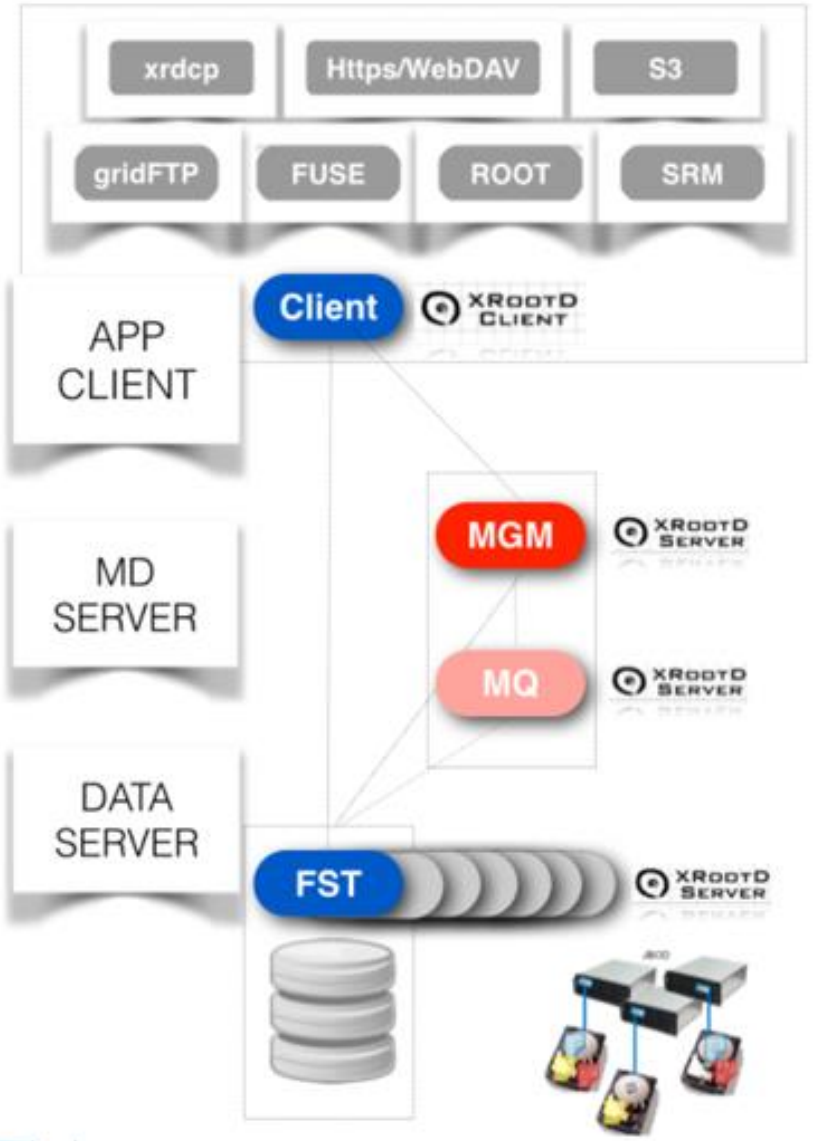
Scaling the EOS namespace

Quick overview, and current status

Georgios Bitzes, Elvin Sindrilaru, Andreas J. Peters, Andrea Manzi (speaker)

Architecture

- File Storage Nodes **(FST)**: Management of physical disks, file serving
- Metadata Servers **(MGM)**: Namespace + client redirection to FSTs
- Message Queue **(MQ)**: Inter-cluster communication, heartbeats, configuration changes



The namespace subsystem

- EOS presents **one single** namespace to files it manages
  - … even though they are typically spread across **hundreds** of disk servers and **thousands** of physical disks
- Handles file permissions, metadata, quota accounting, **mapping** between logical filenames and physical locations
  - `-rw-rw-r-- 1 user group 21 Jul  2 10:02 dir1/filename`

In-memory namespace implementation

- The MGM previously held the **entire** namespace in-memory. Each file / directory entry allocates up to 1kb as a C++ structure in memory.

