LHC Data Analysis Using NFSv4.1 (pNFS):

A Detailed Evaluation

-Short introduction into dCache and NFSv4.1 (pNFS)

-First simple tests

-ATLAS HammerCloud

-CMS Analysis

-Reading ROOT files

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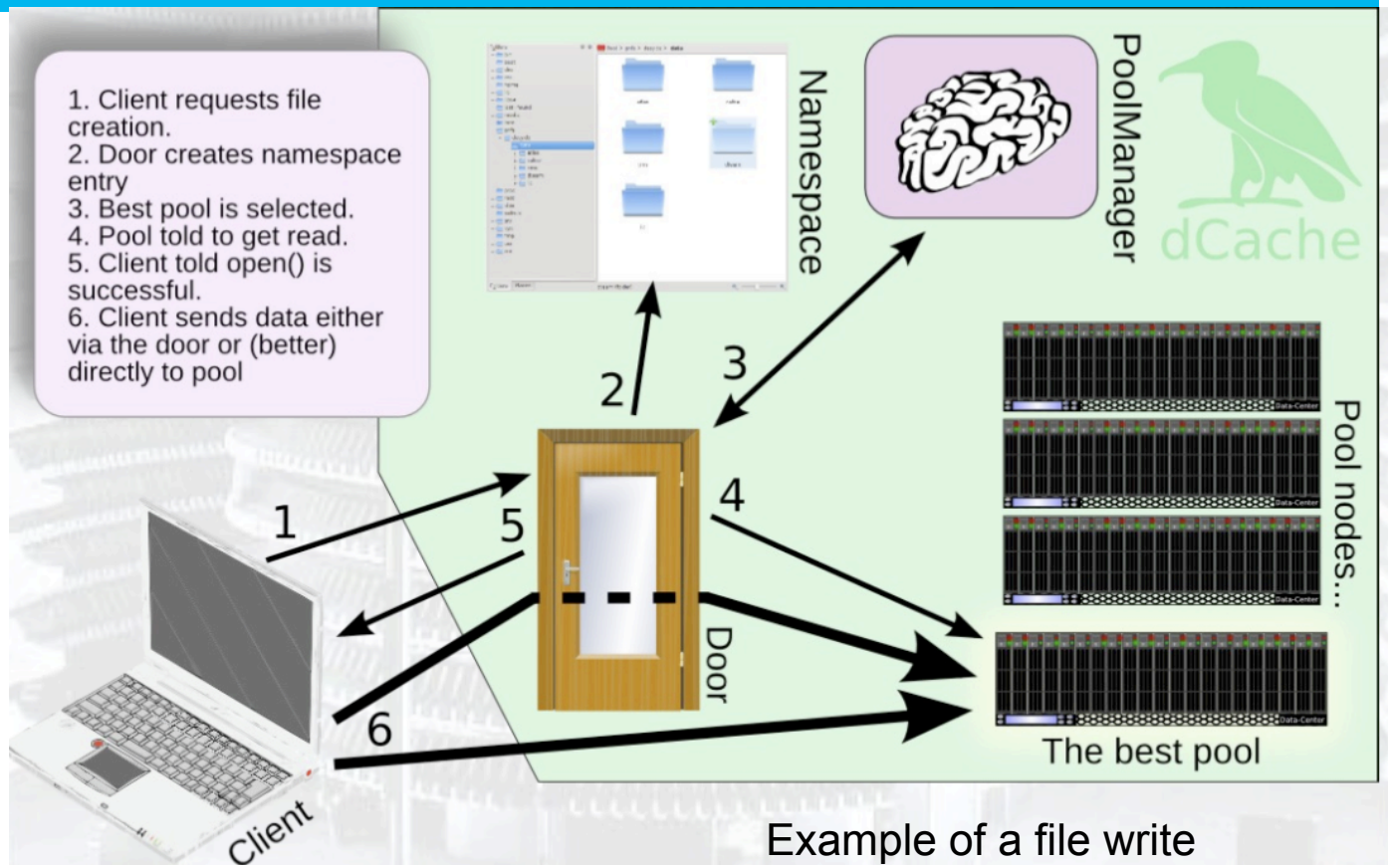
dCache in a nutshell

- Storage system, developed at DESY, FNAL and NDGF
- Objects stored: Files
- Files in pools, pools on poolnodes, many of them
- Client connects to a door, which speaks the desired protocol
- At the end the file is transferred directly between pool and client



Example of a file write

In reality a little bit more complicated
Many talks and posters around dCache at CHEP

