Lustre Resiliency:

Dealing with Message Loss

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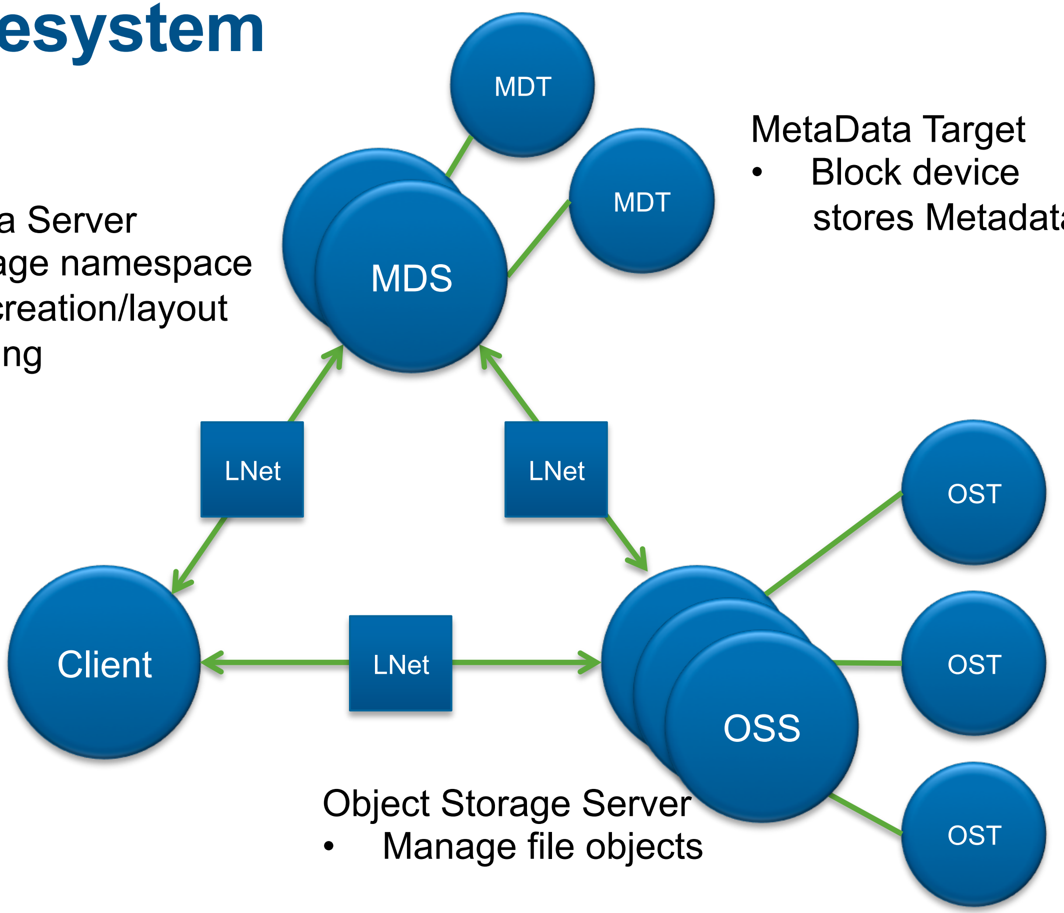
Agenda

- **Background Information**
  - Lustre Basics
  - The problem with dropped messages
  - Resiliency features, Lustre Locking, Lustre Evictions
- **Resiliency Enhancements**
- **Tuning Lustre for Resiliency**
- **Site-specific Tuning**
- **Future Work**
- **Questions**