- Linear on-disk **changelogs** to track all namespace changes
  - file additions, metadata changes, physical location migrations …
  - One for files, one for directories

- The in-memory contents are **reconstructed** on reboot by replaying the changelogs

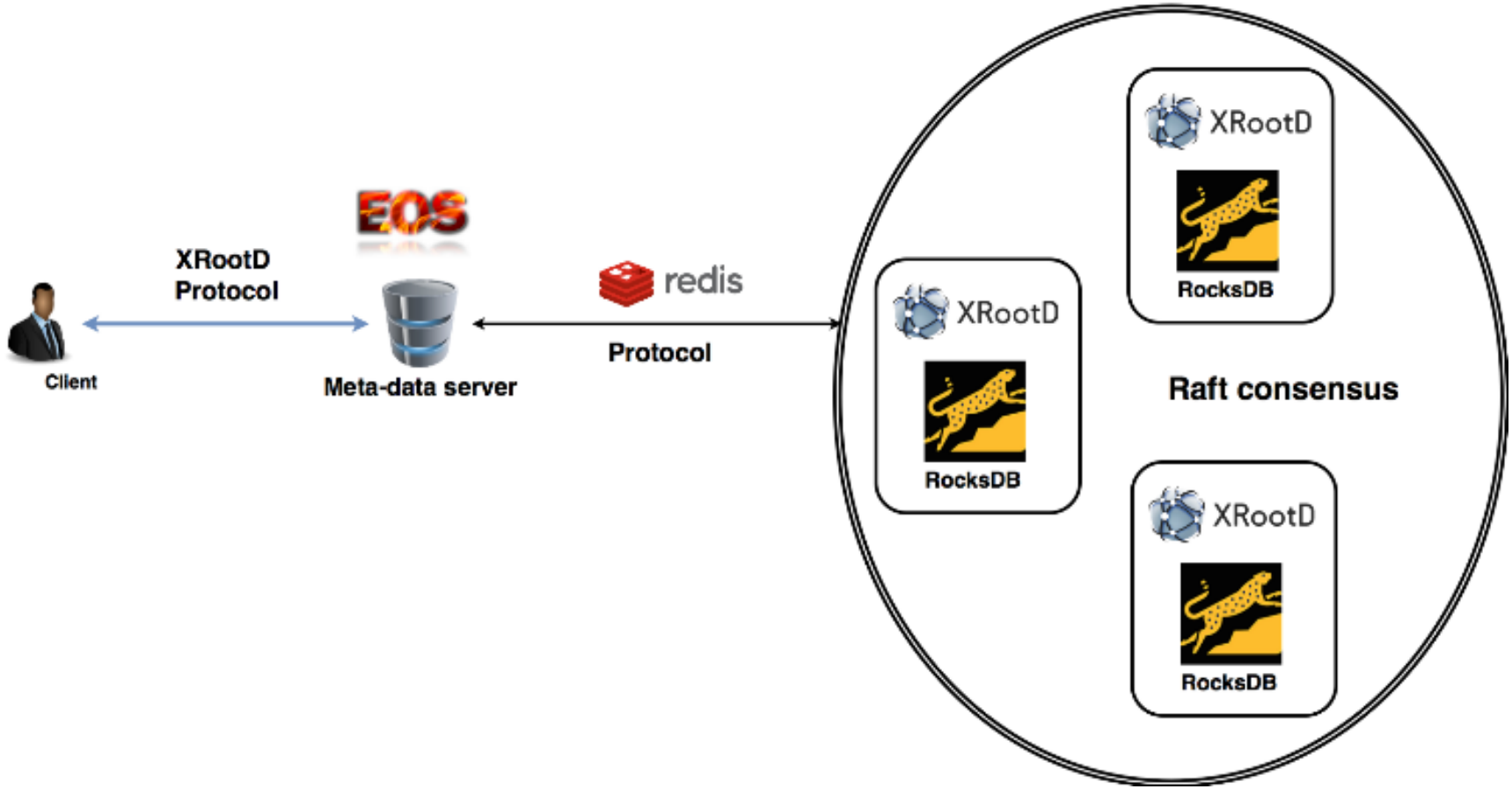
In-memory namespace implementation (2)

- Why replace the namespace implementation?

