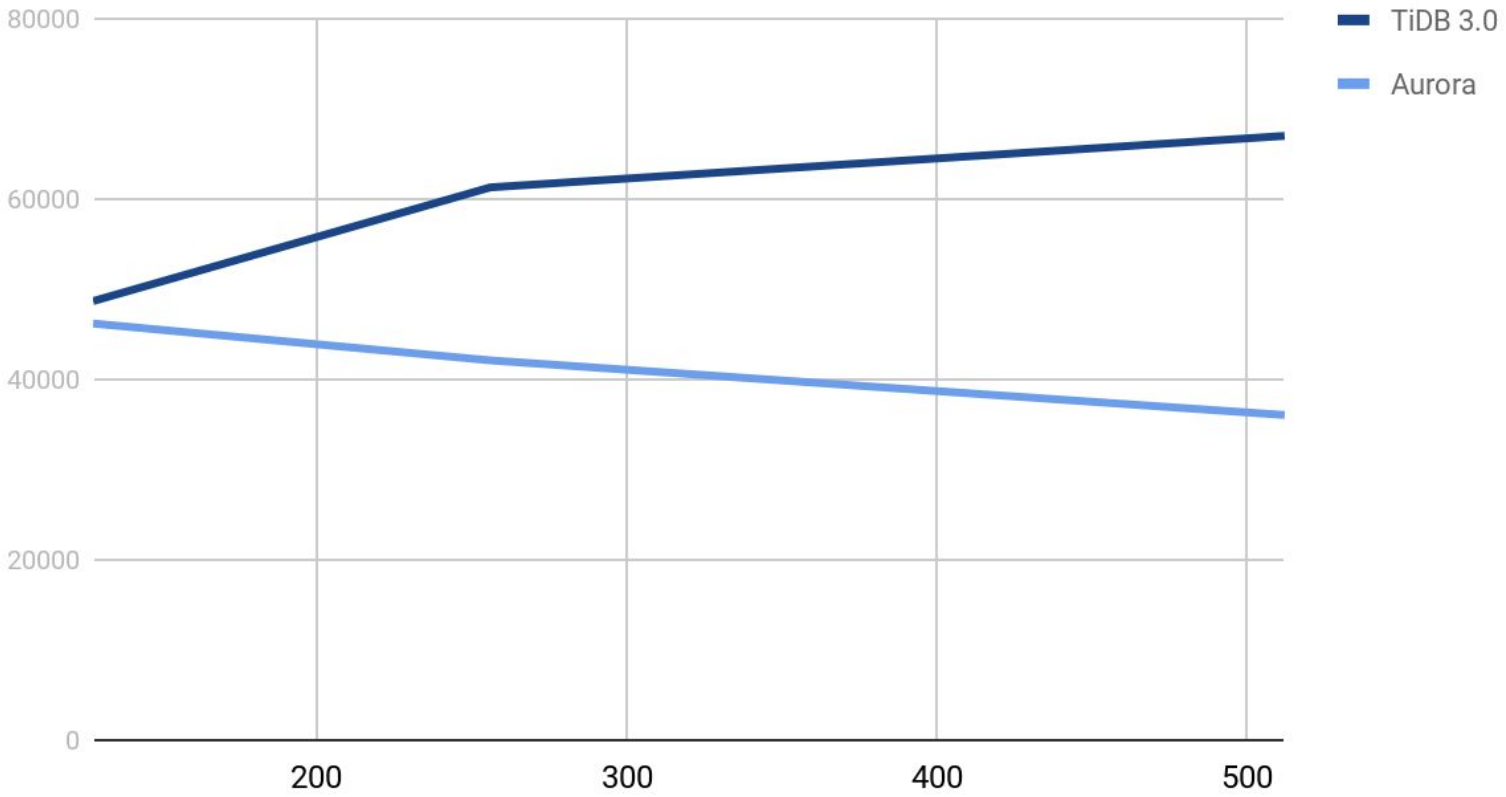
TPCC configuration file https://gist.github.com/c4pt0r/ca9ecdecc45de5d60d334aa80d031243

1000 warehouse

tpmC result:

Terminals	TiDB 3.0	Aurora
128	48681.13	46198.94
256	61293.84	42113.63
512	67002.08	36053.97

