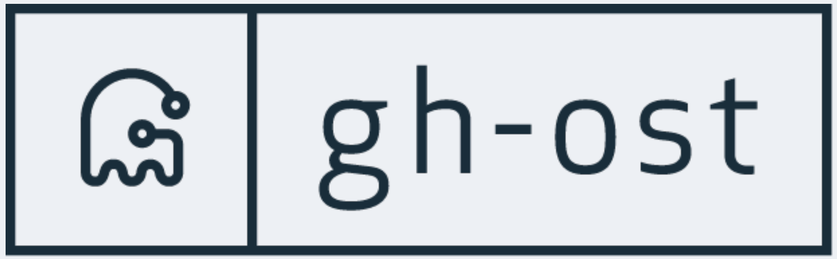
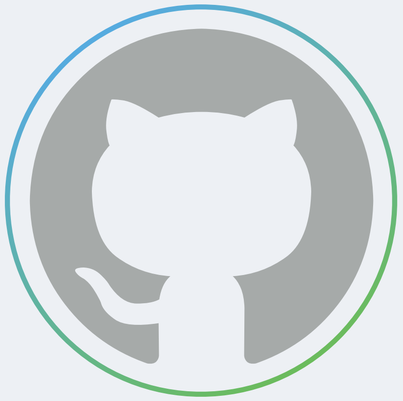




GitHub's online schema migrations for MySQL

Jonah Berquist, Engineering Manager
@github/database-infrastructure

Illustrated with ghosts (and product placement)

GitHub

- The world's largest Octocat T-shirt and stickers store
- And hubot figurines
- And hoodies
- And development platform

gh-ost

- gh-ost is GitHub's MySQL schema migration tool
- GitHub Online Schema Transmogrifier/Transfigurator/Transfer/Thingy
- Developed by @github/database-infrastructure
- Used in production daily
- Open source, github.com/github/gh-ost

But, what is this all about?

MySQL

- **GitHub stores repositories in git, and uses MySQL as the backend database for all related metadata:**
  - Repository metadata, users, issues, pull requests, comments etc.
- **Our MySQL servers must be available, responsive and in good state:**
  - Write throughput expected to be high
  - Write latency expected to be low
  - Replica lag expected to be low

Migrations

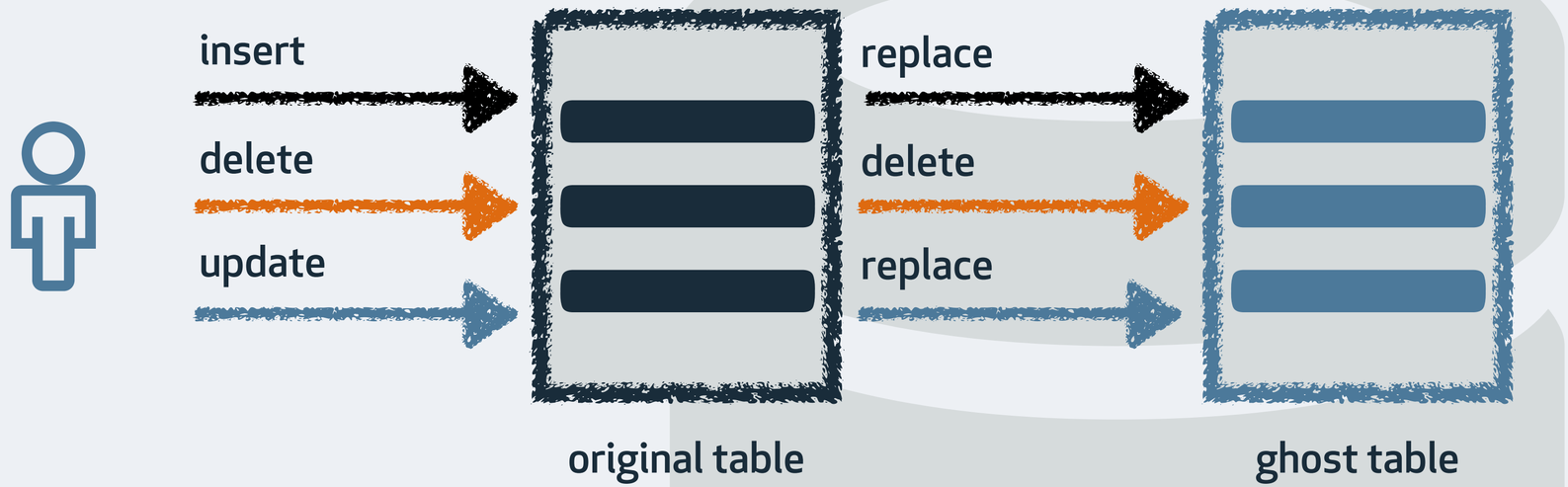
- **MySQL schema migration is a known problem**
- **Addressed by schema migration tools since 2009. Most common are:**
  - pt-online-schema-change by Percona
  - fb-osc by Facebook
- **GitHub develops rapidly. Engineers require changes to MySQL tables daily, and these changes should take place quickly**
  - Migrations must not block development
  - Migrations must not impact availability