- **Long** boot time, proportional to the number of files on an instance. For large namespaces can exceed **1hour**

- Requires **a lot** of RAM

Architectural evolution



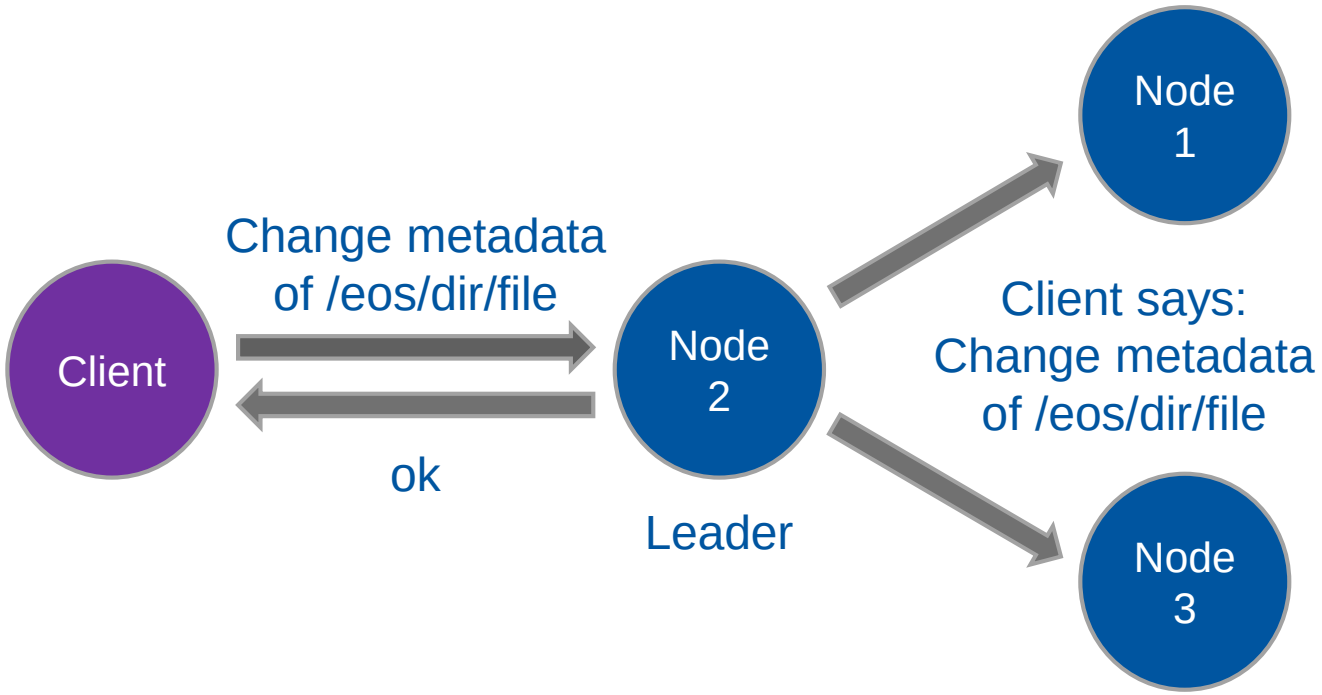
Architectural evolution (2)

- We've designed and implemented **QuarkDB**, a highly available datastore for the namespace.
  - **Redis protocol**, supports a small subset of Redis commands.
  - **RocksDB** as the underlying storage backend.
  - High availability: **Raft consensus** algorithm.

