# Corso sul file system parallelo distribuito GPFS

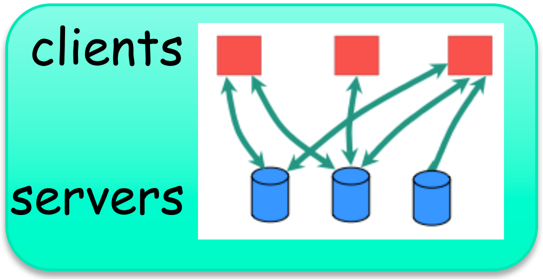
Part 1: General Introduction

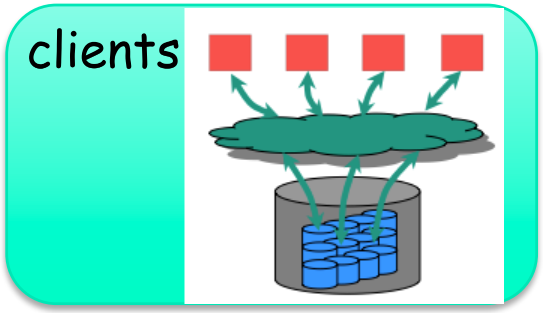
## Outline

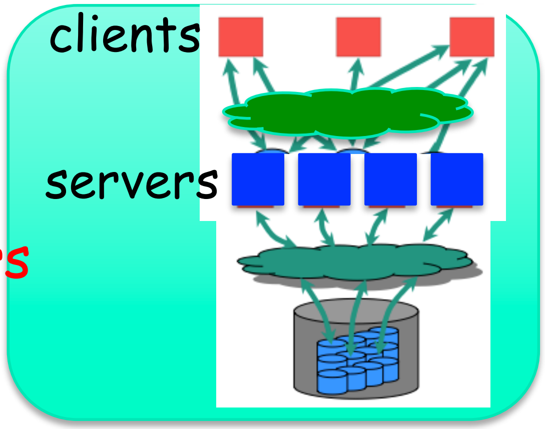
- Parallel I/O, Clustered Files Systems and a Cluster Storage
- Overview of GPFS features and architecture
- Cluster Design options
- GPFS features in depth
- Performance related features
- Management and Overhead Functions
- Configuration examples
- Installation

# File Systems for HPC clusters

- 3 main categories:
  - NFS (protocols: TCP/IP)
    - Easy to setup and use
    - Single point of failure
    - Do not scale in large clusters
  - SAN or Shared Disk File Systems (protocols: Fibre Channel, InfiniBand, Myricom)
    - Extremely high performance
    - Expensive (each node needs HBA)
  - Parallel FS (protocols: any of above)
    - Scalable => high performing
    - Redundant => highly available
    - Management requires skilled administrators







## Parallel and Distributed FS

- Data distribution:
  - Distributed file systems often store entire objects (files) on a single storage node
  - Parallel file systems distribute data of a single object across multiple storage nodes
- Symmetry:
  - Distributed file systems often run on architectures where the storage is co-located with application
  - In Parallel file systems storage often separated from the compute system
- Fault tolerance:
  - Distributed file systems often use object level data protection (replication) on independent storage devices
  - Parallel FS uses block-level data protection (RAID) on shared storage

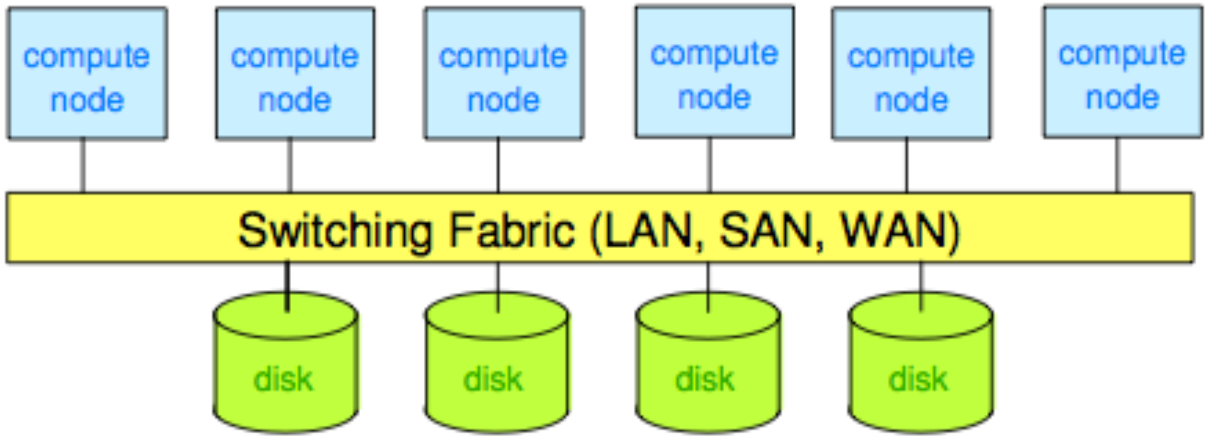
| Name | By | License | OS | Description |
|---|---|---|---|---|
| Ceph | Inktank | LGPL | Linux | A massively scalable object store. Ceph was merged into the linux kernel in 2010. Ceph's foundation is the Reliable Autonomic Distributed Object Store (RADOS), which provides object storage via programmatic interface and S3 or Swift REST APIs, block storage to QEMU/KVM/Linux hosts, and POSIX filesystem storage which can be mounted by linux kernel and FUSE clients. |
| CloudStore | Kosmix | Apache License 2.0 | | Google File System workalike. Replaced by Quantcast File System (QFS) |
| Cosmos | Microsoft internal | internal software | | Focuses on fault tolerance, high throughput and scalability. Designed for terabyte and petabyte sized data sets and processing with Dryad. |
| dCache | DESY and others | | | A write once filesystem, accessible via various protocols |
| FS-Manager | CDNetworks | proprietary software | Linux | Focused on Content Delivery Network |
| Gfarm file system | Asia Pacific Grid | X11 License | Linux, Mac OS X, FreeBSD, NetBSD and Solaris | Uses OpenLDAP or PostgreSQL for metadata and FUSE or LUFS for mounting |
| GPFS | IBM | proprietary | AIX, Linux and Windows | Support replication between attached block storage. Symmetric or asymmetric (configurable) |
| GlusterFS | Gluster, a company acquired by Red Hat | GNU General Public License v3 | Linux, Mac OS X, NetBSD, FreeBSD, OpenSolaris | A general purpose distributed file system for scalable storage. It aggregates various storage bricks over Infiniband RDMA or TCP/IP interconnect into one large parallel network file system. GlusterFS is the main component in Red Hat Storage Server. |
| Google File System (GFS) | Google | internal software | Linux | Focus on fault tolerance, high throughput and scalability |
| Hadoop Distributed File System | Apache Software Foundation | Apache License 2.0 | Cross-platform | Open source GoogleFS clone |

| Name | By | License | OS | Description |
|---|---|---|---|---|
| IBRIX Fusion | IBRIX | proprietary software | Linux | |
| Lustre | supported by Intel (formerly Whamcloud) | GPL | Linux | A POSIX-compliant, high-performance filesystem. Lustre has high availability via storage failover |
| MogileFS | Danga Interactive | GPL | Linux (but may be ported) | Is not POSIX compliant, uses a flat namespace, application level, uses MySQL or Postgres for metadata and HTTP for transport. |
| OneFS distributed file system | Isilon | | FreeBSD | BSD based OS on dedicated Intel based hardware, serving NFS v3 and SMB/CIFS to Windows, Mac OS, Linux and other UNIX clients under a proprietary software |
| Panasas ActiveScale File System (PanFS) | Panasas | proprietary software | Linux | Uses object storage devices |
| PeerFS | Radiant Data Corporation | proprietary software | Linux | Focus on high availability and high performance and uses peer-to-peer replication with multiple sources and targets |
| Tahoe-LAFS | Tahoe-LAFS Software Foundation | GNU GPL 2+ and other[19] | Windows, Linux, OS X | secure, decentralized, fault-tolerant, peer-to-peer distributed data store and distributed file system |
| TerraGrid Cluster File System | Terrascale Technologies Inc | proprietary software | Linux | Implements on demand cache coherency and uses industrial standard iSCSI and a modified version of the XFS file system |
| XtreemFS [4] | Contrail E.U. project, the German MoSGrid project and the German project "First We Take Berlin" | open-source (BSD) | Linux, Solaris | cross-platform file system for wide area networks. It replicates the data for fault tolerance and caches metadata and data to improve performance over high-latency links. SSL and X.509 certificates support makes XtreemFS usable over public networks. It also supports Striping for usage in a cluster. |
| MapR-FS | MapR[3] | Proprietary | Linux | Highly scalable, POSIX compliant, fault tolerant, read/write filesystem with a distributed, fault tolerant metadata service. It provides an HDFS and NFS interface to clients |
| | | | | |