Check http://www.dcache.org/

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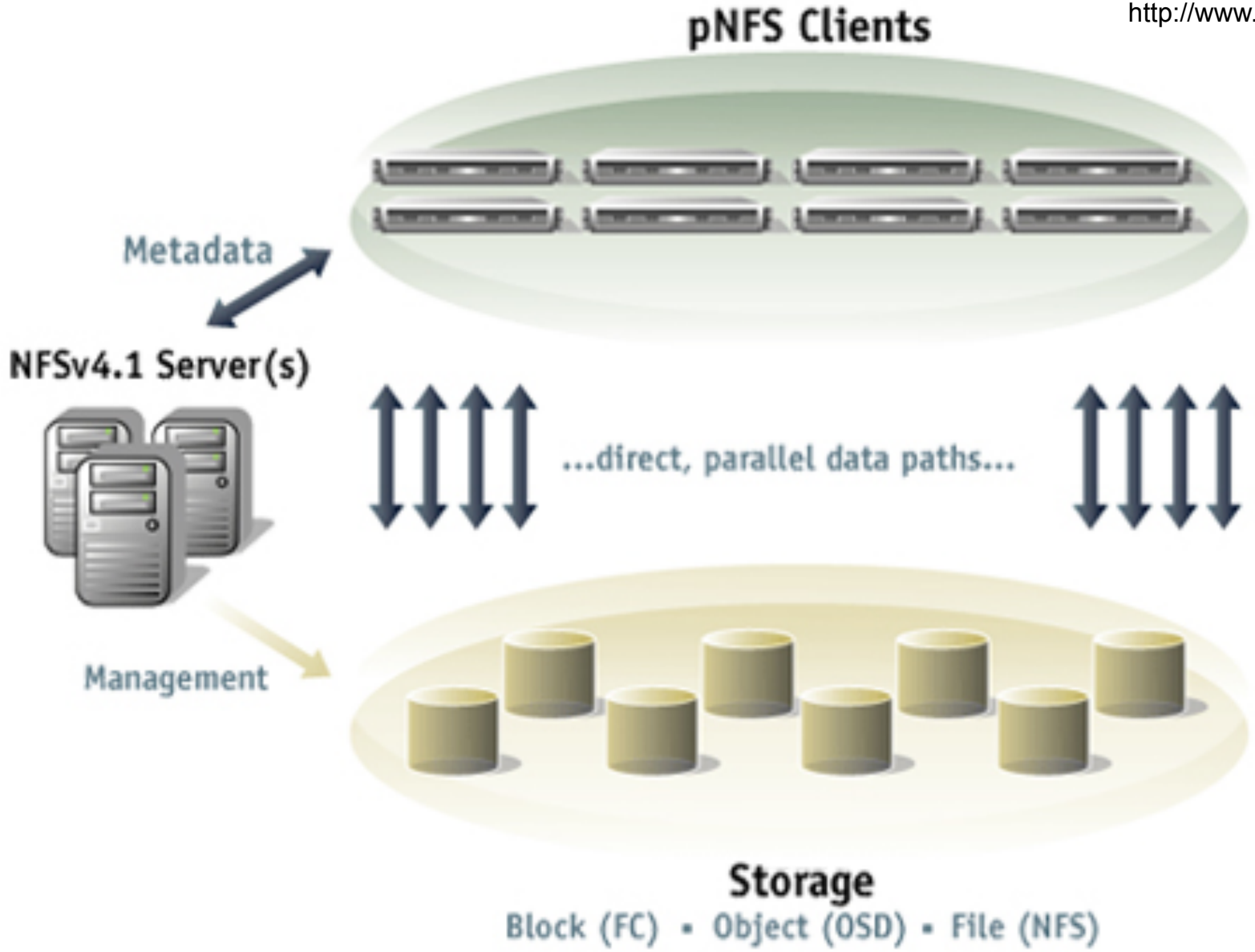
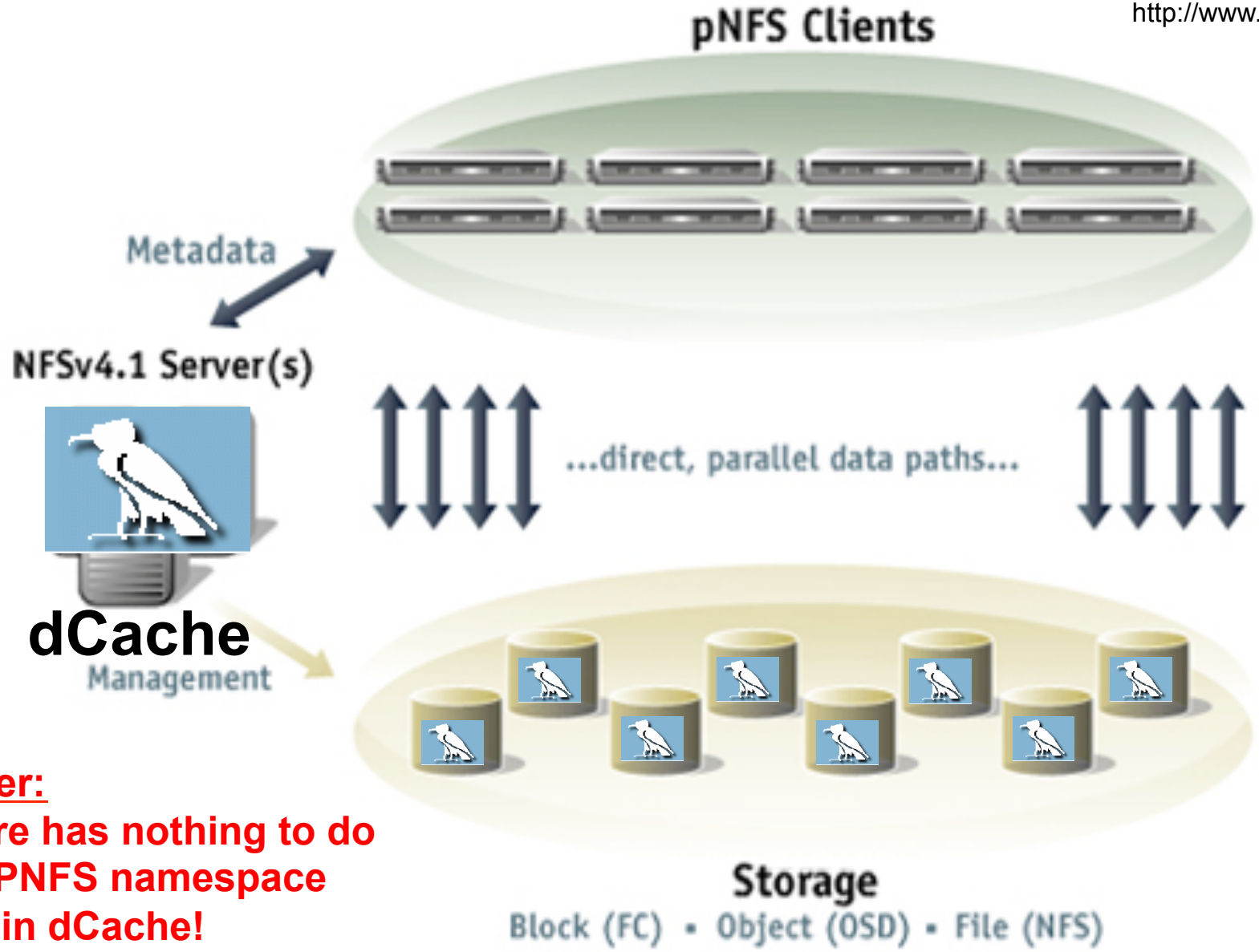
NFS v4.1 / pNFS from the infrastructure view

