Percona Backup for MongoDB

Akira Kurogane
Percona

3 - 2 - 1

MongoDB Community Edition

Percona Server for MongoDB

MongoDB Enterprise Edition

Replica Set

Cluster

Percona Backup for MongoDB

Elements of MongoDB Backups

MongoDB oplog

- MongoDB has logical (not physical) replication.
- Visible to db users in *"local"* db's *oplog.rs* collection.
- User writes will be transformed to idempotent operations:
  - A write modifying *n* docs will become *n* docs in the oplog, each with "_id" value of affected doc.
  - Relative modifications become absolute
    E.g. {"x": {$inc: 1}} → {"$set": {"x": <newX> }}
  - Nested arrays usually $set as whole every modification.
- Transactions pack several ops together for a single apply time.
- Secondaries apply oplog ops with broad-use "applyOps" command.

MongoDB oplog - Extra Use in Backups

A database dump has a phase of copying all collection documents.

Let's say this takes *m* minutes.

- The last dumped doc is as-of time (*T*).
- The first dumped doc is as-of (*T* - *m*) mins.

Inconsistent! But easy fix to make all docs match time (*T*).

- Get oplog slice for those *m* mins.
- Replay the (idempotent) oplog on the dump.

Consistency (Replica Set)

All methods below provide consistent snapshots for replica sets:

- Filesystem snapshot method Storage engine's natural consistency
- Stopped secondary Storage engine's natural consistency
- Dump method + oplog slice during copy
  = reconstructable consistency as-of finish time.

All the DIY scripts or tools use one of the above.

(But don't forget `--oplogFile` if using `mongodump` in own script!)

Consistency (Cluster)

As for a replica set, but synchronized for all replicasets in cluster:

Config server replicaset	as of t_x
Shard 1 replicaset	as of t_x
Shard 2 replicaset	as of t_x
...	...

Consistency (Cluster)

Concept 'gotcha': Simultaneous-for-everyone consistency impossible.

Network latencies to shards == relativity effect.

2 clients. Far shards with 2ms RTT latency, Near shards with 0.2ms RTT.

- Initiate reads to Far shards at -1.5ms
- Read happens on Far shards at -0.5ms
- Initiate writes on Near shards at -0.1ms
- Writes happen at 0 ms
- Writes confirmed by response +0.1ms
- Reads returned in response at +0.5ms

Both observe the Near write before Far read. Asymmetric.

Consistency (Cluster)

Minimal client latency relativity effect per different point-in-time definitions:

- Same wall-clock time by oplog — Clock skew + RTT.
- Same time according to one client — RTT latency.
- Single client's 'checkpoint' write — Perfect to that client; RTT to others.

All approximately same accuracy, on the scale of milliseconds.

- Very accurate by human response times.
- Crude by storage engine op execution time.

Consistency (Cluster)

Minimal client latency relativity effect by point-in-time definitions:

- Parallel filesystem snapshots — Snapshot op time + RTT.
- Hidden secondary snapshots — Shutdown time + RTT.

"`lvcreate -s ...`" ~= several hundred milliseconds (my experience).

Node shutdown: typically several seconds (my experience).

Point-in-time Restores

Backup snapshot at time st_1
Copy of oplog from <= st_1 to t_x

〓 Restore to any point in time between st_1 to t_x

Daily snaps + 24/7 oplog history

〓 PITR from st_{oldest} to now.

Note:

- Large write churn = too much to stream to backup store. Give up PITR.
- Since v3.6 need to skip some system cache collections: *config.system.sessions, config.transactions, etc.*

Transactions - Restore Method

MongoDB 4.0 replica set transactions.

- Appear as one composite oplog doc when the transaction completes.
  Just replay as soon as encountered when restoring.

MongoDB 4.2 distributed transactions

- In most situations the same as above (w/out 16MB limit).
  Just replay as soon as encountered when restoring.
- Only multi-shard transactions use new oplog format.
- Distributed transaction oplog has separate docs for each op.
- Buffer these and don't replay until "completeTransaction" doc found.

