Highly-Available Lustre with SRP-Mirrored LUNs

UF HPC Center
Research Computing
University of Florida

HA Lustre

- **Design Goals**
  - Minimize Cost per TB
  - Maximize Availability
  - Good Performance (within cost constraints)
  - Avoid External SAS/Fibre Attached JBOD
  - Avoid External RAID Controllers
  - Support Ethernet and InfiniBand clients
  - Standard Components
  - Open Source Software

HA Lustre

- **To Minimize Cost**
  - Commodity storage chassis
  - Internal PCIe RAID controllers
  - Inexpensive, high-capacity 7200 rpm drives
- **Problem: How do we enable failover?**
- **Solution: InfiniBand + SRP**
  - SCSI RDMA Protocol

HA Lustre

- **Problem**
  - All storage is internal to each chassis
  - No way for one server to take over the storage of the other server in the event of a server failure
  - Without dual-ported storage and external RAID controllers how can one server take over the other's storage?
- **Solution**
  - InfiniBand
  - SCSI Remote/RDMA Protocol (SRP)

HA Lustre

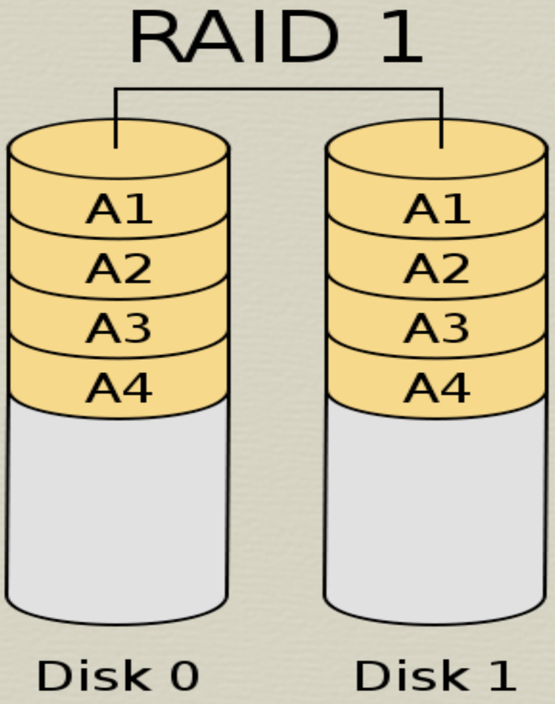
- **InfiniBand**
  - Low-latency, high-bandwidth interconnect
  - Used natively for distributed memory applications (MPI)
  - Encapsulation layer for other protocols (IP, SCSI, FC, etc.)
- **SCSI Remote Protocol (SRP)**
  - Think of it as SCSI over IB
  - Provides a host with block-level access to storage devices in another host.
  - Via SRP host A can see host B's drives and vice-versa

HA Storage

- Host A can see host B's storage and host B can see host A's storage but there's a catch…
- If host A fails completely, host B still won't be able to access host A's storage since host A will be down and all the storage is internal.
- So SRP/IB doesn't solve the whole problem.
- But… what if host B had a local copy of Host A's storage and vice-versa (pictures coming – stay tuned).
- Think of a RAID-1 mirror, where the mirrored volume is comprised of one local drive and one **remote** (via SRP) drive