A Lustre Filesystem



MetaData Server
- Manage namespace
- File creation/layout
- Locking

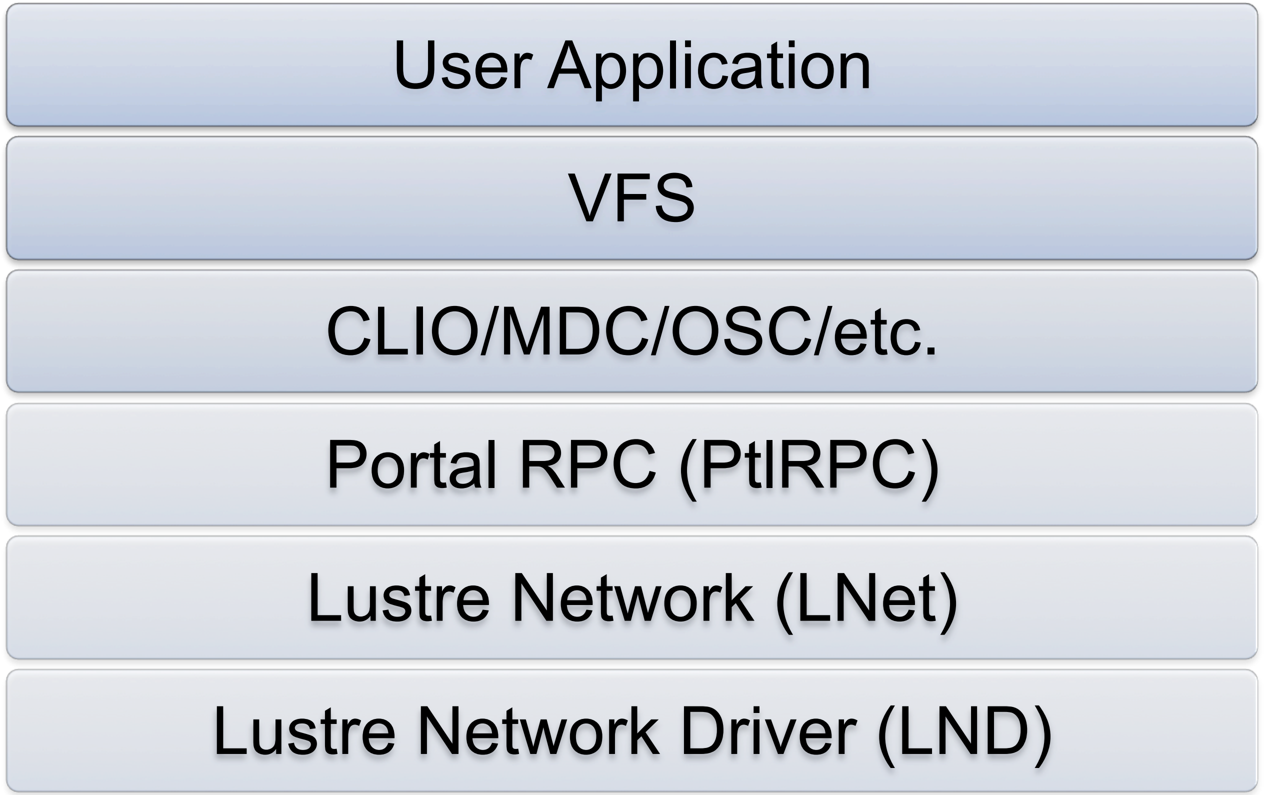
MetaData Target
- Block device stores Metadata