http://www.pnfs.com/



NFS v4.1 / pNFS from the infrastructure view: adding dCache

http://www.pnfs.com/



Disclaimer:
pNFS here has nothing to do with the PNFS namespace provider in dCache!

… a look from the client side

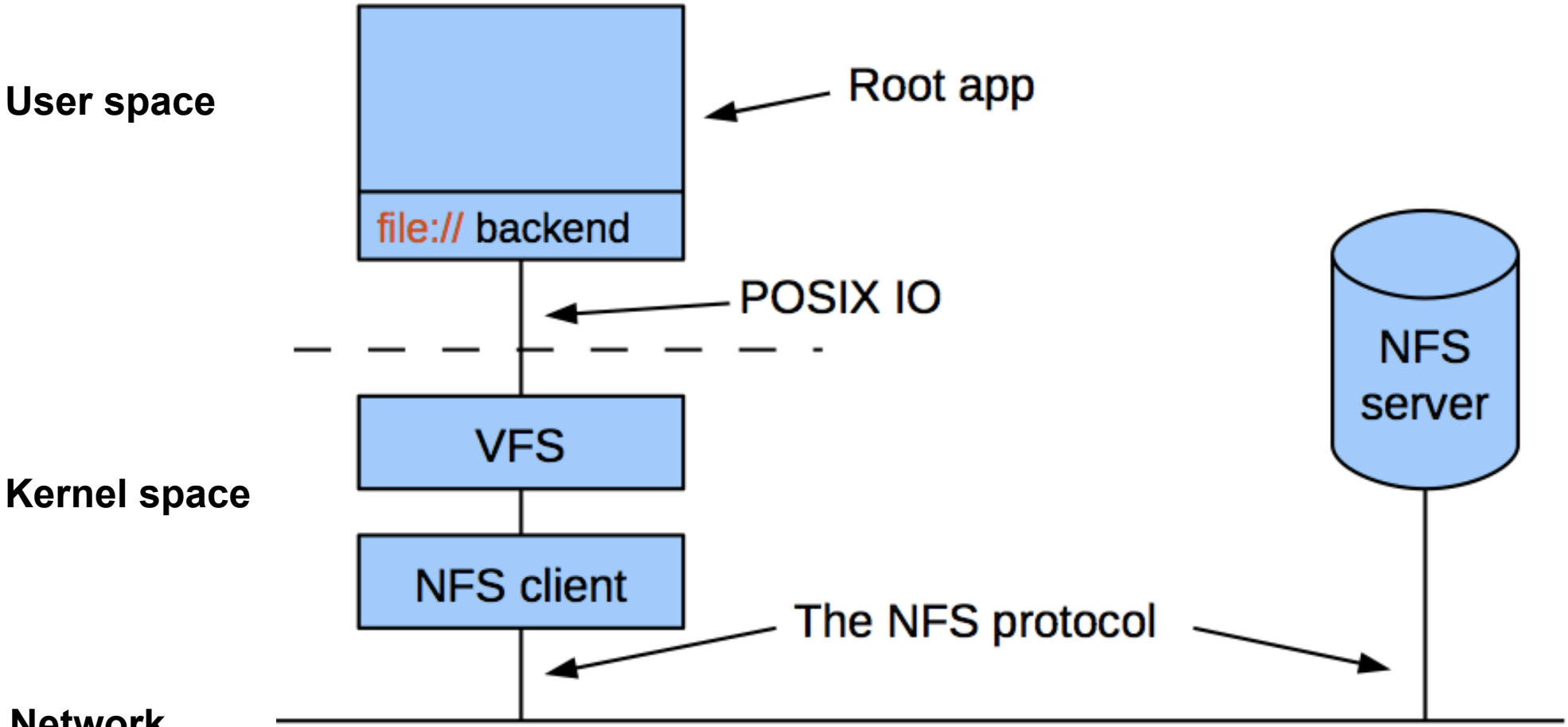


Image stolen from Gerd Behrmann

11 reasons why one should care about NFS 4.1

1) High latency link performance
   - Batching of several components, reducing number of network ops, bidirectional RPC
2) Proper authentication and authorization
   - Kerberos, X509 under investigation, ACL
3) Introduction of sessions with NFS 4.1
   - Decoupling transport from client
4) Parallel NFS (remember the plots to pages before)
5) Standardization: RFC 5661, IETF Proposed Standard
6) Industry backed: NetApp, Microsoft, Panasas, EMC, IBM, …
7) Client availability:
   - Linux (more details later), Solaris available, Windows (U.Michigan)