# Parallel I/O in a cluster

User data and metadata flows between all nodes and all disks in parallel

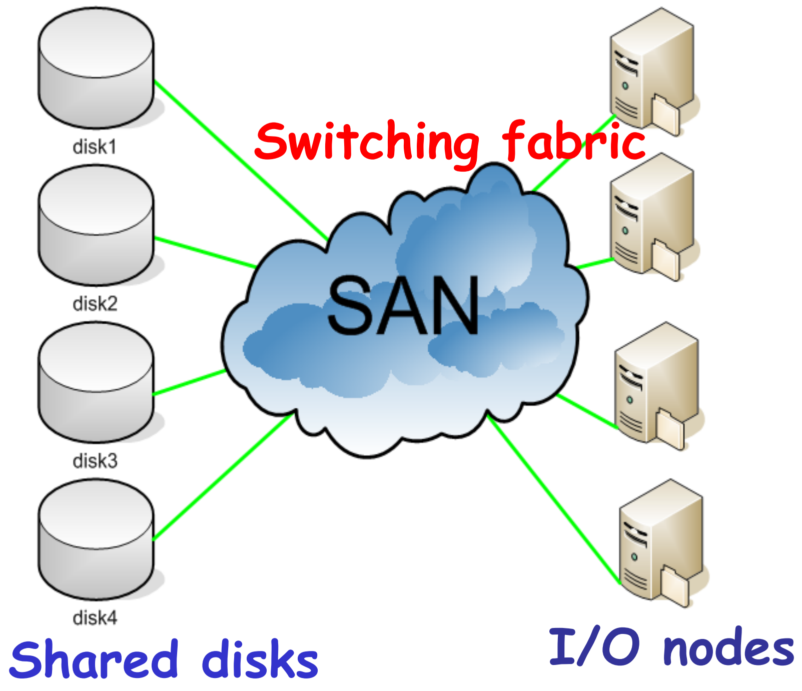
- Multiple tasks distributed over multiple nodes simultaneously access file data
- Multi-task applications access common files in parallel
- Files span multiple disks
- File system overhead operations are distributed and done in parallel
- Provides a consistent global name space across all nodes of the cluster



## GPFS at glance

GPFS= General Parallel File System
IBM's shared-disk distributed parallel clustered file system.

- *Cluster*: 1..8192 nodes, fast reliable communication, common admin domain
- *Shared disk*: all data and metadata on disk accessible from any node through disk I/O interface (i.e., "any to any" connectivity)
- *Parallel*: data and metadata flows from all of the nodes to all of the disks in parallel
- *Scalable*: $2^{63}$ files per file system, max file size $2^{99}$ bytes (= max FS size)
- *In general*: supports wide range of HPC application needs over a wide range of configurations



## Conceptual understanding

- GPFS is not just a clustered file system software – it's a full featured set of file management tools
- GPFS allows a group of computers concurrent access to a common set of data
- The computers can run any mix of AIX, Linux or Windows Server operating systems
- GPFS provides storage management, information life cycle management tools, centralized administration
- Allows shared access to file systems from remote GPFS clusters providing a global namespace

## GPFS features: Cluster

- mature IBM product generally available for more then 10 years (GPFS has been available on AIX since 1998 and Linux since 2001)
- Works on AIX, Linux and (surprise!) Windows Server
- Provides High Availability (when >1 node)
  - can be configured for continued access to data even if cluster nodes or storage systems fail.
  - built-in tools continuously monitors the health of the file system components
- Supports Shared-disk and from v.3.5 Shared-nothing mode

## GPFS features: File System

- Access files through standard POSIX file system interfaces
- supports a wide range of basic configurations and disk technologies
- Journaling
- Provides non-POSIX advanced features
  - e.g., DMAPI, data-shipping, multiple access hints (also used by MPI-IO)
  - ILM, integrated with tape, disaster recovery
  - NFS support (Clustered NFS)
  - Snapshots (copy-on-write)
- Provides good performance for large volume, I/O intensive jobs
- Converting to GPFS does not require application code changes provided the code works in a POSIX compatible environment

## GPFS features: performance and scalability

- GPFS achieves high performance I/O by:
  - Striping data across multiple disks attached to multiple nodes.
  - High performance metadata (inode) scans.
  - Supporting a wide range of file system block sizes to match I/O requirements.
  - Utilizing advanced algorithms to improve read -ahead and write-behind IO operations
    - recognizes typical access patterns including sequential, reverse sequential and random
  - Using block level locking based on a very sophisticated scalable token management system

# What GPFS is NOT

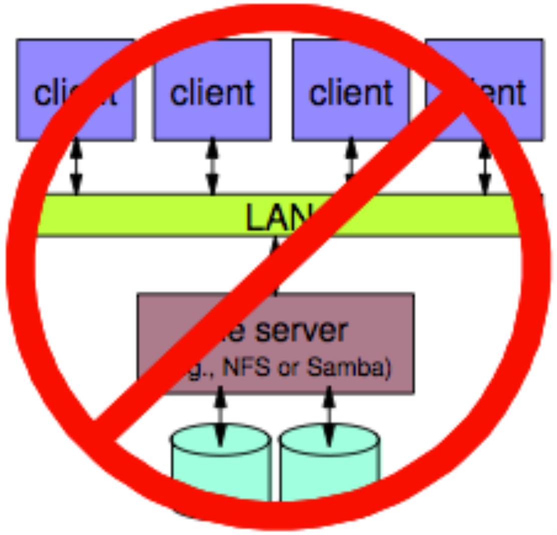
GPFS *is not a client/server file system like NFS, CIFS (Samba) or AFS/ DFS with a single file server.*

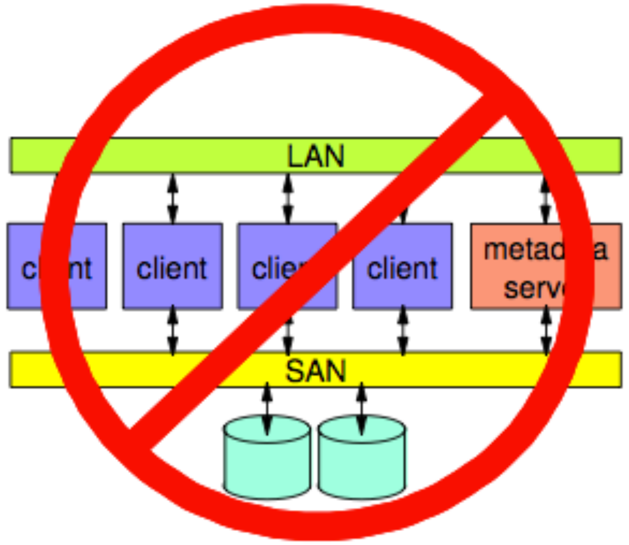
- *GPFS nodes can be an NFS or CIFS server, but GPFS treats them like any other application.*