GitHub migration pains

- **We used pt-online-schema-change for years**
- **As we grew in volume and traffic, we hit more and more problems**
  - Some migrations caused such high load that writes were stalled and GitHub performance degraded
  - Others would cause consistent replication lags
  - Some tables could only be migrated off-peak
  - Some tables could only be migrated during weekend
  - We would attend to running migrations
  - Some tables could not be migrated
  - In 2016, we suffered outages due to migrations on our busiest tables
  - We had a list of “risky” migrations

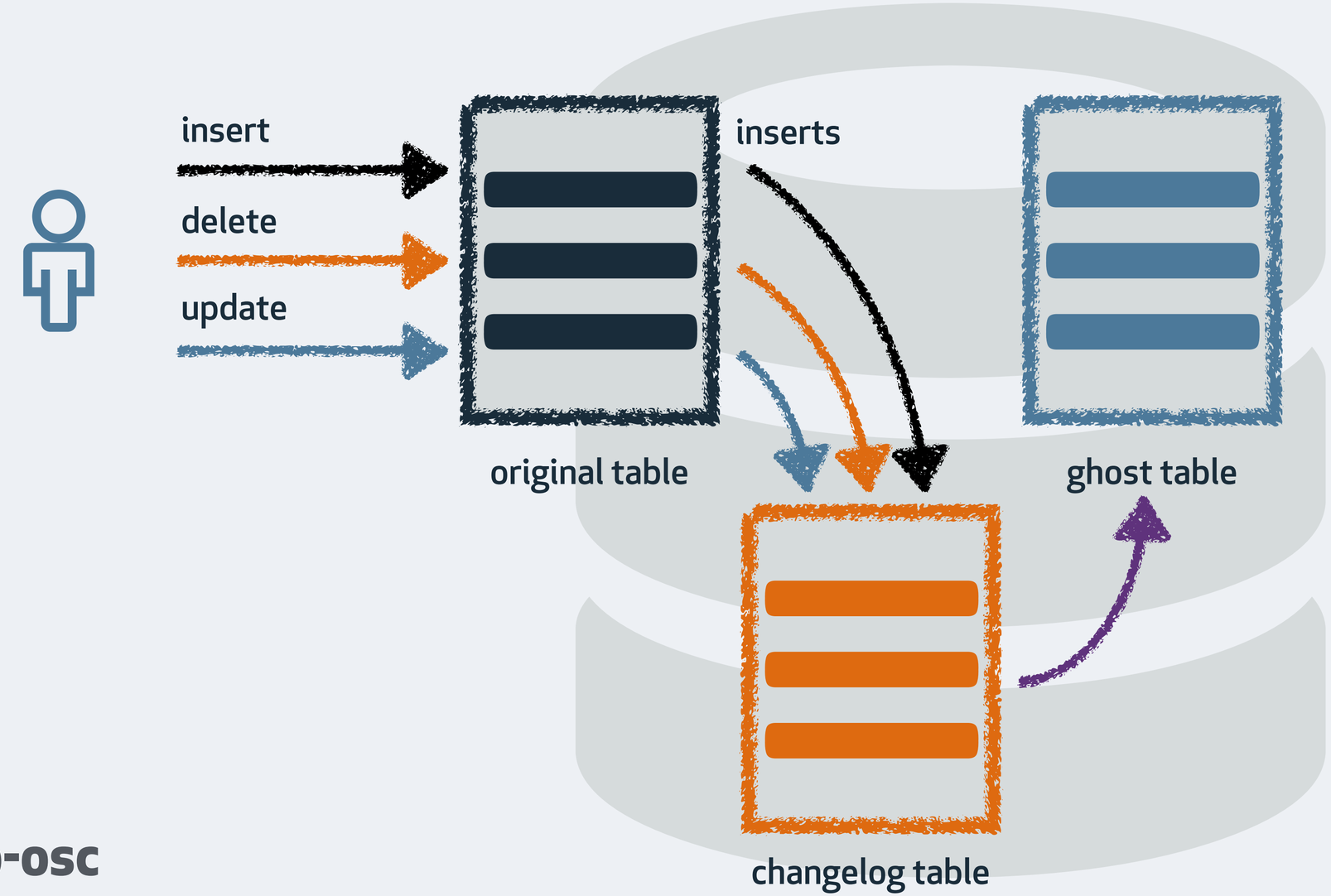
Previous tools

Synchronous triggers based migration



pt-online-schema-change
oak-online-alter-table
LHM

Asynchronous triggers based migration



fb-osc

What's wrong with triggers?