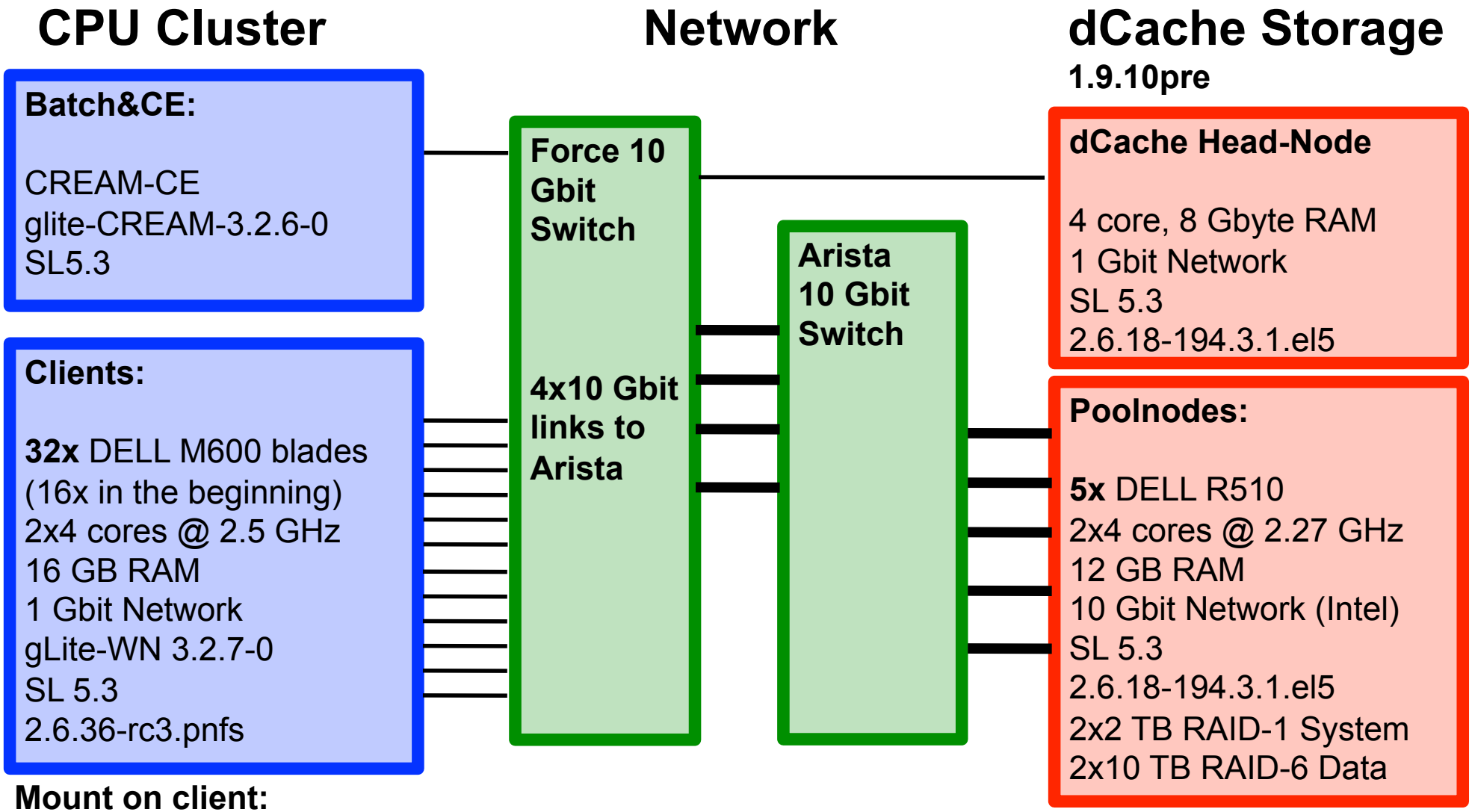
11 reasons why one should care about NFS 4.1 (contd)

8) Server available:
   - NetApp, IBM, Oracle, EMC, IBM,…
   - dCache, DPM in WLCG context
9) Clients provided by industry:
   - Real POSIX IO, caching provided by OS & tuned by experts, no apps modifications
10) Funding secured
   - EMI funds NFS 4.1/pNFS in DPM and dCache, HGF (D) additional funds for dCache
11) Simple migration path
   - Server: No data migration needed, NFSv4.1 (pNFS) is additional protocol
   - Clients: user file:// -> Unifies access for dCache, DPM, GPFS+Storm

OK, and how does the reality look like for HEP applications?

("11 reasons" stolen from Gerd Behrmann)

Evaluation: The testbed in the DESY GridLab



Mount on client:

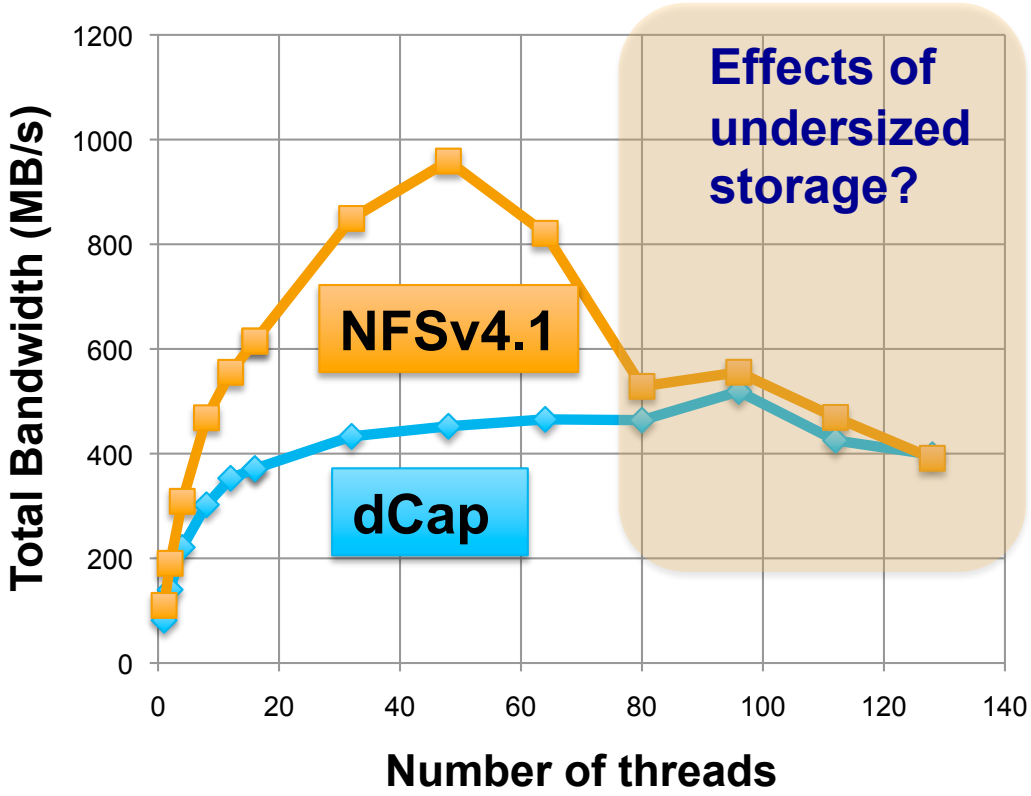
```
dcache-head:/pnfs on /pnfs type nfs4 (rw,minorversion=1,rsize=32768,wsize=32768)
```