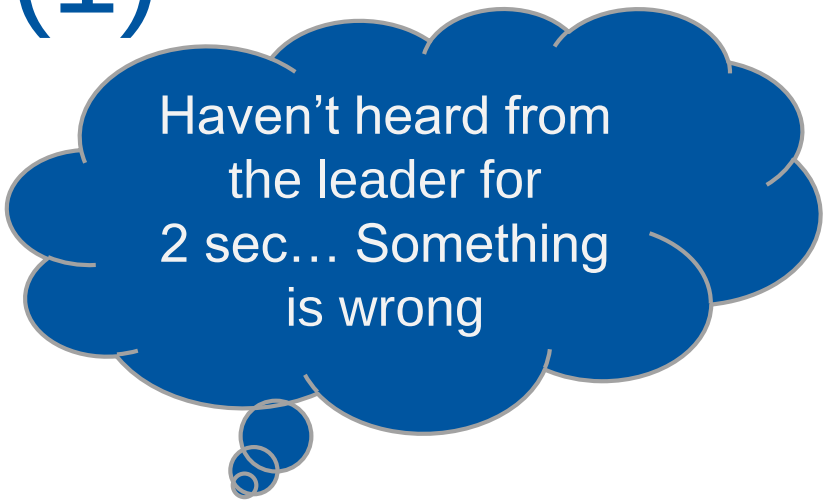
- Implement the minimum necessary, and keep the system simple
  - QuarkDB runs as a plug-in to the **XRootD** server framework used by EOS

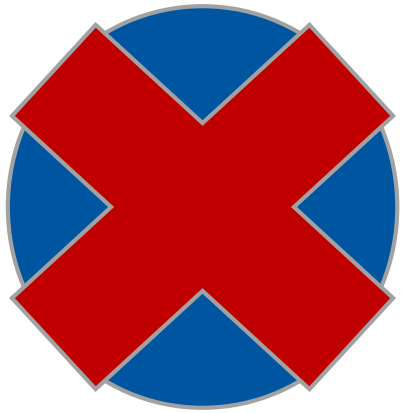
Replication

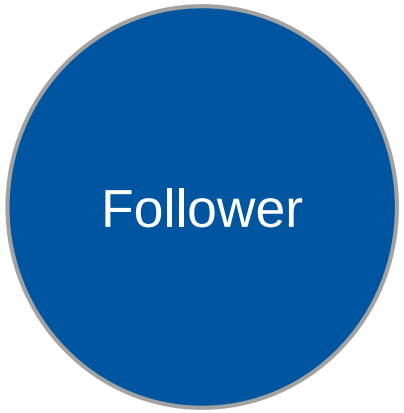
One of the nodes is elected to become the *master* (or *leader*)



Leader election (1)

