CS5412: HOW DURABLE SHOULD IT BE?

Lecture XV

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Durability

- When a system accepts an update and won't lose it, we say that event has become durable
- Everyone jokes that the cloud has a permanent memory and this of course is true
  - Once data enters a cloud system, they rarely discard it
  - More common to make lots of copies, index it…
- But loss of data due to a failure is an issue

Should Consistency "require" Durability?

- The Paxos protocol guarantees durability to the extent that its command lists are durable

- Normally we run Paxos with the command list on disk, and hence Paxos can survive any crash
  - In Isis^2, this is g.SafeSend with the "DiskLogger" active
  - But costly

Consider the first tier of the cloud

- Recall that applications in the first tier are limited to what Brewer calls “Soft State”
  - They are basically prepositioned virtual machines that the cloud can launch or shutdown very elastically
  - But when they shut down, lose their “state” including any temporary files
  - Always restart in the initial state that was wrapped up in the VM when it was built: no durable disk files

Examples of soft state?

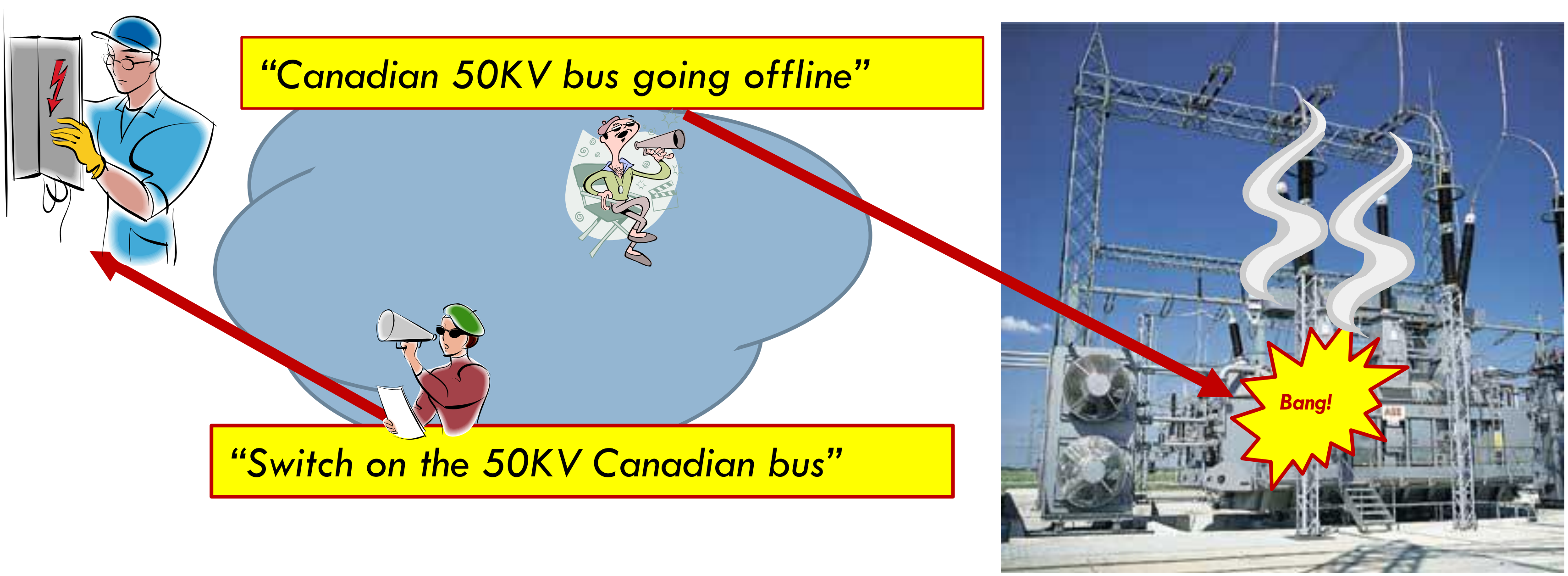
- Anything that was cached but "really" lives in a database or file server elsewhere in the cloud
  - If you wake up with a cold cache, you just need to reload it with fresh data
- Monitoring parameters, control data that you need to get "fresh" in any case
  - Includes data like "The current state of the air traffic control system" – for many applications, your old state is just not used when you resume after being offline
  - Getting fresh, current information guarantees that you'll be in sync with the other cloud components
- Information that gets reloaded in any case, e.g. sensor values

Would it make sense to use Paxos?

- We do maintain sharded data in the first tier and some requests certainly trigger updates
- So that argues in favor of a consistency mechanism
- In fact consistency can be important even in the first tier, for some cloud computing uses

Control of the smart power grid

- Suppose that a cloud control system speaks with "two voices"
- In physical infrastructure settings, consequences can be very costly



So… would we use Paxos here?

- In discussion of the CAP conjecture and their papers on the BASE methodology, authors generally assume that “C” in CAP is about ACID guarantees or Paxos
- Then argue that these bring too much delay to be used in settings where fast response is critical
- Hence they argue against Paxos

By now we've seen a second option

- Virtual synchrony Send is "like" Paxos yet different

- Paxos has a very strong form of durability
- Send has consistency but weak durability unless you use the "Flush" primitive. Send+Flush is amnesia-free

- Further complicating the issue, in Isis^2 Paxos is called SafeSend, and has several options
  - Can set the number of acceptors
  - Can also configure to run in-memory or with disk logging

How would we pick?

- The application code looks nearly identical!
  - g.Send(GRIDCONTROL, *action to take*)
  - g.SafeSend(GRIDCONTROL, *action to take*)

- Yet the behavior is very different!
  - SafeSend is slower
  - … and has stronger durability properties. ***Or does it?***

SafeSend in the first tier

- Observation: like it or not we just don't have a durable place for disk files in the first tier

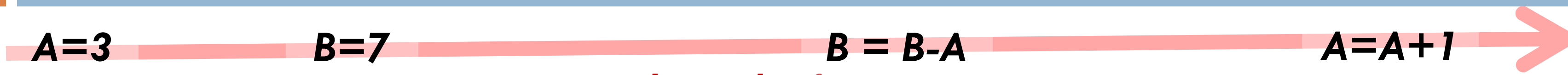
- The *only* forms of durability are
  - In-memory replication within a shard
  - Inner-tier storage subsystems like databases or files

- Moreover, the first tier is expect to be rapidly responsive and to talk to inner tiers asynchronously

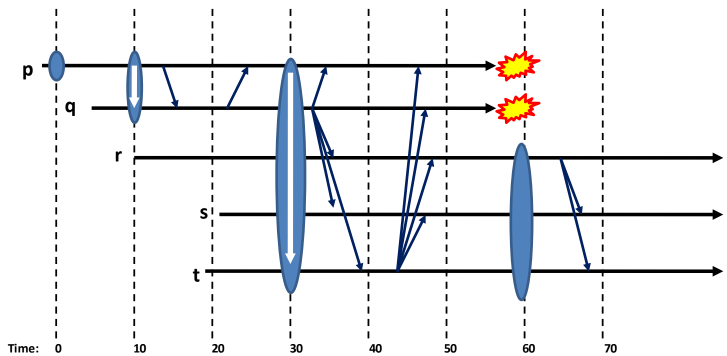
So our choice is simplified

- No matter what anyone might tell you, in fact the only real choices are between two options
  - Send + Flush: Before replying to the external customer, we know that the data is replicated in the shard
  - In-memory SafeSend: On an update by update basis, before each update is taken, we know that the update will be done at every replica in the shard

