Lustre Scalability

Eric Barton
Lead Engineer, Lustre Group
Sun Microsystems

Topics

HPC Trends

Architectural Improvements

General Performance Enhancements

HPC Trends

Processor performance / RAM growing faster than I/O

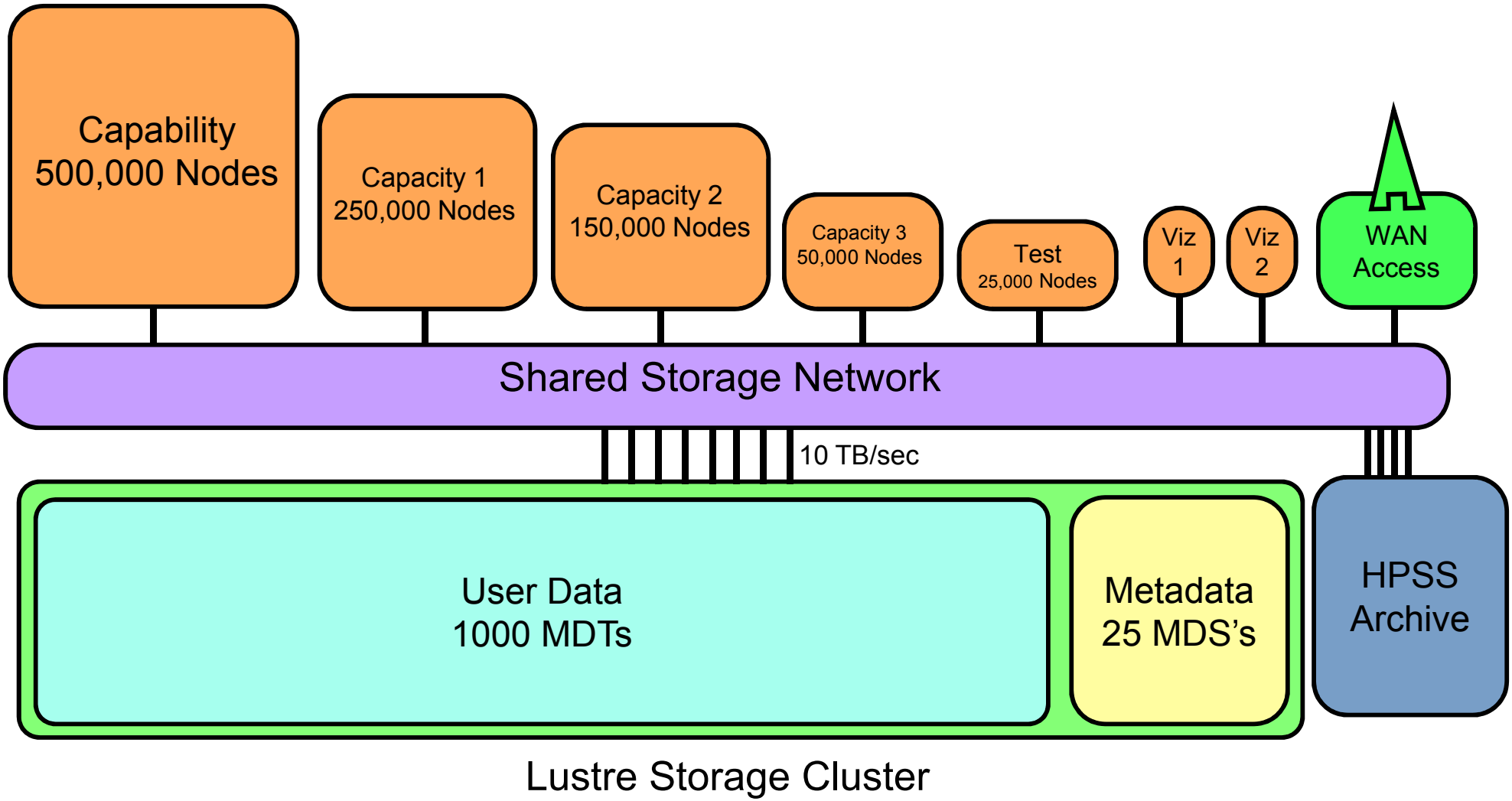
- Relative number of I/O devices must grow to compensate
- Storage component reliability not increasing with capacity
  - > Failure is not an option – it's guaranteed

