NFS Version 4.1

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Contents

- Comparison of NFSv3 and NFSv4.0
- NFSv4.1 Fixes and Improvements
  - ACLs
  - Delegation Management
  - Opens
  - Asynchronous Blocking Locks
  - Callbacks
- NFSv4.1 New Features
  - Sessions
  - Trunking
  - pNFS
  - Directory Delegations and Notifications
  - Non-regular file delegations
  - Global Namespace
- Status
- After NFSv4.1
- Links

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Comparison of NFSv3 and NFSv4

NFSv3

- A collection of protocols (file access, mount, lock, status)
- Stateless
- UNIX-centric, but seen in Windows too
- Deployed with weak authentication
- 32 bit numeric uids/gids
- Ad-hoc caching
- UNIX permissions
- Works over UDP, TCP
- Needs a-priori agreement on character sets

NFSv4

- One protocol to a single port (2049)
- Lease-based state
- Supports UNIX and Windows file semantics
- Mandates strong authentication
- String-based
- Formal handshake
- Windows-like access
- Bans UDP
- Uses universal character set for file names

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Access Control Lists (ACLs)

- NFSv4.0 ACLs are derived from Windows 2000
- NFSv4.1 ACLs add better (read: Windows-like) support for ACL inheritance
- Like Windows, NFSv4.1 ACLs now explicitly separate "discretionary" ACL (dACL) on a file from its "security" ACL (sACL)
  - dACL: ALLOW/DENY Access Control Entries (ACEs)
  - sACL: AUDIT/ALARM ACEs

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Delegation Management

- Delegation Re-Acquisition
  - NFSv4.0 tied delegations to OPEN
  - Only by polling via another OPEN could a client re-acquire delegation
  - NFSv4.1 adds a separate WANT_DELEGATION operation to allow a delegation to be "pushed" to a client via a callback
- Delegation recall
  - Often a server wants to recall delegations due to general resource constraints
  - Server has no idea which delegations to recall
  - NFSv4.1 add a callback that asks the client to retain up to N delegations and return the rest

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Opens

- Parallel Opens
  - NFSv4.0 requires a given "open owner" to serialize all OPENs on the same file
  - NFSv4.1 allows parallel OPEN, and includes a generation number to indicate which OPEN was executed last
- Open By Filehandle
  - NFSv4.0: Except for recovery, OPENs done by name only
  - NFSv4.1: Steady State OPENs can use filehandles
    - Enables proxies (e.g. cache appliances), thinner clients

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Asynchronous Blocking Locks

- NFSv4.0 requires client to poll for a blocking byte range lock
- NFSv4.1 adds a notification callback to indicate when a lock is available

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Callbacks

- NFSv4.0 requires callback to recall delegations
  - A separate connection path was used
  - Not firewall friendly
- NFSv4.1 requires clients to create connections and hand them to servers to be used for callbacks

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Sessions

- NFSv[2,3,4.0] do not support exactly once semantics
  - Approximated with the reply cache that has indefinite size
- Approximation drawbacks:
  - Unbounded size makes persistence across failover and reboot impractical
  - Prone to cache misses
  - Prone to false positives
    - Bad clients
    - Reply caches that are too big

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Sessions (continued)

- NFSv4.1 achieves exactly once semantics via a "slot table"
- Slot table created when session created
- Specific number of slots
- NFSv4.0 requests consist of a list of operations in the COMPOUND request
  - NFSv4.1 mandates each COMPOUND start with SEQUENCE operation that carries a slot number and a sequence number (per slot)
- Each slot corresponds to a request in progress or a completed request
- Each request is either a retry of the last executed request, or a new request with a sequence number exactly one higher than previously executed
  - This series OK:
    - SEQUENCE slot 1, seq #2, SEQUENCE slot 1, seq #2, SEQUENCE slot 1, seq #3
  - This series NOT OK:
    - SEQUENCE slot 1, seq #2, SEQUENCE slot 1, seq #4, SEQUENCE slot 1, seq #5

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Sessions – Slot Table Example

slot number	0	1	2	...	29	30	31
sequence number	100	200	150	...	25	125	175
cached reply	SEQ., PUTFH, WRITE	SEQ., PUTFH, RENAME	SEQ., PUTFH, OPEN, GETFH, **GETATTR**	...	SEQ., PUTFH, REMOVE	SEQ., PUTFH, READ	SEQ., PUTFH, LOOKUP