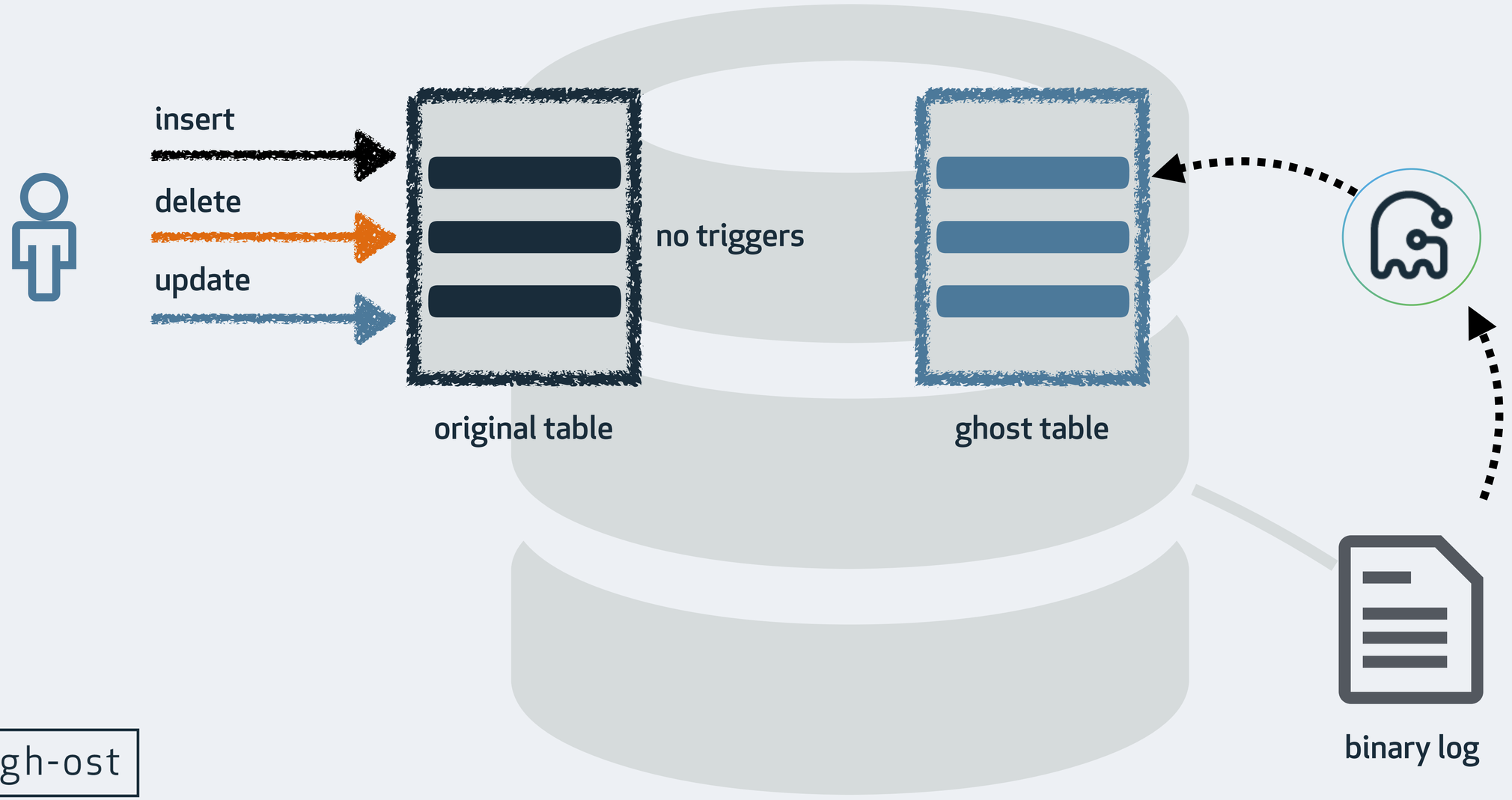
- **Stored routines**
  - Interpreted, not compiled. Latency to each transaction
- **Locks**
  - Transaction space competes for multiple, uncoordinated locks
  - Metadata locks
- **Unsuspendible**
  - Even as throttling is required, triggers must continue to work
- **Concurrent migrations**
  - Trust issues
- **No reliable testing**
  - Either cannot test in production, or test does not get actual write workload