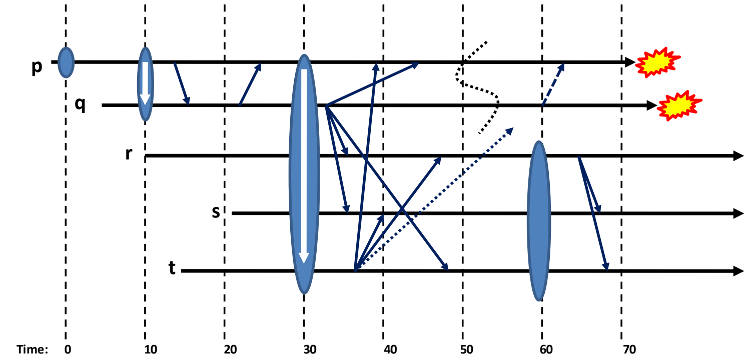
Consistency model: Virtual synchrony meets Paxos (and they live happily ever after…)



Non-replicated reference execution



Synchronous execution



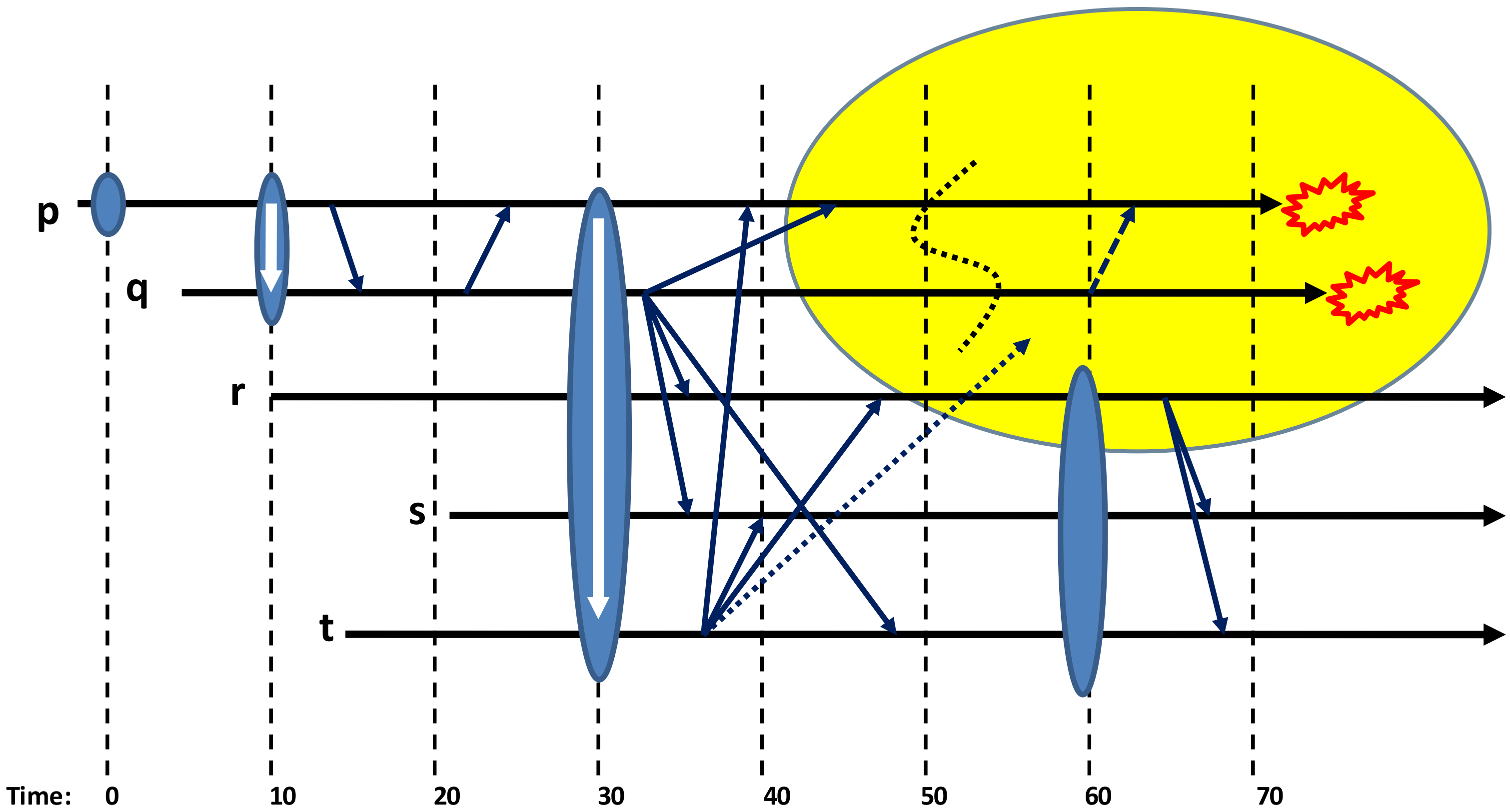
Virtually synchronous execution

- **Virtual synchrony is a "consistency" model:**
  - ***Synchronous runs:* *indistinguishable from non-replicated object that saw the same updates (like Paxos)***
  - ***Virtually synchronous runs* *are indistinguishable from synchronous runs***

SafeSend versus Send

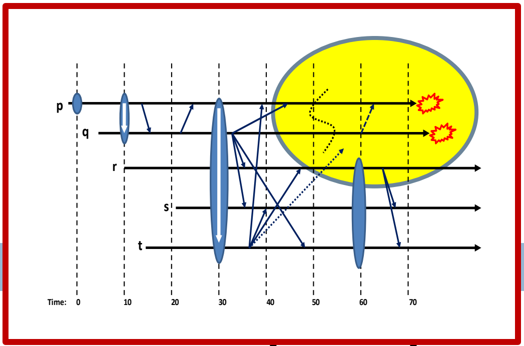
- Send can have different delivery orders if there are different senders
  - In fact Isis[2] offers other options, we'll discuss them next time.
- SafeSend can't have the strange amnesia problem see in the top right corner on the timeline picture
- But these guarantees are pretty costly!

Looking closely at that "oddity"



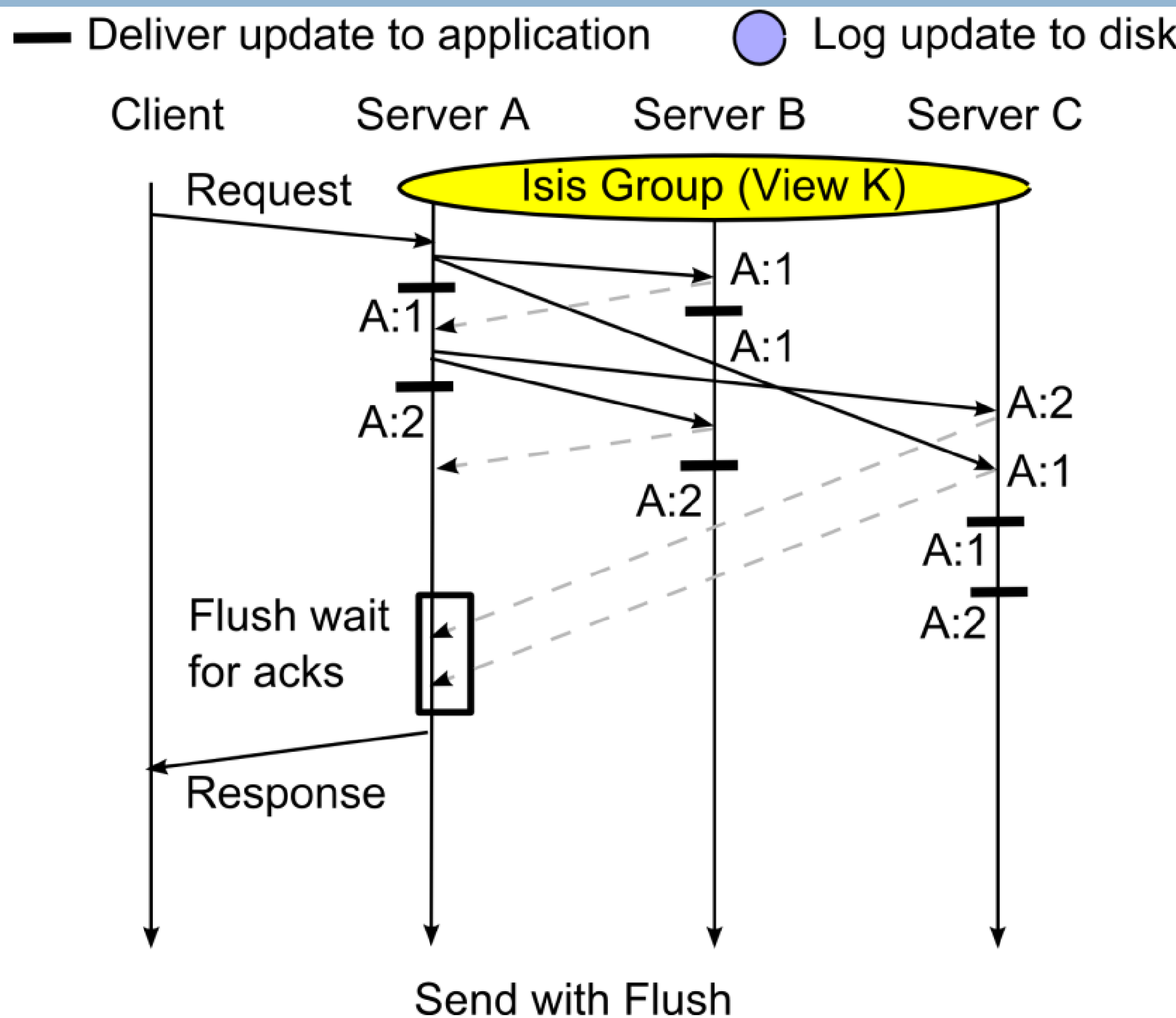
Virtually synchronous execution "amnesia" example (Send but without calling Flush)