Existing MongoDB Backup Tools

MongoDB Backup Methods (DIY)

mongodump / mongorestore:
Simple ✅ Sharding ☒ Easy restore ✅ PITR ☒ S3 store ☒ HW cost $
or
Simple ☒ Sharding ✅ Easy restore ☒ PITR ☒ S3 store ☒ HW cost $

Filesystem snapshots:
Simple ☒ Sharding ✅ Easy restore ☒ PITR ☒ S3 store ✅ HW cost $

Hidden secondary:
Simple ✅ Sharding ✅ Easy restore ☒ PITR ☒ S3 store ✅ HW cost $

MongoDB Backup Methods (PSMDB HB)

Percona Server for MongoDB has command for **hot backup**:

```
> use admin
> db.runCommand({createBackup: 1, <local dir or  S3 store>})
```

PSMDB Hot Backup (Non-sharded replica set):

Simple ✅ Sharding ☒ Easy restore ☒ PITR ☒ S3 store ✅ HW cost $

New in v4.0.12-6

PSMDB Hot Backup (Cluster):

Simple ☒ Sharding ✅ Easy restore ☒ PITR ☒ S3 store ✅ HW cost $

(similar to filesystem snapshot, but extra unix admin for LVM etc. avoided)

MongoDB Backup Methods (Tools)

MongoDB OpsManager *(Paid license; closed source)*
Simple ☒ Sharding ✅ Easy restore ✅ PITR ✅ S3 store ✅ HW cost $$

mongodb-consistent-backup (Percona-Labs repo)
Simple ✅ Sharding ✅ Easy restore ✅ PITR ☒ S3 store ✅ HW cost $

percona-backup-mongodb **v0.5**
Simple ☒ Sharding ✅ Easy restore ✅ PITR ☒ S3 store ✅ HW cost $

MCB; PBM v0.5

mongodb-consistent-backup

- single script
- single-server bottleneck Not suitable for many-shard clusters

percona-backup-mongodb v0.5

- pbm-agent 1-to-1 to mongod (copy bottleneck gone)
- pbm-coordinator Coordinator daemon to agents
- pbm CLI

"Simple ☒" because coordinator-to-agents is an **extra topology**

percona-backup-mongodb v1.0

percona-backup-mongodb v1.0

- pbm-agent 1-to-1 to mongod
- ~~pbm-coordinator~~ ~~Coordinator daemon to agents~~
- pbm CLI

Simple ✅ Sharding ✅ Easy restore ✅ PITR ☒ S3 etc. ✅ HW cost $

Now: Manual PITR on restored snapshot is OK

Full Auto PITR is next major feature on dev roadmap

Percona Backup for MongoDB v0.5 --> v1.0

pbm-coordinator (R.I.P.)

percona-backup-mongodb **v0.5**

- pbm-agent 1-to-1 to mongod
- ~~pbm-coordinator~~ ~~Coordinator daemon to agents~~
- pbm

Why kill the coordinator ...?

"Let's Have a Coordinator Daemon"

Cluster shard and configsvr backup oplog slices must reach same time -> Coordination is needed between the agents.

"So let's have a coordinator daemon. We just need:"

- One or two more setup steps.
- Extra authentication subsystem for agent <-> coordinators.
- A few more ports open (== firewall reconfig).
- New `pbm` commands to list/add/remove agents.
- Users must notice coordinator-agent topology first; troubleshooting hard.

"New Idea: Let's Not!"

But how do we coordinate?

REQUIRED: Some sort of distributed server

- Already present on the MongoDB servers.
- Where we can store and update config data.
- Agents can listen for messages as a stream.
- Has an authentication and authorization system.
- Agents can communicate without firewall issues.
- Automatic failover would be a nice-to-have.
- ...

Coordination Channel = MongoDB

`pbm` sends message by updating a pbm command collection.
`pbm-agent`s update their status likewise.