Time to gh-ost

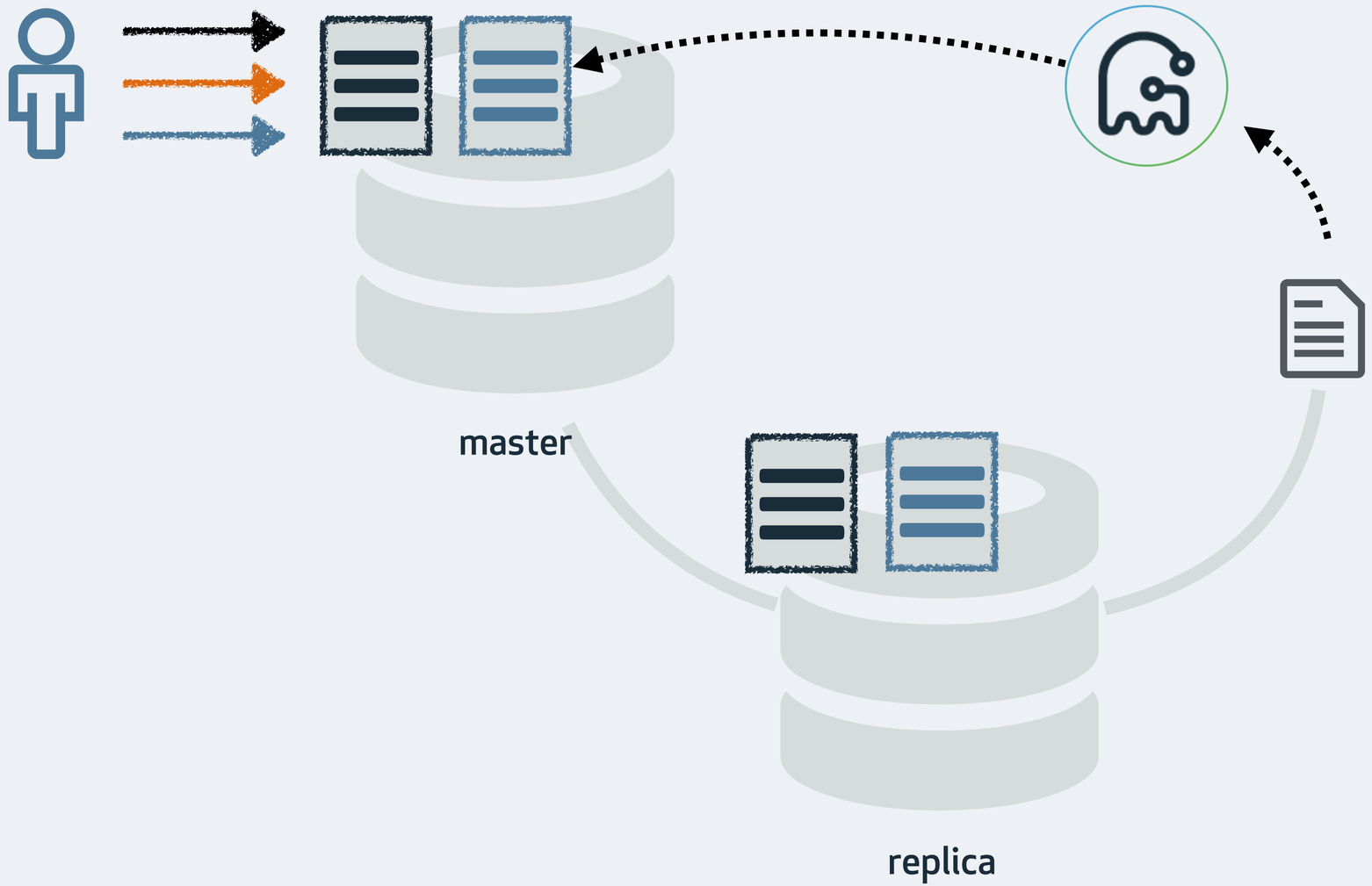
Binlog based design

- **gh-ost connects as replica and pulls binary log entries (RBR format)**
  - Interprets related DML (INSERT, UPDATE, DELETE) entries and transforms them to meet refactored table structure
  - Applies on *ghost* table
- **gh-ost connects to master and iterates rows**
  - One chunk after the other, copies rows from the original table to the *ghost* table
  - Much like existing tools, but more on this later
- **maintains a “changelog” table for internal lightweight bookkeeping**