GPFS *is not a SAN file system with dedicated metadata server.*

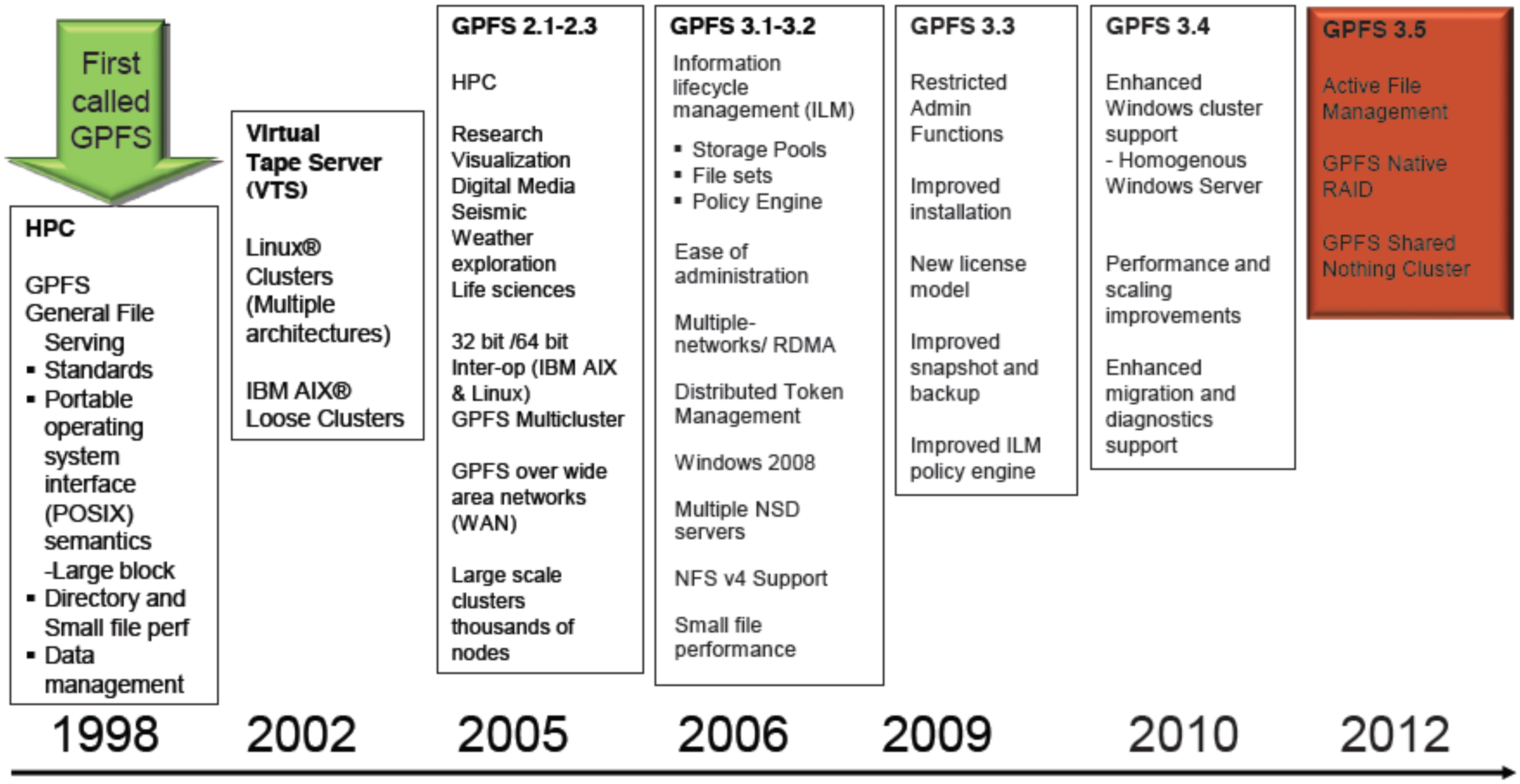
- *GPFS can run in a SAN file system like mode, but it does not have a dedicated metadata server.*

GPFS avoids the bottlenecks introduced by centralized file and/ or metadata servers.





# GPFS history and evolution



First called GPFS

**HPC**

GPFS General File Serving
- Standards
- Portable operating system interface (POSIX) semantics
  -Large block
- Directory and Small file perf
- Data management

**Virtual Tape Server (VTS)**

Linux® Clusters (Multiple architectures)

IBM AIX® Loose Clusters

**GPFS 2.1-2.3**

HPC

Research
Visualization
Digital Media
Seismic
Weather exploration
Life sciences

32 bit /64 bit
Inter-op (IBM AIX & Linux)
GPFS Multicluster

GPFS over wide area networks (WAN)

Large scale clusters thousands of nodes

**GPFS 3.1-3.2**

Information lifecycle management (ILM)
- Storage Pools
- File sets
- Policy Engine

Ease of administration

Multiple-networks/ RDMA

Distributed Token Management

Windows 2008

Multiple NSD servers

NFS v4 Support

Small file performance

**GPFS 3.3**

Restricted Admin Functions

Improved installation

New license model

Improved snapshot and backup

Improved ILM policy engine

**GPFS 3.4**

Enhanced Windows cluster support
- Homogenous Windows Server

Performance and scaling improvements

Enhanced migration and diagnostics support

**GPFS 3.5**

Active File Management

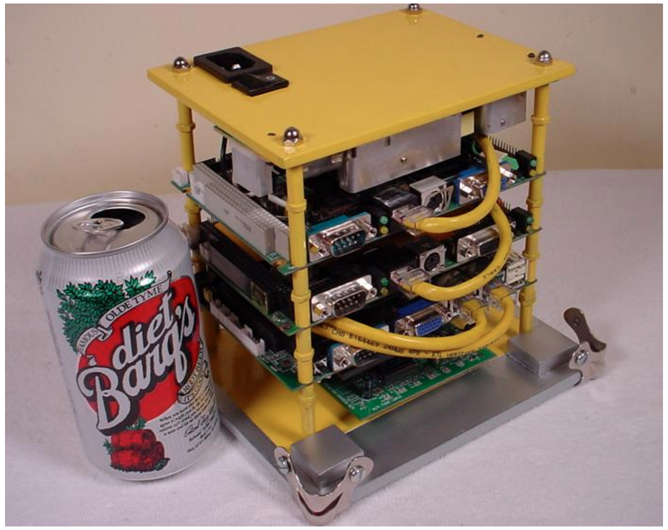
GPFS Native RAID

GPFS Shared Nothing Cluster

1998 2002 2005 2006 2009 2010 2012

## Where GPFS is used

- Aerospace and Automotive
- Banking and Finance
- Bio-informatics and Life Sciences
- Defence
- Digitial Media
- EDA (Electronic Design Automation)
- General Business
- National Labs
- Petroleum SMB (Small and Medium sized Business)
- Universities
- Weather Modeling



## GPFS Architecture

- 1. Client *vs.* Server
- *2. LAN Model*
- *3. SAN Model*
- *4. Mixed SAN/LAN*

## Is GPFS a Client/Server Design?

- **Software Architecture Perspective: No**
  - no single-server bottleneck
  - no protocol manager for data transfer
  - The mmfsd daemon runs symmetrically on all nodes
  - All nodes can and do access the file system via virtual disks (i.e., NSDs).
  - All nodes can, if disks are physically attached to them, provide physical disk access for corresponding virtual disks

## Is GPFS a Client/Server Design?

- **Practical Perspective: Yes**

GPFS is commonly *deployed having dedicated storage servers ("NSD servers") and distinct compute clients ("NSD clients") running applications that access virtual disks (i.e., "NSD devices" or "NSDs") via the file system.*

  - *this is based on economics (its generally too expensive to have 1 storage controller for every 2 nodes)*

*Nodes are designated as clients or servers for licensing.*

  - *client nodes only consume data*
  - *server nodes produce data for other nodes or provide GPFS management functions*
    - *producers: NSD servers, application servers (e.g., CIFS, NFS, FTP, HTTP)*
    - *management function: quorum nodes, manager nodes, cluster manager, configuration manager*

## Servers and clients

- *server functions are commonly overlapped ← This reduces cost, but use caution!*
  - *example: use NSD servers as quorum and manager nodes*
- *client licenses cost less than server licenses. ← The new licensing model is much cheaper!*
- *server nodes can perform client actions, but client nodes can not perform server actions*