- Already present on the MongoDB servers (duh!)
- Store and update config data in *admin.pbm** collections.
- Agents listen for commands using MongoDB change stream.
- Use the MongoDB authentication and role-based access control.
- Agents connect only to mongod hosts so no firewall reconfig needed.
- Automatic failover provided by MongoDB's replication.

PBM's Collections (as of v1.0)

- *admin* database
  - *pbmCmd* The trigger (and state) of a backup or restore
  - *pbmConfig* Remote store location and access credentials
  - *pbmBackups* Status
  - *pbmOp* Coordination locks

Lose DB cluster, Lose Backup System?

Q. If the cluster (or non-sharded replicaset) is gone, how can the `pbm` command line tool communicate with the agents?

A: It can't.

In the event of a complete loss / rebuild of servers:

- Start a fresh, empty cluster with same RS names.
- Create the pbm mongodb user with backup/restore role.
- Re-insert the remote-store config (S3 URL, bucket, etc).
- *"`pbm list`"* --> backups listed by timestamp.
- Restart the pbm-agent processes.
- *"`pbm restore <yyyymmdd_hhmmss>`".*

Demonstration

Demonstration

```
pbm --help
pbm [--mongodb-uri ...] set store --config <S3_config.yaml>

pbm-agent --mongodb-uri mongodb://user:pwd@localhost:port/

pbm [--mongodb-uri ...] backup

(aws s3 ls s3://bucket/...)

pbm [--mongodb-uri ...] list

pbm [--mongodb-uri ...] restore <yyyymmdd_hhmmss>
```

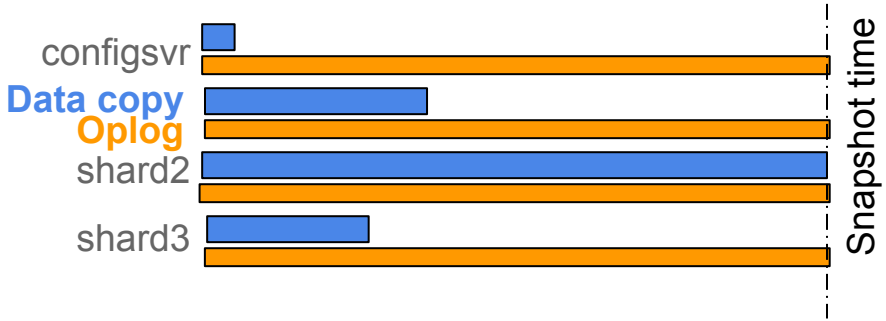
Looking Ahead

Coming Features

- Point-in-time restore.
- `pbm status, pbm log.`
- Distributed transaction oplog handling.

Point-in-time Restore

Agents already copy variable length of oplog for cluster snapshots.



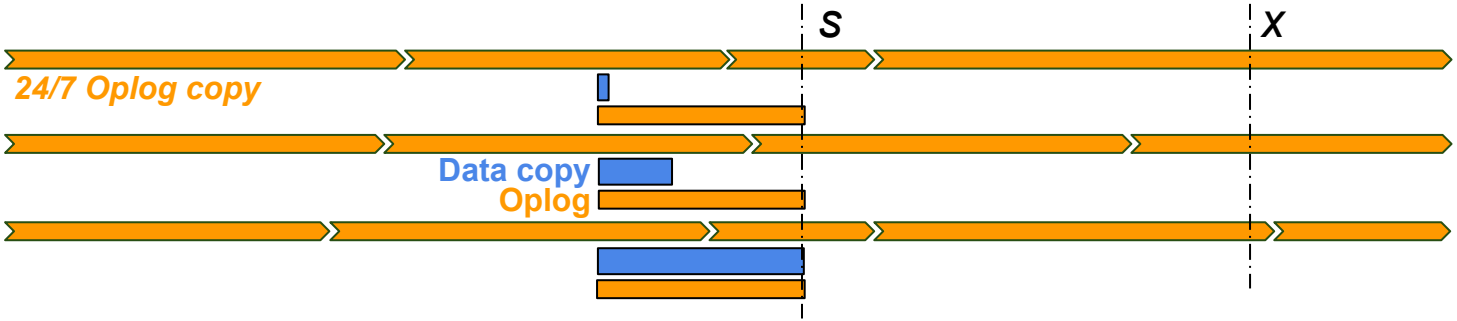
"Snapshot" time == `min(`*oplog slice finish times*`)`
== 0 ~ few secs after slowest data-copy end time

- Agents replay oplog slices only to that snapshot time.
- (Parallel application in each shard and configsvr RS).