What made it odd?



- In this example a network partition occurred and, before anyone noticed, some messages were sent and delivered
  - "Flush" would have blocked the caller, and SafeSend would not have delivered those messages
  - Then the failure *erases* the events in question: no evidence remains at all
  - So was this bad? OK? A kind of transient internal inconsistency that repaired itself?

Looking closely at that "oddity"



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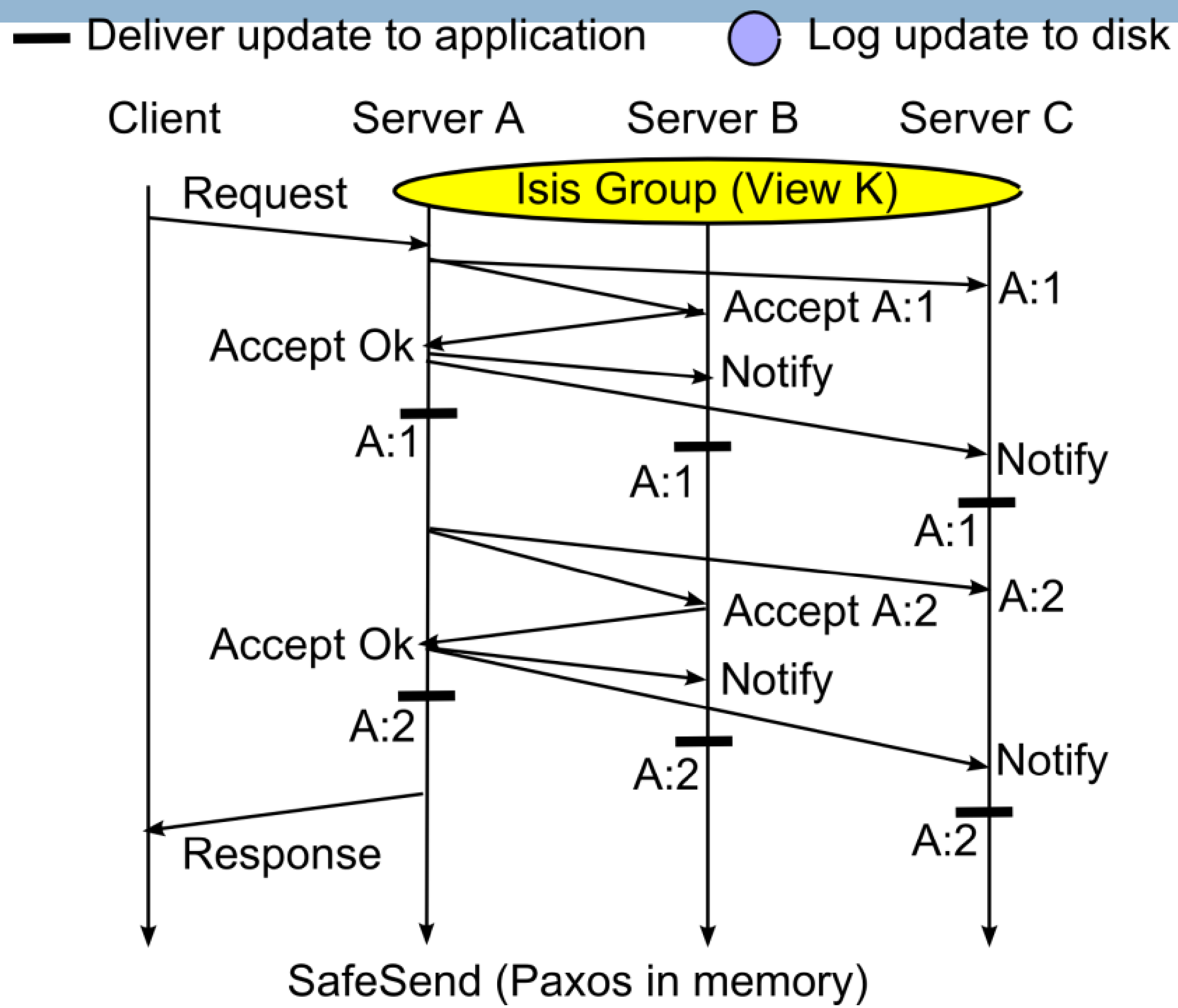
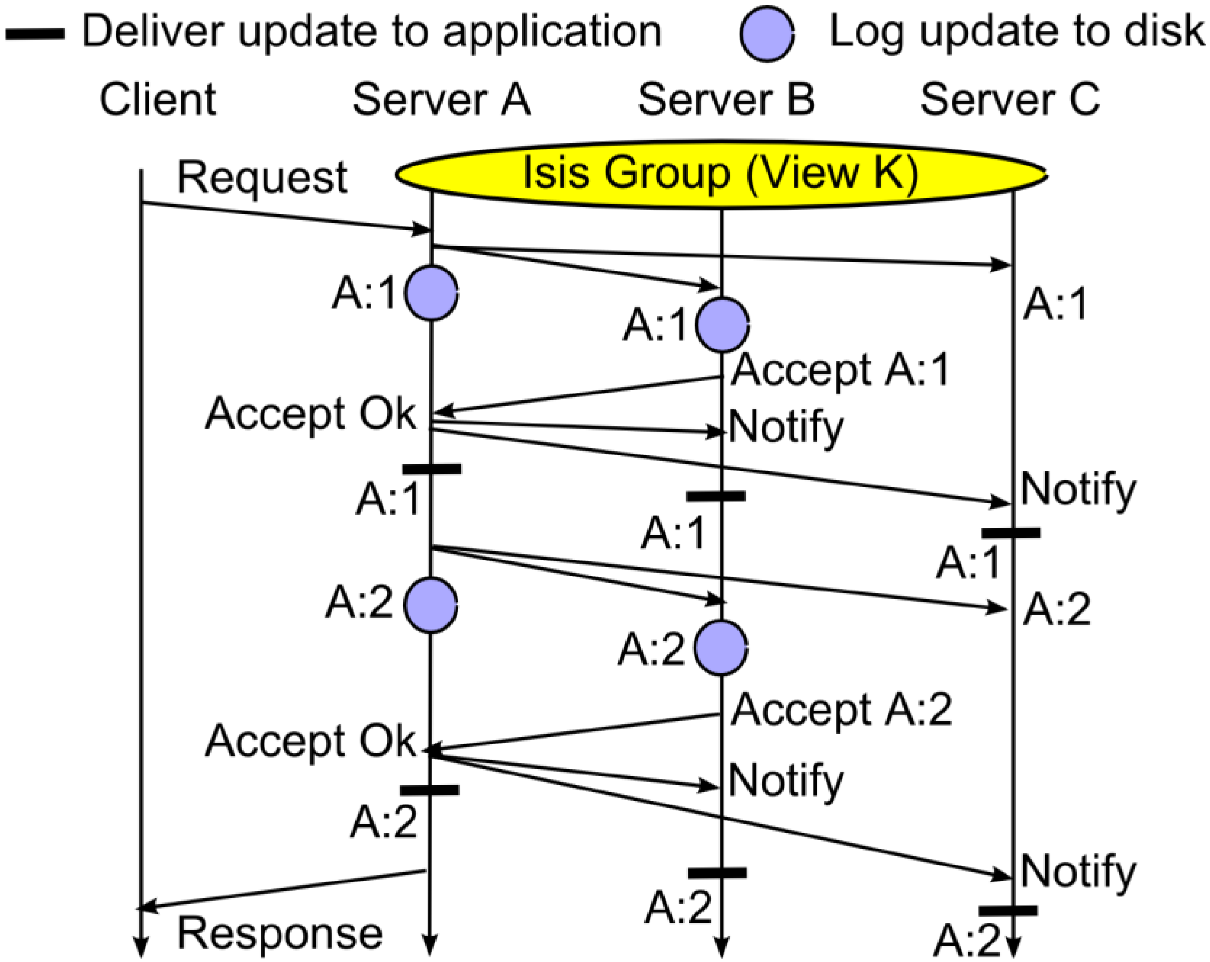


