Evaluating Network Attached Storage Units
Benchmarking Strategies for Home Users, SOHOs and SMBs

Ganesh T S

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Sr. Editor @ AnandTech

- 5+ years reviewing multimedia systems, storage and networking products
  - Communicating with NAS vendors - receiving product pitches & marketing collateral
  - Communicating with readers - both power users and SMB IT administrators
  - First-hand view of NAS market evolution and features gaining market traction

- 10+ years as an ASIC verification engineer
- Coverage primarily from an engineering perspective
- UX aspects also noted
Wide variety of NAS units to target different market segments

- RISC-based (ARM / PowerPC) vs. x86
- Price vs. Performance vs. Feature Set
- Underlying file system - XFS, EXT4, btrfs, ZFS

Success dictated by multiple external factors beyond testing results

- Channel presence
- Bundles - hard drives and NAS, networking gear (switches) and NAS etc.
- Word of mouth - reliability and ease of use
Subjective metrics
- Management interface UX
- Quality of mobile app(s)
- Value added services
  - Media server
  - Dropbox-like sync, backup and replication support
  - Extensibility - third-party apps, virtualization / containers
    - Private cloud - Google Docs / MS Office 365 replacement
    - Centralized management

Objective metrics
- Transfer rates, latency, response times
- Power efficiency
- Failure handling
NAS connected to a power measurement device (Ubiquiti Networks mFi mPower Pro)

Operated in a diskless state, followed by initializing of a single-disk volume, shares configuration and population with a few media files

Disks added one by one to test out online RAID migration (from JBOD to RAID-1 to RAID-5)

Collected metrics
  - Power consumption at the wall every second for each operation
  - Time taken for each operation
  - Extent of disruption in streaming of stored media during each operation
Simulating disk failure
- Randomly selected member disk physically pulled out of the NAS during read / write operation
- Ensure no disruption in data access despite physical failure
- Fresh disk plugged in as replacement
- Power consumption / time taken for rebuild process recorded

Evaluating data recovery options when the NAS hardware fails, but disks are OK
- Connect disks to a PC using JBOD DAS
- Use Ubuntu + mdadm or Windows + commercial software like UFS Explorer to access and save data
- Chance for NAS vendors to differentiate
- Benchmarking with the OS file copy utility for various sets of files - subset of a very limited use-case
- Workload generation - single client vs. multi-client with switch
- Workloads - artificial vs. real-world traces
- Options for benchmarking
  - IOMeter, IOZone, fio, Vdbench etc.
  - Load testing tools - Login VSI, hIOmon Disk I/O Ranger
  - Appliances - LoadDynamiX
  - Intel NAS Performance Toolkit (NASPT)
  - SPEC SFS 2014

- Very important to keep storage media consistent across NAS units for benchmark comparisons
Most NAS units marketed with transfer rates, but easy to saturate network links with appropriate artificial workload traces

Increasing prevalence of multiple clients (streaming devices, IP cameras etc.)

Only high-end SMB NAS units marketed with IOPS numbers - not easy to convey importance to home users

Many workloads run out of IOPS long before bandwidth saturates - storage media is important
Focus on evaluation of CIFS, NFS and iSCSI features across different client platforms

Used only Intel NASPT in the early days
- Evaluates CIFS and iSCSI single client performance for real-life workloads
- Supplied traces include video streaming, recording, office productivity, photo album viewing etc.
- Determining performance penalties for encrypted volumes / shares

NFS evaluation using IOZone and a CentOS client

Unfortunately, not great choices for multi-client scenarios and business workloads
Moved to multi-client testing in late 2012.

- Testbed hardware - 2P Xeon-based system with 6x (1Gbps x 4) PCIe network adapters
- Switch configuration depending on solution under test
Transfer rates and latencies from IOMeter with artificial workloads for benchmarking

- Max. Throughput (Sequential) - 100% Reads
- Max. Throughput (Sequential) - 50% Reads
- Random 8K - 70% Reads
- Real Life - 60% Random, 65% Reads

Benchmark numbers difficult for end-users to relate to

- Doesn’t answer typical end-user questions
  - How many simultaneous videos can the NAS stream out?
  - How many users can work on spreadsheets and documents directly off the NAS simultaneously?
  - How many IP cameras can record to the NAS at the same time reliably?