Object Storage Target
- Block device stores file objects

Object Storage Server
- Manage file objects

COMPUTE | STORE | ANALYZE

(Some of) The Software Stack



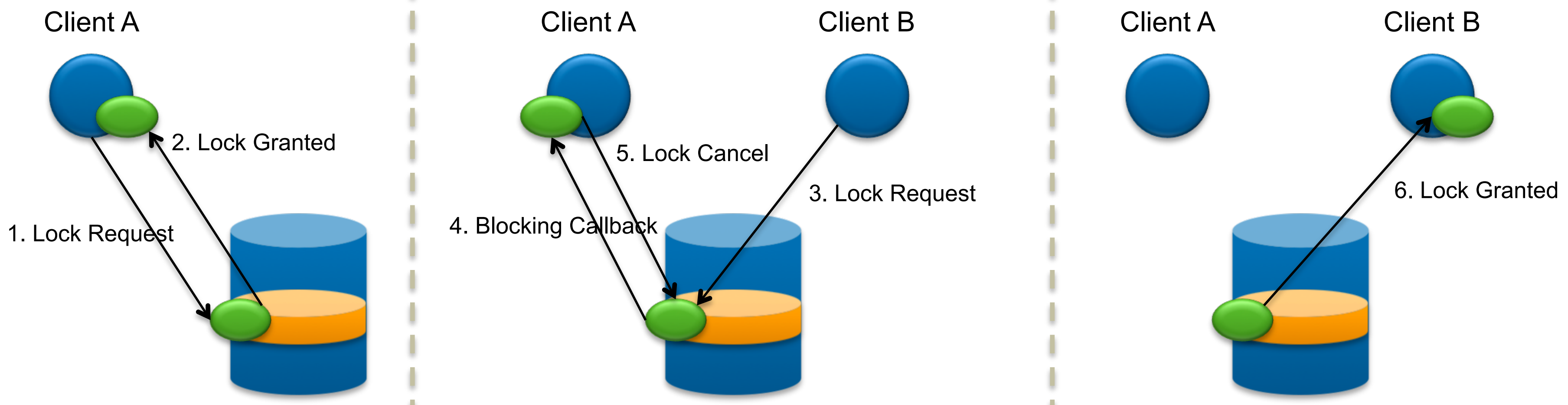
The Problem

- **What: Dropped messages result in performance degradation or application failure**
- **Why:**
  - Lost messages must be resent
    - RPC Timeouts (Fast or several minutes depending on load)
      - Adaptive Timeouts: Network latency + service estimate
    - Avoiding Bad Routes (Minutes)
      - LNet router pinger and asymmetric route failure detection
    - The Connect RPC (Minutes)
      - Sent on an interval
  - Important lock related message was not resent
    - Single point of failure in Lustre protocol
      - bugzilla.lustre.org bug 3622 opened June 2004
- **How: Client, Server, Router crash; Link Failure, etc.**
- **Our Goal: Survive finite network disruption without eviction and minimize performance impact**

Understanding Lustre Locking

- **A lock protects a resource (inode, file, etc.)**
- **MDS provides striping information (open())**
- **Client enqueues lock for each stripe to the respective OST**
- **Server revokes conflicting locks with blocking callback request**
  - Response to blocking RPC must, eventually, be a lock cancel
- **Completion RPC sent to client grants lock**
  - Client must acknowledge receipt of completion RPC