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Sessions Management

- CREATE_SESSION
  - Negotiates the size of the slot table
  - Negotiates persistence of the slot table, enabling true exactly once semantics (EOS) through server reboot
- DESTROY_SESSION
  - Client can indicate explicitly when it non longer needs a session (e.g. when unmounting)
- Thus reply cache size and lifetime are bounded

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Trunking

- BIND_CONN_TO_SESSION
  - Allows client to bind additional connections to the session
  - New connections may be to alternate network interfaces of a multi-homed server
- Trunking over multiple sessions also permitted
  - Enables the use of storage clusters where multiple server nodes have paths or replicas to the same data

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Parallel NFS (pNFS)

- pNFS allows servers to stripe data of regular files across multiple storage devices
- A pNFS server consists of:
  - A metadata server (MDS) that implements the full NFSv4.1 protocol
  - One or more storage devices
- A pNFS client is an NFSv4.1 client that is prepared to directly access storage devices
- The pNFS client finds out about storage devices from the MDS via a new LAYOUTGET operation

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pNFS (continued)

- LAYOUTGET returns a layout that describes the striping pattern for a given file
- Layouts are recallable which allows pNFS servers to re-stripe a file if desired or necessary
- Striping patterns can indicate if some or all of a pattern has mirrors
  - Clients are not required to construct mirrors
  - The pNFS offers RAID 0 and RAID 1+0

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pNFS: Types of Storage Devices

- pNFS supports multiple Storage Device types (aka layout types)
- A layout can stripe a file over just one type of device
- The NFSv4 working group currently specifies three types:
  - Files
    - The storage "device" is an NFSv4.1 server
  - Blocks
    - The storage device is an iSCSI or FC target
  - Objects
    - The storage device is an Object Storage Device (OSD) target
- Additional types require a standards-track specification
- If a client does not support a given device type it can issue I/O directly to the MDS

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pNFS: File Layout

- The file layout can work with or without a backing clustered file system
  - pNFS over a clustered file system is more optimal than conventional NFS access to a clustered file system because the client is directed to the optimal node
- The file layout uses the same security model (authentication, authorization, access control) as NFSv4.1

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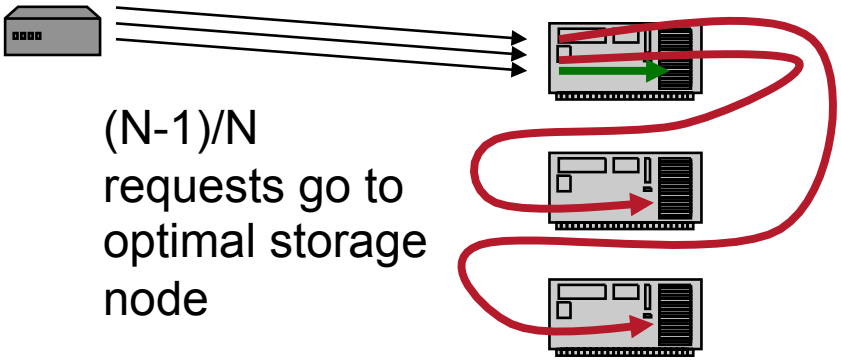
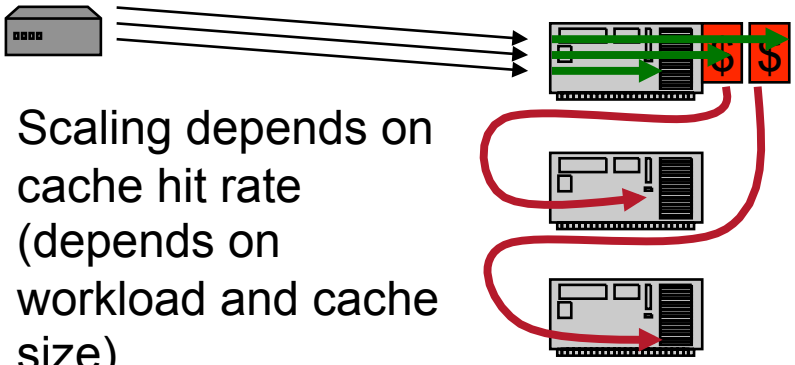
pNFS Optimizes Storage Clusters

