pNFS, parallel storage for grid, virtualization and database computing

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Abstract

pNFS, parallel storage for grid, virtualization and database computing

This session will appeal to Virtual Data Center Managers, Database Server administrators, and those that are seeking a fundamental understanding of pNFS. This session will cover the four key reasons to start working with NFSv4 today. Explain the storage layouts for parallel NFS; NFSv4.1 Files, Blocks and T10 OSD Objects. We’ll conclude the session with use cases for database access, enterprise and desktop virtualization, including deduplication options.
Tutorial Agenda

- Introduction to NFS and NFS Special Interest Group
- NFS v4 – Security, High Availability, Internationalization and Performance (SHIP)
- pNFS – Layout Overview
  - Files based access
  - Block based access
  - Object based access
- pNFS – OpenSource Client Status
- pNFS Use Cases – Virtualization, Database, etc
SNIA’s NFS Special Interest Group

- NFS SIG drives adoption and understanding of pNFS across vendors to constituents
  - Marketing, industry adoption, Open Source updates
- NetApp, EMC, Panasas and Sun founders
  - NetApp and Panasas act as co-chairs
- Deliver Panels/Sessions on NFSv4.1 when possible
  - E.g. SNW Europe in October, Super Computing 2009
- Developing (Q3CY09) pNFS 101 document
  - Scale-out paradigm Enterprise and HPC
Network File System
- Protocol to make data stored on file servers available to any computer on a network
- NFS clients are included in all common Operating Systems, e.g. Linux, Solaris, AIX, Windows etc..
- Application and OSI layers (remote procedure calls)

NFS Server; Inspiration to NAS and appliances
- Commodity Operating Systems have NFS servers
- NAS Appliance – Control, Consistency and Cadence
- Vendors offer commodity hardware, w/ management software
### NFSv4 SHIP is sailing

<table>
<thead>
<tr>
<th>Functional</th>
<th>Business Benefit</th>
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<tbody>
<tr>
<td><strong>Security</strong></td>
<td></td>
</tr>
<tr>
<td>ACLs for authorization</td>
<td>Compliance, improved access, storage efficiency</td>
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<tr>
<td>Kerberos for authentication</td>
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<tr>
<td><strong>High availability</strong></td>
<td></td>
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<tr>
<td>Client and server lease management</td>
<td>High Availability, Operations simplicity, cost</td>
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<tr>
<td>with fail over</td>
<td>containment</td>
</tr>
<tr>
<td><strong>International characters</strong></td>
<td></td>
</tr>
<tr>
<td>Unicode support for utf8 characters</td>
<td>Global file system for multinational organizations</td>
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<tr>
<td><strong>Performance</strong></td>
<td></td>
</tr>
<tr>
<td>Multiple read, write, delete</td>
<td>Better network utilization for all NFS clients</td>
</tr>
<tr>
<td>operations per RPC call</td>
<td></td>
</tr>
<tr>
<td>Delegate locks, read and write</td>
<td>Leverage NFS client hardware for better I/O</td>
</tr>
<tr>
<td>procedures to clients</td>
<td></td>
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</tbody>
</table>

Lower costs and increase productivity with NFSv4
NFSv4 - HA and Performance

- **High Availability via Leased Lock**
  - Client renews lease on server file lock @ n Seconds
  - Client fails, lock is not renewed, server releases lock
  - Server fails, on reboot all files locked for n Seconds
    - Gives clients an n Second grace period to reclaim locks

- **Performance via Delegations**
  - File Delegations allow client workloads for single writer and multiple reader
  - Clients can perform all reads/writes in local client cache
  - Delegations are leased and must be renewed
  - Delegations reduce lease lock renewal traffic
The Evolution of Storage

Market Adoption Cycles

Direct-Attached Storage  Networked Storage  Future

2000  2010?  ?

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Evolving Requirements

- Economic Trends
  - Cheap and fast computing clusters
  - Cheap and fast network (GigE to 10GigE)

- Performance
  - Exposes single threaded bottlenecks in applications
  - Evolution of computing models
  - Reduced time to market, response time

- Powerful compute systems
  - Analysis begets more data, at exponential rates
  - Competitive edge (IOPS)
NFS – What’s the problem?