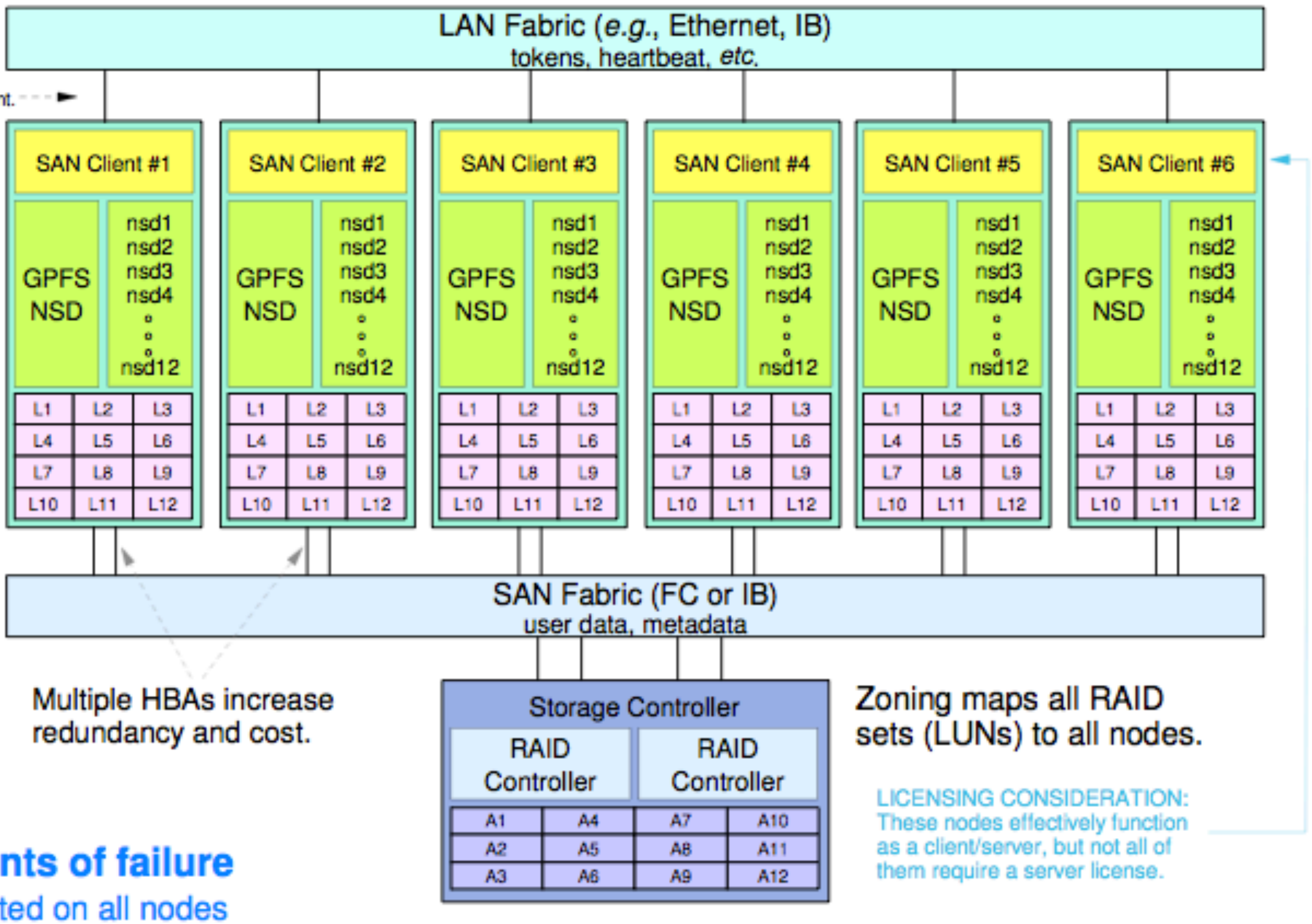
# SAN topology

1 Gb/s connections are sufficient.

All nodes act both as client and server.

All LUNs are mounted on all nodes.

GPFS is **not** a SAN file system; it merely can run in a SAN centric mode.



Multiple HBAs increase redundancy and cost.

Zoning maps all RAID sets (LUNs) to all nodes.

LICENSING CONSIDERATION: These nodes effectively function as a client/server, but not all of them require a server license.

**No single points of failure**

- All LUNs mounted on all nodes
- SAN connection (FC or IB) fail over
- Dual RAID controllers

**CAUTION:**
A SAN configuration is ***not*** recommended for larger clusters (*e.g.*, >= 64 since queue depth must be set small (*e.g.*, 1)

The largest SAN topologies in producton today are 256 nodes, but require special tuning.

# LAN topology

**NSD**

- SW layer in GPFS providing a "virtual" view of a disk
- virtual disks which correspond to LUNs in the NSD servers with a bijective mapping

**LUN**

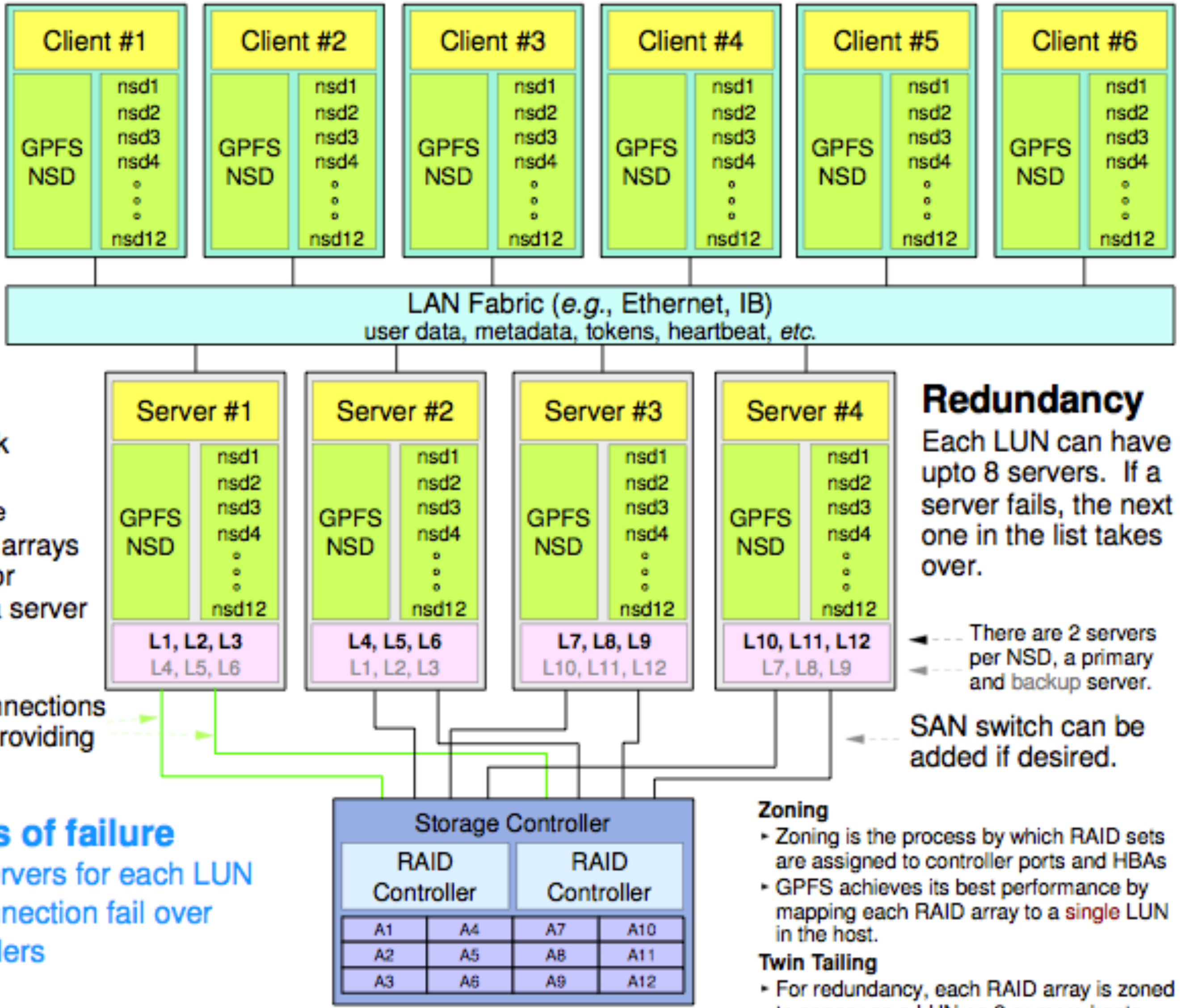
- Logical Unit
- Abstraction of a disk
  - AIX - hdisk
  - Linux - SCSI device
- LUNs map to RAID arrays in a disk controller or "physical disks" in a server

**Redundancy**

Each server has 2 connections to the disk controller providing redundancy

**No single points of failure**

- primary/backup servers for each LUN
- controller/host connection fail over
- Dual RAID controllers



**Redundancy**

Each LUN can have upto 8 servers. If a server fails, the next one in the list takes over.

There are 2 servers per NSD, a primary and backup server.

SAN switch can be added if desired.

**Zoning**

- Zoning is the process by which RAID sets are assigned to controller ports and HBAs
- GPFS achieves its best performance by mapping each RAID array to a single LUN in the host.

**Twin Tailing**

- For redundancy, each RAID array is zoned to appear as a LUN on 2 or more hosts.