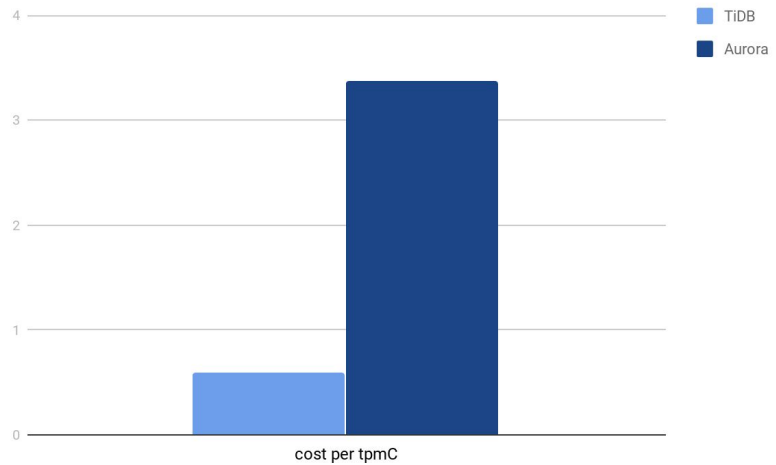
tpmC



PingCAP

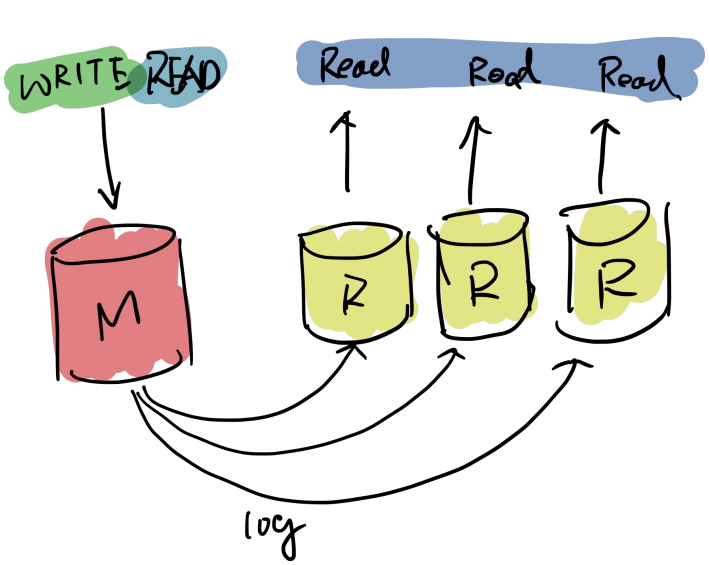
Cost comparsion with similar hardware

- Hourly cost of TiDB = 6 * c5d.4xlarge = $0.7680 * 6 = $4.56
  - Yearly cost of TiDB: ~$39945.6
- Hourly cost of Aurora = 6 * r4.4xlarge = $2.32 * 6 = $13.92 + ? (storage cost, $0.20 per 1 million requests)
  - example: storage cost of a 10000 reqs/second cluster = $7.2
  - Yearly cost of Aurora: $121,939~$185,011
- Cost per tpmC:
  - TiDB: $0.59
  - Aurora: $3.38 (without storage cost)

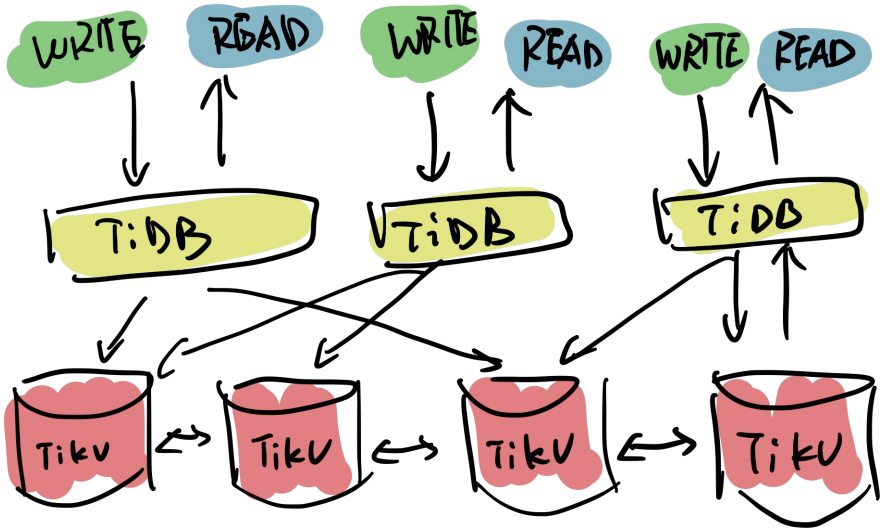


PingCAP

Why?