Triggerless, binlog based migration



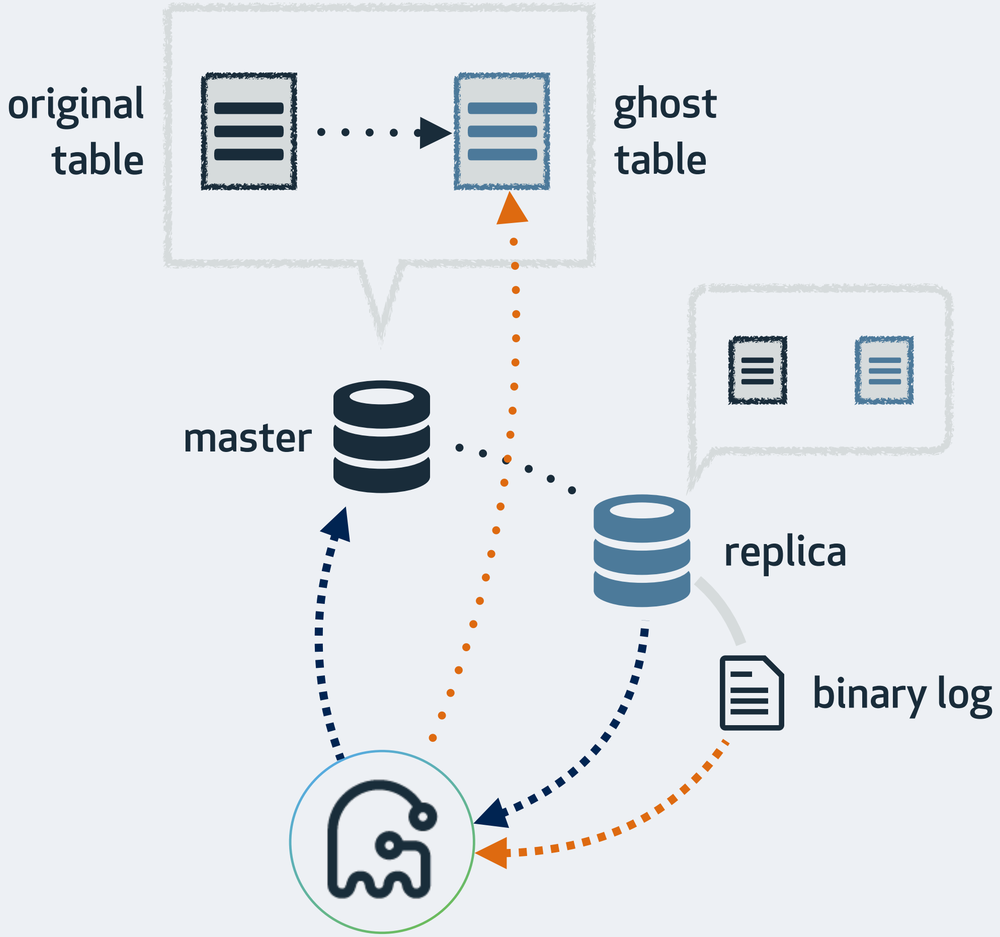
Binlog based migration, utilize replica



Binlog based design implications

- **Binary logs can be read from anywhere**
  - gh-ost prefers connecting to a replica, offloading work from master
- **gh-ost controls the entire data flow**
  - It can truly throttle, suspending all writes on the migrated server
- **gh-ost writes are decoupled from the master workload**
  - Write concurrency on master turns irrelevant
- **gh-ost's design is to issue all writes sequentially**
  - Completely avoiding locking contention
  - Migrated server only sees a single connection issuing writes
  - Migration algorithm simplified

gh-ost design

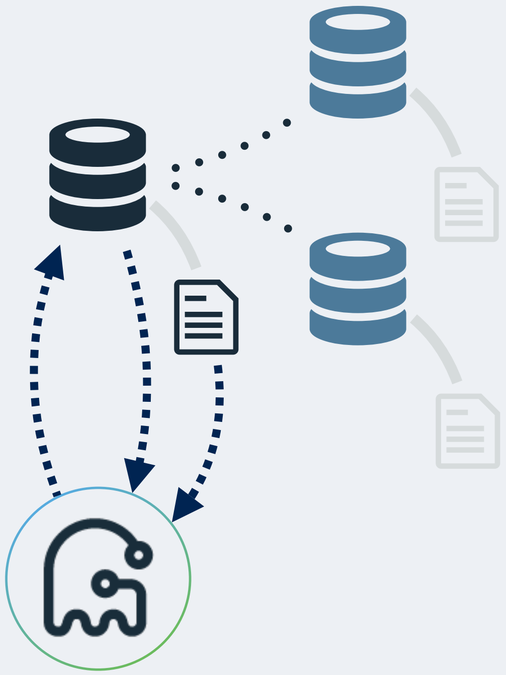


gh-ost migration:
- creates *ghost* table on migrated server
- alters *ghost* table
- hooks up as a MySQL replica, streams binary log events
- interchangeably:
  - applies events on *ghost* table
  - copies rows from original table onto *ghost* table
- cut-over

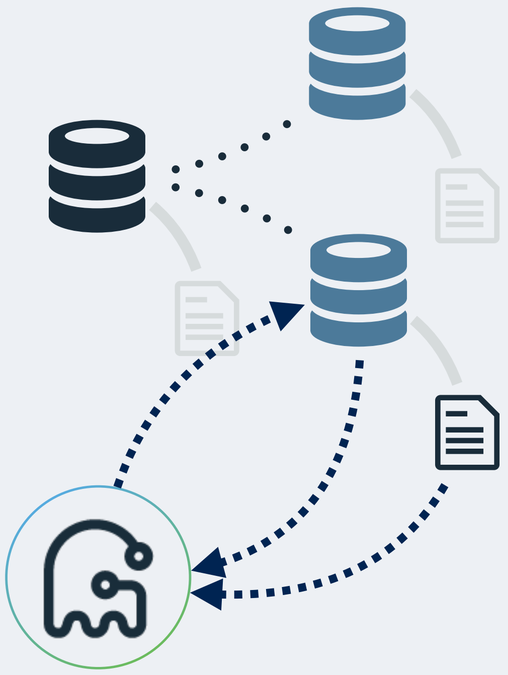
Preferred setup:
- connects to replica
- inspects table structure, table dimensions on replica
- hooks as replica onto replica
- apply all changes on master
- writes internal & heartbeat events onto master, expects them on replica