- New approach based on the concept of business metrics
NAS Performance Toolkit - released by Intel in 2007
- Ships with a library of traces representing home usage scenarios
- Traces replayed on target devices and response times / performance metrics recorded
- Includes visualizer for dissecting results

EOL software, but source code available

Very susceptible to client caching, requires RAM limiting / source code modifications for running on modern systems

Important to ensure client is same across different evaluations
<table>
<thead>
<tr>
<th>Test</th>
<th># files</th>
<th>% seq.</th>
<th>Bytes Rd/Wr</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD Video Play</td>
<td>1</td>
<td>99.5%</td>
<td>2.0GB Rd</td>
<td>256kB reads</td>
</tr>
<tr>
<td>HD Video Record</td>
<td>1</td>
<td>99.9%</td>
<td>2.0 GB Wr</td>
<td>256kB writes</td>
</tr>
<tr>
<td>Directory Copy From NAS</td>
<td>2833</td>
<td>52.5%</td>
<td>0.20 GB Rd</td>
<td>64kB reads</td>
</tr>
<tr>
<td>Directory Copy To NAS</td>
<td>2833</td>
<td>52.5%</td>
<td>70B Rd</td>
<td>Predominantly 64kB writes, wide scattering under 16kB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.25GB Wr</td>
<td></td>
</tr>
<tr>
<td>File Copy From NAS</td>
<td>1</td>
<td>100%</td>
<td>4.3GB Rd</td>
<td>64kB reads</td>
</tr>
<tr>
<td>File Copy To NAS</td>
<td>1</td>
<td>100%</td>
<td>4.3GB Wr</td>
<td>64kB writes</td>
</tr>
<tr>
<td>Photo Album</td>
<td>169</td>
<td>80%</td>
<td>0.81GB</td>
<td>All reads – wide distribution of sizes</td>
</tr>
<tr>
<td>Office Productivity</td>
<td>607</td>
<td>81.3%</td>
<td>1.4GB Rd</td>
<td>Reads &amp; writes; small, 1kB &amp; 4kB reads; Mostly 1kB writes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.4GB Wr</td>
<td></td>
</tr>
<tr>
<td>Content Creation</td>
<td>98</td>
<td>38.6%</td>
<td>12MB Rd</td>
<td>95% writes; 1k, 4k &amp; little reads; Writes up to 64kB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14MB Wr</td>
<td></td>
</tr>
</tbody>
</table>

Additional workloads (extensions of the above) available . . .
Focus of NASPT on single-user performance, workload traces are a bit dated

Trace replay component is still a valuable resource

Taking advantage of NASPT for multi-client scenarios
- Reuse existing workload traces and trace replay program
- Add wrapper to farm out and synchronize across multiple clients
- Run each workload on multiple clients simultaneously

Determine number of clients that can provide acceptable performance
- Failure to scale throughput linearly without saturating link
- Sudden spike in average response times
Netgear ReadyNAS RN202 - Folder Copy from NAS

Multi-Client NASPT Benchmark - Transfer Rates / Response Times vs. Number of Clients

- Red: Transfer Rate
- Green: Read Response
- Blue: Write Response
Standard Performance Evaluation Corporation SFS Benchmark

- SPEC benchmarks - long-standing, accepted industry-wide
- SFS (Solution File Server) benchmarks since 1993 - initially NFS-only
- SPEC SFS 2014 - multi-platform / CIFS & NFS evaluation
- Benchmark binaries & source (based on IOZone) licensed from SPEC
- Workloads beased on real-world application traces, measures quality of service
- Simulates multi-client workloads, records op rate, throughput and response times
Real-life Workload Traces

- **Video Data Acquisition (IP cameras)**
  - VDA1 - high bitrate sequential writes
  - VDA2 - companion applications / user access

- **Virtual Desktop Infrastructure (hypervisors)**
  - VDI - data-heavy workload, direct I/O, compressible large files

- **Software Build (software project compilation)**
  - SWBUILD - reads & writes to 573K highly compressible files

- **Database (OLTP database consolidation scenario)**
  - DB_TABLE - Random reads & writes to same dataset from multiple threads
  - DB_LOG - Mostly sequential writes
Metrics collected in each load run
- Average latency
- Per-process operate
- Read and write throughputs

Final results measured in business metrics
- VDA: Number of concurrent STREAMS
- VDI: Number of concurrent DESKTOPS
- SWBUILD: Number of concurrent BUILDS
- DB: Number of concurrent DATABASES

Success criteria at each load point
- Per-process operate
- Overall operate
- Component workload variance

Publishable results require success with at least 10 load points
Most small-scale NAS units with 7200 RPM SATA drives fail operate criteria
Software investigation
- Reduce caching impacts / force direct I/O in NASPT
- Generate new NASPT traces for contemporary workloads
- Formalise *metrics* determination for NASPT workloads
- Investigate / minimize hypervisor effects on performance
- Move to Windows 8+ VMs for SMB 3.x testing

Hardware upgrades
- Residential lab setting - always looking to drive down power and noise
- Increase number of virtual machines - looking at Xeon-D based systems with a 10G switch

Monitor feedback from NAS vendors and readers
Further Reading

- Intel NASPT - User Guides, Whitepaper, IDF Presentation
- SPEC SFS 2014 Benchmark Home Page
- AnandTech NAS Coverage - News & Reviews
Q & A
Thank You!