## Comparing LAN and SAN Topologies

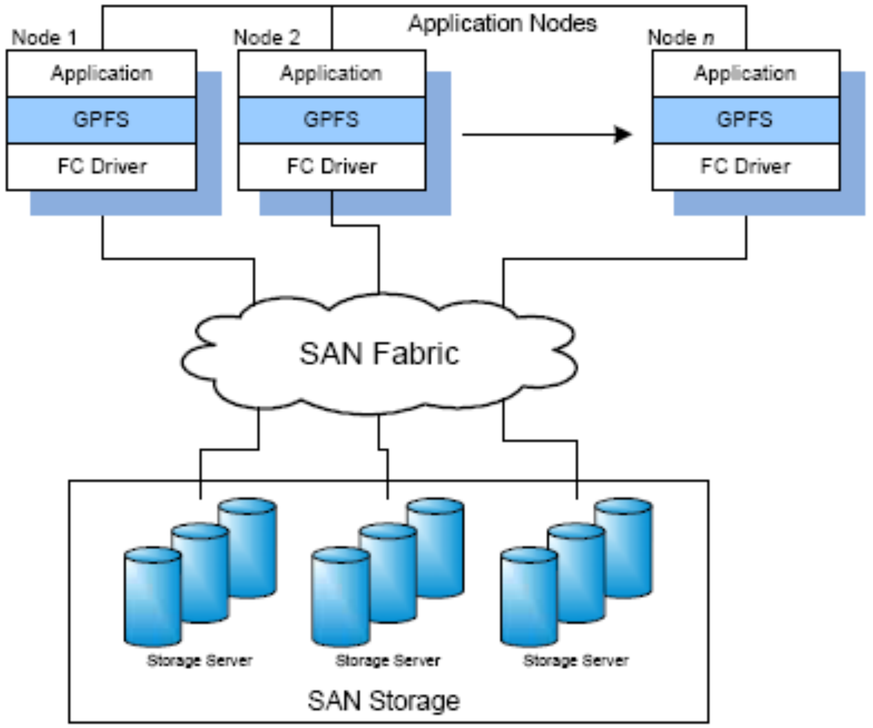
LAN Topology

- All GPFS traffic (user data, metadata, overhead) traverses LAN fabric
- Disks attach only to servers (also called NSD servers)
- Applications generally run only on the clients (also called GPFS clients); however, applications can also run on servers
  - cycle stealing on the server can adversely affect synchronous applications
- Economically scales out to large clusters
  - ideal for an "army of ants" configuration (*i.e., large number of small systems)*
- *Potential bottleneck: LAN adapters*
  - *e.g., GbE adapter limits peak BW per node to 80 MB/s; "channel aggregation" improves BW*

# Comparing LAN and SAN Topologies (2)

*SAN Topology*

- *User data and metadata only traverse SAN; only overhead data traverses the LAN*
- *Disks attach to all nodes in the cluster*
- *Applications run on all nodes in the cluster*
- *Works well for small clusters*
  - *too expense to scale out to large clusters (e.g., largest production SAN cluster is 250+ nodes)*
  - *ideal for a "herd of elephants" configuration (i.e., small number of large systems)*
- *Potential bottleneck: HBA (Host Bus Adapters) e.g., assume 180 MB/s effect BW per 4 Gb/s HBA; multiple HBAs improves BW*

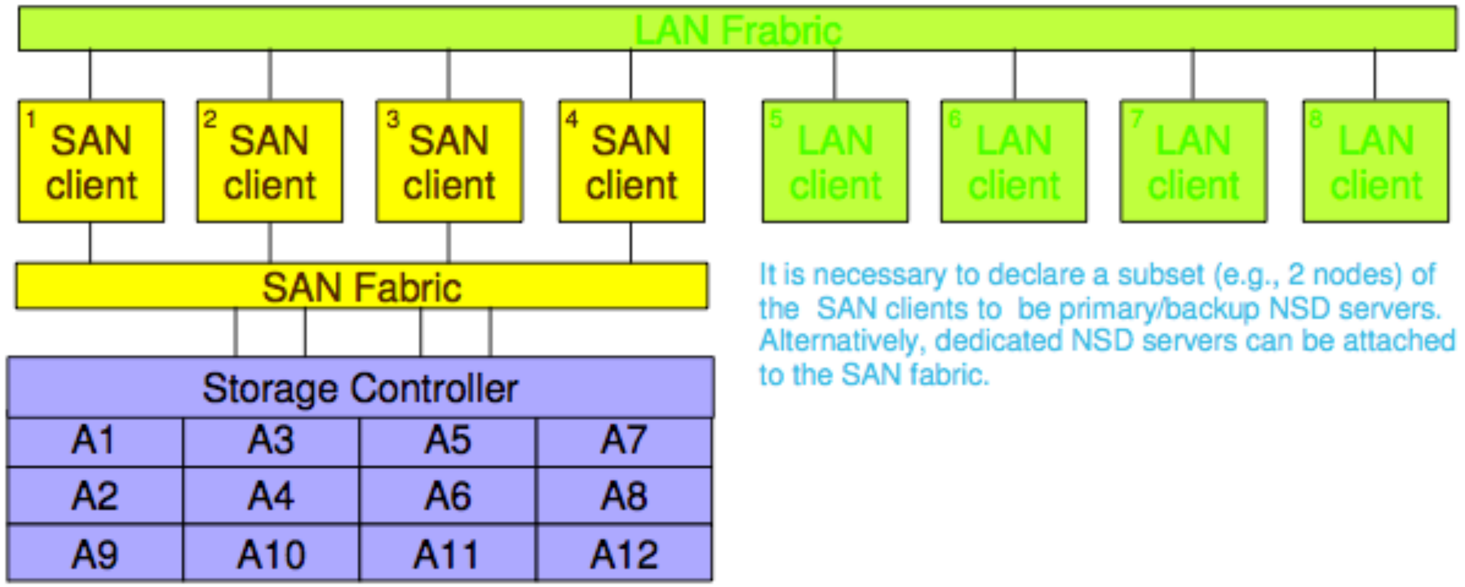


## Comparing LAN and SAN Topologies (3)

- From application point of view data access on network attached nodes is exactly the same as on storage area network attached node.

  GPFS transparently sends the block-level I/O over TCP/IP network.

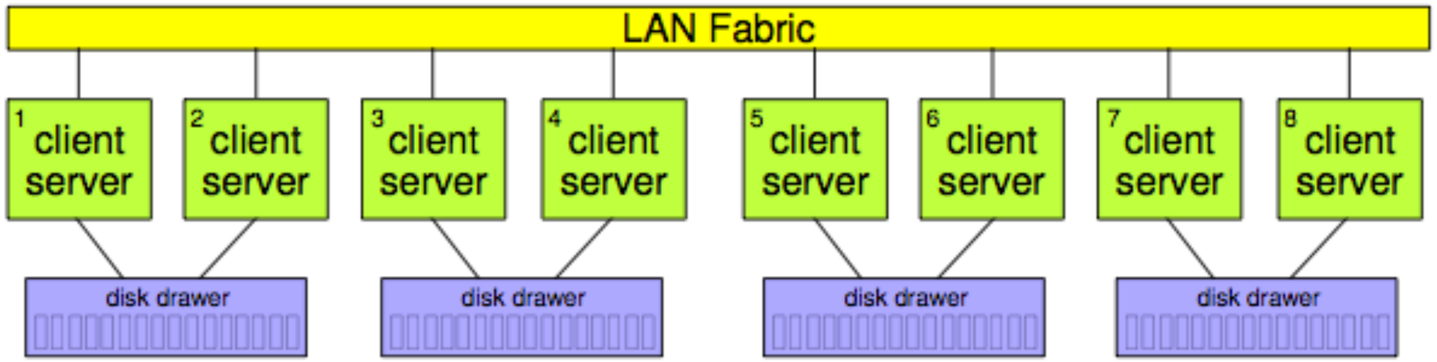
# Mixed LAN/SAN topology



It is necessary to declare a subset (e.g., 2 nodes) of the SAN clients to be primary/backup NSD servers. Alternatively, dedicated NSD servers can be attached to the SAN fabric.

