GFS and Friends

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http://sources.redhat.com/cluster/
http://www.redhat.com/software/rha

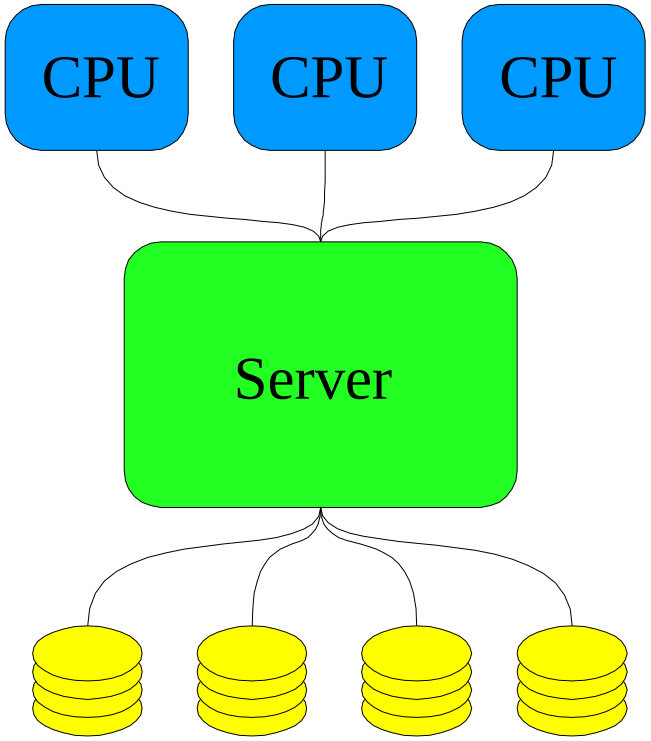
Slides:
http://people.redhat.com/kpreslan/gfs-fosdem05.pdf

Many Parts

- GNBD -- Block over IP driver
- CCS -- Cluster Configuration
- Fence -- I/O Fencing
- GULM -- Centralized Lock Server
- CMAN -- Distributed Cluster Manager
- GDLM -- Distributed Lock Manager
- CLVM – Cluster Volume Manager
- GFS -- Cluster Filesystem
- Userspace application failover server

Traditional File Server

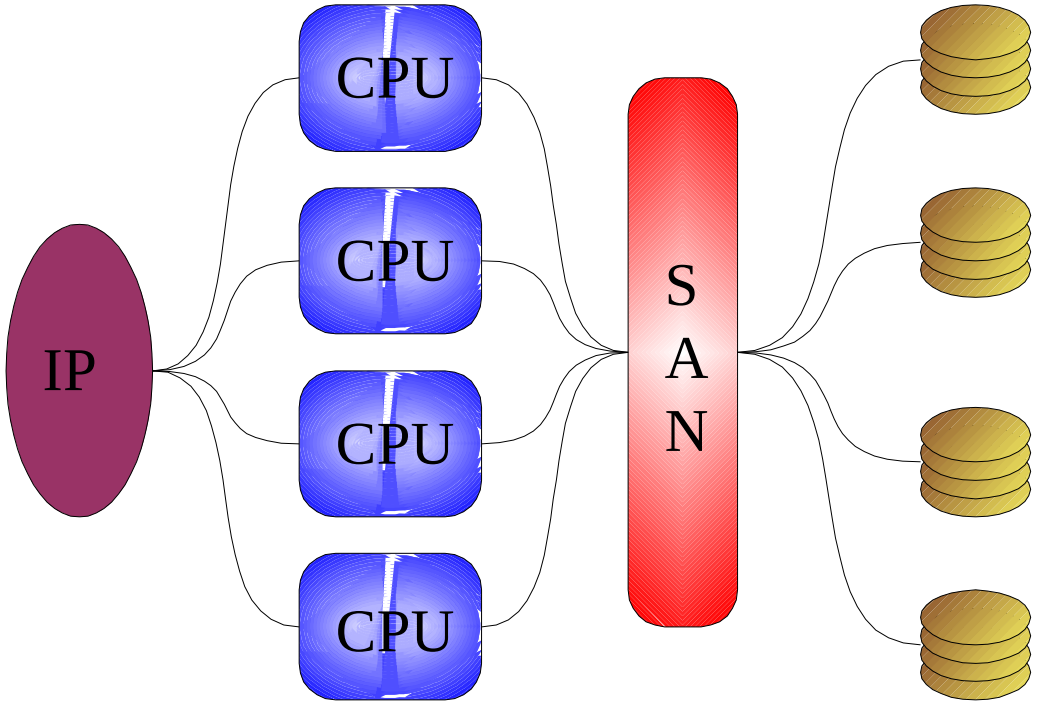
- NFS/CIFS/Apache
- Server a bottleneck
- Server a single point of failure
- Upgrade path
  - Replace with a bigger server ($$$)
  - Add another server (Data replication problems)