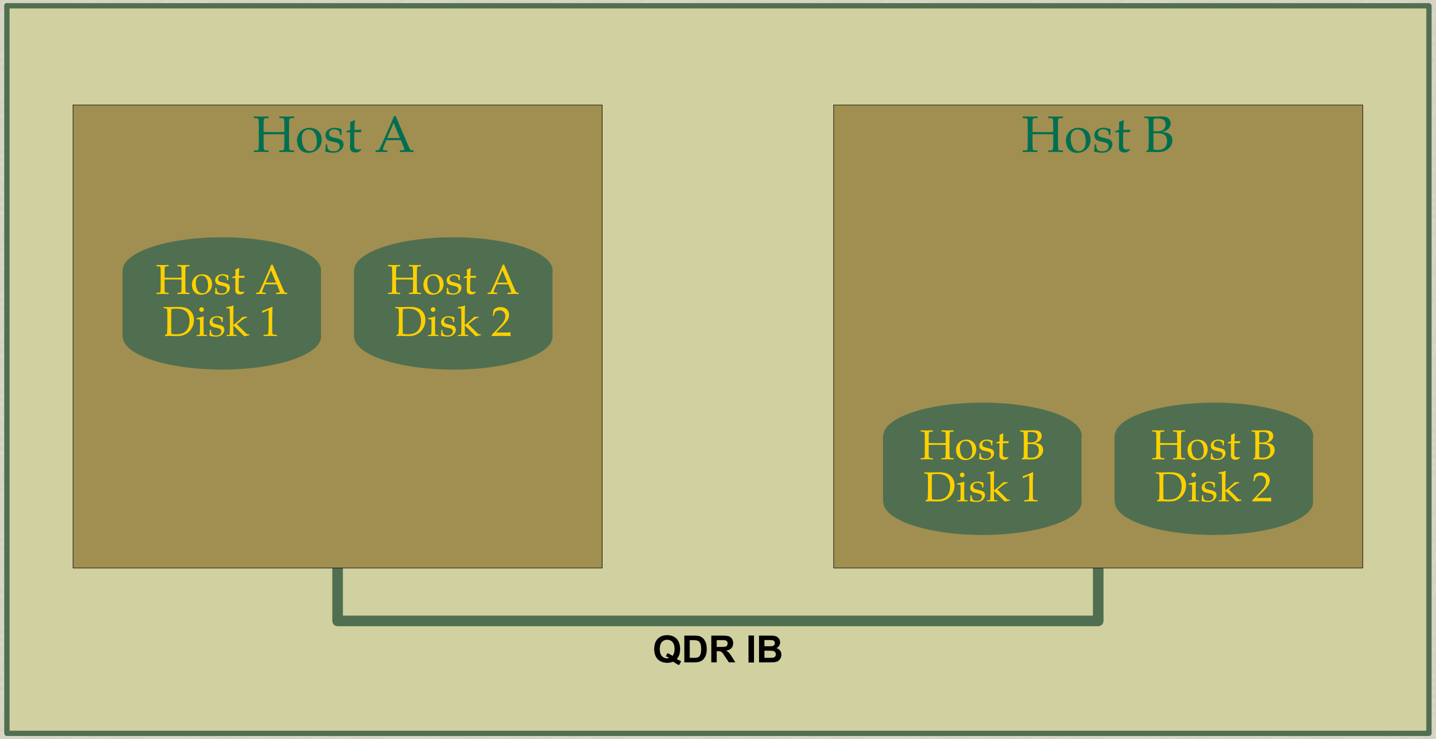
HA Lustre

- **Mirrored (RAID-1) Volumes**
  - Two (or more) drives
  - Data is kept consistent across both/all drives
  - Writes are duplicated to each disk
  - Reads can take place from either/all disk(s)



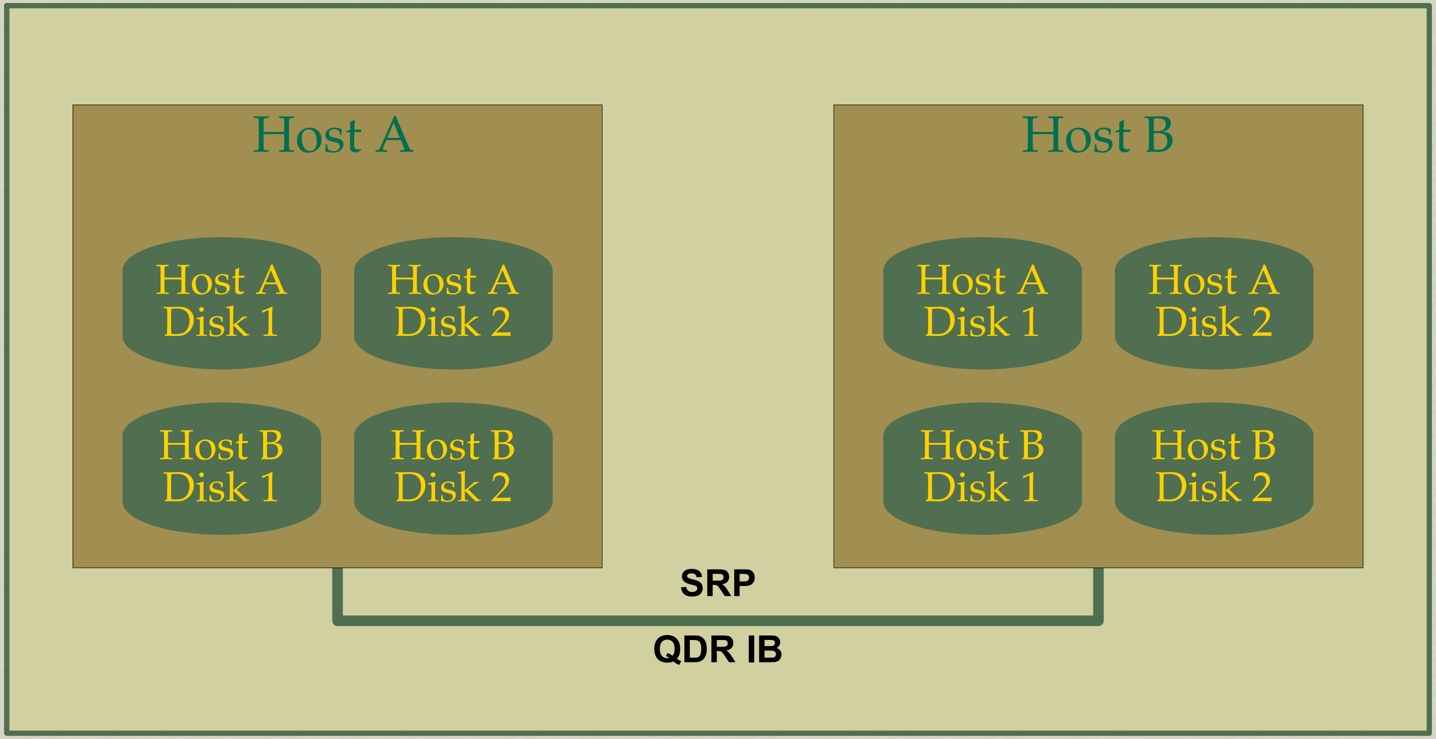
Remote Mirrors

- Not Possible?