What to expect from testbed?

- Maximum BW from server ➔ Clients: 40 Gbit (link between two switches)
- Maximum BW from one pool ➔ Clients (alone): Theoretical 10 Gbit
  - Measured to 5.6 Gbit/s using iperf
- Maximum BW from Disk RAID ➔ local /dev/null
  - Measured between 520 MByte/s (few streams) and ~300 MBytes/s (random read)
- So, maximum bandwidth from Server-Disks ➔ Network ➔ Client /dev/null
  - Something between 1.5 GByte and 2.5 GByte/s
  - 32x1-Gbit clients can saturate this
- CPU ~ ½ Tier-2 whereas Storage ~¼ Tier-2
  - Clients able to really stress the storage system
  - **Storage undersized (on purpose!)**

First simple test

- Simple I/O
  - Reading file to /dev/null
  - No caching (read once, not jumping around in file)
  - A maximum of 128 clients (16 nodes)



- NFS behaves better than dCap up to a certain limit
- We have no definite answer for this effect, suppose congestion on the server
  - Probably due to undersized storage

➔ **Needs further investigation**

Stability tests

- Untaring the Linux Kernel into NFS 4.1 ✔
  - up to 16 parallel jobs (only 16 clients)
  - Works, slowly, but no problems observed with recent kernels
- CFEL Production Transfers from SLAC to DESY ✔
  - 13 TBytes over 10 days
  - 100 GBytes average file size
  - No crash
- High-Latency test: “recursive ls –l” 60k files over DSL from home ✔
  - Slow, but works
- 128 clients simultaneously writing into same file (by mistake) ✖
  - Client nodes got stuck
  - Server OK
- Clients got stuck once during ROOT tests, needed reboot ✖

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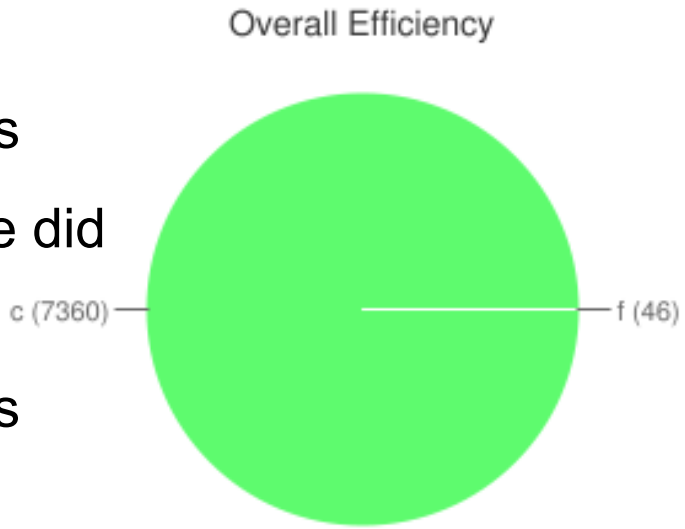
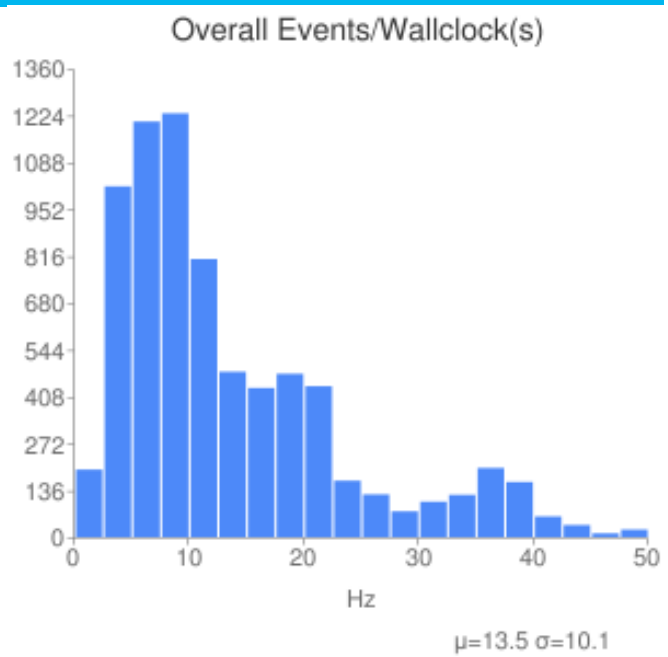
ATLAS HammerCloud test: The setup

