Replication notes

Oct 25, 2018

CPSC 416

How'd we get here?

- Failures & single systems; fault tolerance techniques added redundancy (ECC memory, RAID, etc.)
- Conceptually, ECC & RAID both put a "master" in front of the redundancy to mask it from clients -- ECC handled by memory controller, RAID looks like a very reliable hard drive behind a (special) controller

Simpler examples...

- Replicated web sites
- e.g., Yahoo! or Amazon:
  - DNS-based load balancing (DNS returns multiple IP addresses for each name)
  - Hardware load balancers put multiple machines behind each IP address
  - (Diagram. :)

Read-only content

- Easy to replicate - just make multiple copies of it.
  - Performance boost 1: Get to use multiple servers to handle the load (scalability!)
  - Perf boost 2: Locality. We'll see this later when we discuss CDNs, can often direct client to a replica *near* it
  - Availability boost: Can fail-over (done at both DNS level -- slower, because clients cache DNS answers -- and at front-end hardware level)

But for read-write data...

- Must implement write replication, typically with some degree of consistency

What consistency model?

- Just like in distributed filesystems, must consider consistency model you supply
- R/L example: Google mail (mix of consistency models)
  - *Sending mail* is replicated to ~2 physically separated datacenters (users hate it when they think they sent mail and it got lost); mail will pause while doing this replication.
  - *Marking mail read* is only replicated in the background - you can mark it read, the replication can fail, and you'll have no clue (re-reading a read email once in a while is no big deal)
- Weaker consistency is cheaper if you can get away with it.

Goal

- Provide a service
- Survive the failure of up to *f* replicas
- Provide identical service as a non-replicated version (except more reliable, and perhaps different performance)

- Also known as the "replicated state machine" (**RSM**) abstraction
  - As with other abstractions (e.g., RPC), there are many ways to achieve/implement a RSM