- **In-band data access model**
  - Easy to build, Limited in scale
  - Well-defined failure modes
  - Limited load balancing options

- **Results in Limitations**
  - Islands of storage
  - Server and Appliance HW
  - Networking and I/O
Performance, Management and Reliability

- Random I/O and Metadata intensive workloads
  - Memory and CPU are hot spots
  - Load balancing limited to pair of NFS heads
  - Limited to dual-head configuration

- Compute farms are growing larger in size
  - NFS head can handle a 1000+ NFS clients
  - NFS head hardware comparable to client CPU, I/O, Memory
  - NFS head requires more spindles to distribute the I/O

- Reliability and availability are challenging
  - Data striping limited to single head and disks
  - Non-disruptive upgrades affect dual-head configurations
  - Access and load balancing are typically limited to a pair of NFS server heads
What is the Solution?

Market Adoption Cycles

- Direct-Attached Storage
- Networked Storage
- Scale-Out Storage

NFSv4.1 Parallel NFS

2000
2010
2020
NFSv4.1 – Parallel Data Storage

- NFSv4.1 – Three Storage Types
  - Files – NFSv4.1
  - Blocks – SCSI
  - Objects – OSD T10

- Results in Improvements
  - Global Name Space
  - Head and Storage scaling
  - Non disruptive upgrades while maintaining performance
**pNFS protocol**

- Standardized: NFSv4.1

**Storage-access protocol**

- Files (NFSv4.1)
- Block (iSCSI, FCP)
- Object (OSD2)

**Control protocol**

- Not covered by spec; no generally agreed upon characteristic
pNFS Operations

- **LAYOUTGET**
  - Obtains the data server map from the meta-data server

- **LAYOUTCOMMIT**
  - Servers commit the layout and update the meta-data maps

- **LAYOUTRETURN**
  - Returns the layout; Or the new layout, if the data is modified

- **GETDEVICEINFO**
  - Client gets updated information on a data server in the storage cluster

- **GETDEVICELIST**
  - Clients requests the list of all data servers participating in the storage cluster

- **CB_LAYOUT**
  - Server recalls the data layout from a client; if conflicts are detected
Client and Server
- Support files (NFSv4.1)
- Support in progress blocks (SCSI), objects (OSD T10)
- Client consists of generic pNFS client and “plug ins” for “layout drivers”

Predicted timeline:
- Basic NFSv4.1 features 1H2009
- NFSv4.1 pNFS and layout drivers by 2H2009
- Linux distributions shipping supported pNFS in 2010
NFSv4.1 – OpenSource Status

- Two OpenSource Implementations
  - OpenSolaris and Linux

- OpenSolaris Client and Server
  - Support only file-based layout
  - Support for multi-device striping already present (NFSv4.1 + pNFS)
  - “Simple Policy Engine” for policy-driven layouts also in the gate

- Linux Client and Server
  - Support files (NFSv4.1)
  - Support in progress blocks (SCSI), objects (OSD T10)
  - Client consists of generic pNFS client and “plug ins” for “layout drivers”

- Predicted timeline for Linux:
  - Basic NFSv4.1 features 1H2009
  - NFSv4.1 pNFS and layout drivers by 2H2009
  - Linux distributions shipping supported pNFS in 2010
- Client mounts and opens a file on the server
- Servers grants the open and a file stripe map (layout) to the client
- The client can read/write in parallel directly to the NFSv4.1 data servers

Diagram:
- NFSv4.1 Client(s)
- Mount, Open & Get layout
- File Handle
- R/W Request issued in parallel
- Control protocol
- Metadata Server
- Data Servers
pNFS Blocks Access Model

- Client mounts and opens a file on the server.
- Servers grants the open and a block map (layout) to the client.
- Based on the layout obtained (read or write); the client can read/write in parallel directly to the SCSI target's.
pNFS Objects Access Model

- Client mounts and opens Object
- Servers grants the open and an object stripe map and object capabilities (layout) to the client
- Based on the layout obtained (read or write); the client can read/write in parallel directly to the OSD targets
Traditional HPC Use Cases

- Seismic Data Processing / Geosciences' Applications
- Broadcast & Video Production
- High Performance Streaming Video
- Finite Element Analysis for Modeling & Simulation
- HPC for Simulation & Modeling
- Data Intensive Searching for Computational Infrastructures
Original pNFS use case
- 100’s of hosts to storage
- 16+ Cores in future
- Single NFS Datastore
- Multiple-heads across multiple disks
- Trunking
- Directory/File Delegations