gh-ost operation modes

a. connect to replica



b. connect to master



c. migrate/test on replica


Trust

Operations

Throttling

- **There are no triggers. gh-ost can completely throttle the operation when it chooses to.**
- **Throttling based on multiple criteria:**
  - Master metrics thresholds (e.g. Threads_running)
  - Replication lag
  - Arbitrary query
  - HTTP endpoint
  - Flag file
  - Use command
- **Trust: you could choose, at any time and effective immediately, to throttle gh-ost's operation and resume normal master workload.**
  - And you may resume operation once satisfied

Cut-over

- **The final migration step: replacing the original table with the *ghost* table, incurs a brief table lock**
  - This metadata-locks-involved step is a critical point for the migration
  - During brief lock time, number of connections may escalate
- **People tend to stick around during this phase.**
  - People actually plan ahead migration start time based on the estimated completion time, so they can guarantee to be around
- **gh-ost offers postponed cut-over (optional, configurable)**
  - As cut-over is ready, gh-ost just keeps synching the tables via binlog events
  - Requires an explicit command/hint to cut-over
- **Trust: I can safely go to bed**

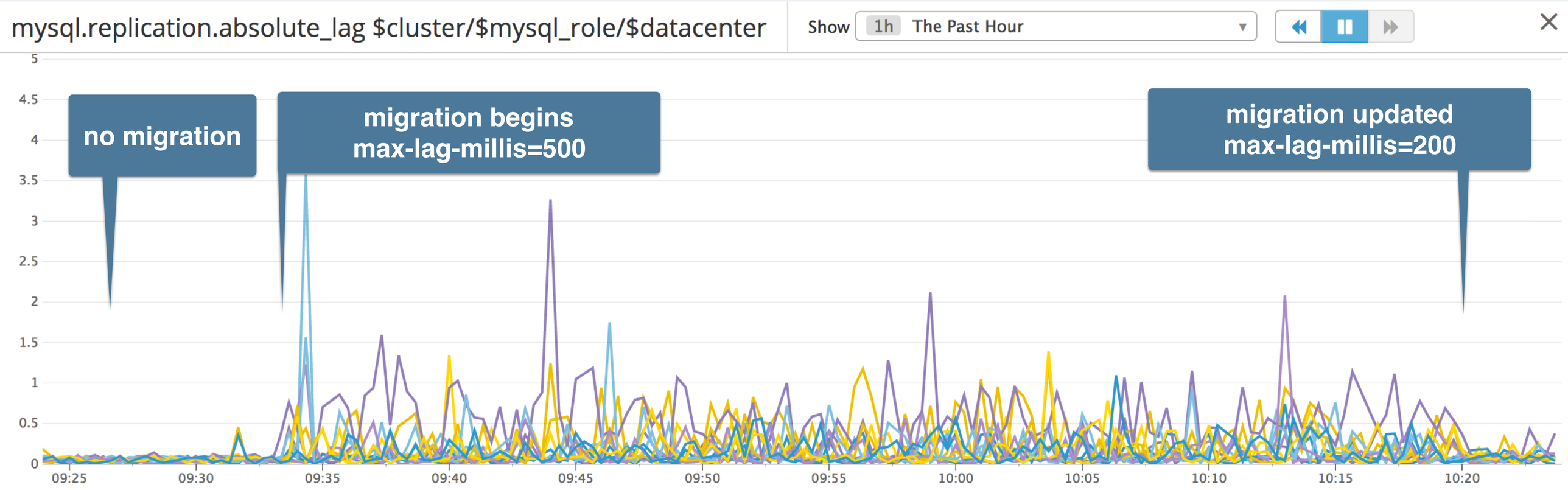
Subsecond replication lag

- **gh-ost monitors replication lag in subsecond-resolution**
- **At GitHub replication lag is normally kept subsecond**
  - We don't like it when we see 5 second lag
  - We really don't like it when we see 10 second lag
  - 20 second lag often leads to investigation
- **We are able to migrate our busiest tables, during rush hour, and keep replication lag below 1s**
- **Trust: migrations will do *whatever it takes* to keep replicas up-to-date**

throttling in production

Our production replication lag, before and during migration on one of our busiest tables

CEST tz



Dynamic visibility & control

- With existing tools, you run your migration tool based on some configuration.
- If configuration does not match your workload, you kill the migration and start a new one with more relaxed/aggressive config
- gh-ost listens on Unix socket file and/or TCP
- You can connect to a running migration and ask:
  - status
  - max-lag-millis=500
  - throttle
  - cut-over
- Trust: you can always get a reliable status or reconfigure as you see fit