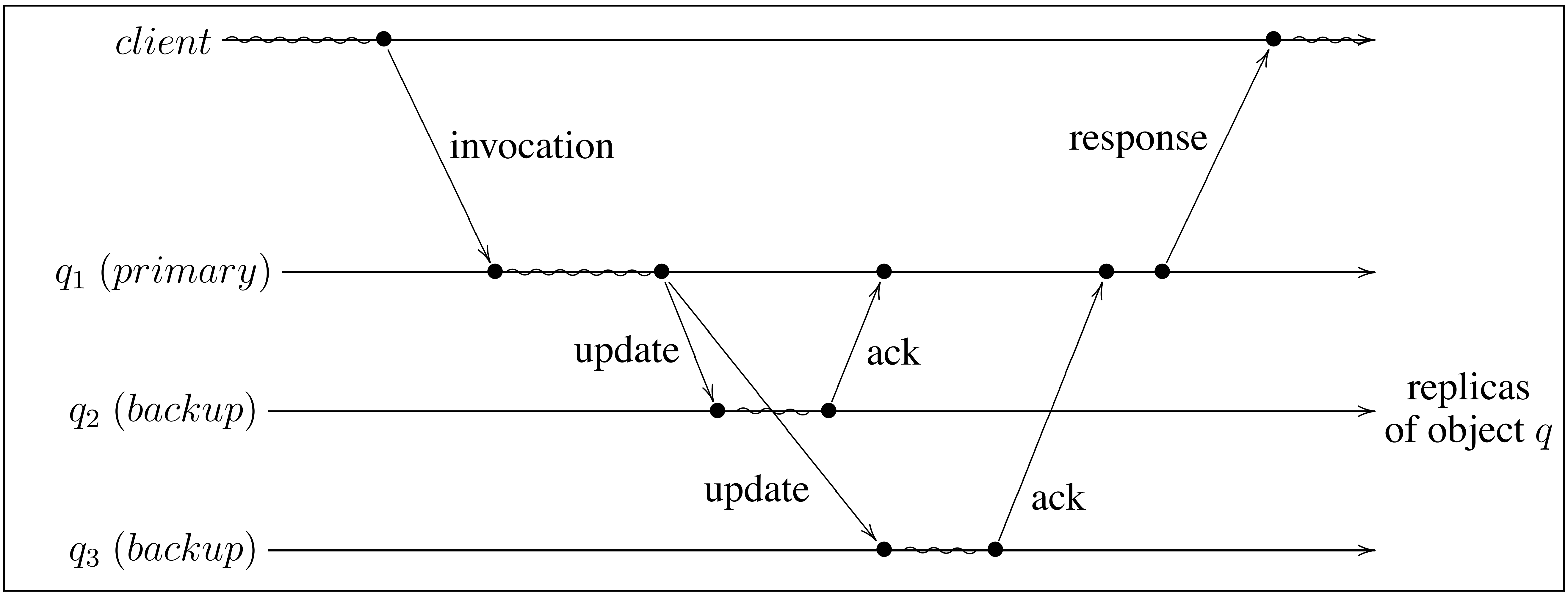
We'll cover

- Primary-backup
  - Operations handled by primary, it streams copies to backup(s)
  - Replicas are "passive"
  - Good: Simple protocol. Bad: Clients must participate in recovery.
- Quorum consensus using Paxos or Raft (later in the course)
  - Designed to have fast response time even under failures
  - Replicas are "active" - participate in protocol; there is no master, per se.
  - Good: Clients don't even see the failures. Bad: More complex.

primary-backup

- Clients talk to a primary
- The primary handles requests, atomically and idempotently
- Executes them
- Sends the request to the backups
- Backups reply, “OK”
- Primary ACKs to the client

primary-backup



primary-backup

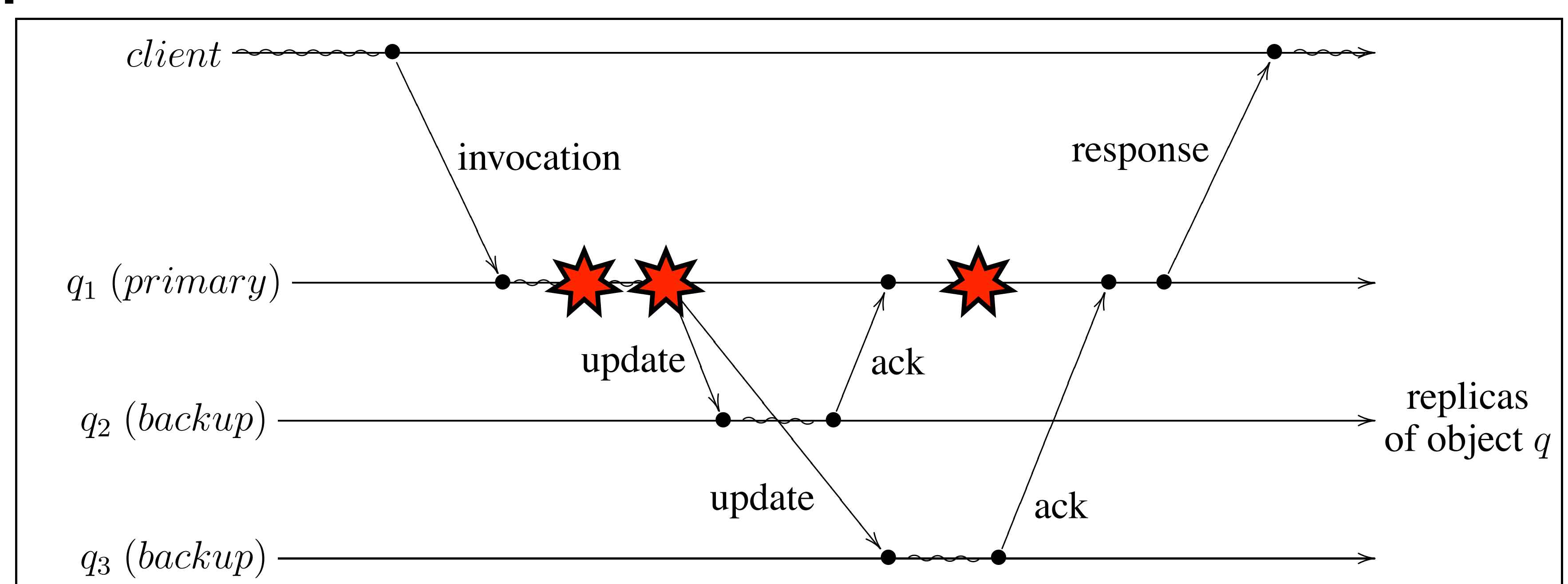
- Note: If you don't care about strong consistency (e.g., the "mail read" flag), you can reply to client *before* reaching agreement with backups (sometimes called "asynchronous replication").
- This looks cool. What's the problem?
- This is OK for some services, not OK for others
- Advantage: With N servers, can tolerate loss of N-1 copies