Looking closely at that "oddity"

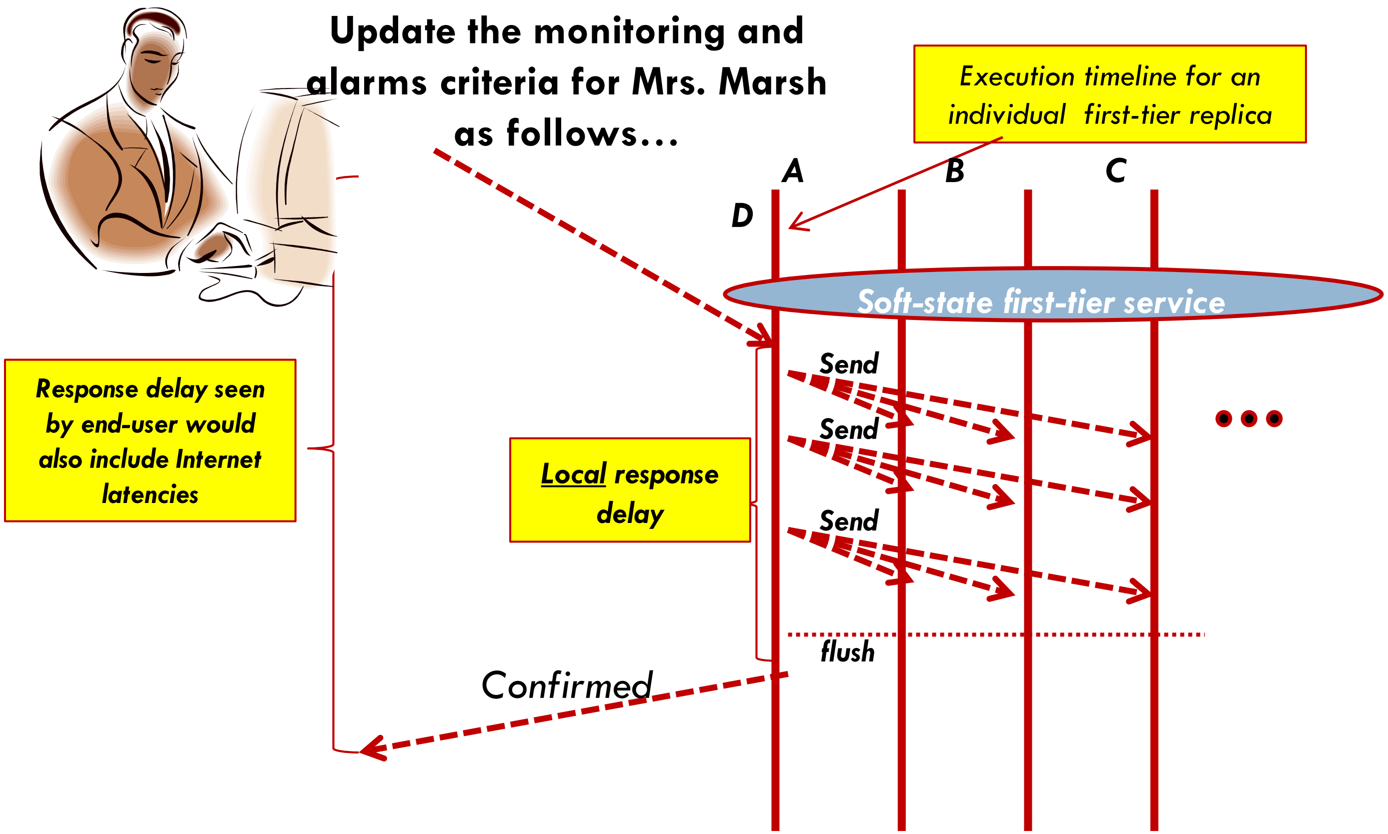


Durable (disk-logged) Paxos

Paxos avoided the issue… at a price

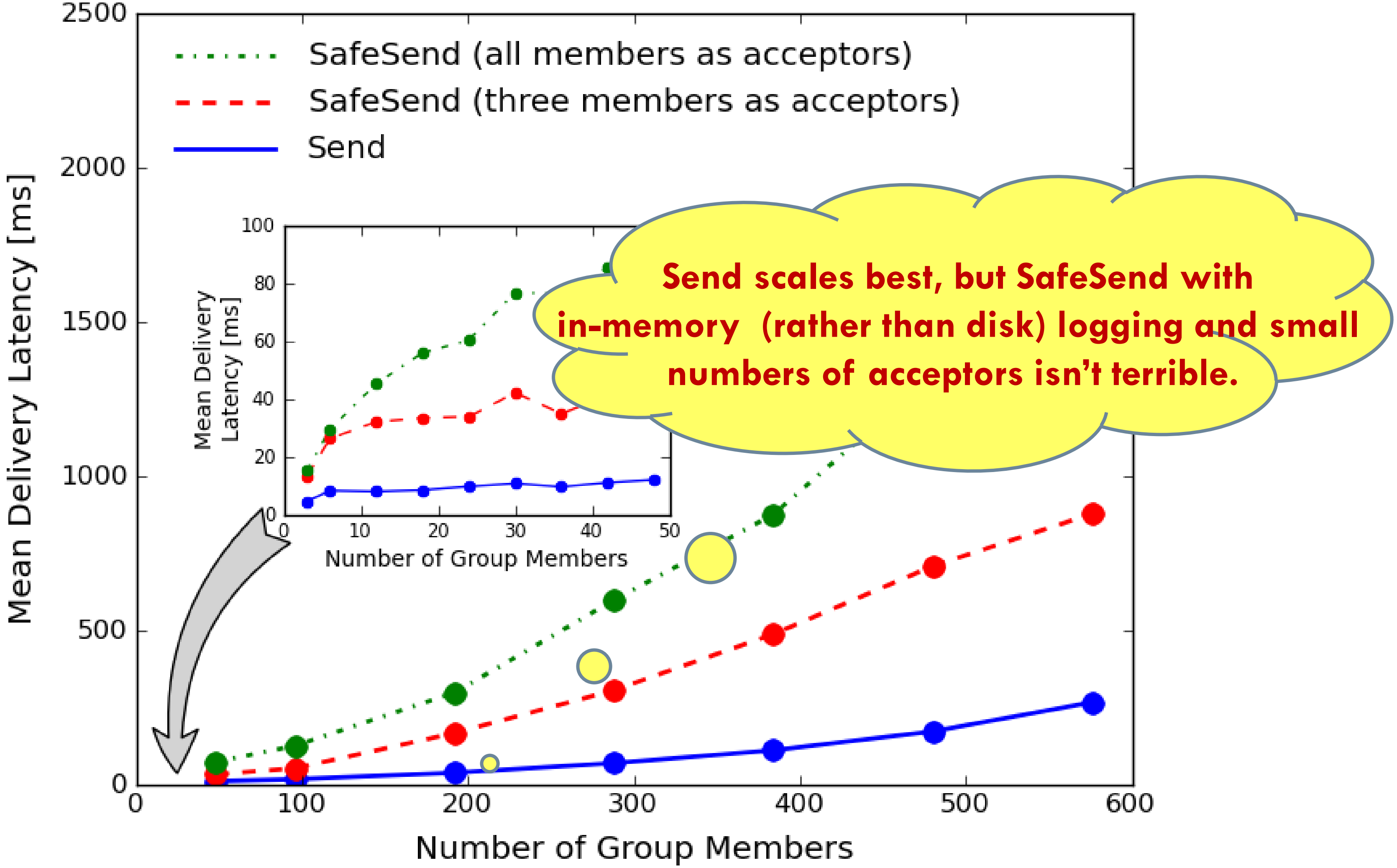
- SafeSend, Paxos and other multi-phase protocols don't deliver in the first round/phase
- This gives them stronger safety on a message by message basis, but also makes them slower and less scalable
- Is this a price we should pay for better speed?