- Nodes 1 - 4 (*i.e., SAN clients)*
  - *GPFS operates in SAN mode*
  - *User and meta data traverse the SAN*
  - *Tokens and heartbeat traverse the LAN*
- *Nodes 5 - 8 (i.e., LAN clients)*
  - *GPFS operates in LAN mode*
  - *User data, meta data, tokens, heartbeat traverse the LAN*

# Symmetric clusters



- No distinction between NSD clients and NSD servers
  - not well suited for synchronous applications
- Provides excellent scaling and performance
- Not common today given the cost associated with disk controllers
- Use "twin tailed disk" to avoid single point of failure risks
- Can be done using internal SCSI
  - Problem: exposed to single point of failure risk
  - Solution: use GPFS mirroring

## Performance related features in GPFS

- 1. Multithreading
- 2. Striping
- 3. File caching
- 4. Byte range locking
- 5. Blocks and sub-blocks
- 6. Access pattern optimization

## Multithreaded Architecture

- GPFS can spawn up to
  - 512 threads/node for 32 bit kernels
  - 1024 threads/node for 64 bit kernels
    - there is one thread per block (i.e., each block is an IOP)large records may require multiple threads
- The key to GPFS performance is "deep prefetch" which due its multithreaded architecture and is facilitated by
  - GPFS pagepool
  - striping (which allows multiple disks to spin simultaneously)
  - access pattern optimizations for sequential and strided access or the explicit use of hints

## Data Striping

- GPFS stripes successive blocks of each file across successive disks
- Disk I/O for sequential reads and writes is done in parallel (prefetch, write behind)
- Make no assumptions about the striping pattern
- Block size is configured when file system is configured, and is not programmable
- transparent to programmer

# GPFS File Caching

## GPFS Pagepool

- What is the pagepool?
  - It is a pinned memory cache used exclusively by GPFS
    - The pagepool is independent of the VMM subsystem
      - vmtune has no direct impact on the pagepool
    - GPFS uses mmap, schmat or kernel calls to do the pinning operation
  - It is used by GPFS for file data, indirect blocks and "system metadata" blocks
    - map blocks inodes in transit
    - recovery log buffers
    - emergency buffers

# GPFS pagepool

- Pagepool size Set by
  `mmchconfig pagepool= {value}`
  - default: 64M
  - min value: 4M These values are generally too small, especially for large blocks (*e.g., 4M)*
  - max value:
    - 256G for 64 bit OS,
    - 2G for 32 bit OS
- BUT GPFS will not
  - allocate more than the pagepool parameter setting
  - allocate more than 75% of physical memory
    - This can be changed to values between 10% to 90% *e.g.,*
      *`mmchconfig pagepoolMaxPhysMemPct=90`*
  - request more memory than the OS will allow

## Optimum size of the pagepool

- Best determined empirically
  - Optimum pagepool sizing is partially workload dependent
  - File systems with a large blocksize and/or a larger number of LUNs requires a larger pagepool
    - assume blocksize <= 1 MB and number of LUNs <= 12, then let sizeof(pagepool) <= 256 MB
    - assume blocksize >= 2 MB and number of LUNs >= 24, then let sizeof(pagepool) >= 512 MB
  - Optimizing streaming access requires a smaller pagepool (*e.g., up to 1 GB)*
  - *Optimizing irregular access requires a larger pagepool (e.g., > 1 GB, enough to hold working set)*
- *Once max performance is achieved, larger pagepools yield diminishing returns*

# GPFS pagepool

## Miscellaneous observations

- If you change both the maxblocksize and pagepool parameters at the same time
  - specify pagepool first if you increase the values
  - specify maxblocksize first if you decrease the values
- Large pagepools are most helpful when
  - writes can overlap computation
  - heavy reuse of file records (*n.b., good temporal locality)*
  - *semi-random access patterns with acceptable temporal locality*
  - *a GPFS node is used as a login node or an NFS server for large clusters*
- *Pagepool size on NSD servers*
  - *general principle: NSD servers do not cache data; they use the pagepool for transient buffers*
  - *Formula*

pagepool_size = largest blocksize * NSDThreads NSDThreads = min(A1, max(A2, A3)) A1 = nsdMaxWorkerThreads A2 = nsdMinWorkerThreads A3 = K * nsdThreadsPerDisk K = number of LUNs per NSD server

## GPFS Management and Overhead Functions

- Metanode
- Configuration Manager
  - AKA "cluster configuration manager"
- Cluster Manager
- Manager Nodes
  - File System Managers
    - File system configuration
    - Manage disk space allocation
    - Quota management
    - Security services Token Managers
- Quorum Nodes

# Metanode

- (one per file) collects file size, mtime/atime, and indirect block updates from other nodes
- is elected dynamically and can move dynamically
- Only the metanode reads & writes inode and indirect blocks
- Merges inode updates by keeping largest file size and latest mtime
- Does Synchronization
  - Shared write lock allows concurrent updates to file size and mtime.
  - Operations that require exact file size/mtime (e.g., stat) conflict with the shared write locks.
  - Operations that may decrease file size or mtime

## Configuration Manager

- There is a primary and backup configuration manager per GPF Scluster
  - Specified when the cluster is created using mmcrcluster
  - Common practice
    - assign to manager nodes and/or NSD servers.
  - Function
    - Maintains the GPFS configuration file /var/mmfs/gen/mmsdrfs on all nodes in the GPFS cluster.This configuration file can not be updated unless both the primary and backup configuration managers are functioning.
  - Minimal overhead

## Cluster Manager

- There is one cluster manager per GPFS cluster
- Selected by election from the set of quorum nodes
  - can be changed using mmchmgr
- Functions
  - Monitors disk leases (*i.e., "heartbeat"*)
  - *Detects failures and directs recovery within a GPFS cluster*
  - *determines whether quorum exists*
    - *This guarantees that a consistent token management domain exists; if communication were lost between nodes without this rule, the cluster would become partitioned and the partition without a token manager would launch another token management domain (i.e., "split brain")*
  - *Manages communications with remote clusters*
    - *distributes certain configuration changes to remote clusters*
    - *handles GID/UID mapping requests from remote clusters*
  - *Selects the file system manager node*
    - *by default, it is chosen from the set of designated manager nodes*
    - *choice can be overridden using mmchmgr or mmchconfig commands*

# Cluster manager (2)
## network considerations

- Heartbeat network traffic is light and packets are small
  - default heartbeat rate = 1 disk lease / 30 sec per node
  - cluster manager for a 4000 node cluster receives 133 disk leases per second
- But network congestion **must not be allowed** to interfere with the heartbeat
  - by default, disk lease lasts 35 sec, but a node has last 5 sec to renew lease
  - best practice: assign to a lightly used or dedicated node in clusters over 1000 nodes

## Manager Nodes

- Designating manager nodes
  - They are specified when a cluster is created (using mmcrcluster)
    - can be changed using mmchnode
  - Can specify up to 128 manager nodes
    - If not specified, GPFS selects 1 node to be a combined file system and token manager node.
- Function
  - File system managers
  - Token managers
- Best practices
  - smaller clusters (less than 1000 nodes):
    - commonly overlaped with NSD servers and/or quorum nodes
  - larger clusters (more than 1000 nodes):
    - assign to lightly used or dedicated nodes do not overlap with NSD servers

## File System Managers

- There is exactly one file system manager per file system
  - File system managers are uniformly distributed over manager nodes
    - A file system manager never spans more than 1 node, but if there are more file systems than manager nodes, there will be multiple file system managers per manager node.
  - Choice can be overridden by mmchmgr command
    - any node can be chosen (*n.b., it does not have to be a manager node)*
- File system manager functions (see next slide)
- Low overhead

# File system manager functions

- file system configuration
  - adding disks
  - changing disk availability
  - repairing the file system
  - mount/umount processing (this is also done the node requesting the operation)
- disk space allocation management
  - controls which regions of each disk are allocated to each node (striping management)
- quota management
  - enforces quotas if it has been enabled (see mmcrfs and mmchfs commands)
  - allocates disk blocks to nodes writing to the file system
  - generally more disk blocks are allocated than requested to reduce need for frequent requests
- security services
  - see manual for details
  - some differences *appear to exist between AIX and Linux based systems*

# Token Managers

- Token managers run on manager nodes
  - GPFS selects some number of manager nodes to run token managers
    - GPFS will only use manager nodes for token managers
    - the number of manager nodes selected is based on the number of GPFS client nodes
  - Token state for each file system is uniformly distributed over the selected manager nodes
    - there is 1 token manager per mounted file system on each selected manager node
  - 1 manager node can process >= 500,000 "tokens" using default settings
    - In this context, a token is a set of several tokens ~= 600 bytes on average.
    - total number of tokens = number of nodes * (maxFilesToCache + maxStatCache) + all currently open files
    - If the selected manager nodes can not hold all of the tokens, GPFS will revoke unused tokens, but if that does not work, the token manager will generate an ENOMEM error. (This usually happens when not enough manager nodes were desigинated.)

## Token Managers

- Overhead
  - CPU usage is light
  - Memory usage is light to moderate
    - *(e.g., at most 512 MB by default) can be changed using* `mmchconfig tokenMemLimit=<value>`
  - *Message traffic is variable, but not excessive. It is characterized by many small packets*
    - *If network congestion impedes token traffic, performance will be compromised, but it will not cause instability.*
    - *If NSD servers and GPFS clients are also used for token management, large block transfers (e.g., >= 512 KB)* may impede token messages.
      - If these issues are impeding token response, chances are good that users will never notice.