Trend to shared file systems

- Multiple compute clusters
- Direct access from specialized systems

Storage scalability critical

HPC Center of the Future



Lustre Scalability

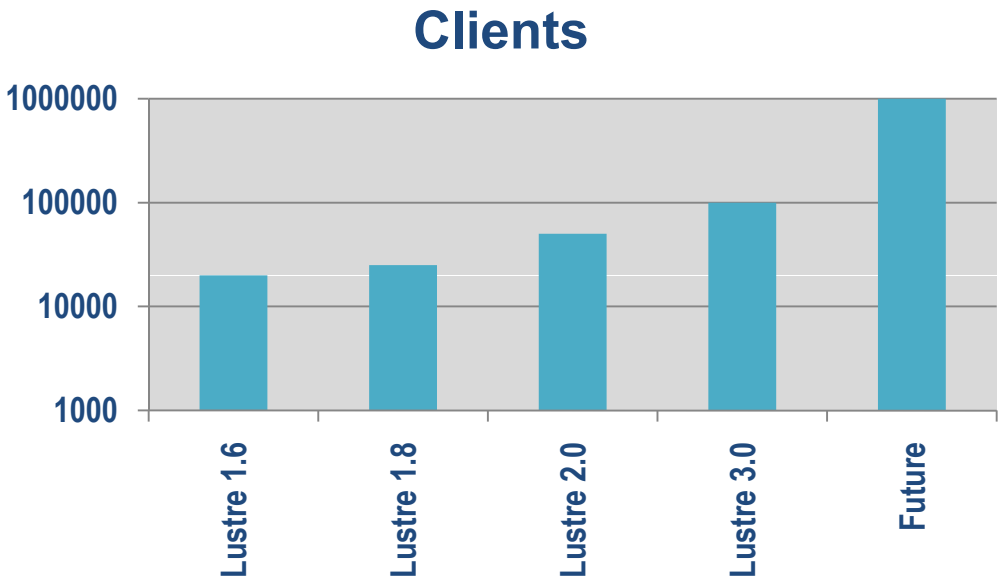
Definition

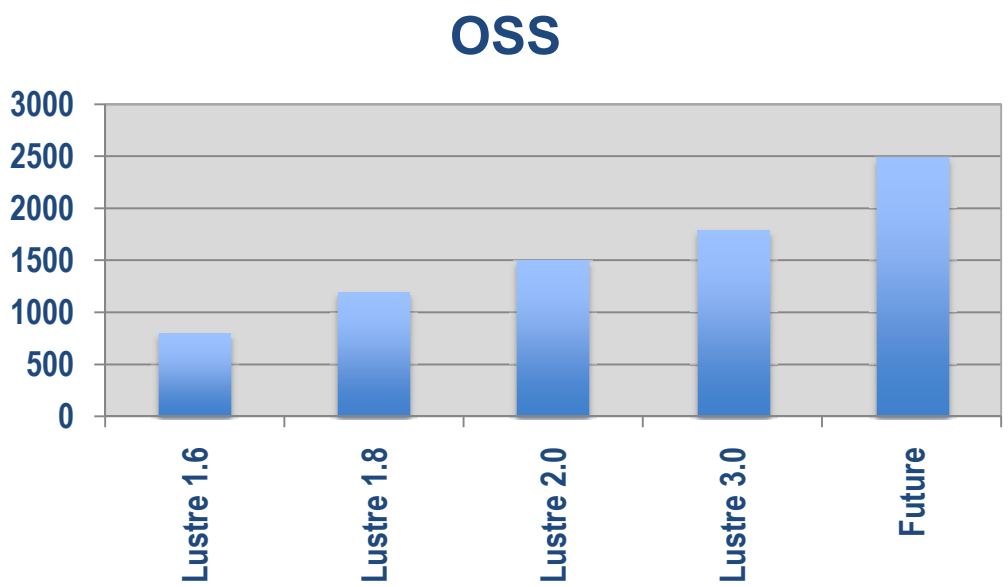
- Performance / capacity grows nearly linearly with hardware
- Component failure does not have a disproportionate impact on availability