Revisiting our medical scenario

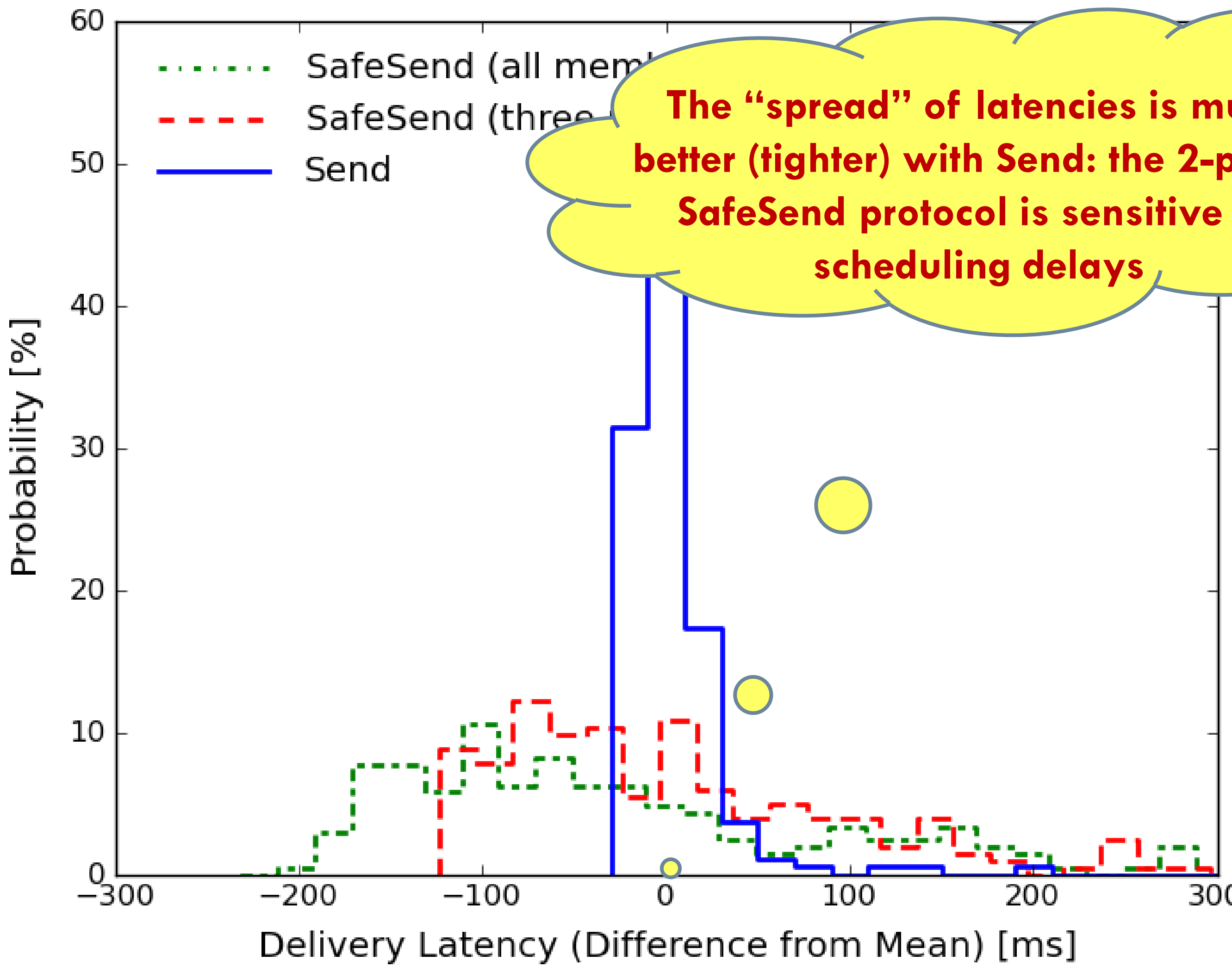


- An online monitoring system might focus on real-time response and be less concerned with data durability