"Share Nothing" Architecture w/out pNFS



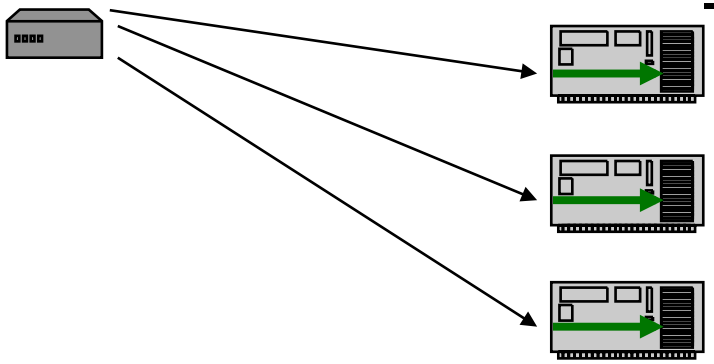
(N-1)/N requests go to optimal storage node

Cache Coherent Architecture w/out pNFS

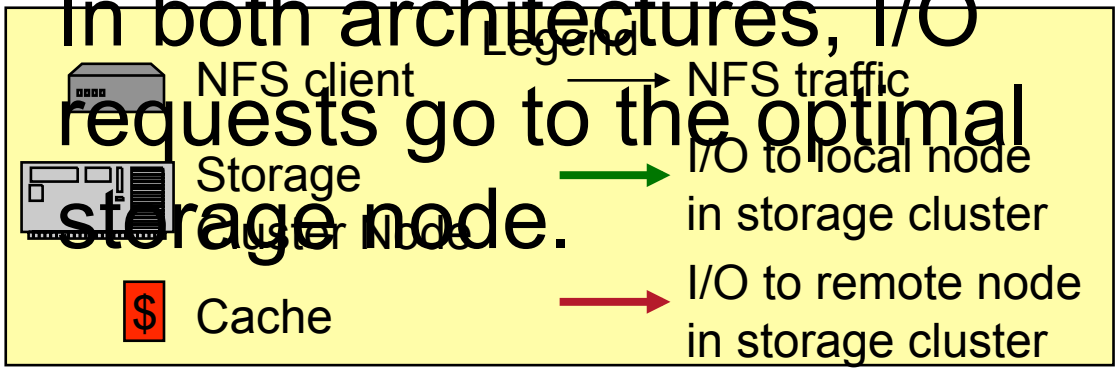


Scaling depends on cache hit rate (depends on workload and cache size)

With pNFS



In both architectures, I/O requests go to the optimal storage node.



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Data Retention

- Intended to be compatible with SNIA XAM API
- Three new attributes:
  - *Retention*: if set, forces a file to be retained for a specified period of time
  - *Retention_event*: like retention for event-based retention
  - *Retention_hold*: bit mask of up to 64 administrative holds
    - If any bit set, file is retained regardless of state of *retention*, *retention_event*

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Directory Delegations and Notifications

- Enabled by new GET_DIR_DELEGATION operation
- Directory Delegations are read-only in NFSv4.1
  - Optimal for workloads where directories are rarely updated
  - Write delegations for directories are difficult because creating entries requires a directory entry offset and a file inode number which only the server can produce
- Directory notifications allow client to be notified of updates to directories
  - Similar to CIFS change/notify
  - Optimal for workloads where directories are updated more frequently
  - Allows server to push changes to name caches versus existing poll model
  - Notifications are asynchronous
    - Designers did not believe synchronous notification would scale
    - Asynchronous model no worse than existing NFS directory caching implementations

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Non-regular file delegations

- The new WANT_DELEGATION operation works on all types of files except directories
- Allows one to cache contents of symbolic links
  - Symbolic links are read-only content so delegations are very apropos

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Global Namespace

- NFSv4.0 has a "referral" feature that allows a server to re-direct a client to another NFSv4.0 server
- NFSv4.1 builds on referrals to produce a more complete definition of multi-server global namespace
  - Defines lock and session state transitions
  - Indicates whether key attributes like inode number survive migration events

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Status of NFSv4.1 RFC

- NFSv4.1 Internet Drafts have moved to IESG review
- Expect RFC to be available at the end of 2008

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After NFSv4.1

- NFSv4 WG will be re-chartered
- Confirmed Items on New Charter
  - Federated File System
- Proposed Items include:
  - Metadata Striping
  - Mandatory Access Control and Labeling
  - Client Aware De-duplication
  - End-to-End Data Integrity
- IETF and the NFSv4 WG are an open and free (like beer) process
  - Now is the time to suggest, persuade, influence, and contribute

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Helpful Links

- NFSv4 working group:
  - www.ietf.org/html.charters/nfsv4-charter.html
- Current Internet Draft
  - tools.ietf.org/wg/nfsv4/draft-ietf-nfsv4-minorversion1
  - blogs.netapp.com/eislers_nfs_blog
  - shepler.blogspot.com

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