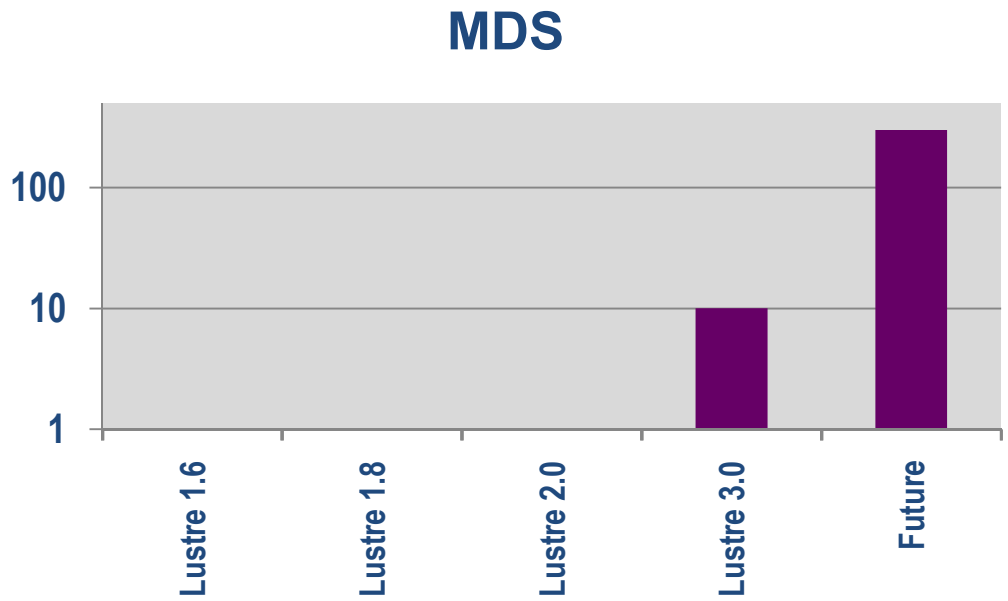
Requirements

- Scalable I/O & MD performance
- Expanded component size/count limits
- Increased robustness to component failure
- Overhead grows sub-linearly with system size
- Timely failure detection & recovery