Caveat
- Limit on VMs per LUNs
NFSv4.1 – Virtualized Data Center

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Single NFSv4.1 namespace

Name Space

/  

VM
HV1  HV2

DB
Srv1  Srv2  Srv3

HyperVisor Cluster Nodes

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Single NFSv4.1 datastore

Name Space

/  
VM  DB
HV1  HV2  Srv1  Srv2  Srv3

HyperVisor Cluster Nodes

HV1  Srv1  Srv2
HV2  Srv3
VM Cluster Datastore

Name Space

Cluster Datastore
Mount Server: /

HyperVisor Cluster Nodes

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VMs accessing volume w/layout

VMs accessing volume w/layout

Name Space

/VM/DB

HV1 HV2 Srv1 Srv2 Srv3

HyperVisor Cluster Nodes

HV1 Srv1 Srv2

HV2 Srv3

Cluster Datastore
Mount Server:/

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1. A single connection limits data throughput based on protocol.
2. Trunking expands throughput and can reduce latency by opening multiple sessions to the same file handle/server resource.
   - Host application consumes 10GigE bandwidth.
VM Access using single mount

Name Space

Cluster Datastore
Mount Server:/

HyperVisor Cluster Nodes

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VM access using pNFS + Trunking

Name Space

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Delegations available in NFSv4
- Reduce renewals for locks
- Improve R/W performance
- Remove getattr storms

Set NFS Swap File to SSD/Flash I/O Card, single write read/write delegations allow applications to write through changes but keep most data “delegated” on Flash Swap.
NFSv4.1 – Database enhancements

- Use Ethernet and pNFS infrastructure for VM
- Multiple-heads across multiple disks
- Trunking & Delegations

Diagram:
- Name Space
  - / (Root)
  - VM
    - HV1
    - HV2
  - DB
    - Srv1
    - Srv2
    - Srv3
- HyperVisor Cluster Nodes
  - HV1
  - HV2
  - Srv1
  - Srv2
  - Srv3
- Cluster Datastore
- Mount Server: /

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DB access using pNFS + Trunking

- Multiple-heads across multiple disks
- Trunking enables highest IOPS and lowest latency
Non-disruptive data moves using storage control protocols

Name Space

HyperVisor Cluster Nodes

DB (Replica)

DB
NFSv4.1 – Virtualized Data Center

Name Space

/  
  /VM  /DB
    /HV1  /HV2  /Srv1  /Srv2  /Srv3  

HyperVisor Cluster Nodes

HV1  HV2
 / Srv1  Srv2  Srv3

Cluster Datastore
Mount Server:/

VM

DB

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Deduplication specification for NFSv4.1

http://tools.ietf.org/id/draft-eisler-nfsv4-pnfs-dedupe-00.txt
Q&A / Feedback

Please send any questions or comments on this presentation to SNIA: tracknetworking@snia.org

Many thanks to the following individuals for their contributions to this tutorial.

- SNIA Education Committee

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NFSv4.1 – Status and Overview

- 2004 – CMU, NetApp and Panasas draft pNFS problem and requirement statements
- 2005 – CITI, EMC, NetApp and Panasas draft pNFS extensions to NFS
- 2005 – NetApp and Sun demonstrate pNFS at Connectathon
- 2005 – pNFS added to NFSv4.1 draft
- 2006 – 2008 – specification baked
  - Bake/Connect a thons; 29 iterations of NFSv4.1/pNFS spec
- 2008 – NFSv4.1/pNFS reaches IETF Approval (December)
pNFS Standards Status

- NFSv4.1/pNFS were standardized at IETF
  - NFSv4 working group (WG)
- All done except for RFCs:
  - WG last call (DONE)
  - Area Director review (DONE)
  - IETF last call (DONE)
  - IESG approval for publication (DONE)
  - IANA review (TBD)
  - RFC publication (Expected 2009)
- Will consist of several documents:
  - NFSv4.1/pNFS/file layout
  - NFSv4.1 protocol description for IDL (rpcgen) compiler
  - blocks layout
  - objects layout
  - netid specification for transport protocol independence (IPv4, IPv6, RDMA)