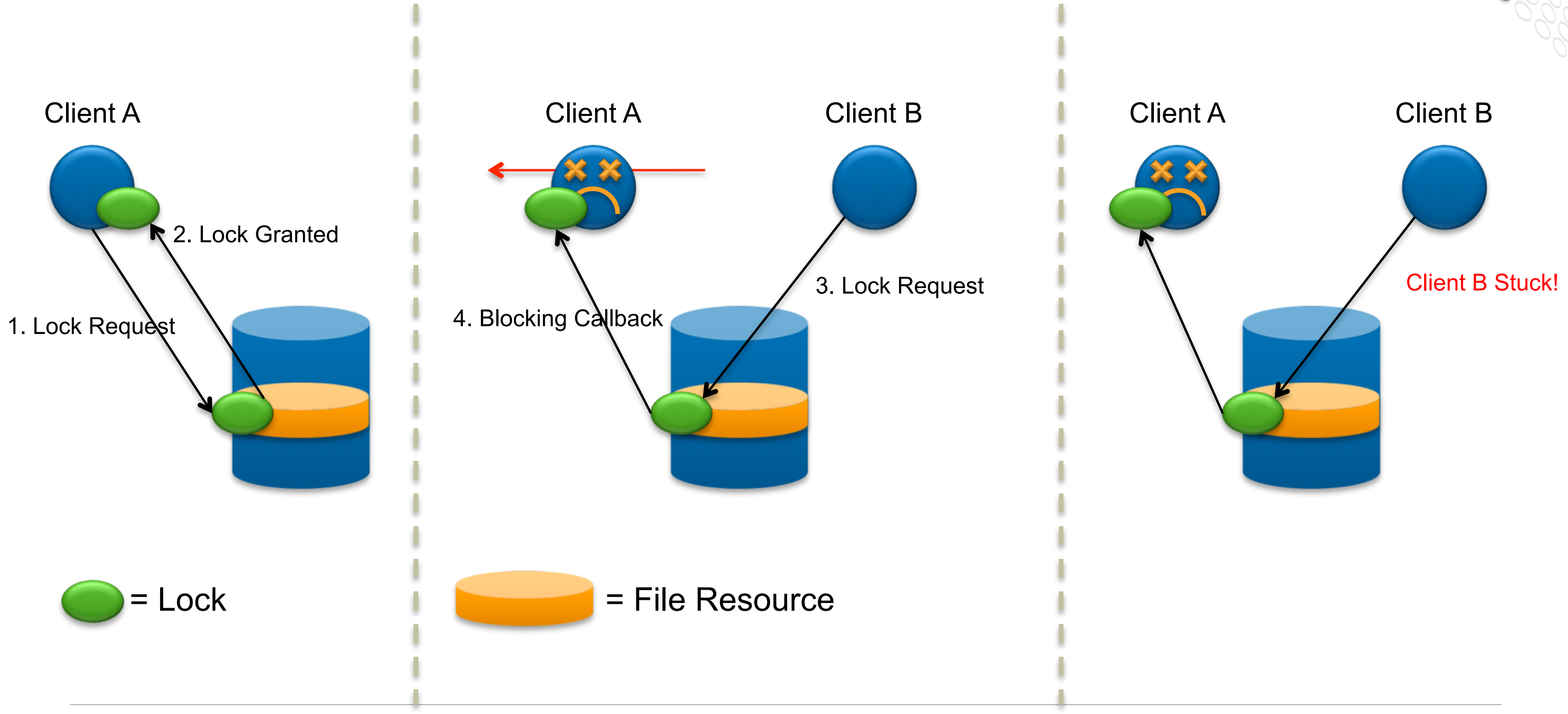
Locking in Lustre



● = Lock

▬ = File Resource

Client Crash While Holding Lock



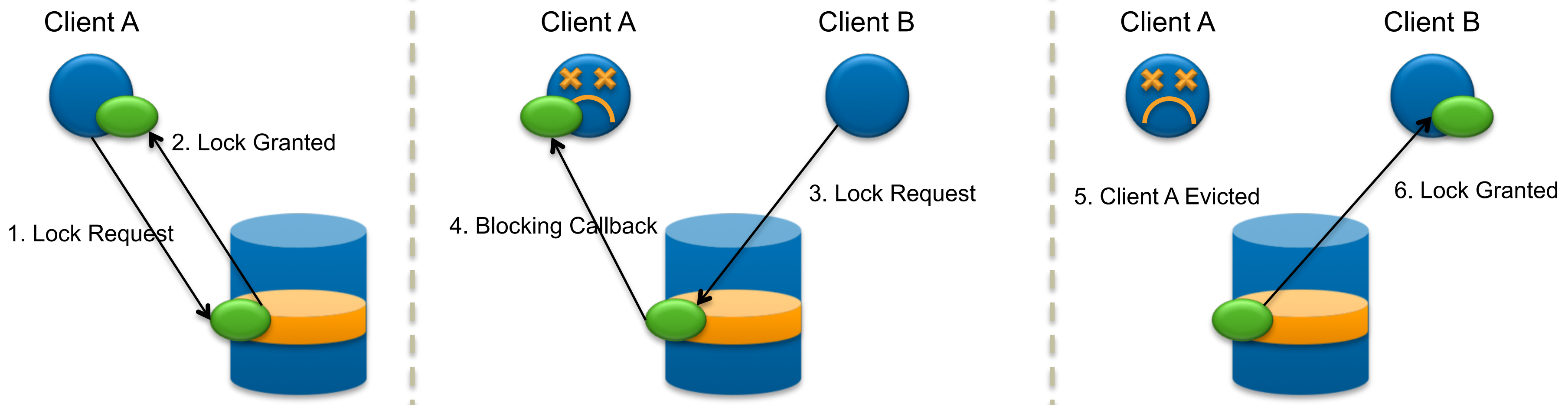
Understanding Lustre Evictions

- **What: Server's way of reclaiming resources held by a client and preventing further participation in file system operations**
- **Why: Server perceives client as misbehaving**
  - Failure to respond to certain requests or communicate regularly
  - Client side bugs, kernel panic or OOPs, heavy load, LBUGs, network errors
- **How: Server revokes all locks held by client**
  - Invalidates client's cached inodes and dirty pages
- **Things to know:**
  - Servers decide for themselves whether and when to evict a client
  - Clients don't learn that they are evicted until they reconnect to server
  - Clients then drop all locks and all dirty pages
  - Clients typically return -EIO (-5) up to user from syscalls
  - User programs typically exit on -EIO, but check your return codes!
  - Clients could be unaware if no outstanding user request (buffered I/O)
  - This is just POSIX semantics; check return codes and/or use fsync(2)
  - Unaware users call this silent data corruption

What is the Lock Callback Timer?