Lustre Scaling





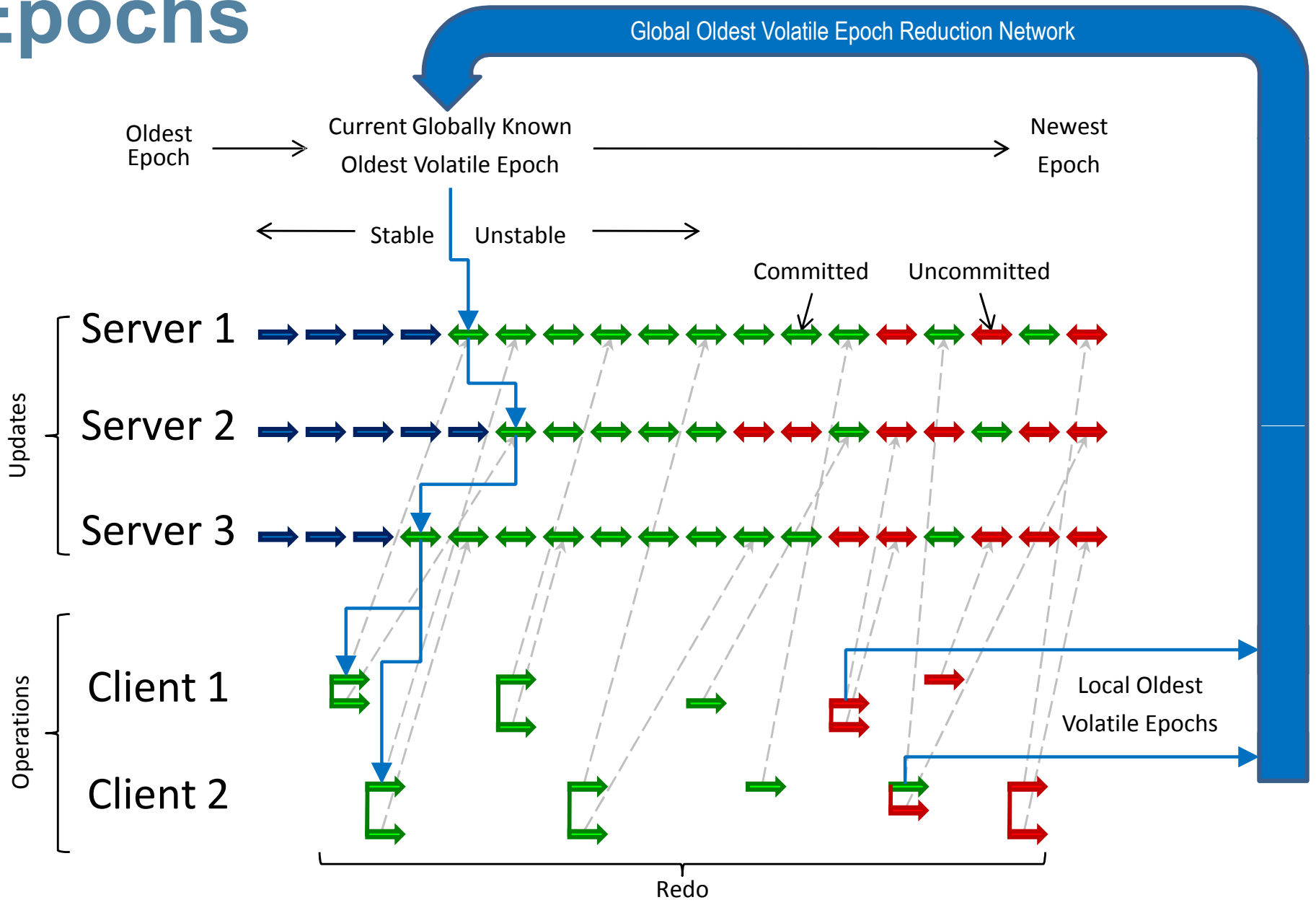


Architectural Improvements

Clustered Metadata (CMD)

- 10s – 100s of metadata servers
- Distributed inodes
  - Files local to parent directory entry / subdirs may be non-local
- Distributed directories
  - Hashing ⇔ Striping
- Distributed Operation Resilience/Recovery
  - Uncommon HPC workload
    - Cross-directory rename
  - Short term
    - Sequenced cross-MDS ops
  - Longer term
    - Transactional - ACID
    - Non-blocking - deeper pipelines
    - Hard - cascading aborts, synch ops

Epochs


Global Oldest Volatile Epoch Reduction Network
Oldest Epoch
Current Globally Known Oldest Volatile Epoch
Newest Epoch
Stable
Unstable
Committed
Uncommitted
Server 1
Server 2
Server 3
Updates
Client 1
Client 2
Operations
Local Oldest Volatile Epochs
Redo

Architectural Improvements

Fault Detection Today

- RPC timeout
  - > Timeouts must scale O(n) to distinguish death / congestion
- Pinger
  - > No aggregation across clients or servers
  - > O(n) ping overhead
- Routed Networks
  - > Router failure can be confused with end-to-end peer failure
- Fully automatic failover scales with slowest time constant
  - > Many 10s of minutes on large clusters ☹
  - > Failover could be much faster if “useless” waiting eliminated ☺