Hooks

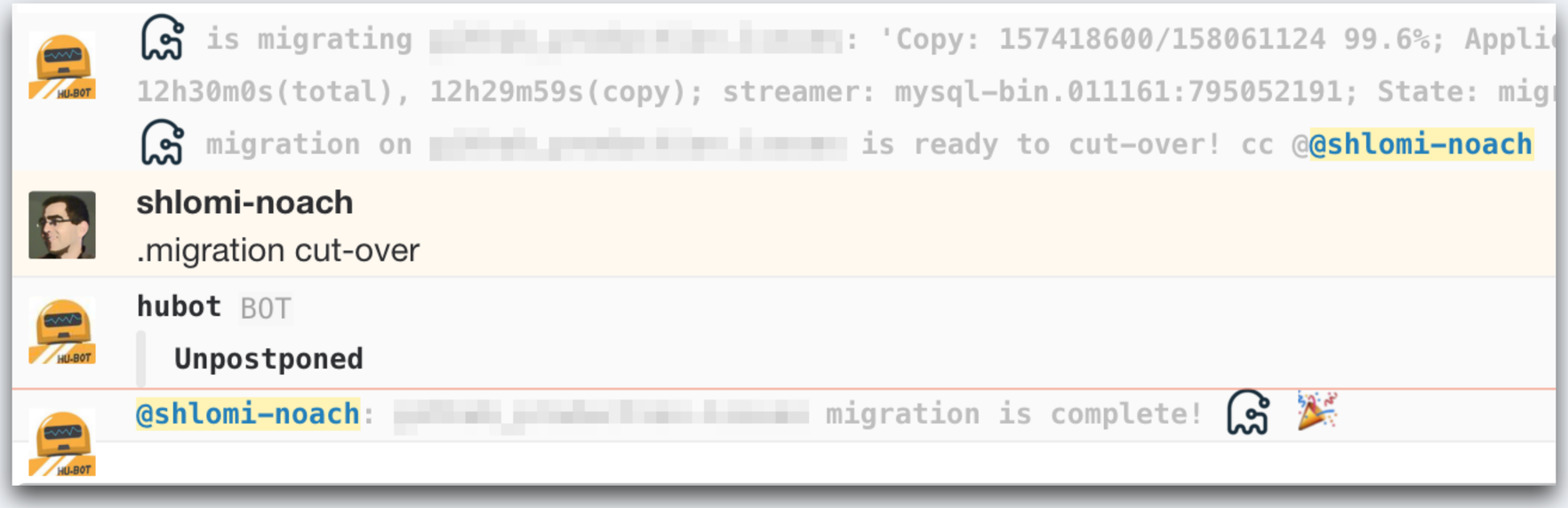
- **gh-ost will invoke your hooks at points of interest**
  - If you like, do your own cleanup, collecting, auditing, chatting.
- **Hooks available for:**
  - startup, validated, row-copy about to begin, routinely status, about to cut-over, stop-replication, success, failure
- **gh-ost will populate environment variables for your process**
- **https://github.com/github/gh-ost/blob/master/doc/hooks.md**
- **Trust: integrate with your infrastructure**

gh-ost @ GitHub

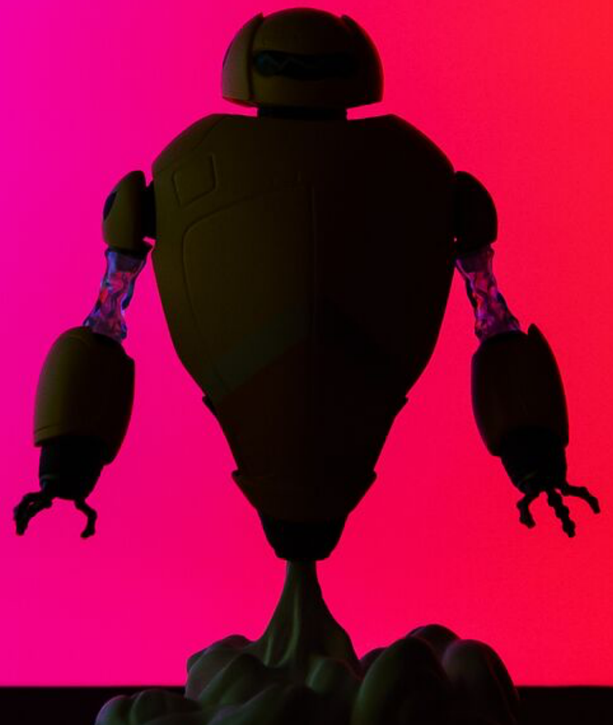
- We work from/with ChatOps
- Are integrate gh-ost into our flow and ChatOps
- We control migrations via chat:
  - .migration sup
  - .migration max-lag-millis 300
  - .migration cut-over <table>
- Migrations ping us in chat to let us know their status; or if they're ready to cut-over
- Migrations are accessible to everyone, not just DBAs

gh-ost chatops @ GitHub

- We control gh-ost via chatops
- And gh-ost chats to us
  - The chat is a changelog visible to all. It tells us *what* happened *when*, and *who* did *what*.