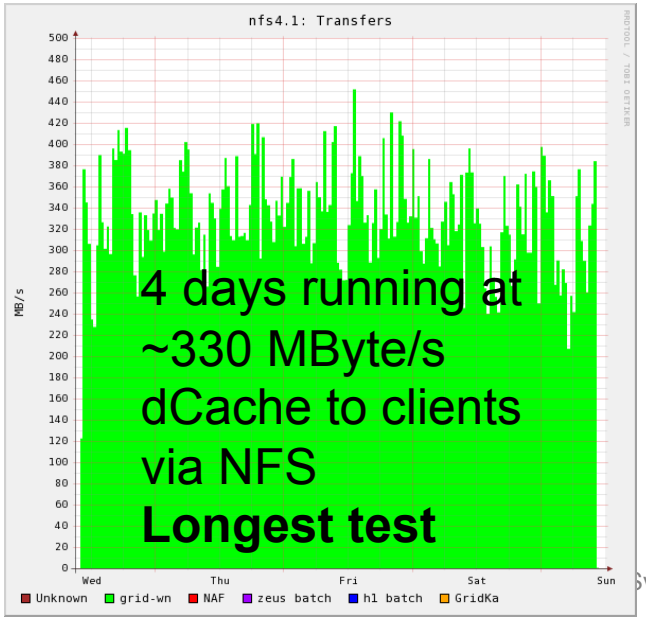
- The Data:
  - Official ATLAS MC samples (7 TeV, prefereably no minbias, few jets)
  - AODs, reconstructed with athena 15.6.8
  - 33 TB data in total
- The Analysis
  - standard AOD analysis reading Trigger and many Muon variable
  - Athena 15.6.6, ROOT 5.22/00h (no ttreecache reading used)
- Initial difficulties:
  - CREAM-CE not visible, neither in Information System, nor “in the Cloud”
  - dCache not a fully Grid-SE, had to provide file lists as input
- More on HammerCloud
  - This is the standard ATLAS application to test the performance of sites
  - Parallel session 36, Dan van der Ster
  - Poster PO-MON-036, Federica Legger

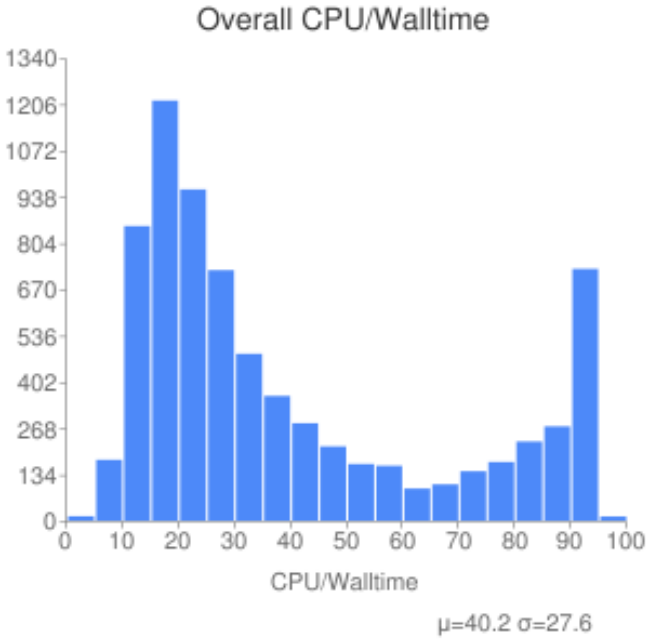
ATLAS HammerCloud test: The results

- 8248 jobs in total
- Cancelled after 4 days
- Longest single test we did
  - No trouble during test
- Reasonable outcomes (events/s,…)
- No comparison made to dCap (yet)









CMS Analysis: Setup

- Job submission done via the Grid and *grid-control*
  - Ability to freely define CE (which was “hidden” in our case)
  - Make use of “private” SE: Custom manipulation of the CMS Trivial File Catalogue
  - https://ekptrac.physik.uni-karlsruhe.de/trac/grid-control
- Muon analysis. Dataset: 1.7 TB in 308 RECO files
- Executable: filestest is stripping into PAT Ntuple out of the CMSSW framework
  - Using 5.22 ROOT version shipped with CMSSW
- One typical use-case on the DESY National Analysis Facility
- Not much CPU, nearly only I/O
- Evaluation of performance metrics in CMSSW framework job report (Andrzej Wronka (summerstudent at DESY))