Architectural Improvements

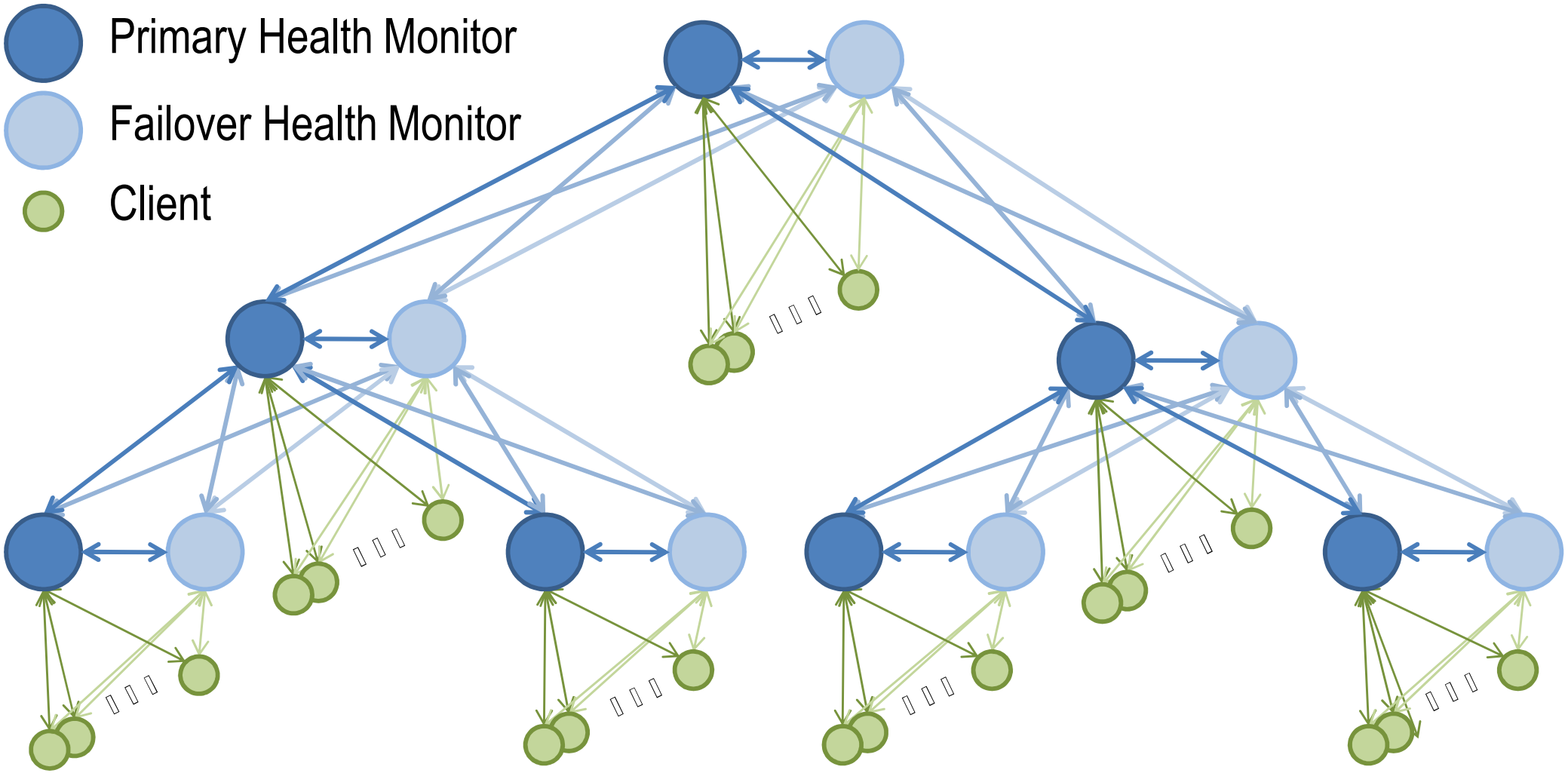
Scalable Health Network

- Burden of monitoring clients distributed – not replicated
  - ORNL – 35,000 clients, 192 OSSs, 7 OSTs/OSS
- Fault-tolerant status reduction/broadcast network
  - Servers and LNET routers
- LNET high-priority small message support
  - Health network stays responsive
- Prompt, reliable detection
  - Time constants in seconds
  - Failed servers, clients and routers
  - Recovering servers and routers

Interface with existing RAS infrastructure

- Receive and deliver status notification

Health Monitoring Network



Architectural Improvements

Metadata Writeback Cache

- Avoids unnecessary server communications
  - > Operations logged/cached locally
  - > Performance of a local file system when uncontended
- Aggregated distributed operations
  - > Server updates batched and tranferred using bulk protocols (RDMA)
  - > Reduced network and service overhead

Sub-Tree Locking

- > Lock aggregation – a single lock protects a whole subtree
- > Reduce lock traffic and server load