Block-based interconnects

- Fibre Channel
- FireWire
- iSCSI
- GNBD
- HyperSCSI
- Many others

Symmetric Shared-Disk Architecture



Possible Applications

- Web (http, ftp) serving clusters
- NFS/CIFS serving clusters
- Shared root clusters
- I/O-intensive scientific compute clusters
- Software build clusters
- Parallel Databases (Oracle)

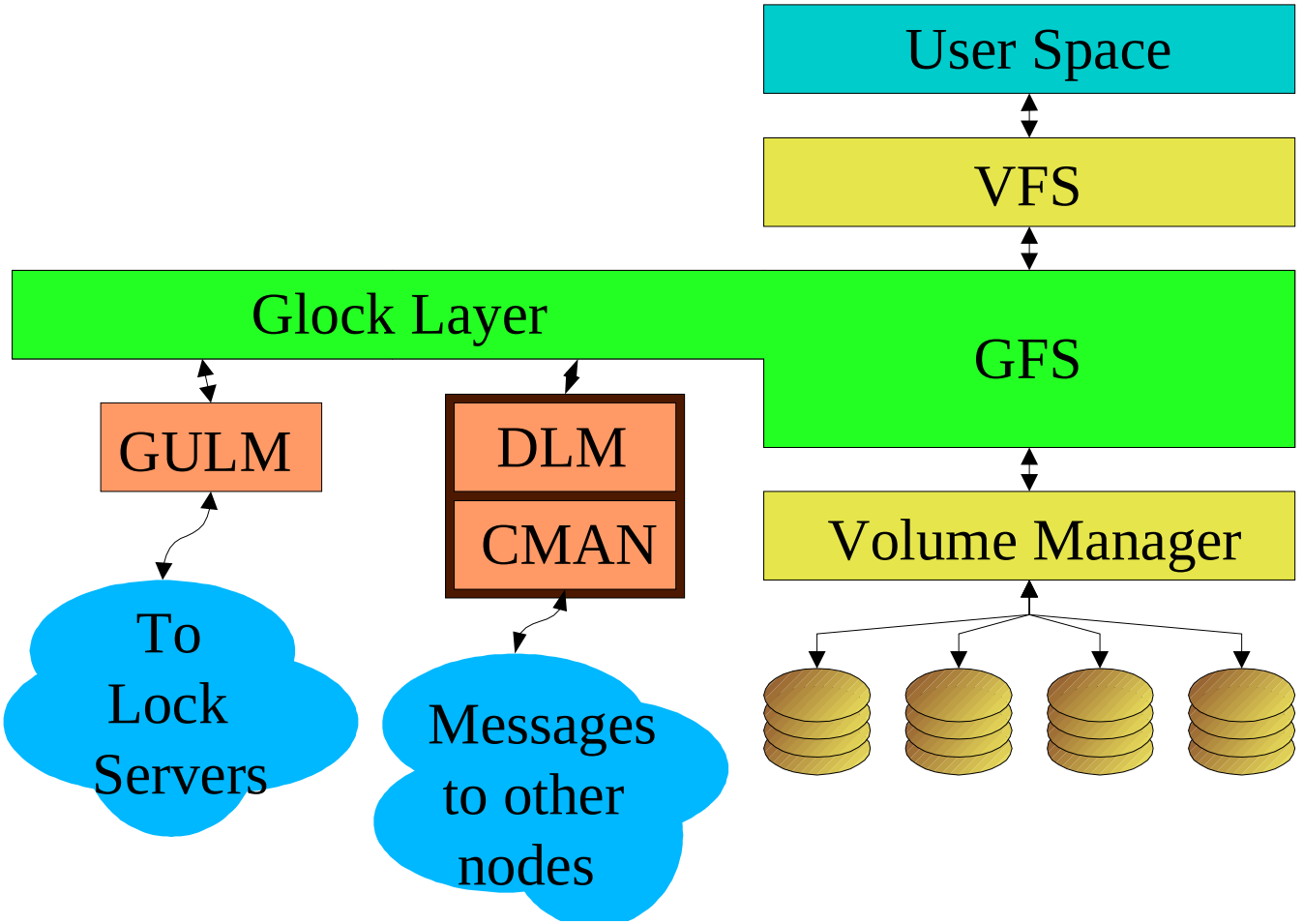
GFS Basics

- Symmetric
- Journaled (1 journal per machine)
- 64-bit
- Works like a local filesystem but inter-machine locks are acquired as operations occur
- Goals
  - Flexibility in terms of locking
  - Flexibility in terms of block transport

GFS vs a Local FS

- Locality not always a good thing
- Deadlock ordering for locks affects a lot
- Journaling/replay more complicated
- Filesystem tree walking has more overhead
- Avoidance of central data structures
  - Inode tables
  - StatFS info
- Some Relaxing of semantics: Fuzzy-ness of quotas, atime, StatFS(soon)

Internal Layout



Older Features

- Asynchronous journaling
- Multiple journals – one per node
- ExHash directories
- Online Growable (data space and journals)
- Lock caching
- Full read and write-back caching
- Dynamic Inodes
- 64-bits everywhere
- Deadlock avoidance through lock sorting

New Features since 4.2

- Asynchronous locking
- Quotas
- Extended Attributes
- ACLs
- Shared locks are shared between processes
- Multi-writer Direct I/O
- Improved unlink/deallocation
- Improved allocation algorithms
- Improved flock/fcntl()-lock code

New Features since 4.2

- Journaled data
- FS quiese support
- Better response to memory pressure
- Better transaction/log code
- Ability to convert metadata blocks back to data blocks
- Better NFS support
- Coherent shared mmap() support

New Features since 4.2

- Context Dependent Path Names
- Lots of bug fixes
- Lots of cleanup

Asynchronous Locking

- Lock modules and glock layer rewritten to support async locking