Isis²: Send v.s. in-memory SafeSend

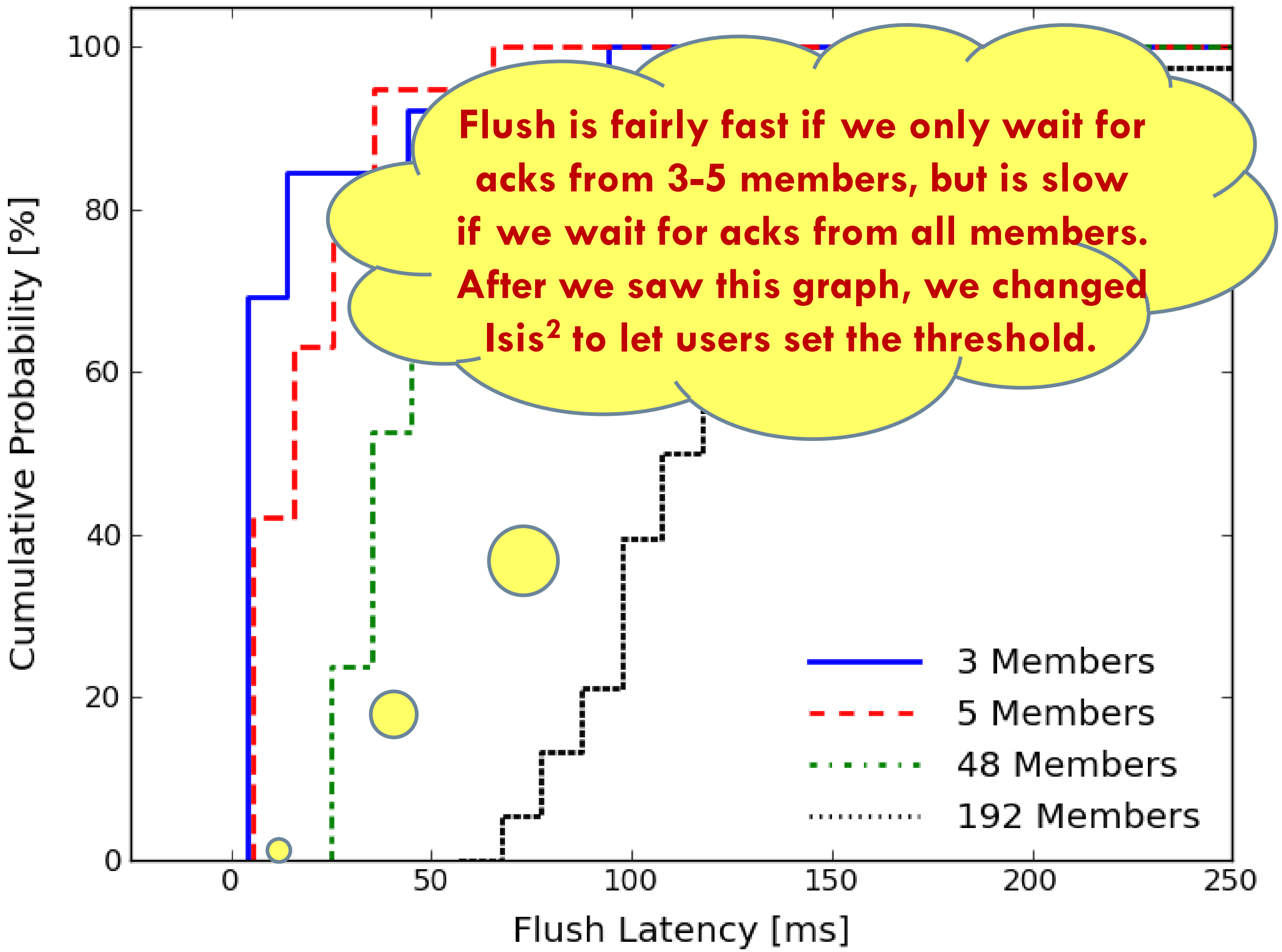


Jitter: how "steady" are latencies?



The "spread" of latencies is much better (tighter) with Send: the 2-phase SafeSend protocol is sensitive to scheduling delays

Flush delay as function of shard size



First-tier "mindset" for tolerant *f* faults

- Suppose we do this:
  - Receive request
  - Compute locally using consistent data and perform updates on sharded replicated data, consistently
  - Asynchronously forward updates to services deeper in cloud but don't wait for them to be performed
  - Use the "flush" to make sure we have $f+1$ replicas

- Call this an "amnesia free" solution. Will it be fast enough? Durable enough?

Which replicas?

- One worry is this
  - If the first tier is totally under control of a cloud management infrastructure, elasticity could cause our shard to be entirely shut down "abruptly"
- Fortunately, most cloud platforms do have some ways to notify management system of shard membership
  - This allows the membership system to shut down members of multiple shards without ever depopulating any single shard
  - Now the odds of a sudden amnesia event become low

Advantage: Send+Flush?

- It seems that way, but there is a counter-argument

- The problem centers on the Flush delay
  - We pay it both on writes and on *some reads*
  - If a replica has been updated by an unstable multicast, it can't safely be read until a Flush occurs
  - Thus need to call Flush prior to replying to client even in a read-only procedure
    - Delay will occur *only* if there are pending unstable multicasts

We don't need this with SafeSend

- In effect, it does the work of Flush prior to the delivery ("learn") event
- So we have slower delivery, but now any replica is always safe to read and we can reply to the client instantly
- In effect the updater sees delay on his critical path, but the reader has no delays, ever

Advantage: SafeSend?

- Argument would be that with both protocols, there is a delay on the critical path where the update was initiated

- But only Send+Flush ever delays in a pure reader

- So SafeSend is faster!
  - But this argument is flawed…

Flaws in that argument

- The delays aren't of the same length (in fact the pure reader calls Flush but would rarely be delayed)
- Moreover, if a request does multiple updates, we delay on each of them for SafeSend, but delay just once if we do Send…Send…Send…Flush
- How to resolve?

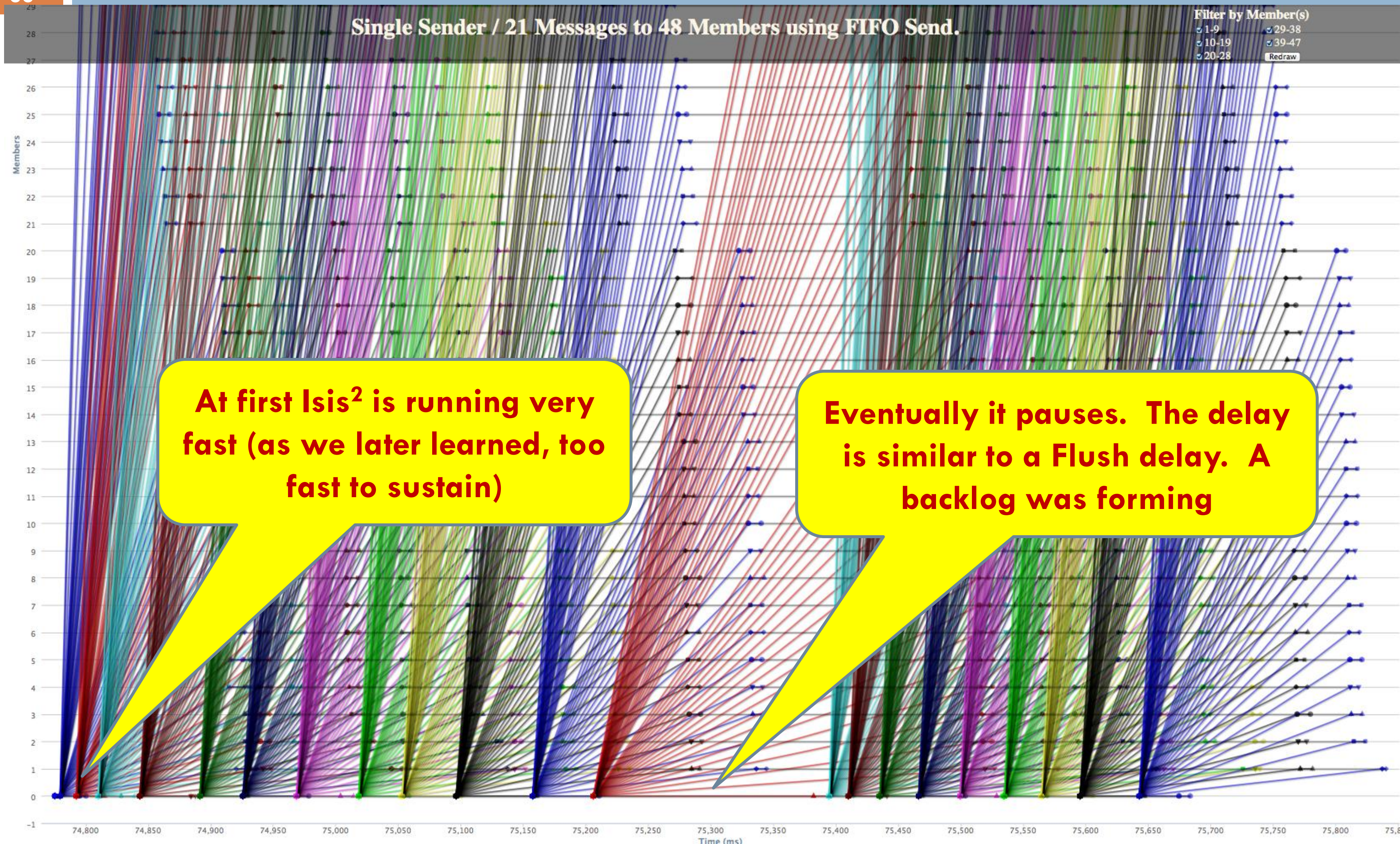
Only real option is to experiment

- In the cloud we often see questions that arise at
  - Large scale,
  - High event rates,
  - … and where millisecond timings matter
- Best to use tools to help visualize performance
- Let's see how one was used in developing Isis^2