WRITE
READ
Read
Read
Read
M
R
R
R
log

VS


WRITE
READ
WRITE
READ
WRITE
READ
TiDB
TiDB
TiDB
TiKV
TiKV
TiKV
TiKV

Why?

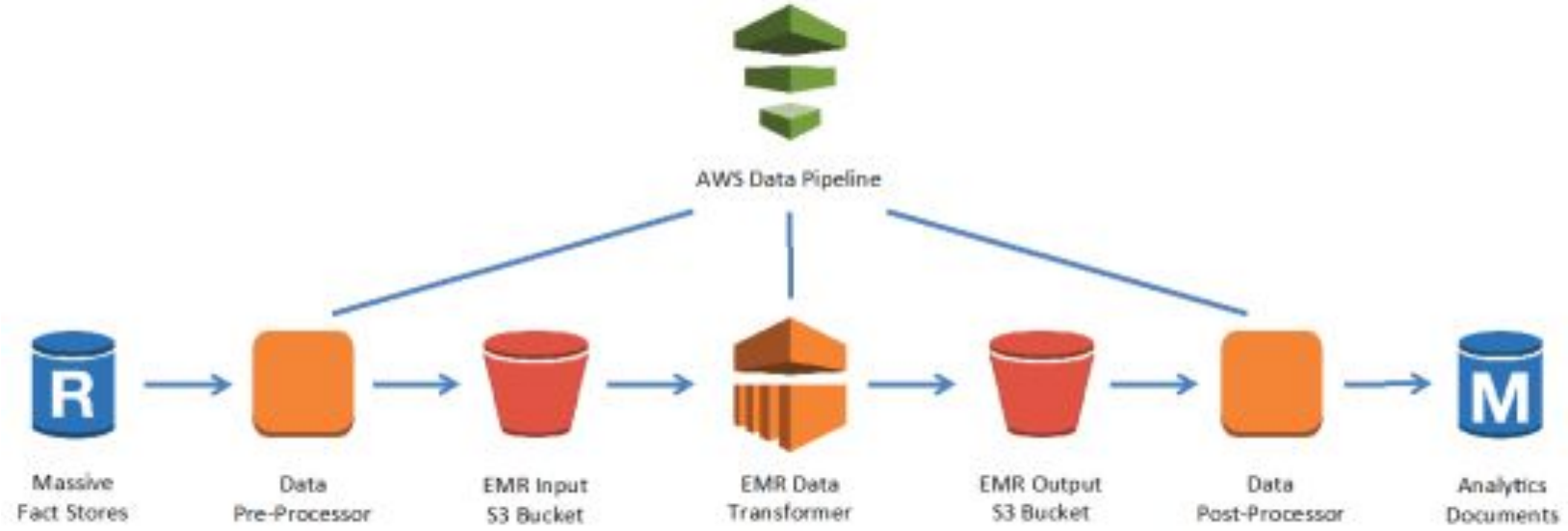
A Query Execution Plan Example:

```
TiDB(root@127.0.0.1:test) > explain select count(*) from t1, t2 where t1.a=t2.a;
+--------------------------+----------+------+-------------------------------------------------------------------+
| id                       | count    | task | operator info                                                     |
+--------------------------+----------+------+-------------------------------------------------------------------+
| StreamAgg_13             | 1.00     | root | funcs:count(1)                                                    |
| └─MergeJoin_33           | 12500.00 | root | inner join, left key:test.t1.a, right key:test.t2.a               |
|   ├─IndexReader_25       | 10000.00 | root | index:IndexScan_24                                                |
|   | └─IndexScan_24       | 10000.00 | cop  | table:t1, index:a, range:[NULL,+inf], keep order:true, stats:pseudo |
|   └─IndexReader_28       | 10000.00 | root | index:IndexScan_27                                                |
|     └─IndexScan_27       | 10000.00 | cop  | table:t2, index:a, range:[NULL,+inf], keep order:true, stats:pseudo |
+--------------------------+----------+------+-------------------------------------------------------------------+
6 rows in set (0.00 sec)
```