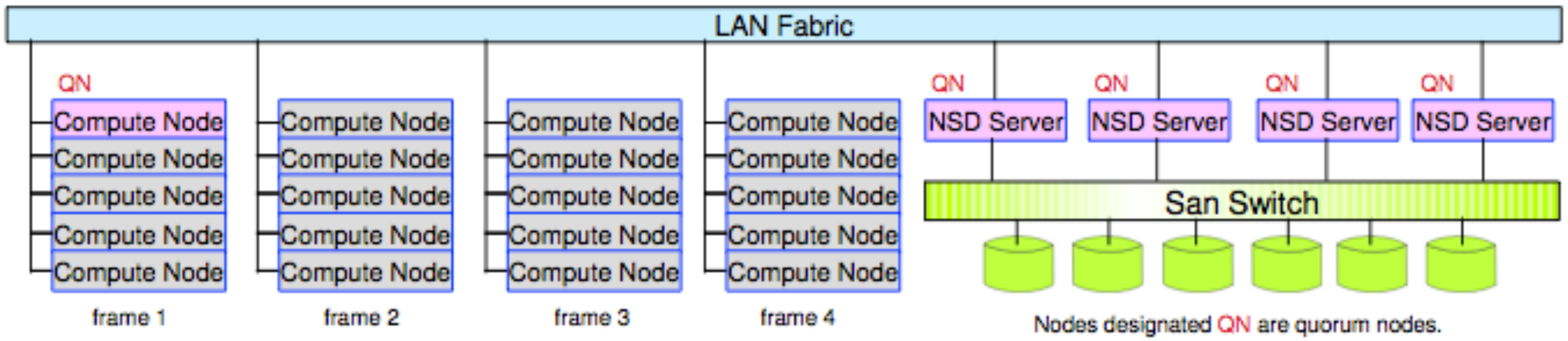
## Quorum

- Problem
  - If a key resource fails (*e.g., cluster manager or token manager) GPFS will spawn a new one to take over. But if the other one is not truly dead (e.g., network failure), this could create 2 independent resources and corrupt the file system.*
- *Solution*
  - *Quorum must be maintained to recover failing nodes.*
  - *2 options*
    - *Node quorum (default): must have at least 3 quorum nodes*
    - *Node quorum with tiebreaker disks: used in 1 or 2 node clusters*

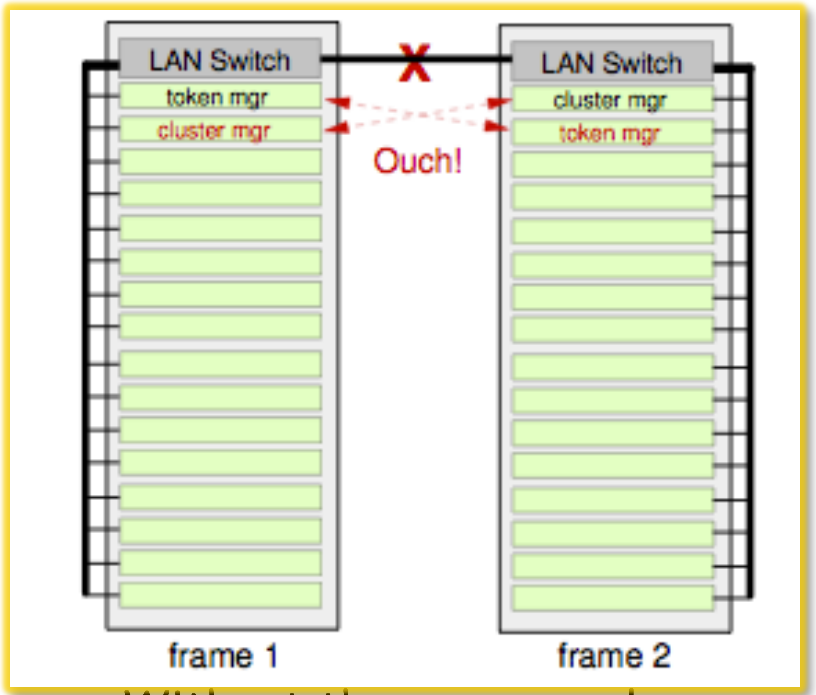
# Quorum

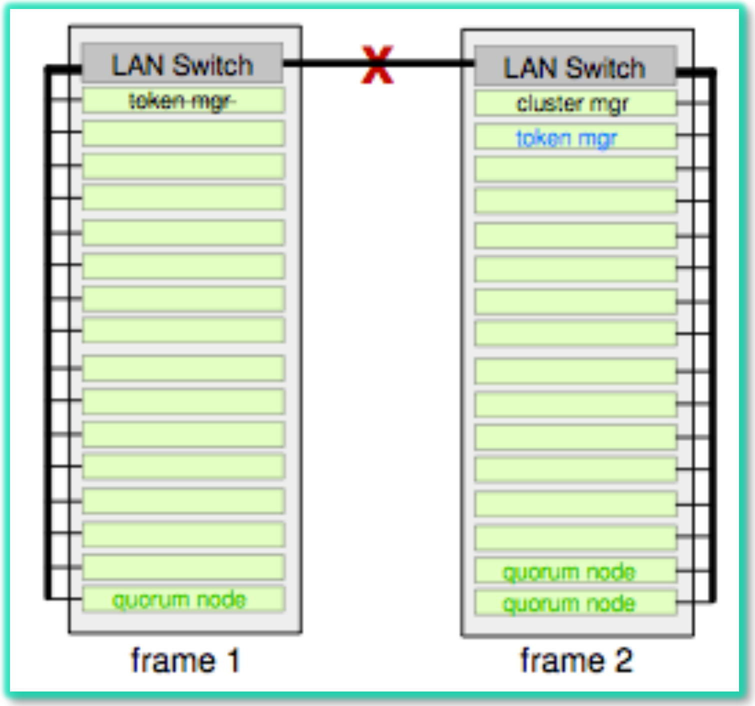
- Node quorum is defined as one plus half of the explicitly defined quorum nodes in the GPFS cluster. There are no default quorum nodes. The smallest node quorum is 3 nodes.
- Selecting quorum nodes: best practices
  - Select nodes most adapted to remain active
  - Select nodes that rely on different failure points
    - example: select nodes in different racks or on different power panels.
  - In smaller clusters (*e.g., < 1000 nodes) select administrative nodes*
    - *common examples: NSD servers, login nodes*
  - *In large clusters, either select dedicated nodes or overlap with manager nodes.*
    - *do not overlap with NSD servers*
  - *Select an odd number of nodes (e.g., 3, 5, or 7 nodes)*
    - *More than 7 nodes is not necessary; it increases failiure recovery time without increasing availability.*

# Quorum


LAN Fabric
QN
Compute Node
Compute Node
Compute Node
Compute Node
Compute Node
frame 1
Compute Node
Compute Node
Compute Node
Compute Node
Compute Node
frame 2
Compute Node
Compute Node
Compute Node
Compute Node
Compute Node
frame 3
Compute Node
Compute Node
Compute Node
Compute Node
Compute Node
frame 4
QN
NSD Server
QN
NSD Server
QN
NSD Server
QN
NSD Server
San Switch
Nodes designated QN are quorum nodes.

# Split brain

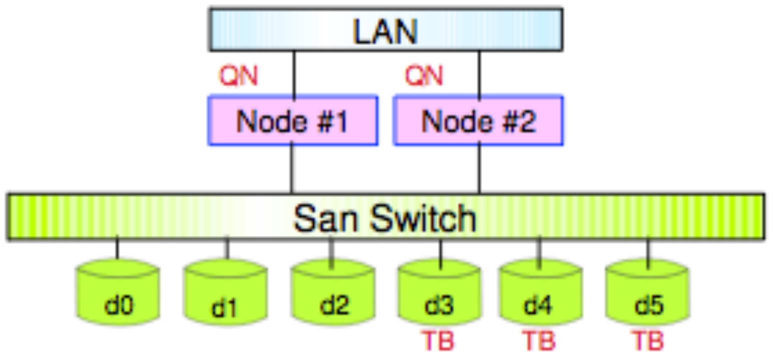




- Without the quorum rule:
  - frame 1 could start an independent cluster manager
  - frame 2 could start an independent token manager
- file system would be corrupted!