- Glock layer calls into the LM with request
- LM issues a callback with result
- Allows speedups due to parallelization of lock requests

Async Locking (Glock)

- Two options:
  - Prefetch
  - The calling code passes in a structure that defines the request. That structure can be polled or slept on
- Main users:
  - Prefetch inode locks on readdir
  - Statfs
  - Optimization acquiring multiple locks
  - Unlock

Quotas

- Quotas are fuzzy
- Overruns are tunable
- Trade-off: More accuracy means more contention
- User and Group quotas
- Usage limit and Warn limit

Quotas

- Current quota values are cached in lock LVBs (to minimize quota file reads)
- Quota changes are cached in the filesystem in per-node areas
- Changes are synced back to the quota file periodically
- Changes are also synced more often when the user gets closer to their limit
- Idea is to decouple quota handling as much as possible from the quota file

Withdraw

- A new way for a machine to leave the cluster
  - A machine stops all new I/O, waits for pending I/O to complete
  - Calls into lock module with withdraw command
  - Another node does all recovery steps but fencing
- Allows a machine seeing critical I/O or consistency errors to stop accessing the filesystem
- Replaces way over-used panic calls

Lock Module Interface

- Lock_harness – lightweight, GFS-specific CI switch
- Very lock-centric (VCDLM subset)
- Minimal cluster management
- Mount, unmount, lock/LVB operations, plock operations, withdraw, a callback (completion, blocking, recover-journal), recover-journal-done
- Maps Journal ID to nodes
- Handles all GFS inter-node communication

GULM

- Centralized lock/cluster manager
- Up to 5 redundant servers
- Handles membership, quorum, fencing, and locking
- Very GFS-specific
- Older, stable code
- May offer better performance in very large compute clusters