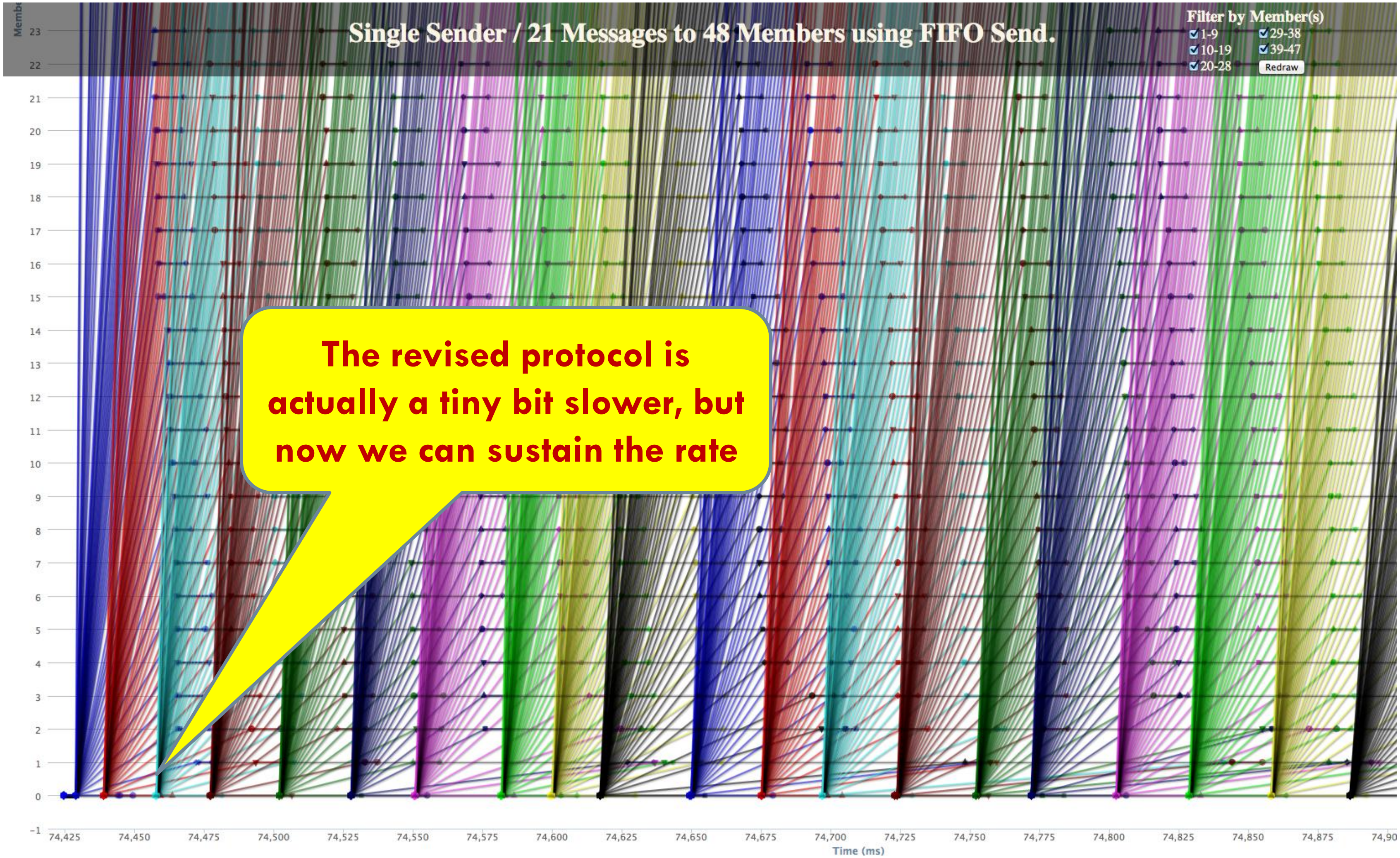
Something was… strangely slow

- We weren't sure why or where
- Only saw it at high data rates in big shards
- So we ended up creating a visualization tool just to see how long the system needed from when a message was sent until it was delivered
- Here's what we saw