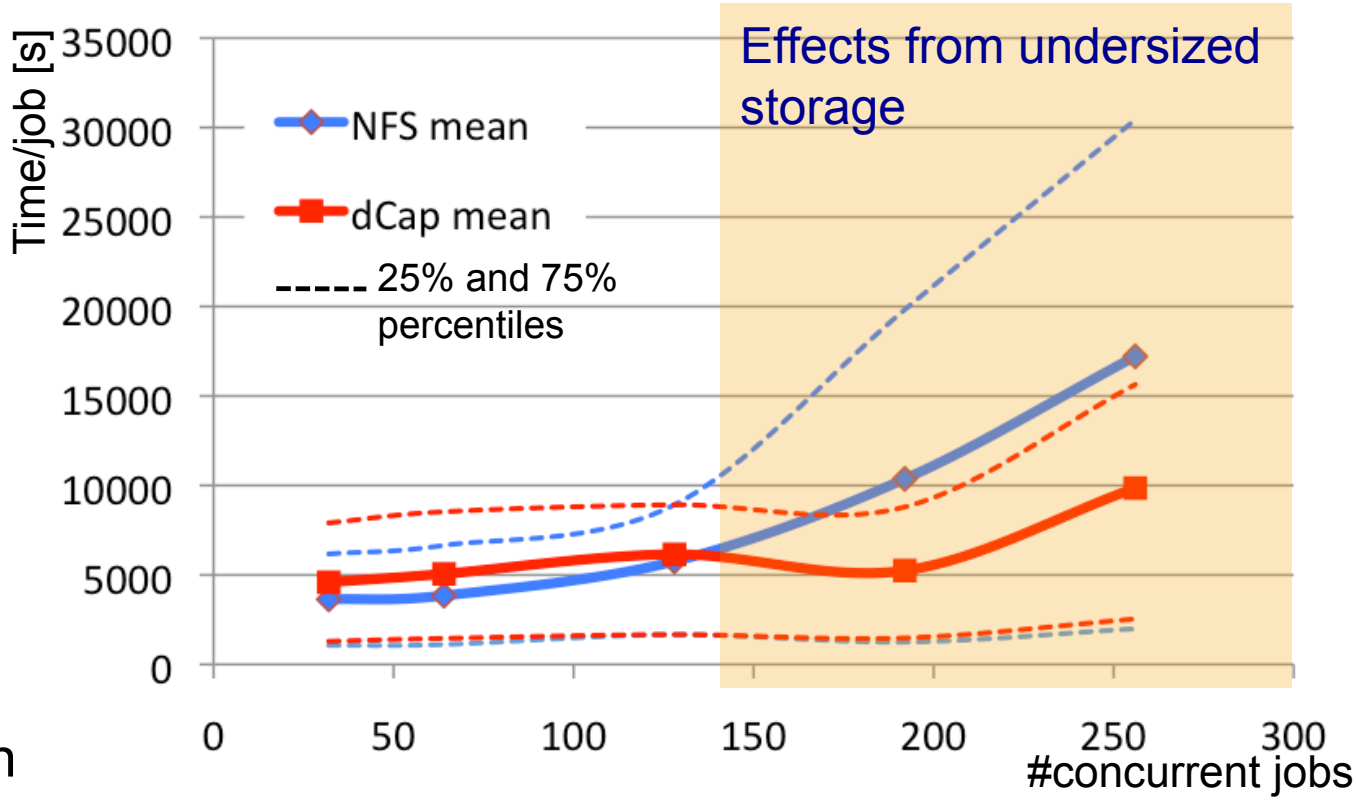
CMS Analysis: Results

Below ~128 jobs:

- NFS 20% faster than dcap

Above ~128 jobs:

- NFS performance degrades, dcap only slightly degrades
- Not yet fully understood, suspect numbers of threads in dCache NFS server
- Checked that client congestion not fault



Effects of File system cache:

- dCap reads 2.5 times more data than NFSv4.1 (dCache billing logs and network monitoring plots): Next slide:

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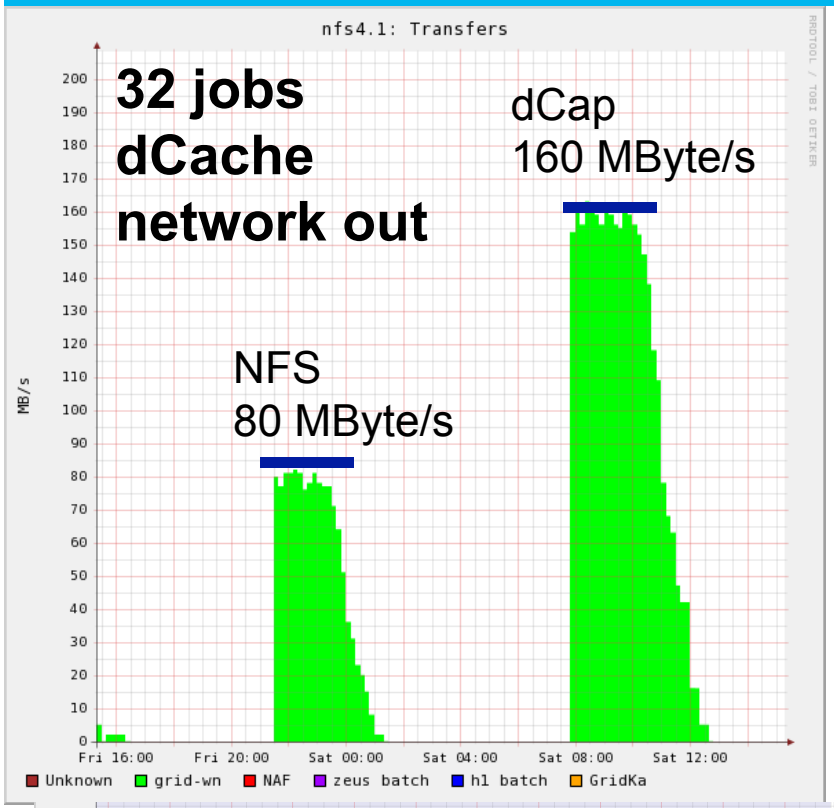
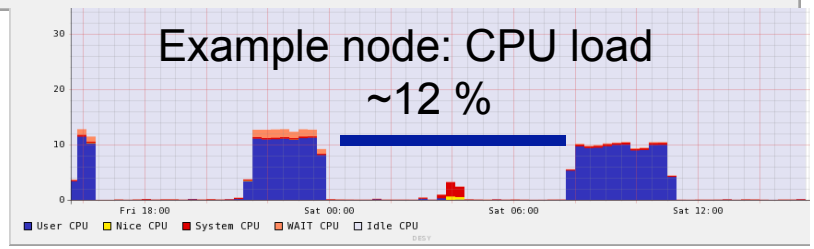
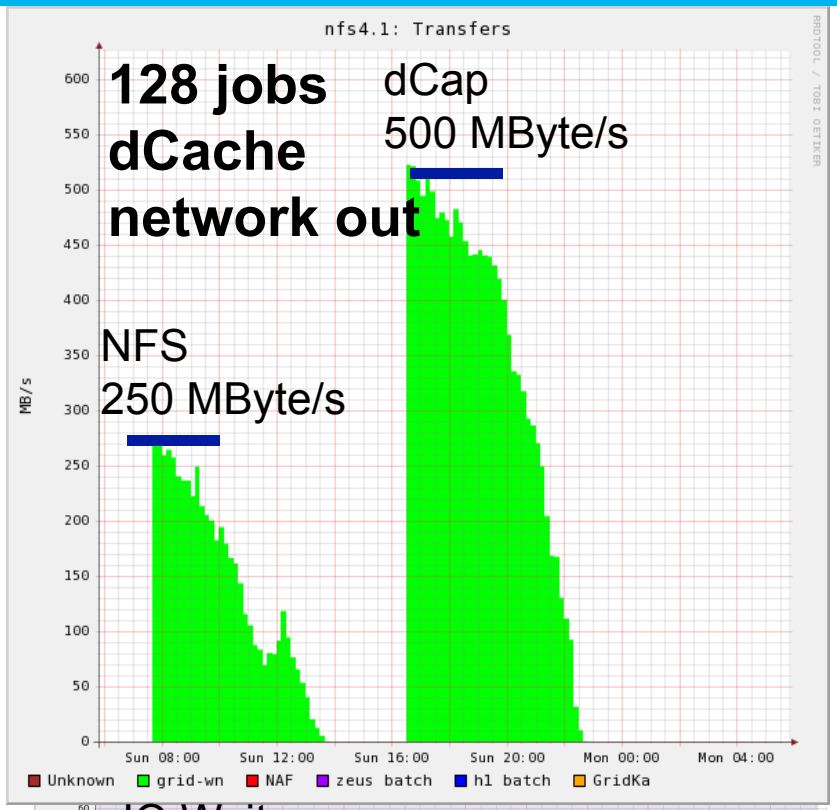
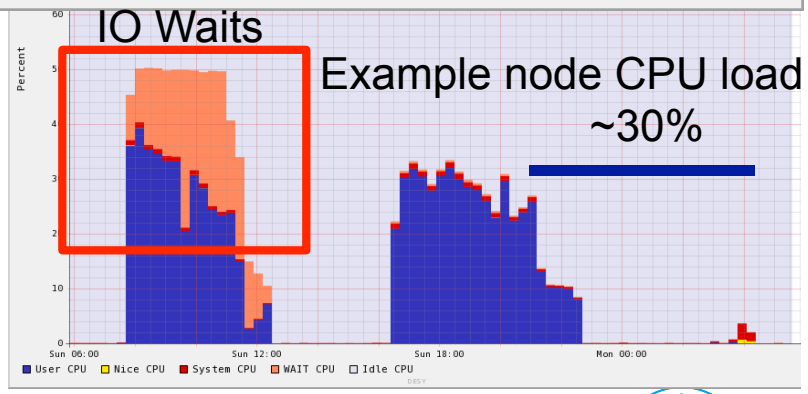
CMS Tests: A look at dCache and one node