primary-backup

- Note: If you don't care about strong consistency (e.g., the "mail read" flag), you can reply to client *before* reaching agreement with backups (sometimes called "asynchronous replication").
- This looks cool. What's the problem?
  - What do we do if a replica has failed?
  - We wait... how long? Until it's marked dead.
  - Primary-backup has a strong dependency on the failure detector
- This is OK for some services, not OK for others
- Advantage: With N servers, can tolerate loss of N-1 copies

failures in p-b

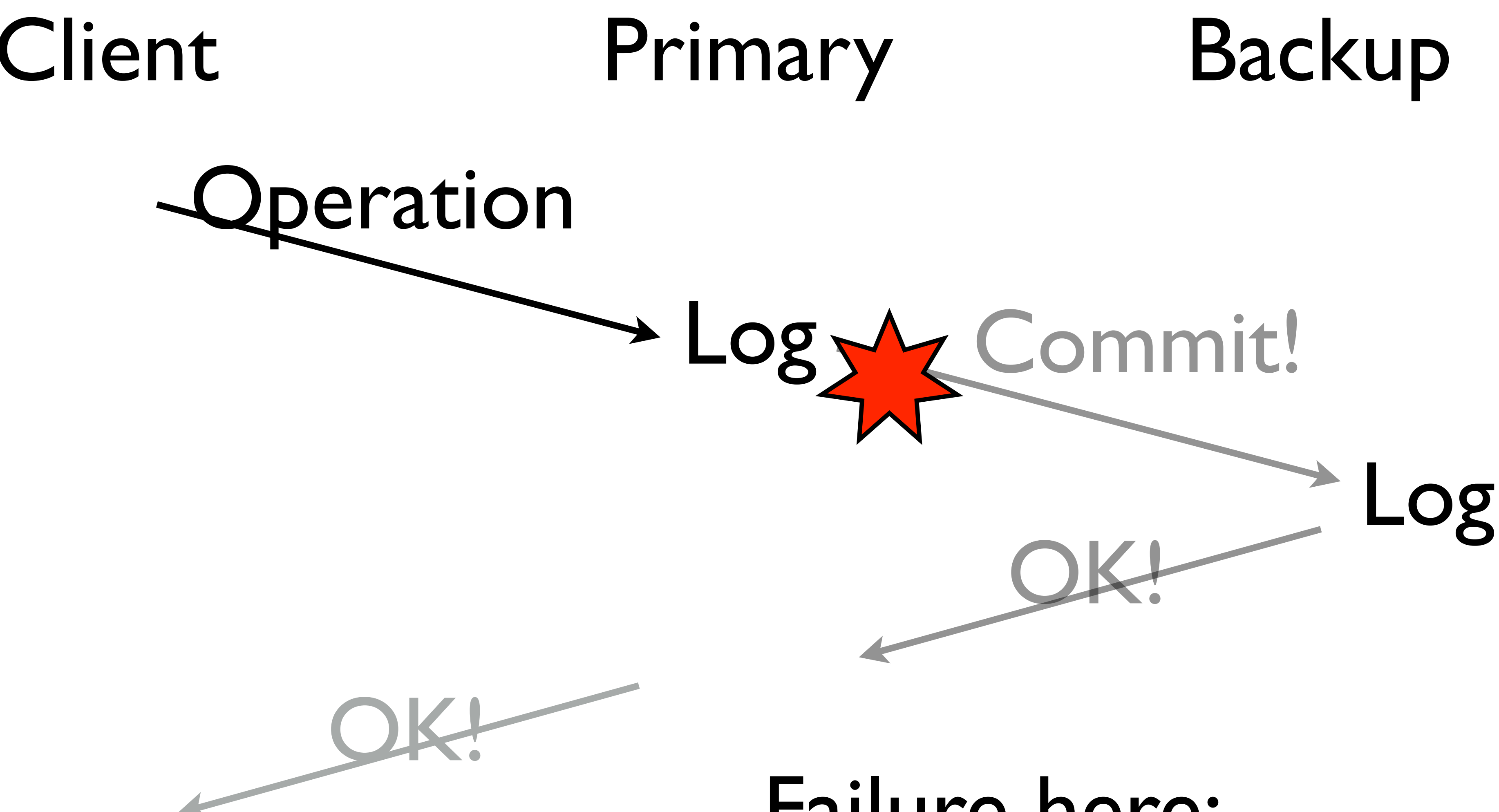
- Use timeout-based failure detector for detection
- Backup failures: timeout and remove from set (later add new backups)
- Primary failures: complex because unclear when the primary failed (before/after replicating)
- Handling primary failures requires client participation