CMAN + GDLM

- Modularization allows us to expose the clustering/locking support developed for GFS for other systems to use as well (CLVM, other CFSs)
- Don't expect that CMAN+GDLM will be useful for everyone, but willing to work to make it useful for others
- Can be used independently of CLVM or GFS
- Newer than GULM, still testing

CMAN

- Cluster Manager
- Heavy VaxCluster influence
- Membership events
- Quorum
- Start/Stop of core cluster services
- Accessable from kernel and user space
- Currently in-kernel, moving to user-space soon

CMAN

- Part 1: Cluster Manager
- A cluster has a unique name and ID on the network
- Multiple clusters can exist on network
- A node can only join one cluster
- All nodes broadcast/multicast heartbeats
- First node to detect a failed heartbeat begins a transition to remove failed node
- Multi-step transition makes sure all nodes are in agreement over new membership

CMAN (quorum)

- Each node in cluster gets a number of votes
- Cluster has an expected number of votes
- CMAN determines if cluster is quorate
- Other subsystems can use this to regulate operation

CMAN

- Other systems can get a list of current members (name, nodeID, IPaddr)
- Other systems can register for callbacks for membership changes
- Available to kernel or user space

Service Manager

- Basic cnxman API not sufficient for GFS or DLM
- Requirement for layered recovery
- Requirement for GFS/GDLM to suspended on all nodes before any node does recovery
- Requirement for GDLM to complete recovery on all nodes before GFS restarts on any node
- Second part of CMAN required: the Service Manager
- For core services only – Userspace servers (apache, NFS, etc..) handled elsewhere

Service Manger

- Symmetric
- Managers which nodes in the cluster are using a particular GFS or GDLM LS
- Represents each GFS or GDLM LS generically as a “Service Group”
- Manages nodes joining or leaving SGs

Service Manager

- SGs are layered for recovery order
- Link from cnxman to SM is: cnxman tells SM when a node fails, SM starts recovery for any SMs the failed node was in
- Members of a SG are all stopped before recovery is started
- All SGs at a certain level complete recovery before any SGs at a higher level are started
- SM factors a lot of cluster management detail out of individual symmetric services and handles it generically for them.

GDLM

- Looks similar to DLM in VMS clusters
- Supports many independent lock-spaces
- Nodes “join” a lock space to begin acquiring locks
- Runs entirely in the kernel
- Heavy use by GFS makes userspace DLM impractical (performance/latency, memory, callbacks)
- Depends on CMAN for cluster management

Fencing

- Generic infrastructure to support I/O fencing
- Pluggable agents to support different hardware
- About 20 agents currently
- Various different methodologies
  - Power cycling
  - Fencing in I/O path (fabrics, switches)
  - Fencing of I/O device (iSCSI, GNBD)
- “Easy” to add another method

Fencing

- GULM: GULM master server fences dead client
- CMAN/GDLM:
  - Fence system for CLVM/GFS is a simple userspace daemon controlled by CMAN (SM)
  - Fencing is also symmetric (any node can fence any other)
  - Using input from CMAN/SM, fenced decides who needs to be fenced
  - Fenced is just a SM Service Group
  - Fenced registers at the lowest level so a node is fenced before DLM/GFS recovery happens

CCS

- Cluster Configuration system
- XML-based configuration files
- Mostly there to define fencing methods for nodes
- Configuration files replicated and kept in sync on all nodes of cluster
- No longer requires shared storage

CLVM

- A userspace daemon layered on top of LVM2/DM
- Uses CMAN+GDLM (GULM?)
- Working on clustered mirror and snapshot targets

Future Work

- Big short-term targets
  - Small file performance
  - FSCK speed improvements
  - Local storage utilization
- Shared Root
- File locality controls
- Metadata locality to specific devices
- Block based file backup support

Future Work

- B-Trees instead of allocation bitmaps
- File System shrink
- Dynamic hotspot elimination
- Forced Unmount
- I/O load balancing
- Range-level locking
- DMAPI?

Future Work

- Buffer Passing
- Operation Passing
- Filesystem Snapshotting
- File Versioning