Architectural Improvements

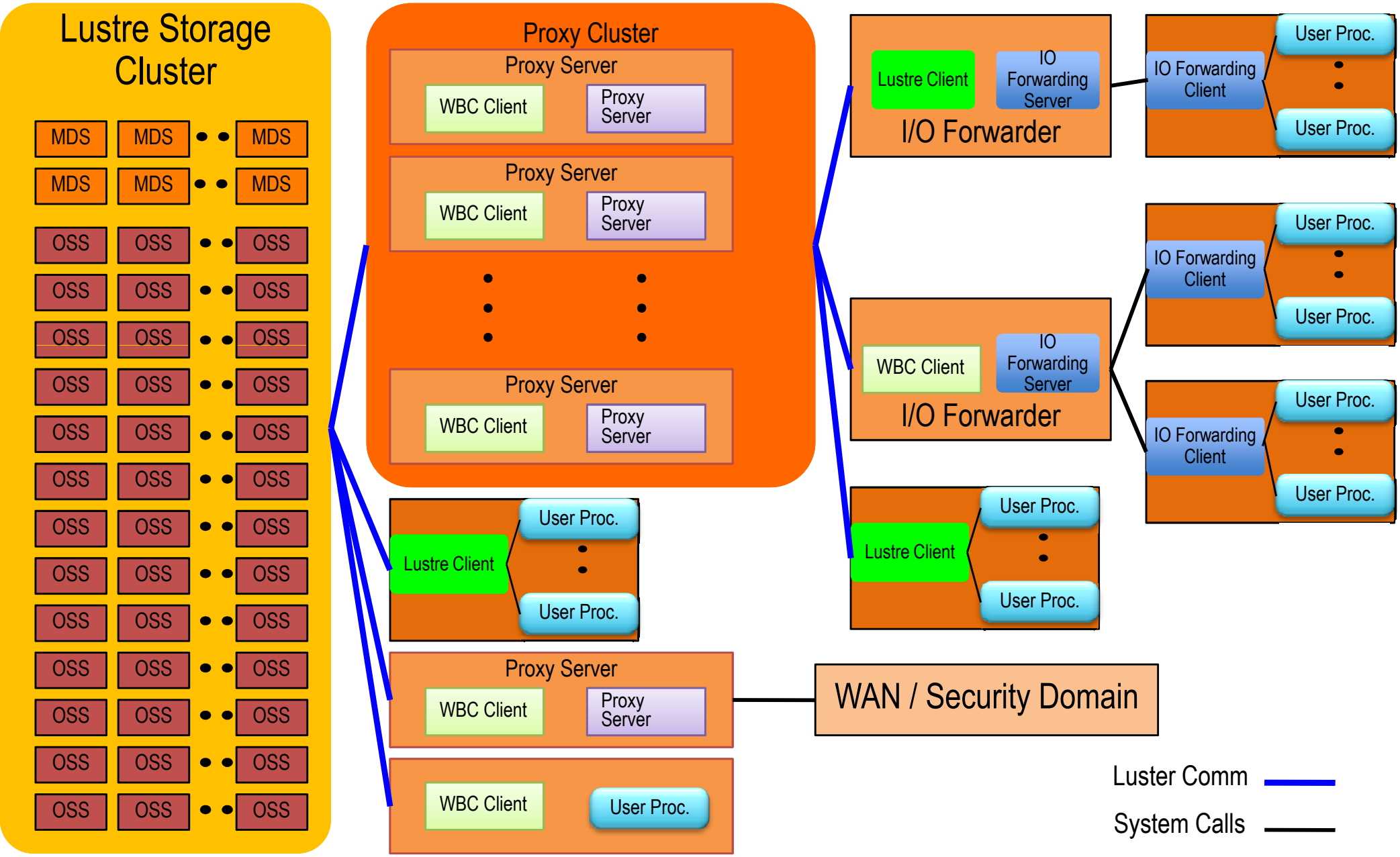
Current - Flat Communications model

- Stateful client/server connection required for coherence and performance
- Every client connects to every server
- O(n) lock conflict resolution

Future - Hierarchical Communications Model

- Aggregate connections, locking, I/O, metadata ops
- Caching clients
  - > Aggregate local processes (cores)
  - > I/O Forwarders scale another 32x or more
- Caching Proxies
  - > Aggregate whole clusters
  - > Implicit Broadcast - scalable conflict resolution

Hierarchical Communications



Performance Improvements

Network Request Scheduler (NRS)

- Much larger working set than disk elevator
- Higher level information - client, object, offset, job/rank

Prototype

- Initial development on simulator
- Scheduling strategies - quanta, offset, fairness etc.
- Testing at ORNL pending