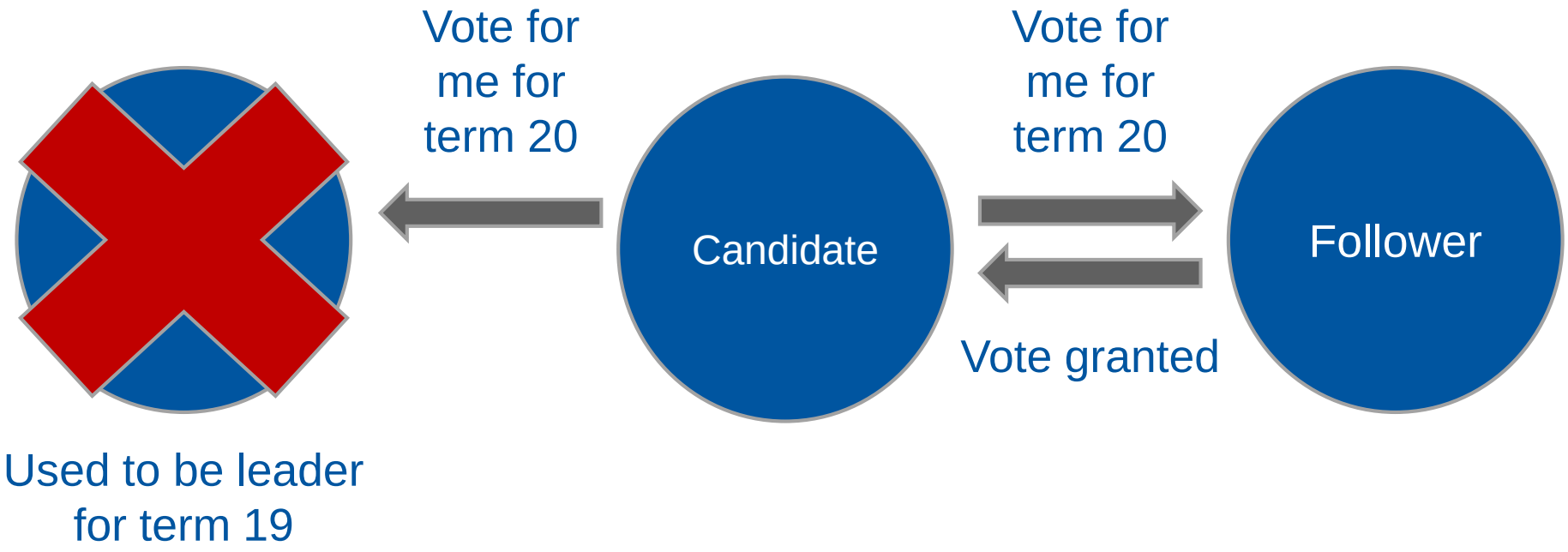




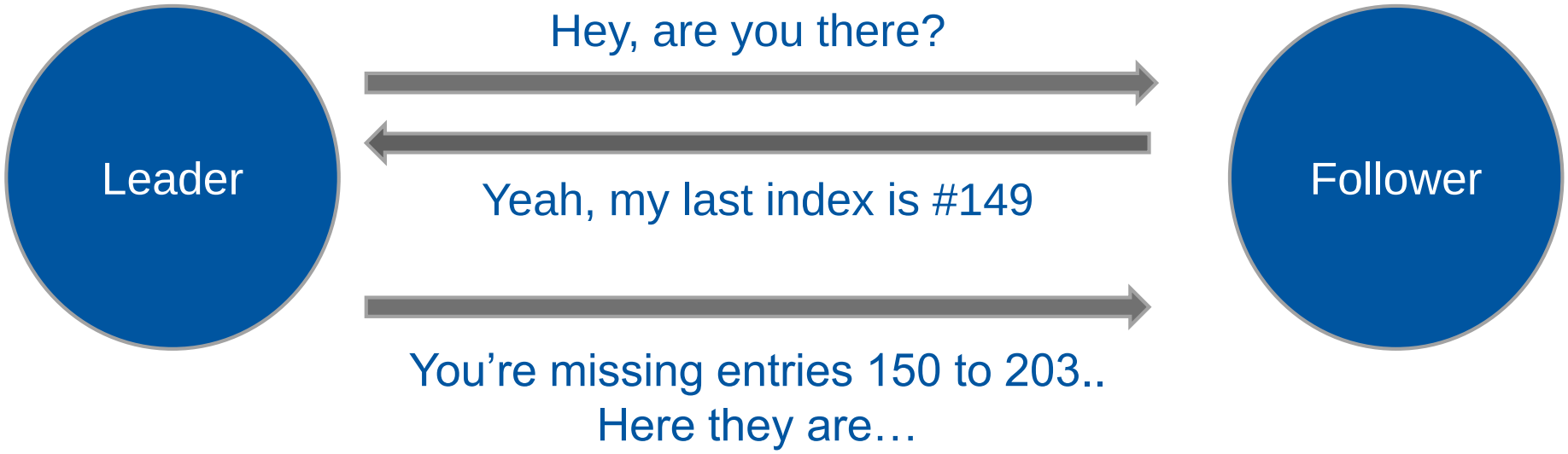


Leader election (2)

A successful election: 2 out of 3 nodes agree on the new leader



Log replication



QuarkDB Testing

- Consensus bugs would be hard to trace, it *has* to be correct.