PingCAP

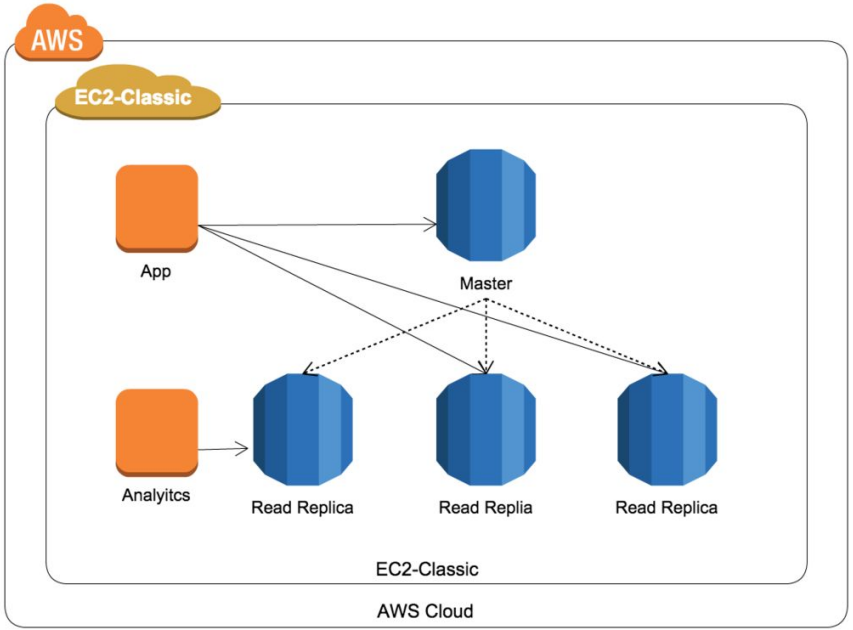
Combine

ETL pipeline



I just want a simple join with 2 tables in my DB….

Analytics on Read-Replica?




```
SELECT 100.00 * SUM(CASE WHEN p_type LIKE 'PROMO%' THEN
l_extendedprice * ( 1 - l_discount ) ELSE 0 END) /
SUM(l_extendedprice * ( 1 - l_discount )) AS
       promo_revenue
FROM   lineitem,
       part
WHERE  l_partkey = p_partkey
       AND l_shipdate >= DATE '1996-12-01'
       AND l_shipdate < DATE '1996-12-01' + interval '1'
month;
```