- **Lock Callback Timer: Client must fulfill callback request before the timer expires or the client will be evicted**
  - Blocking callbacks are subject to a lock callback timer
    - A blocking callback can be embedded in a completion callback request
  - Started on the server when callback is sent
  - Extended when client performs I/O under the lock

Eviction to Reclaim Lock



🟢 = Lock

🟧 = File Resource

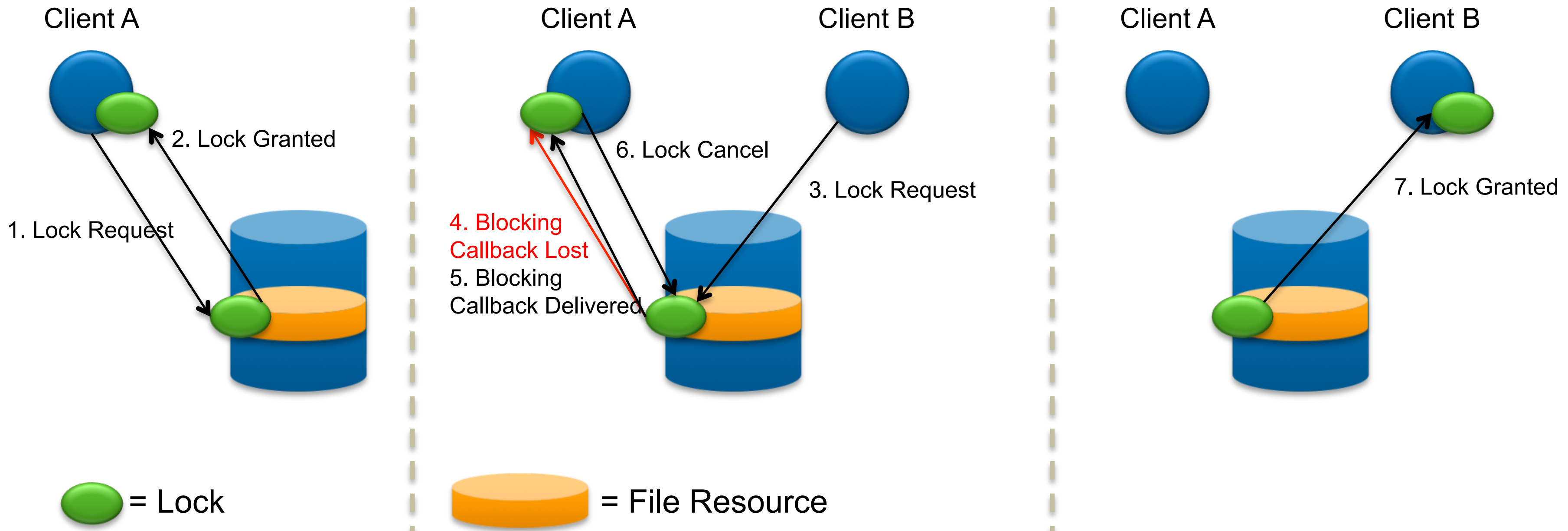
What Scenarios Result in Message Loss

- **Route and Router Death**
  - Rely on router pinger and asymmetric route failure detection
- **Client Death**
  - Dead clients evicted by lock callback timer or ping evictor
- **Server Death**
  - Lustre recovery should ensure filesystem returns to useable state
    - See Lustre Operations Manual
- **Link Resiliency**
  - HSN quiesce causes headaches for Lustre
  - Servers have no knowledge of quiesce

Enhancement: Lock Callback Resend

- **Reduces occurrence of evictions by resending lock callbacks**
- **Lock callbacks are resent over the duration of the lock callback timer**
  - RPC timeout: Lock callback timer expired?
    - Yes: Evict client
    - No: Resend RPC
- **Feature landed for Lustre 2.7.0**
  - CLE 5.2 clients mounting Sonexion w/NEO 1.3.1SU14