Point-in-time Restore

Let's use the same oplog capture and replay functionality.
To come as **next main feature** in PBM:

- Option to add oplog capture 24/7 to enable PITR.



- After restore of backup snapshot at t_s replay oplog from t_s to t_x
- (Parallel application in each shard and configsvr RS).

Point-in-time Restore

Manual PITR is already possible on top of a PMB v1.0-restored backup if

- The cluster isn't already erased, and;
- The oplog(s) start before that backup's time.

Method:

1. Dump the oplog(s) elsewhere before doing "`pbm restore`"
2. Use mongorestore --oplogReplay --oplogFile ....

https://www.percona.com/blog/2019/07/05/mongodb-disaster-snapshot-restore-and-point-in-time-replay/

User Interface

`pbm status`
Show the progress of running backups

`pbm log`
Centralized agent log display

Transaction Consistency Now

Transactions consistency supported by PBM so far (v0.5, v1.0)

- 4.0 Replica set transactions.
- 4.2 Single shard-affecting transactions.

Mechanism for these transactions:

- MongoDB creates single oplog doc at commit time.
- Transaction's write ops wrapped in a nested "applyOps" array.
- Just apply as the next op, like classic oplog mechanism.

Not unique to PBM. `mongorestore` can restore these too.

```
{
      "ts" : Timestamp(1567058020, 1),
      ...
      "op" : "c",
      "ns" : "admin.$cmd",
      ...
      "txnNumber" : NumberLong(2),
      ...
      "o" : {
            "applyOps" : [
                  {     "op" : "i",
                        "ns" : "test.baz",
                        "ui" : UUID("54b05710-ee45-4cca-9bd1-63b749ed6557"),
                        "o" : { "_id" : ObjectId("5d676859138f17a8d8a27bb8") } },
                  {     "op" : "i",
                        "ns" : "test.bar",
                        "ui" : UUID("5c65df08-da5e-4ef8-8bb0-27bfa3b50c80"),
                        "o" : { "_id" : ObjectId("5d67685f138f17a8d8a27bb9") } }
            ]
      }
}
```

4.2 Distributed Transactions

Transactions not supported so far (<= v1.0)

- 4.2 Multiple shard-affecting transactions.

Mechanism:

- Transaction ops written separately ({.., "txnNumber": ..., {.., "**prepare**": true}}).
- Don't apply immediately. Buffer in chain for that txn.
- Apply all when 'completeTransaction' reached.
- Discard buffered ops if 'abortTransaction', or if replay simply finishes.

```
{
        "ts" : Timestamp(1567134752, 6),
        ...
        "op" : "d",
        "ns" : "config.transaction_coordinators ",
        ...
        "o" : {
                "_id" : {
                        "lsid" : {
                                "id" : UUID("995ad9a8-9d95-43c5-acbe-1a987df4fc95"),
                                "uid" :
BinData(0,"kanlvzjTP1bYGUTMfQK71txdM8LpbSXTMtQ+b8M4WTA=")
                        },
                        "txnNumber" : NumberLong(0)
                }
        }
}
```

4.2 Distributed Transactions

Backup tools supporting 4.2 Distributed Transactions as of now.

Needed only if your backup snapshot time bisects multi-shard transactions.

- MongoDB Ops Manager v4.2 ✅
- mongodump + mongorestore ☒
- Filesystem snapshot method ☒
- Percona Backup for MongoDB v1.0 ☒

Roadmap: Percona Backup for MongoDB to be PITR ✅ in v1.2.