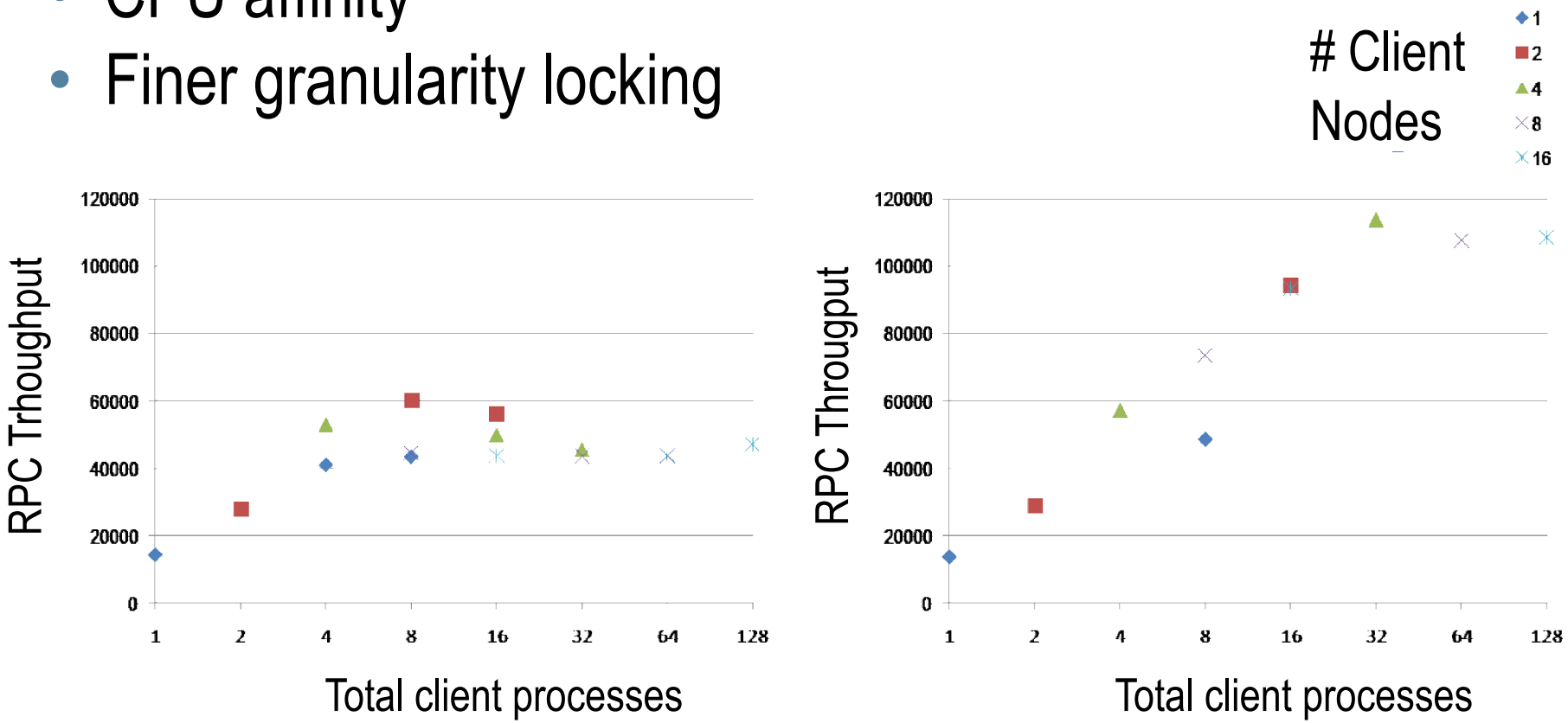
Future

- Exchange global information - gang scheduling
- QoS - Real time / Bandwidth reservation (min/max)

Performance Improvements

SMP Scaling

- Improve MDS performance / small message handling
- CPU affinity
- Finer granularity locking



Performance Improvements

Metadata Protocol

- Size on MDT (SOM)
  - > Avoid multiple RPCs for attributes derived from OSTs
  - > OSTs remain definitive while file open
  - > Compute on close and cache on MDT
- Readdir+
  - > Aggregation
    - Directory I/O
    - Getattrs
    - Locking

Performance Improvements

ZFS

- Remove ldiskfs size limits
- End-to-end data integrity
- Hybrid storage

Channel bonding

- Combine multiple Network Interfaces
- Failover
- Capacity

Performance Improvements

Rebuild performance

- Frequent disk failures
  - > Rebuild quickly to prevent data loss on next failure
- Disk group remains in operation during rebuild
  - > Avoid using OST during rebuild
    - Speed rebuild
    - Amdahl's law
- ZFS rebuild improvements

Lustre Scalability

Attribute	Today	Future
Number of Clients	10,000s Flat comms model	1,000,000s Hierarchical comms model
Server Capacity	Ext3 – 8TB	ZFS - Petabytes
Metadata Performance	Single MDS	Single MDS improvements CMD
Recovery Time	RPC timeout - O(n)	Health Network - O(log n)

THANK YOU

Eric Barton
eeb@sun.com
lustre-discuss@sun.com