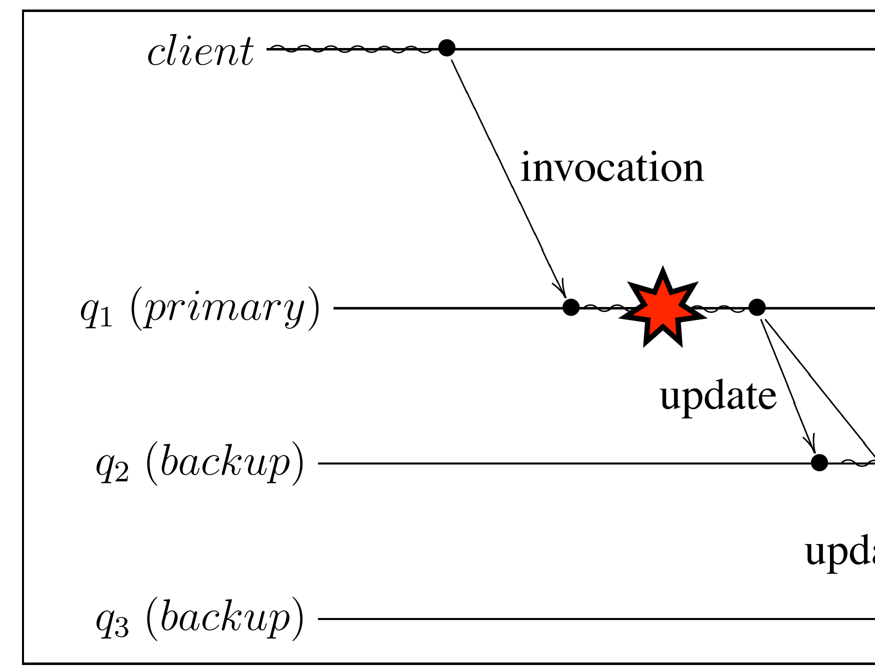


implementing primary-backup

- Remember logging (if you've taken databases)
- Common technique for replication in databases and filesystem-like things: Stream the log to the backup. They don't have to actually apply the changes before replying, just make the log durable (i.e., on disk).
- You have to replay the log before you can be online again, but it's pretty cheap.

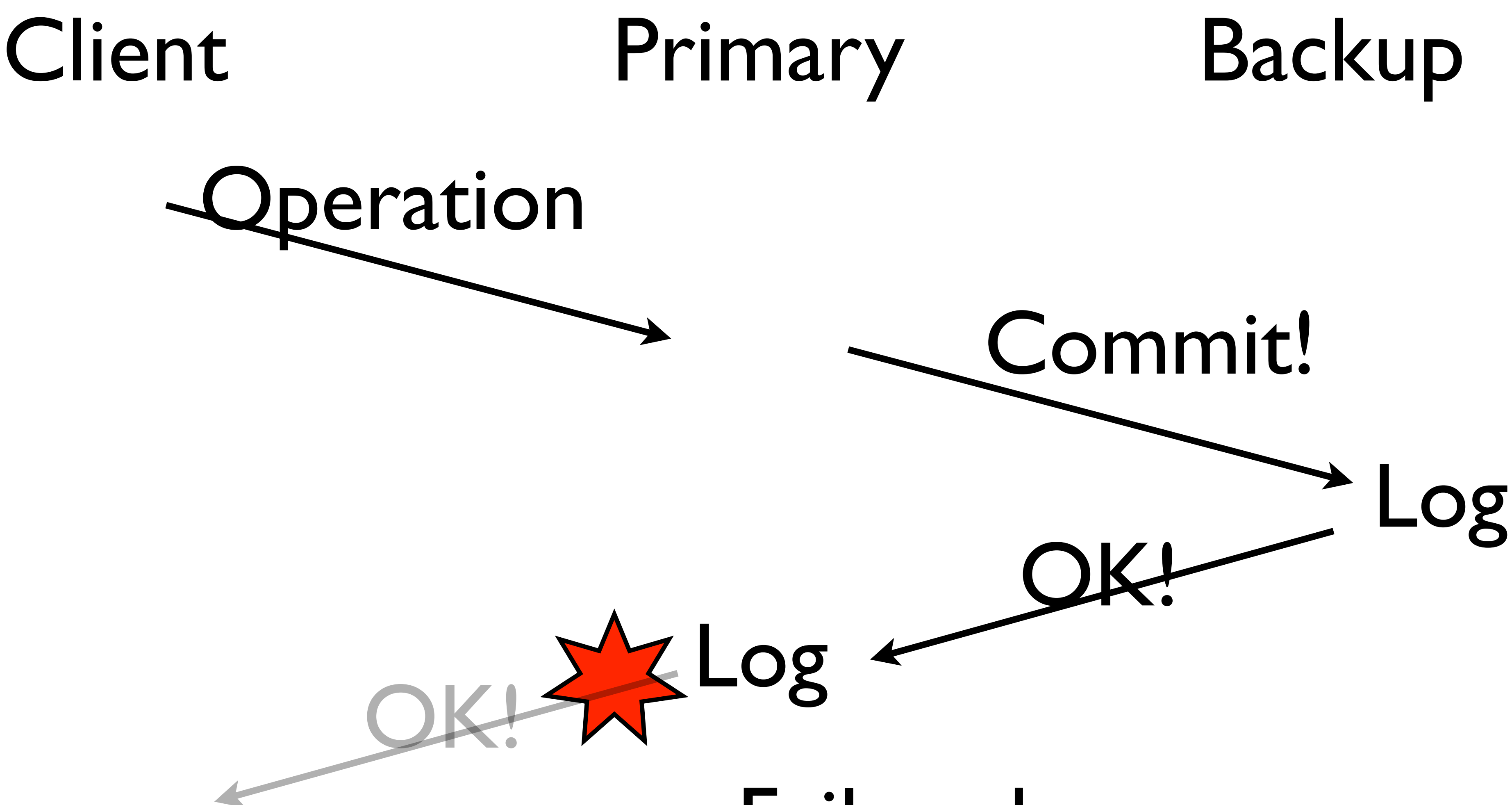
p-b: Did it happen?