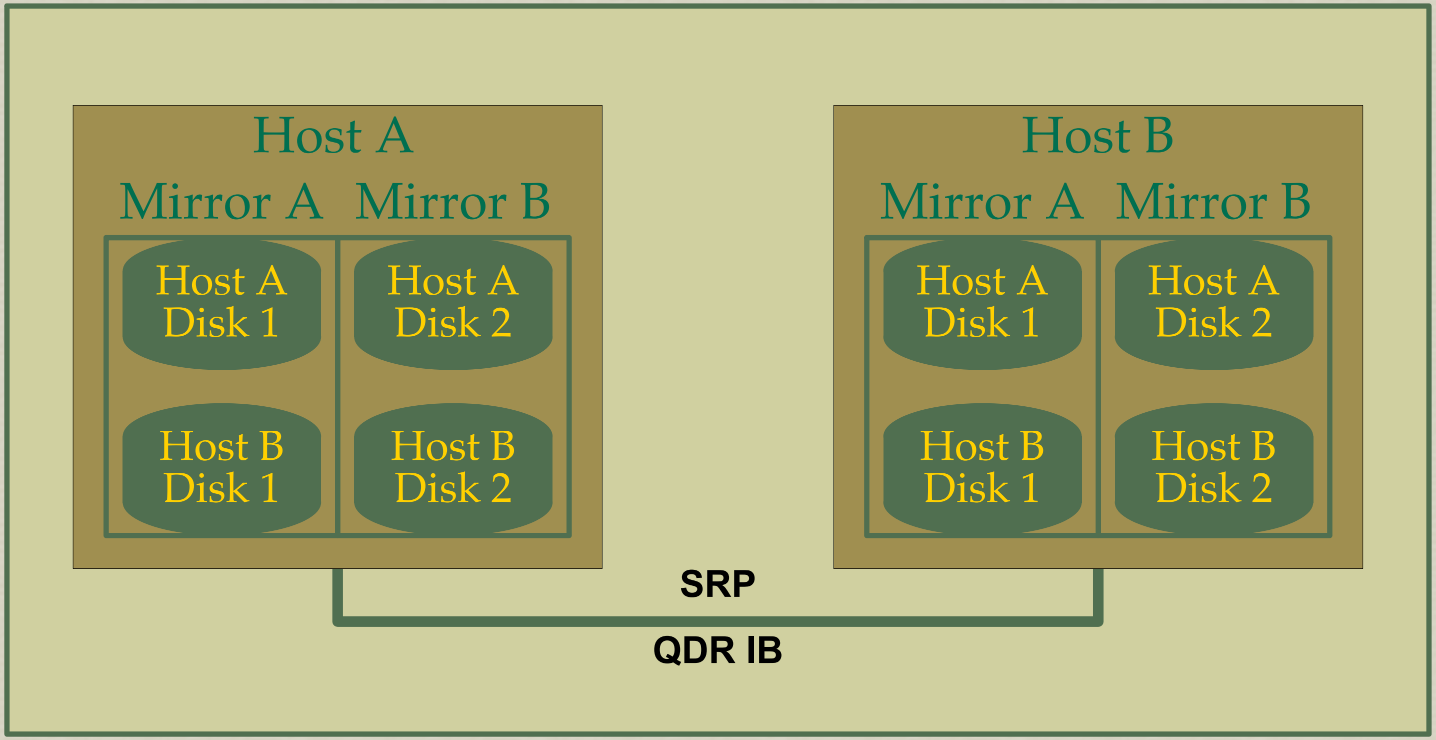
Remote Mirrors

- Remote targets exposed via SRP



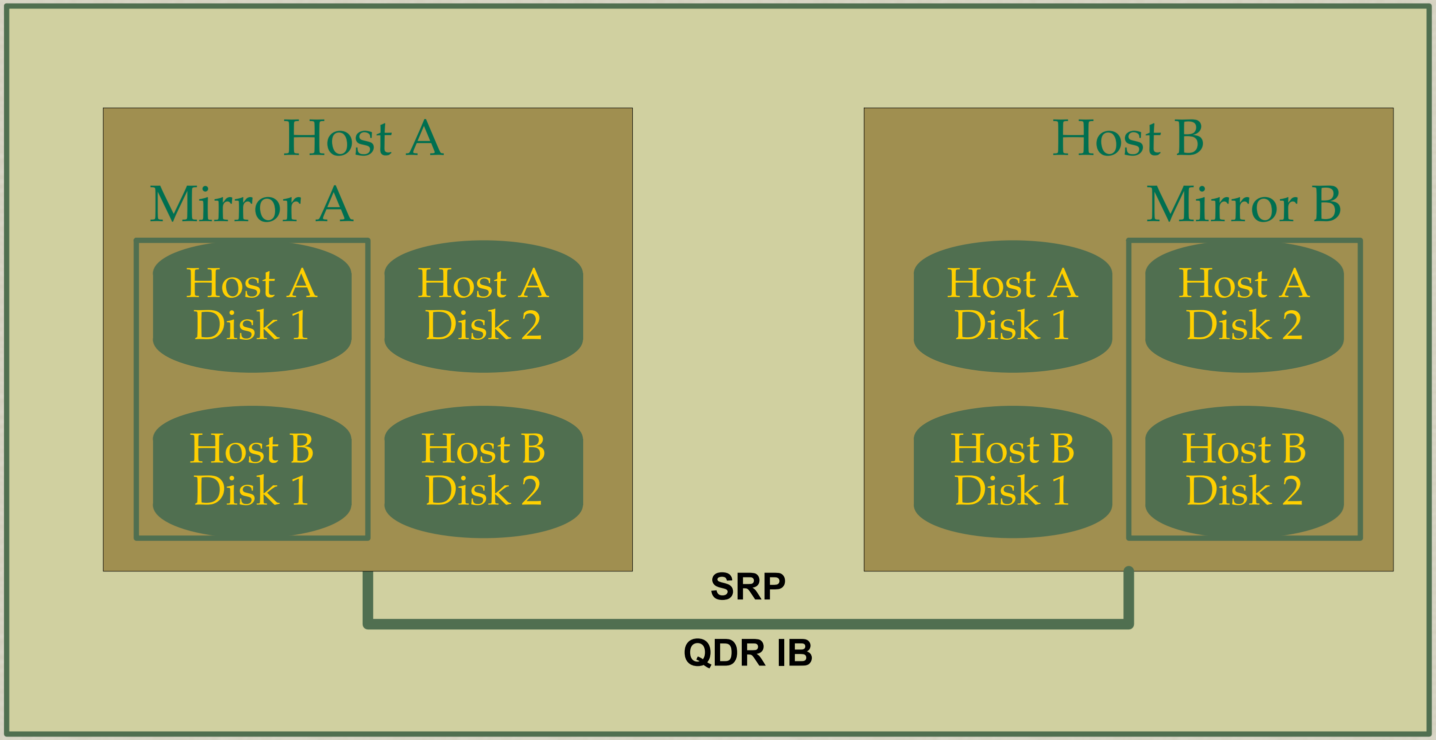
Remote Mirrors

- Mirroring Possibilities



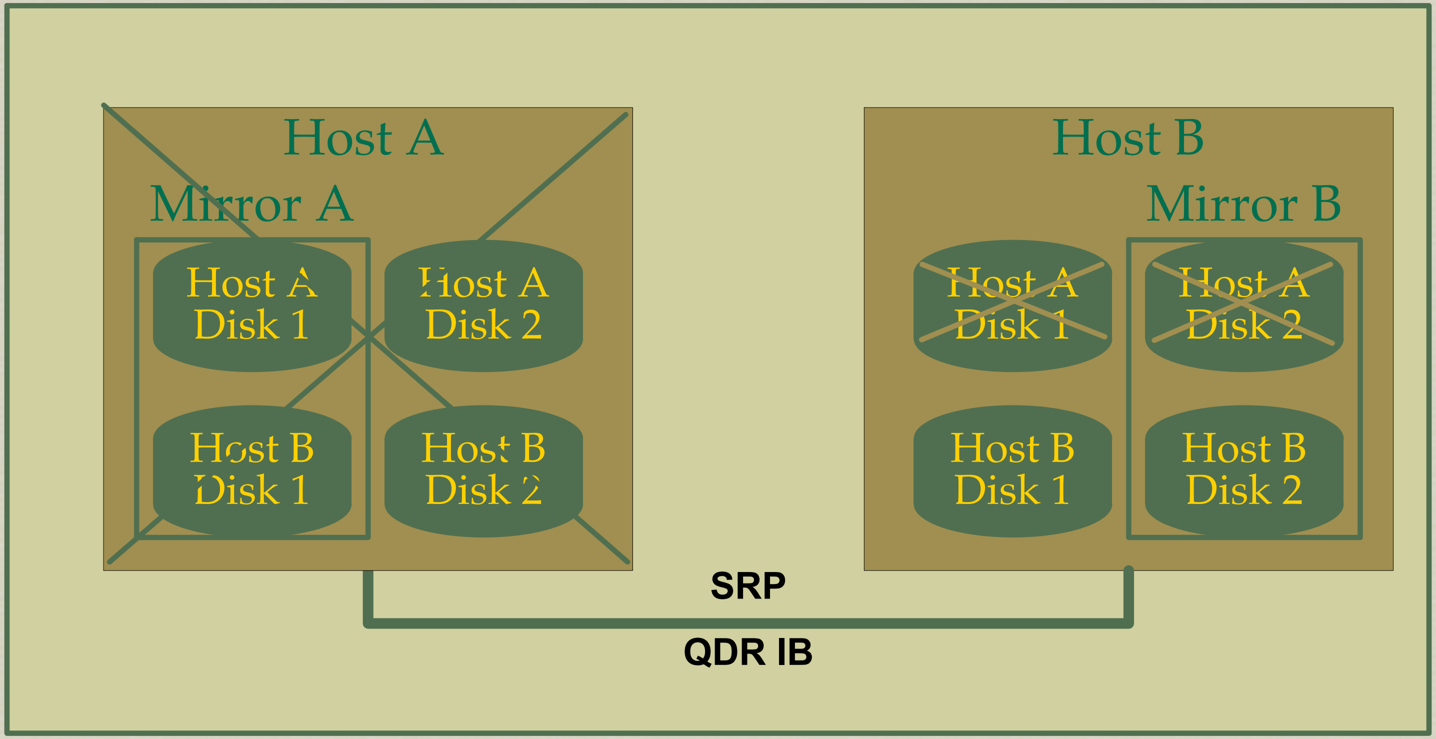
Remote Mirrors

- Normal Operating Conditions



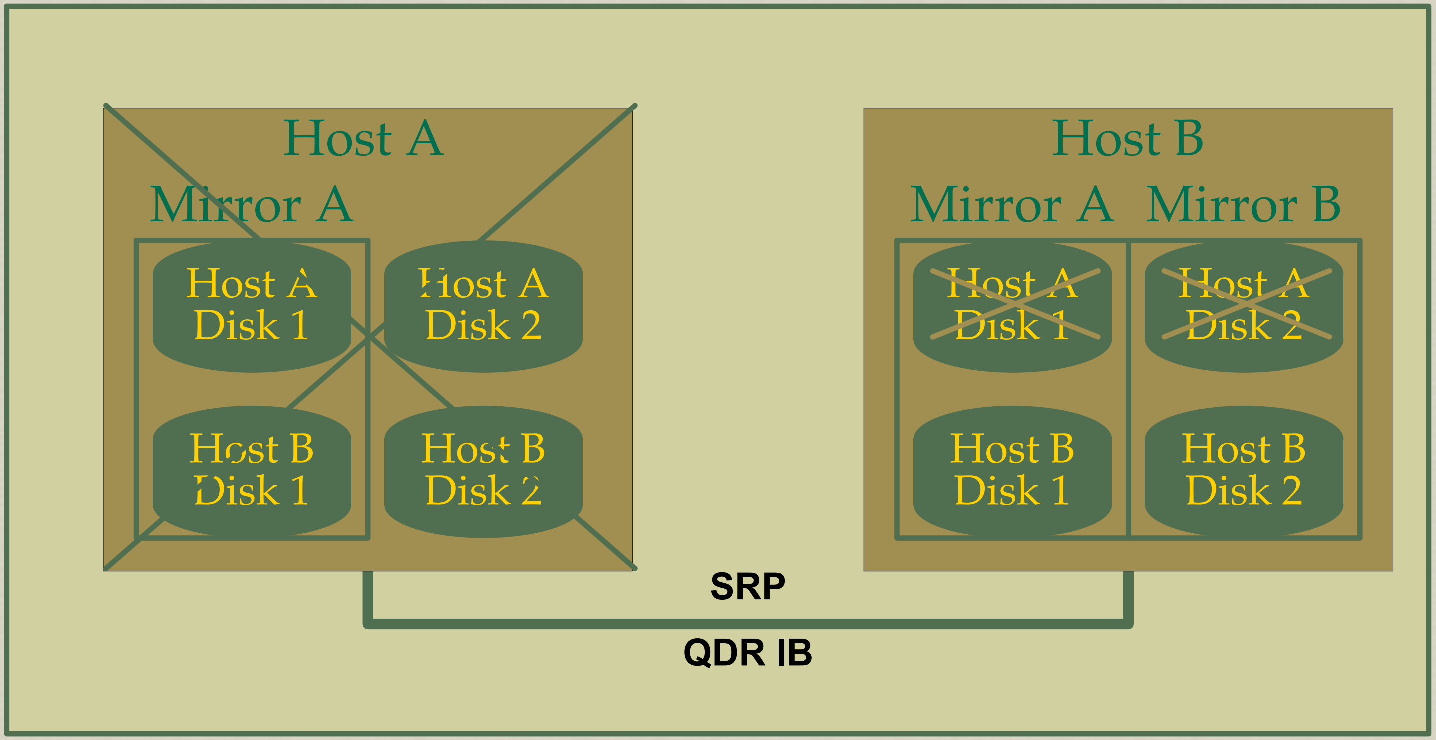
Remote Mirrors

- Host A is down



Remote Mirrors

- Degraded mirrors on host B



HA Lustre

- Hardware Configuration
  - Chenbro RM91250 Chassis (50 Drives, 9U)
  - SuperMicro X8DAH System Board
    - PCIe Slots: 2 x16, 4 x8, 1 x4
  - Intel E5620 Processors (2)
  - 24 GB RAM
  - Adaptec 51245 PCI-E RAID Controller (4) (x8 slots)
  - Mellanox MT26428 ConnectX QDR IB HCA (2) (x16 slot)
  - Mellanox MT25204 InfiniHost III SDR IB HCA (1) (x4 slot)

HA Lustre

- RAID Configuration
  - Adaptic 51245 (4)
  - RAID-6 (4+2) (to stay below 8 TB LUN)
  - 7.6 TiB per LUN
  - 2 LUNs per controller
  - 8 LUNs per OSS
  - 60.8 TiB per OSS

HA Lustre

- **LVM2 Configuration**
  - **Encapsulate each LUN in an LV**
    - Identification
    - Convenience
  - **LVs named by host, controller, LUN**
    - h<L>c<M>v<N>
    - h1c1v0, h1c1v1
h1c2v0, h1c2v1
h1c3v0, h1c3v1
h1c4v0,h1c4v1