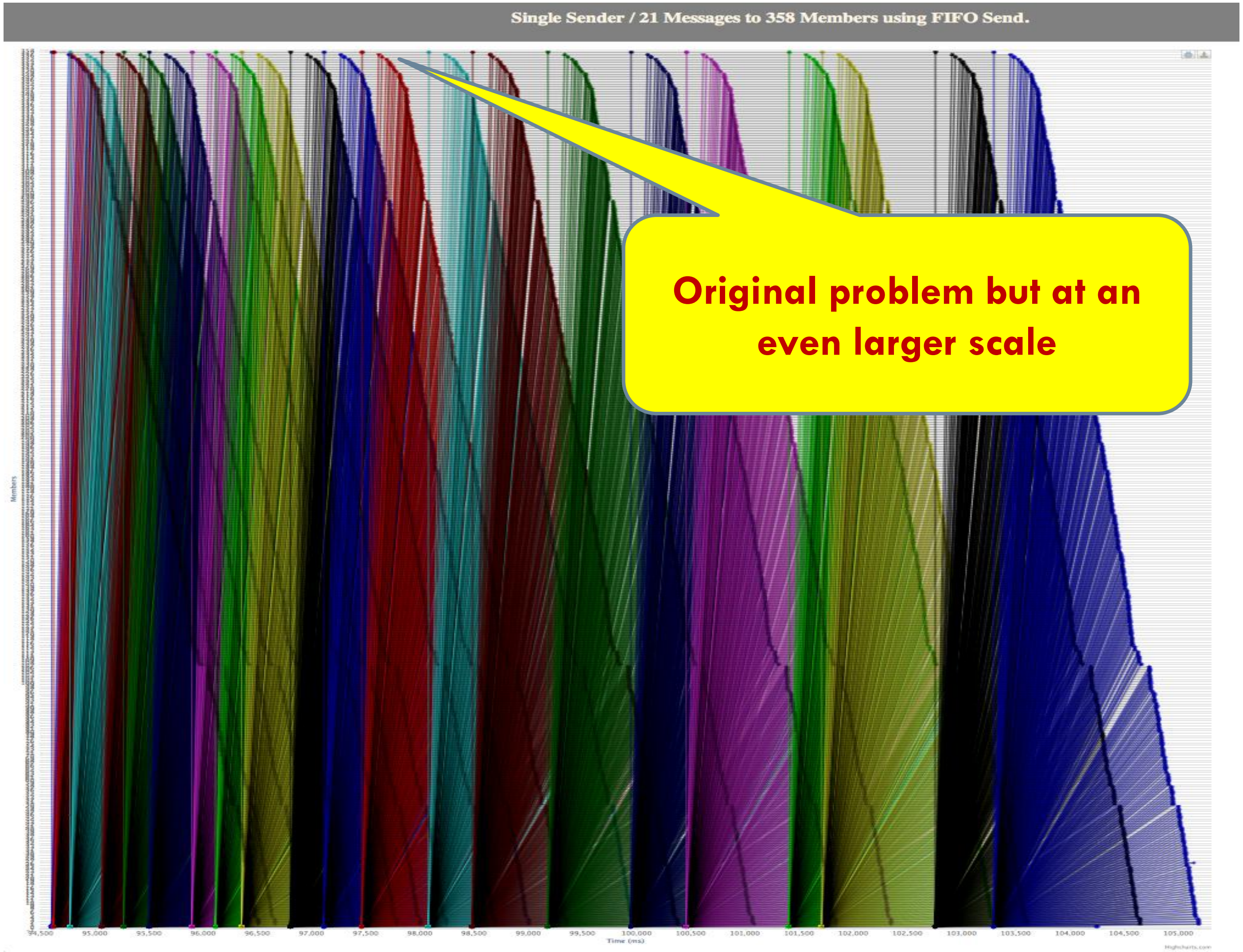
Debugging: Stabilization bug



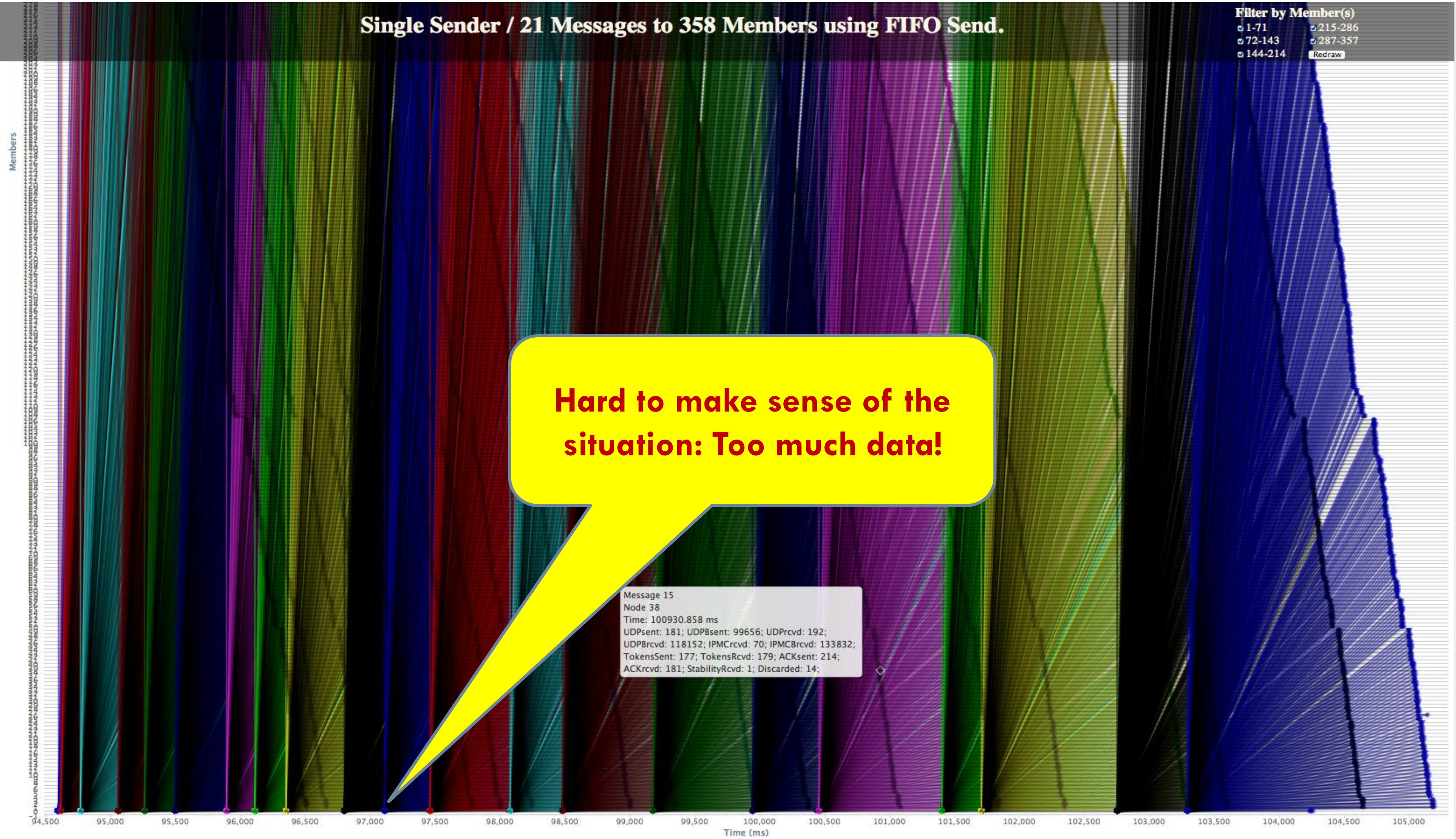
Debugging : Stabilization bug fixed



Debugging : 358-node run slowdown

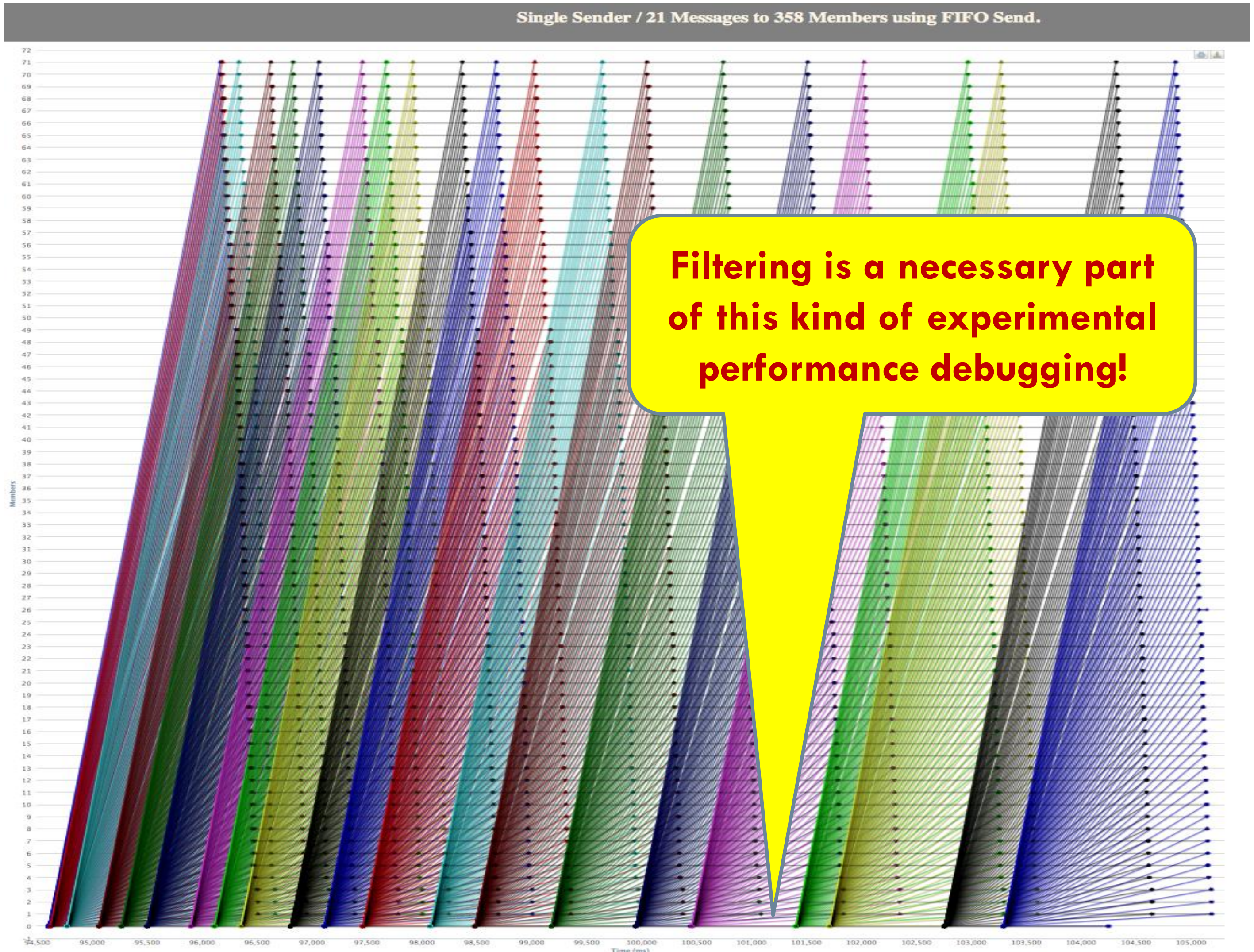


358-node run slowdown: Zoom in



Hard to make sense of the situation: Too much data!

358-node run slowdown: Filter



Conclusions?

- A question like "how much durability do I need in the first tier of the cloud" is easy to ask…
  - … much harder to answer!

- Study of the choices reveals that there are really two options
  - Send + Flush
  - SafeSend, in-memory

- They actually are similar but SafeSend has an internal "flush" before any delivery occurs, on each request
  - SafeSend seems more costly
  - But must do experiments to really answer such questions