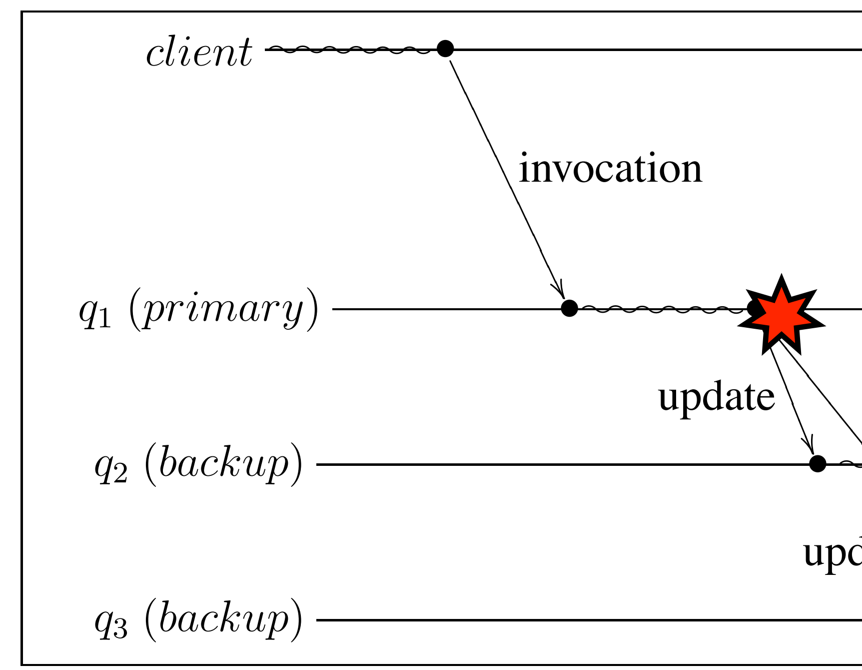




Failure here:
Commit logged only at primary
Primary dies? **Client** must re-send to backup
(idempotency important)

p-b: Happened twice





Failure here:

Commit logged at backup

Primary dies? **Client** must check with backup

(Seems like at-most-once / at-least-once... :)

Problems with p-b

- Not a great solution if you want very tight response time even when something has failed: Must wait for failure detector
- For that, *quorum* based schemes are used
- As name implies, different result:
  - To handle f failures, must have $2f + 1$ replicas. Why?

Problems with p-b

- Client must be involved in primary recovery
- Requires client state (at least operation + id)
- Client must be aware of backups (violates the RSM abstraction)
- Bringing up a new primary is complicated
    - All clients must sign off on their outstanding ops
    - Vote a new backup to become primary?
    - Download all state to new primary?

Problems with p-b

- Not a great solution if you want very tight response time even when something has failed: Must wait for failure detector
- For that, *quorum* based schemes are used
- As name implies, different result:
  - To handle *f* failures, must have 2*f* + 1 replicas. Why? so that a majority (f+1) is still alive after (f) failures