Testing



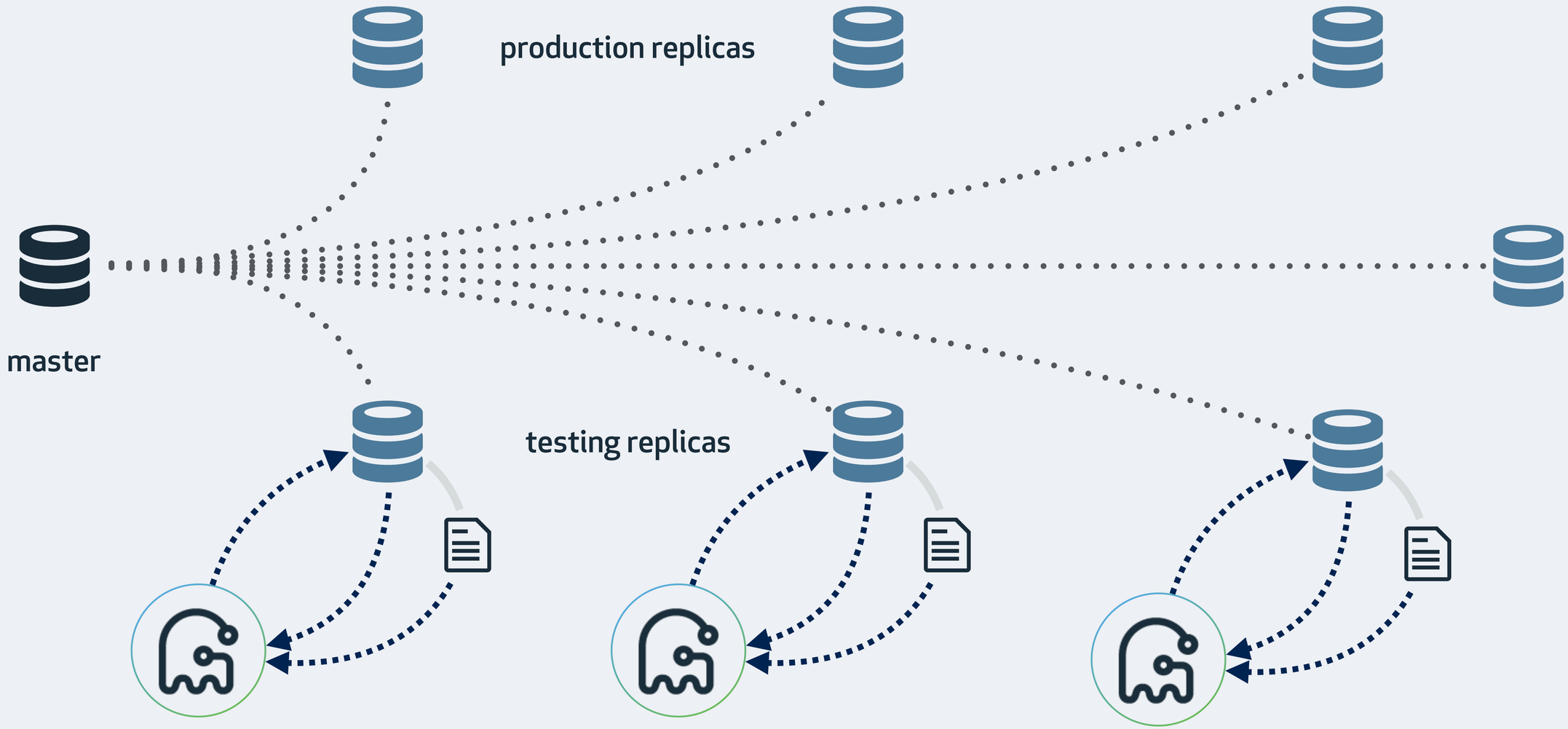
Testing

- gh-ost works perfectly well on our data
- Tested, re-tested, and tested again
- Full coverage of production tables
- Dedicated servers that run continuous tests

gh-ost dedicated test servers

- Trivial **ENGINE=INNODB** migration
- Stop replication
- Cut-over, cut-back
- Checksum both tables, compare
- Checksum failure: **stop the world, alert**
- Success/failure: event
- Drop ghost table
- Catch up
- Next table

Testing in production



Open source

Open source

- **gh-ost is released under the MIT license**
- **We encourage collaboration**
  - Issues
    - Bugs
    - Questions
    - Feature requests
    - Sharing experience
  - **Pull requests**
    - Code
    - Documentation
- **https://github.com/github/gh-ost**


Thank you!