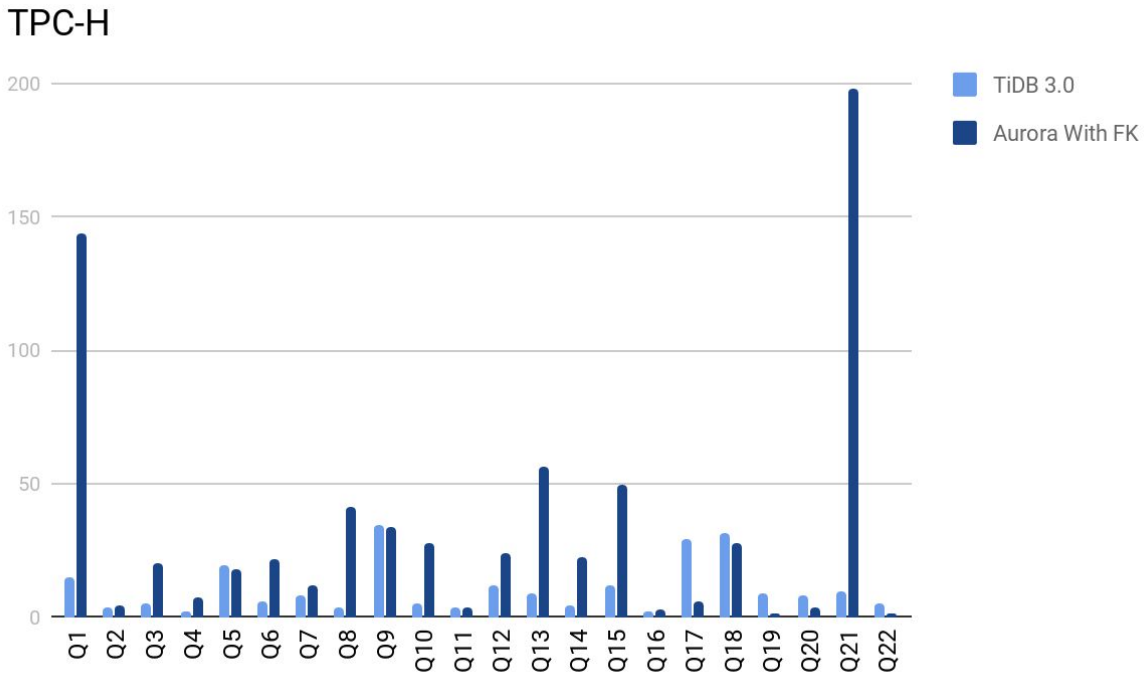
Benchmark - TPC-H

TPC-H scale factor: dbgen -s 10

TiDB variables:

```
set global tidb_max_chunk_size=1024;
set global tidb_hashagg_partial_concurrency=16;
set global tidb_projection_concurrency=4;
set global tidb_distsql_scan_concurrency=20;
set global tidb_index_lookup_concurrency=20;
set global tidb_index_join_batch_size=25000;
set global tidb_index_lookup_join_concurrency=20;
set global tidb_index_lookup_concurrency=20;
set global tidb_hash_join_concurrency=10;
```

Benchmark - TPC-H



[Result in text]

Note:
parallel scanning is not enabled for Aurora, because Aurora in China region doesn't have this feature yet.

Query duration in second, the lower the better

PingCAP

Benchmark TPC-H

Query	TiDB	Aurora Without FK
1	15.28s	144.13s
2	4.09s	4.21s
3	4.93s	34.18s
4	2.3s	7.49s
5	19.44s	22.43s
6	5.96s	21.94s
7	8.42s	81.83s
8	3.49s	53.99s
9	34.71s	442.26s
10	4.9s	27.37s
11	3.96s	38.35s
12	11.66s	24.30s
13	8.72s	>30min
14	4.36s	22.20s
15	11.94s	49.21s
16	2.14s	3.25s
17	29.29s	>30min
18	31.44s	27.99s
19	8.78s	36.67s
20	7.95s	>30min
21	10s	>30min
22	5.06s	>30min

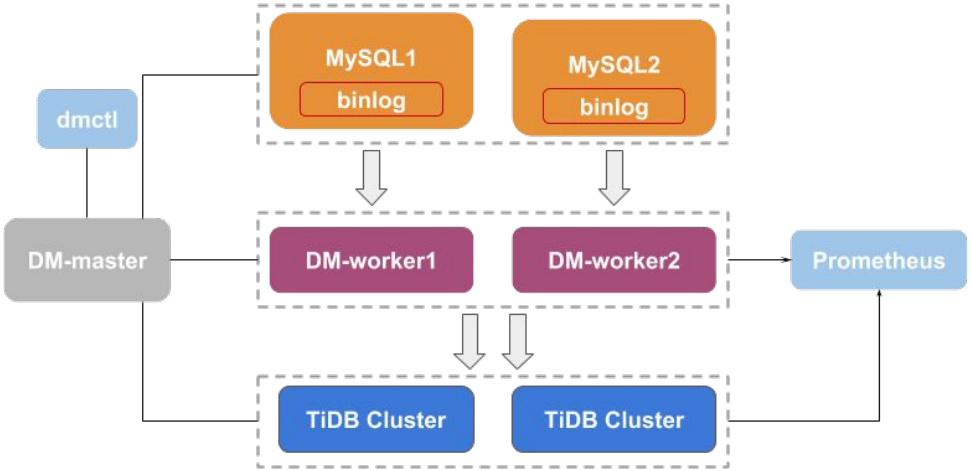
PingCAP

TiDB DM: TiDB Data Migration Tool

TiDB DM (Data Migration) is an integrated data replication task management platform that supports:

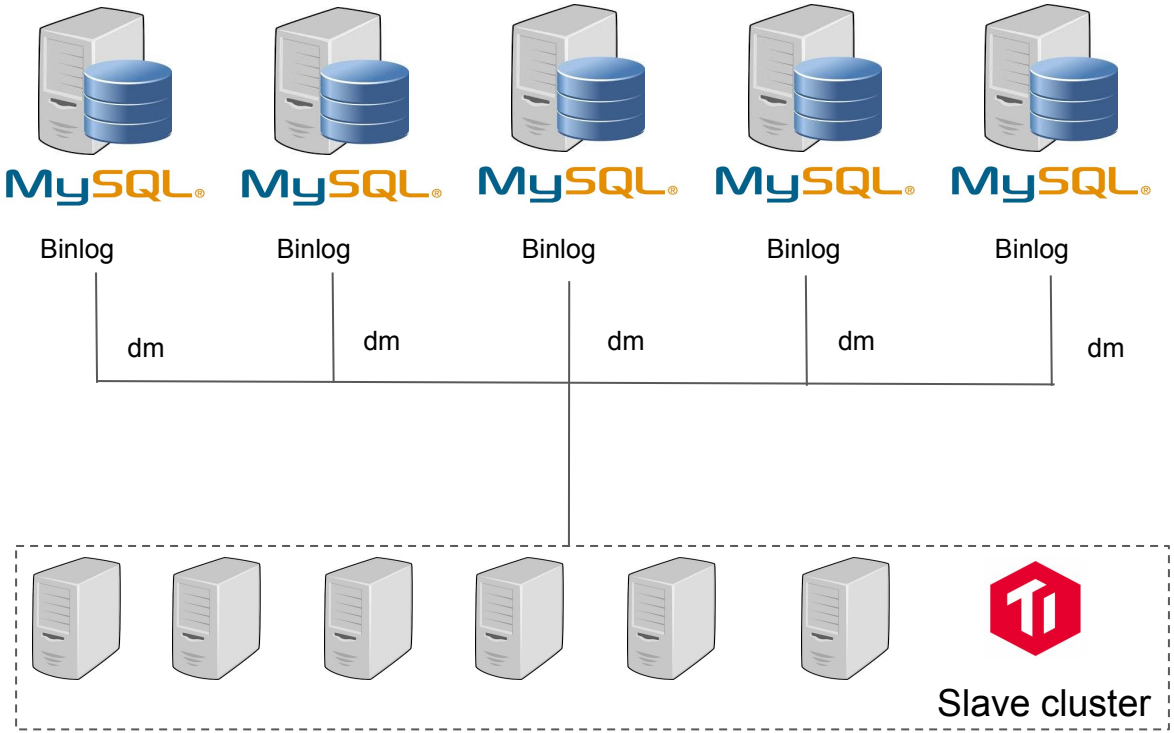
- full data migration
- incremental data migration