- QuarkDB is being tested extensively.
  - Unit, stress, chaos tests: From testing parsing utility functions, to simulating constant leader crashes and ensuring nodes stay in sync.
  - Test coverage: **91%**, measured on each commit.

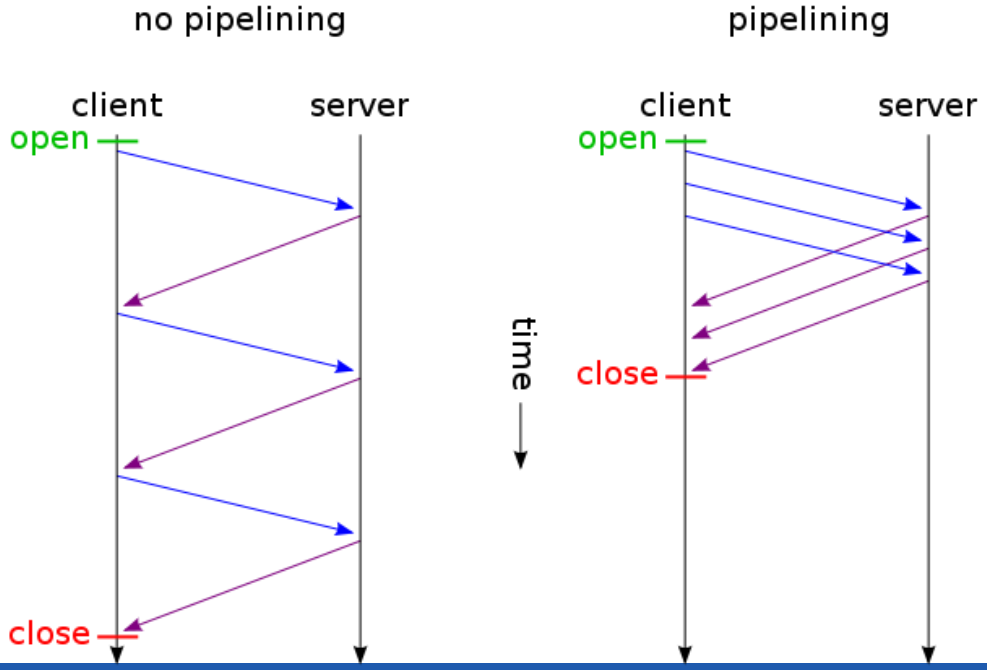
  - All tests running under AddressSanitizer & ThreadSanitizer, on each commit.

Problem: Network latency

- Previous assumption throughout the MGM code: Access latency to the NS is *minimal*, all lives in-memory.
- But with QDB, metadata lives a network roundtrip away…
  - Caching frequently accessed entries in the MGM helps a lot.
- Certain **locks** which were fine to hold for in-memory NS operations, were causing trouble for new NS.

Problem: Network latency (2)

- Using prefetching to first load metadata into the MGM cache, **before** holding any locks.
  - Allows staging in-flight requests from many clients simultaneously.
  - Allows pipelining, virtually eliminating effects of network latency for many operations
    (notably “ls”)



Current status

- **EOSPPS**: our pre-production instance runs NS on QuarkDB since 7 months
- **3.4 billion files** (most are empty) – larger namespace than all other instances combined
- **Boot time:** A couple of minutes 

- **Next steps:** Implementing HA at the MGM level. Multiple standby MGMs, coordination through QuarkDB on who becomes active

Thanks

- https://gitlab.cern.ch/eos/quarkdb
- Current status: **~18k** lines of code
  - including tests, tools
  - excluding dependencies

- More on Raft:
  - https://raft.github.io/raft.pdf
  - https://thesecretlivesofdata.com/raft/

Questions, comments?