## Node Quorum with Tiebreaker Disks

- Node quorum with tiebreaker disks runs with as little as **one quorum node** available so long as there is access to a ***majority of the quorum disks***.
- there can be a maximum of only 2 quorum nodes
- the number of non-quorum nodes is unlimited (can be as small as zero)
- there can be 1 to 3 tiebreaker disks (n.b., odd number of disks is best)
  - tiebreakers disks must be directly accessible from the quorum nodes, but do not have to belong to any particular file system
  - must have a cluster-wide NSD name as defined through the mmcrnsd command
  - tiebreaker disks must be SAN attached (FC or IP) or VSDs
- same rules apply in selecting quorum nodes for both quorum options
- select quorum nodes with mmcrcluster or mmchconfig commands
- select tiebreaker disks with mmchconfig command



Nodes designated QN are quorum nodes
Disks designated TB are tiebreaker disks

## Installation

## Very simple (3 steps)

- Install Base version 3.5.0-0 provided by IBM
  rpm -i

  ```
  gpfs.base-3.5.0-0.x86_64.rpm
  gpfs.docs-3.5.0-0.noarch.rpm
  gpfs.gpl-3.5.0-0.noarch.rpm
  gpfs.msg.en_US-3.5.0-0.noarch.rpm
  ```

- Download and install updates from IBM site
  rpm -U

  ```
  gpfs.base-3.5.0-13.x86_64.rpm
  gpfs.docs-3.5.0-13.noarch.rpm
  gpfs.gpl-3.5.0-13.noarch.rpm
  gpfs.msg.en_US-3.5.0-13.noarch.rpm
  ```

- Build Linux portability interface
  see /usr/lpp/mmfs/src/README

```
cd /usr/lpp/mmfs/src
make LINUX_DISTRIBUTION=REDHAT_AS_LINUX Autoconfig
make World
make InstallImages
    or build RPM package:
make rpm
```

## Installation (cont.)

- Updates are freely available from official GPFS site
  - Registration required
- *Passwordless access needed from any to any node within cluster (this can be limited to few admin nodes)*
  - *`Rsh` or `Ssh` must be configured accordingly*
- *Dependencies*
  - *`compat-libstdc++33`*
  - *`imake`* `(required for Autoconfig)`
  - *`Rsh, ksh`*
  - *`Kernel-devel`*
- No need to repeat portability layer build on all hosts.
  - Once compiled, copy the binaries (5 kernel modules) to all other nodes (with the same kernel and arch/hardware) or use the RPM package

# Administration

- Consistent with standard Linux file system administration
  - Simple CLI, most commands can be issued from any node in the cluster
  - No Java and graphic libraries dependency
- Extensions for clustering aspects
  - A single command can perform an action across the entire cluster (mmdsh)
- Support for Data Management API (IBM's implementation of X/Open data storage management API)
- Rolling upgrades
  - allow to upgrade individual nodes in the cluster while the file system remains online.
- Quotas management
  - Enable control and monitor file system usage by users and groups across the cluster
- Snapshot function
  - Can be used to preserve the file system's contents at a single point in time
- SNMP interface

# Where GPFS lives?

- **Some useful GPFS directories**
  - /usr/lpp/mmfs
    - /bin... commands (binary and scripts)
      - most GPFS commands begin with "mm"
    - /gpfsdocs... pdf and html versions of basic GPFS documents
    - /include... include files for GPFS specific APIs, etc.
    - /lib... GPFS libraries (*e.g.*, libgpfs.a, libdmapi.a)
    - /samples... sample scripts, benchmark codes, etc.
  - /var/adm/ras
    - error logs
      - files... mmfs.log.<time stamp>.<hostname> (new log every time GPFS restarted)
      - links... mmfs.log.latest, mmfs.log.previous
  - /tmp/mmfs
    - used for GPFS dumps
    - sysadm must create this directory
    - see **mmconfig** and **mmchconfig**
  - /var/mmfs
    - GPFS configuration files
  - same directory structure for both AIX and Linux systems
- Almost all GPFS commands starts with “mm”

Add it to your PATH

The first place to look in case of problems

Main cluster configuration (must be the same on all nodes)

## Basic commands

GPFS provides a number of commands needed to create cluster and the file system.

These commands require root authority to execute.

- "`mmcrcluster`" - run once
- "`mmchlicense`" - define type of license (client, server, FPO)
- "`mmstartup`" - start node (-N) or cluster (-a)
- "`mmgetstate`" - show node (-N) or cluster (-a) status
- "`mmlsconfig`" - show configuration parameters
- Before issuing any command check man pages
- Keep an eye on GPFS log: "`/var/adm/ras /mmfs.log.latest`"

## Today's trivia question:

Question: What does `mmfs` stand for?

Answer: **Multi-Media File System**… predecessor to GPFS in the research lab

Second question: But some low-level GPFS commands starts with "`ts`", what does it mean?

Answer: It referenced to earlier research project "**Tiger Shark**" (1993, IBM's lab)

## Example: creating GPFS Cluster

- **mmcrcluster** - Creates a GPFS cluster from a set of nodes.

```
>mmcrcluster -N gpfs.nodelist \
             -p c1-serv1 \
             -s c1-serv2 \
             -r /usr/bin/ssh \
             -R /usr/bin/scp \
             -C c1.openlab.infn.it \
             -U openlab.infn.it
>
>cat gpfs.nodelist
C1-serv1:quorum-manager
C2-serv2:quorum-manager
C3-serv3:quorum
```

Primary config Server
Secondary config server
Remote shell command
Remote copy command
Cluster name
Domain name

# Startup and shutdown

- Before you start cluster define license for each node:

```
[root] mmchlicense server –accept –N gpfs.nodelist
```

- **mmstartup and mmshutdown**
  - startup and shutdown the **mmfsd** daemons
  - if necessary, mount file system after running **mmstartup**
    - properly configured, mmfsd will startup automatically (n.b., no need to run **mmstartup**); if it can not start for some reason, you will see **runmmfs** running and a lot of messages in /var/adm/ras/mmfs.log.latest
  - mmgetstate - displays the state of the GPFS daemon on one or more nodes:

```
[root@gpfs-01-01 ~]# mmgetstate -a

 Node number  Node name        GPFS state
------------------------------------------
       1      gpfs-01-01       active
       2      gpfs-01-02       active
       3      gpfs-01-03       active
       4      TSM-TEST-1       active
```

## GPFS FAQs

- Common GPFS FAQs
  - http://publib.boulder.ibm.com/infocenter/clresctr/vxrx/topic/com.ibm.cluster.gpfs.doc/gpfsbooks.html
- GPFS user forum:
  - **https://www.ibm.com/developerworks/community/forums/html/forum?id=11111111-0000-0000-0000-000000000479**
- GPFS public WIKI:
  - **https://www.ibm.com/developerworks/community/wikis/home?lang=en#!/wiki/General%20Parallel%20File%20System%20%28GPFS%29/page/GPFS%20Wiki**
- COMMENT
  - These web pages are very helpful documents on GPFS.
  - The GPFS development team keeps them relatively up to date.

## Comments on Selected GPFS Manuals in

- GPFS Documentation
  - **Concepts, Planning and Installation Guide**
    - One of the most helpful manuals on GPFS... it provides an excellent conceptual overview of GPFS.
    - If this were a university class, this manual would be your assigned reading. :->
  - **Administration and Programming Reference**
    - Documents GPFS related administrative procedures and commands as well as an API guide for GPFS extensions to the POSIX API. The command reference is identical to man pages.
  - **Problem Determination Guide**
    - Many times, GPFS error messages in the mmfs.log files have an error number. You can generally find these referenced in this guide with a brief explanation regarding the cause of the message. They will often point to likely earlier error messages helping you to find the cause of the problem as opposed to its symptom.
  - **Data Management API Guide**
- Documentation available online at...
  - http://publib.boulder.ibm.com/infocenter/clresctr/vxrx/index.jsp
  - Available with the GPFS SW distribution in `/usr/lpp/mmfs/gpfsdocs`
    - note to sysadm's... Be sure to install this directory! **Also install the man pages!**
- IBM Redbooks and Redpapers
  - **http://w3.itso.ibm.com/...** do a search on GPFS

# Acknowledgements

Materials used in this presentation, along with presenter's own experience, have been mainly obtained from the following sources:

- **"GPFS Best Practices Programming, Configuration, Environment and Performance Perspectives"** by Raymond L. Paden, Deep Computing, IBM, 2010
- **"An Introduction to GPFS Version 3.5"** by Scott Fadden, IBM Corporation, 2012
- IBM Cluster Information Center Website: http://publib.boulder.ibm.com

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