Resend of Callback Avoids Eviction



Enhancement: Router Failure Detection

- **Decreases time to detect failed routers from ~110 seconds to ~30 seconds**
- **Cray's gnilnd subscribes to node failure events available on the HSN**
- **Used for LNet peer health feature on routers**
  - Routers immediately drop messages being sent to down peers
- **Clients now use this for router health**
  - LNet on a client is notified of down routers
  - Down routers are not used as next-hop on future sends
  - Faster than relying on router ping

Enhancement: Gnilnd Fast Reconnect

- **Quickly restore client <-> router connections following link resiliency event**
- **Historically, gnilnd only established connections when there was an outstanding transmit**
  - Connection between clients and routers often timeout during HSN quiesce
  - Router pings often timeout during HSN quiesce
  - No available routes means the only new transmits are router pings
- **With fast reconnect gnilnd is more aggressive with re-establishing connection**
  - Disabled on routers
  - LNet is notified upon reconnect

Tuning for Resiliency – Adaptive Timeouts

- **Upper and lower bounds are configurable**
  - Lower bound = at_min
  - Upper bound = at_max
- **Generally want lower timeouts so lost messages are detected quickly, but we don't want false positives**
- **Upper bound limits potential impact of lost RPCs**
  - Able to lower time to recovery from link resiliency from ~20 minutes to ~15 minutes simply by lowering at_max

Tuning for Resiliency – Lock Callback Timer

- Callback RPCs use same timeouts as other RPCs
- Lower bound of lock callback timer configured separately: ldlm_enqueue_min
- The lock callback timer should allow enough time for at least one resend
  - Tradeoff: Time to detect misbehaving client vs. Time for resend
- ldlm_enqueue_min = max(2*net_latency, net_latency + quiesce_time) + 2*service_time
- quiesce_time may vary on system size, number of clients, number of mounted filesystems, etc.

Tuning for Resiliency – LNet

- **Router Pinger**
  - Faster/more pings on server side
  - Slower/fewer pings on client side
- **Asymmetric Route Failure Detection**
  - Disabled on routers
  - Enabled everywhere else
- **Peer Health**
  - Enabled on routers
  - Disabled everywhere else
- **Lustre Network Driver**
  - ko2iblnd timeout default is too high

Site-specific Tuning

- **Try to measure quiesce time -> increase/decrease ldlm_enqueue_min appropriately**
  - 21:26:51.388273-05:00 c1-0c2s5n0 LNet: Quiesce start: hardware quiesce
  - 21:27:06.393195-05:00 c1-0c2s5n0 LNet: Quiesce complete: hardware quiesce
  - 21:27:13.429388-05:00 c1-0c2s5n0 LNet: Quiesce start: hardware quiesce
  - 21:27:23.435159-05:00 c1-0c2s5n0 LNet: Quiesce complete: hardware quiesce
  - 21:28:24.938501-05:00 c1-0c2s5n0 Lustre: snx11023-OST0009-osc-ffff880833997000: Connection restored to snx11023-OST0009 (at 10.149.4.7@o2ib)
  - 21:28:49.952123-05:00 c1-0c2s5n0 Lustre: snx11023-OST0002-osc-ffff880833997000: Connection restored to snx11023-OST0002 (at 10.149.4.5@o2ib)
  - 21:29:05.252357-05:00 c1-0c2s5n0 Lustre: snx11023-OST000c-osc-ffff880833997000: Connection restored to snx11023-OST000c (at 10.149.4.8@o2ib)
  - Time from first quiesce message to last “Connection restored” is 124 seconds
- **at_max adjusted based on server load/worst case timeouts**
  - Lustre: ost_io: This server is not able to keep up with request traffic (cpu-bound).

Future Work

- **NRS Delay**
  - Details in https://jira.hpdd.intel.com/browse/LU-6283
- **Imperative Eviction**
- **at_net_min, at_net_max**
- **Add resend for other request types**

Summary

- Lustre does not deal with dropped messages very well
- Hole in Lustre protocol has been fixed
- Occurrence of client eviction resulting from message loss reduced
- Performance impact from message loss reduced
- More information and detailed tuning advice in the paper
- Our team is committed to continued improvements

Q&A

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