HA Lustre

- **MD (Mirror) Configuration**
  - **Mirror consists of 1 local and 1 remote LUN**
  - **Host 1**
    - /dev/<vg>/<lv>: /dev/h1c1v0/h1c1v0 (local)
      /dev/h2c1v0/h2c1v0 (remote)
    - Device: /dev/md/ost0000
  - **Host 2**
    - /dev/<vg>/<lv>: /dev/h1c1v1/h1c1v1 (remote)
      /dev/h2c1v1/h2c1v1 (local)
    - Device: /dev/md/ost0004

HA Lustre

Host 1

LVs

md100 = h1c1v0 + h2c1v0

md101 = h1c2v0 + h2c2v0

md102 = h1c3v0 + h2c3v0

md103 = h1c4v0 + h2c4v0

OSTs

ost0000 = md100

ost0001 = md101

ost0002 = md102

ost0003 = md103

Host 2

LVs

md104 = h1c1v1 + h2c1v1

md105 = h1c2v1 + h2c2v1

md106 = h1c3v1 + h2c3v1

md107 = h1c4v1 + h2c4v1

OSTs

ost0004 = md104

ost0005 = md105

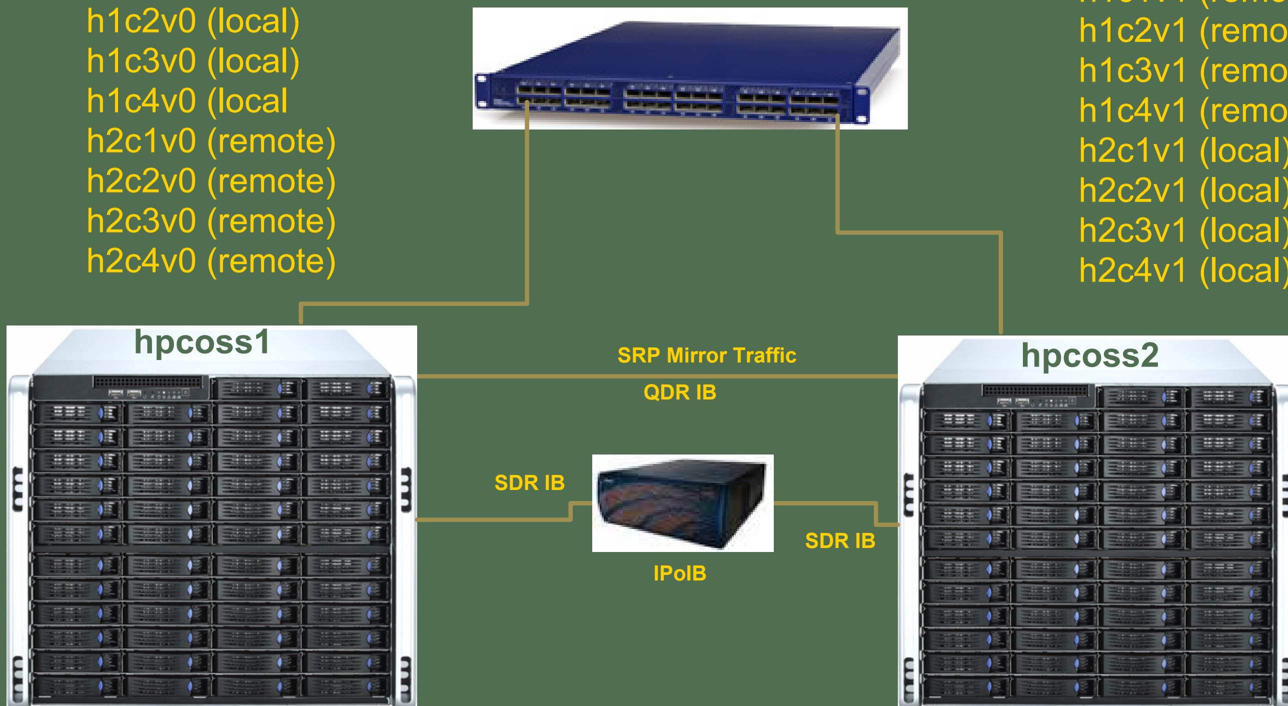
ost0006 = md106

ost0007 = md107

SRP Mirrored Lustre HA OSS Pair

h1c1v0 (local)
h1c2v0 (local)
h1c3v0 (local)
h1c4v0 (local
h2c1v0 (remote)
h2c2v0 (remote)
h2c3v0 (remote)
h2c4v0 (remote)

h1c1v1 (remote)
h1c2v1 (remote)
h1c3v1 (remote)
h1c4v1 (remote)
h2c1v1 (local)
h2c2v1 (local)
h2c3v1 (local)
h2c4v1 (local)