from MySQL/MariaDB/Aurora MySQL into TiDB

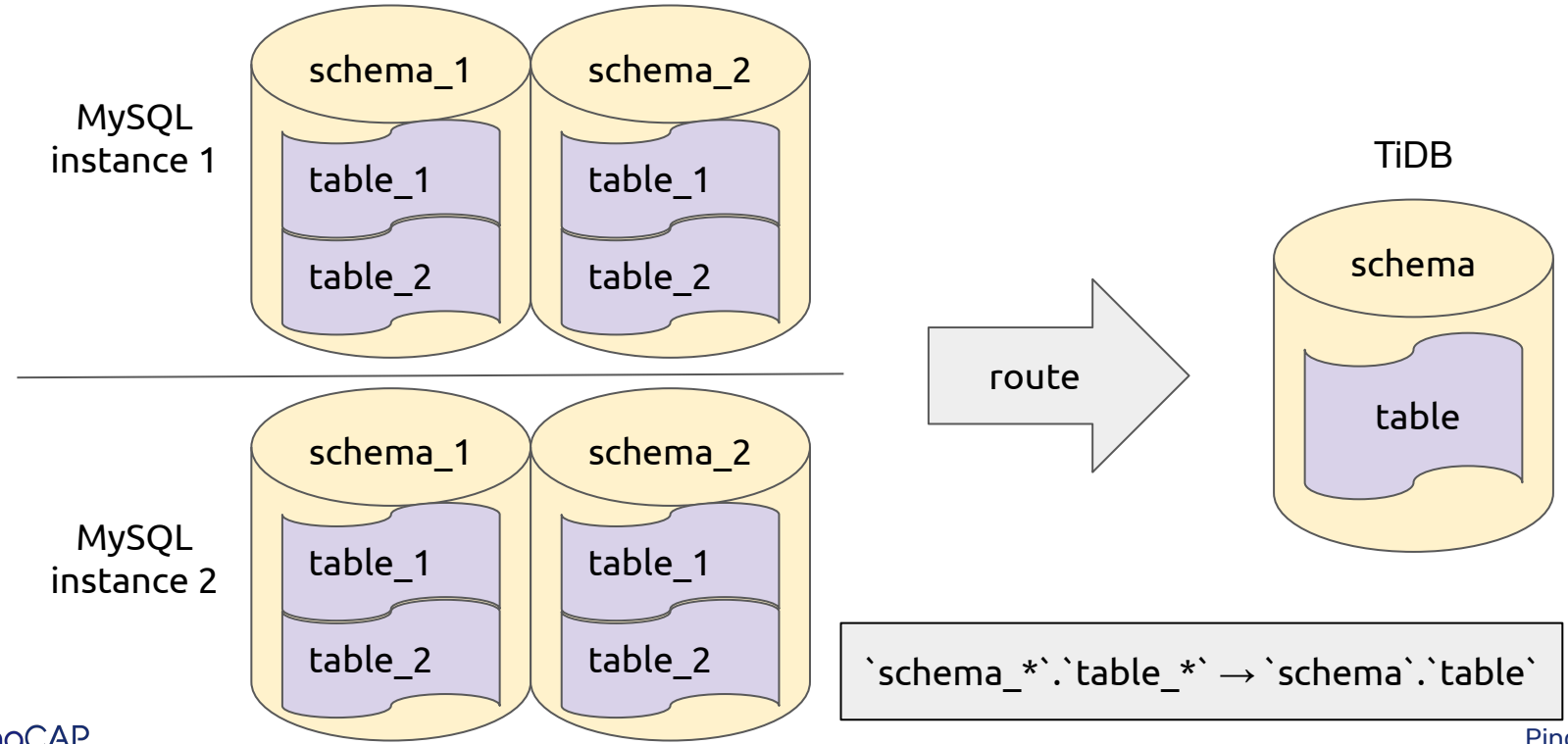


https://github.com/pingcap/dm

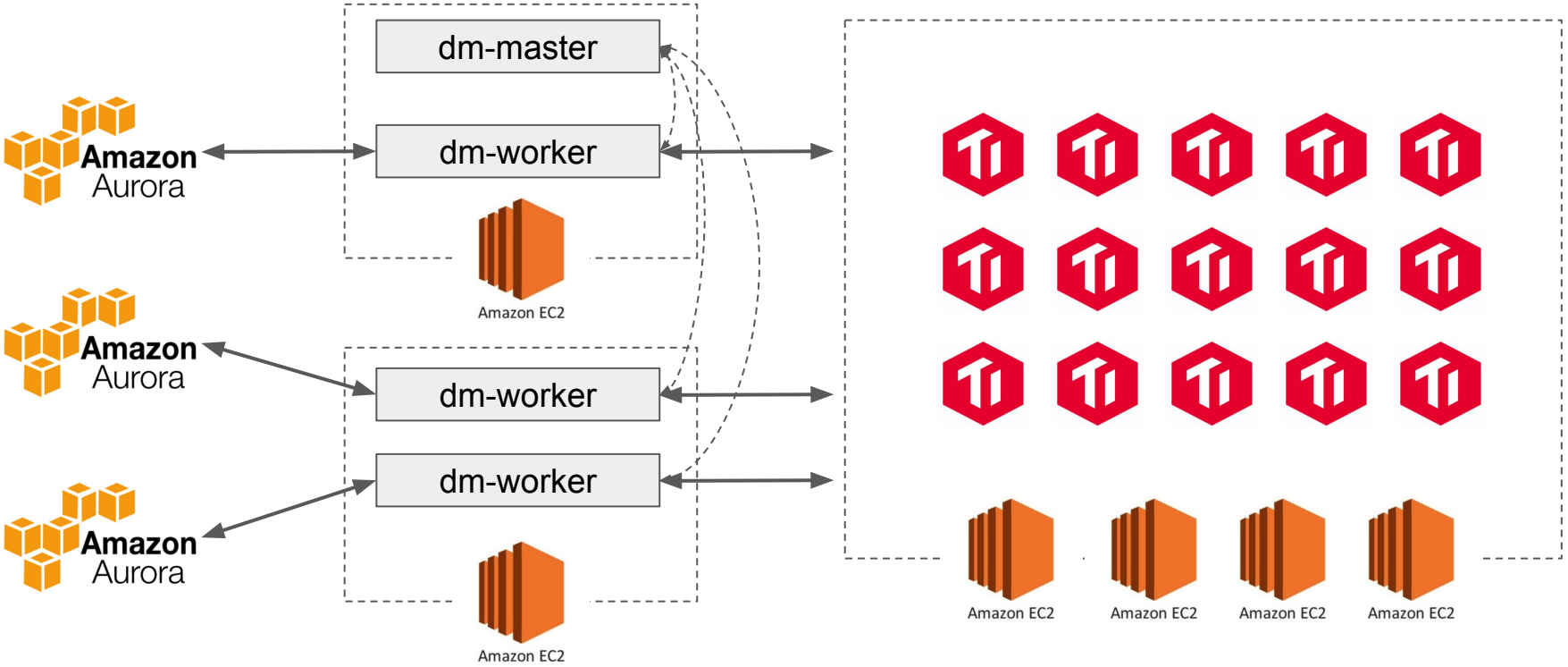
https://pingcap.com/docs/tools/dm/overview/


MySQL
MySQL
MySQL
MySQL
MySQL
Binlog
Binlog
Binlog
Binlog
Binlog
dm
dm
dm
dm
dm
Slave cluster

Sharded MySQL consolidation



Using TiDB DM to replicate data from Aurora



PingCAP

Demo

1. Launch an empty TiDB cluster
2. Import data to AWS Aurora (TPC-H sample data)
    a. http://download.pingcap.org/tispark-sample-data.tar.gz
3. Deploy DM
    a. configure `dm-worker`
    b. configure `dm-master`
4. Launch `dm-master`
5. Launch `dm-worker`
6. use `dmctl` create a synchronization task (AWS Aurora->TiDB)
    a. Sample task: https://gist.github.com/c4pt0r/bcbf645ab475e5a603ad3d79d95c1757
7. Run the queries!
    a. https://github.com/catarinaribeir0/queries-tpch-dbgen-mysql

Check list

- Enable binlog for Amazon Aurora, use ‘ROW’ mode
  - https://aws.amazon.com/premiumsupport/knowledge-center/enable-binary-logging-aurora/
- Enable GTID for Amazon Aurora
  - https://docs.aws.amazon.com/AmazonRDS/latest/AuroraUserGuide/mysql-replication-gtid.html#mysql-replication-gtid.configuring-aurora
- Make sure DM can connect to Amazon Aurora master (check security group rules)
- Ignore some unsupported syntax
  - ignore-checking-items: ["dump_privilege", "replication_privilege"]
  - example task.yaml: https://gist.github.com/c4pt0r/bcbf645ab475e5a603ad3d79d95c1757

Conclusion

- Aurora is a great alternative to MySQL in the case of small and medium data size.
- Due to the problem of single writer, scale-out write still requires middleware or manually sharding
- Aurora is difficult to handle complex queries due to the reuse of MySQL optimizer
- Compared to Aurora, TiDB costs less under large data size
- TiDB supports elastic scaling both read and write
- TiDB has a full-featured SQL designed for distributed computing
- TiDB can synchronize data in real time as Aurora's replica on AWS using TiDB-DM
- TiDB's OLAP capabilities will be a good complement to Aurora

Thank You !

GitHub:github.com/pingcap/tidb
Email: info@pingcap.com

TiDB Community Slack Channel
https://pingcap.com/tidbslack/