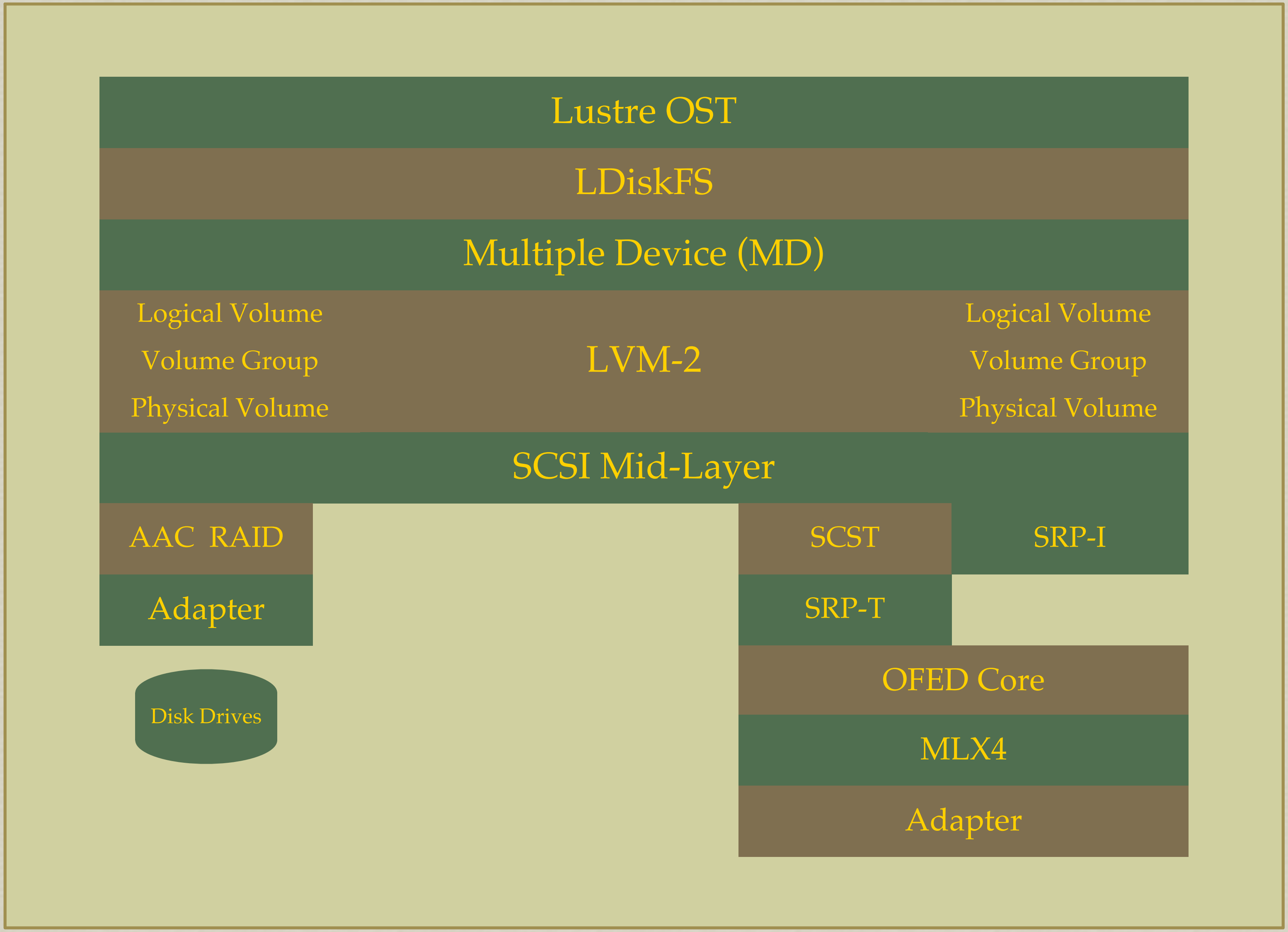


Each OSS:

Chenbro RM91250
SuperMicro X8DAH
2 x Intel E5620
24 GB RAM
2 x QDR IB
1 x SDR IB
4 x Adaptec 51245
RAID-6 (4+2)
8 x 8TB LUNs

OST0000 => MD100 => h1c1v0 + h2c1v0
OST0001 => MD101 => h1c2v0 + h2c2v0
OST0002 => MD102 => h1c3v0 + h2c3v0
OST0003 => MD103 => h1c4v0 + h2c4v0

OST0004 => MD104 => h1c1v1 + h2c1v1
OST0005 => MD105 => h1c2v1 + h2c2v1
OST0006 => MD106 => h1c3v1 + h2c3v1
OST0007 => MD107 => h1c4v1 + h2c4v1


Lustre OST
LDiskFS
Multiple Device (MD)
Logical Volume
Volume Group
Physical Volume
LVM-2
Logical Volume
Volume Group
Physical Volume
SCSI Mid-Layer
AAC RAID
Adapter
Disk Drives
SCST
SRP-I
SRP-T
OFED Core
MLX4
Adapter

HA Lustre

- **High-Availability Software (Open Source)**
  - Corosync
  - Pacemaker
- **Corosync**
  - Membership
  - Messaging
- **Pacemaker**
  - Resource monitoring and management framework
  - Extensible via Resource agent templates
  - Policy Engine

HA Lustre

- **Corosync Configuration**
  - **Dual Rings**
    - Back-to-Back ethernet
    - IPoIB via SRP IB Interface
  - **clear_node_high_bit: yes**
  - **rrp_mode: passive**
  - **rrp_problem_count_threshold: 20**
  - **retransmits_before_loss: 6**

HA Lustre

- **Pacemaker Configuration**
  - **Resources**
    - Stonith (modified to control multiple smart pdus)
    - MD (custom)
    - Filesystem (stock)
  - **Resource Groups (managed together)**
    - One per OST (grp_ostNNNN)
    - MD + File system
    - Not LVs – some disappear if a node goes down

HA Lustre

- **Performance**
  - **4 PCI-E RAID Controllers per Server**
    - 2 RAID-6 (4+2) Logical Disk per Controller
    - 8 Logical Disks per Server (4 local, 4 remote)
    - 490 MB/sec per Logical Disk
    - 650 MB/sec per Controller (parity limited)
  - **Three IB Interfaces per Server**
    - IB Clients (QDR, Dedicated)
    - IPoIB Clients (SDR, Dedicated)
    - SRP Mirror Traffic (QDR, Dedicated)

HA Lustre

- **Performance (continued)**
  - **Per Server Throughput**
    - 1.1 GB/sec per server (writes – as seen by clients)
    - 1.7 GB/sec per server (reads – as seen by clients)
  - **Actual server throughput is 2x for writing (mirrors!)**
  - **That’s 2.2 GB/s per Server**
  - **85% of the 2.6 GB/s for the raw storage**

HA Lustre

- **Performance – Didn't come easy**
  - **Defaults for everything, no mirroring**
    - Default PV alignment (??)
    - RAID stripe unit size (256 KB)
    - aacraid *max_hw_sectors_kb* (256 KB, controlled by acbsize)
    - MD device *max_sectors_kb* (128 KB)
    - Lustre max RPC size (1024 KB)
  - **Per-OST streaming throughput, no mirroring**
    - **Ugh!**
      - Reads: ~253 MB/s
      - Writes: ~173 MB/s

HA Lustre

- **Performance – Didn't come easy**
  - **Alignment PVs to RAID stripe boundary**
    - Streaming reads: ~333 MB/s
    - Streaming writes: ~280 MB/s
  - **Increase MD max I/O = RAID stripe size = aacraid max I/O**
    - Required patch to MD RAID1 module (hardwired)
    - Only improved streaming reads: ~360 MB/s
  - **Increase max I/O size (MD + aacraid) => 512KB**
    - aacraid acbsize=4096 (driver unstable beyond 4096)
    - Streaming writes: ~305MB/s
    - Could not reach a 1MB max I/O size

HA Lustre

- **Performance – Didn't come easy**
  - **Introduce SRP Mirrors…**
  - **Lustre RPC size = aacraid max I/O =**
    SRP target RDMA size = MD max I/O = 512 KB
  - **Per-OST streaming reads: ~433 MB/s**
    - Improvement via MD read balancing
  - **Per-OST streaming writes: ~280 MB/s**
    - Slight penalty with SRP – can be CPU-bound on the core that handles the SRP HCA interrupts
    - Slightly faster OSS CPU would presumably help this

HA Lustre

- **Performance – Summary**
  - **HA OSS (4 SRP-mirrored OSTs total)**
  - **Streaming writes: 1.1 GB/s (i.e 2.2 GB/s)**
  - **85% of sgpdd-survey result**
  - **Reads: 3.4 GB/s (per pair)**
    - 1.7 GB/s observed from each HA OSS
  - **Considerable improvement over defaults**

HA Lustre

- **Keeping the data safe**
  - **Mirrors enable failover**
  - **Provide a second copy of the data**
  - **Each Mirror**
    - Hardware RAID
    - RAID-6 (4+2), two copies of parity data
  - **Servers protected by UPS**
    - Orderly shutdown of servers in the event of a sudden power outage.
    - 3+1 Redundant power supplies each to a different UPS.

HA Lustre

- **Problems Encountered**
  - **Unstable SRP Target: OFED SRP target proved unstable**
    - Used SCST SRP target (started w/ pre 2.0 release)
  - **MD Mirror Assembly**
    - May choose wrong mirror under corosync.
    - Could not duplicate outside of corosync control
    - Requires deactivating the out-of-sync volume, assembling the degraded mirror, then adding the out-of-sync volume. Not ideal
  - **Poor Initial Performance**
    - Resolved through tuning (described previously)

HA Lustre

- **Problems Encountered (continued)**
  - Zone Allocator killed us
  - Blocked monitoring agents led to many needless remounts and sometimes STONITH events
  - Could not pinpoint the problem which often but not always seemed correlated with load
  - Seems we were the last to know about the long delays caused by the zone allocator
  - Many timeout parameters unnecessarily adjusted to be very loooong.
  - vm.zone_reclaim_mode = 0
  - 100% stable now

HA Lustre

- **Future Improvements**
  - SSD cache (i.e Adaptec maxCache)
  - External journal device
  - 6 Gbps RAID cards capable of > 512KB I/Os
  - Faster processor (for SRP interrupt handling)
  - 8+2 RAID-6 OSTs
    - More efficient disk utilization (4/5 vs 2/3)
    - Affects chassis and backplane choices

HA Lustre

- **Thank You**
- **Questions or Comments?**