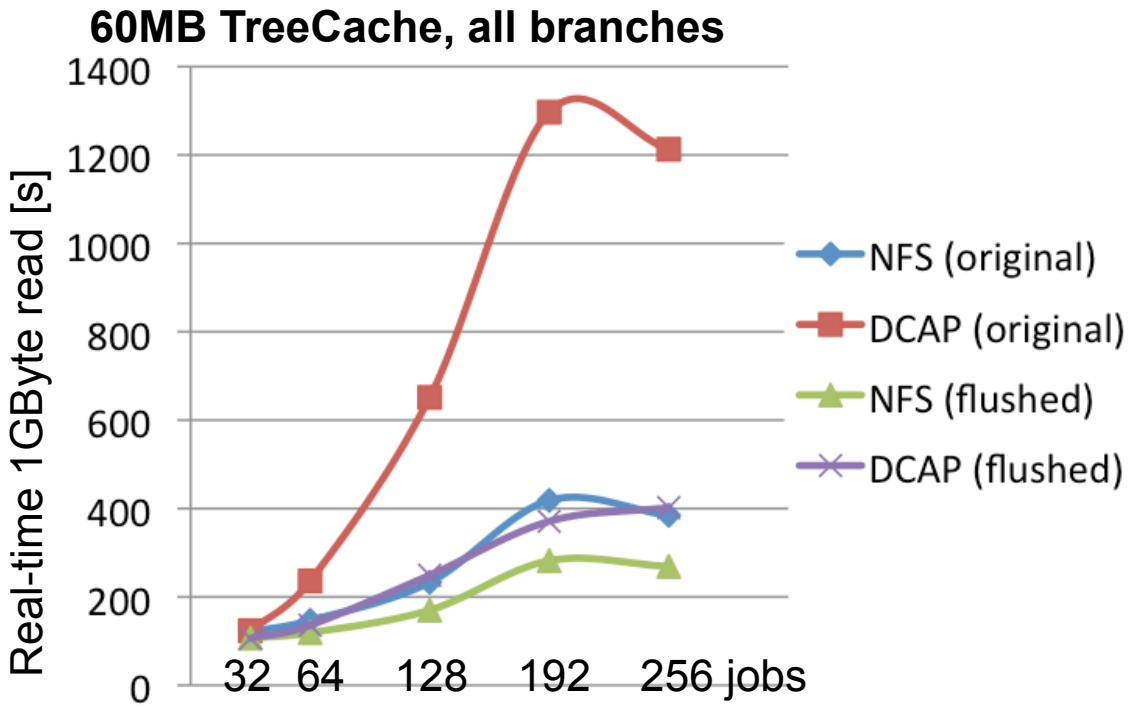
- IO waits gets more important for NFS at higher numbers of concurrent jobs
- Less network traffic for NFS

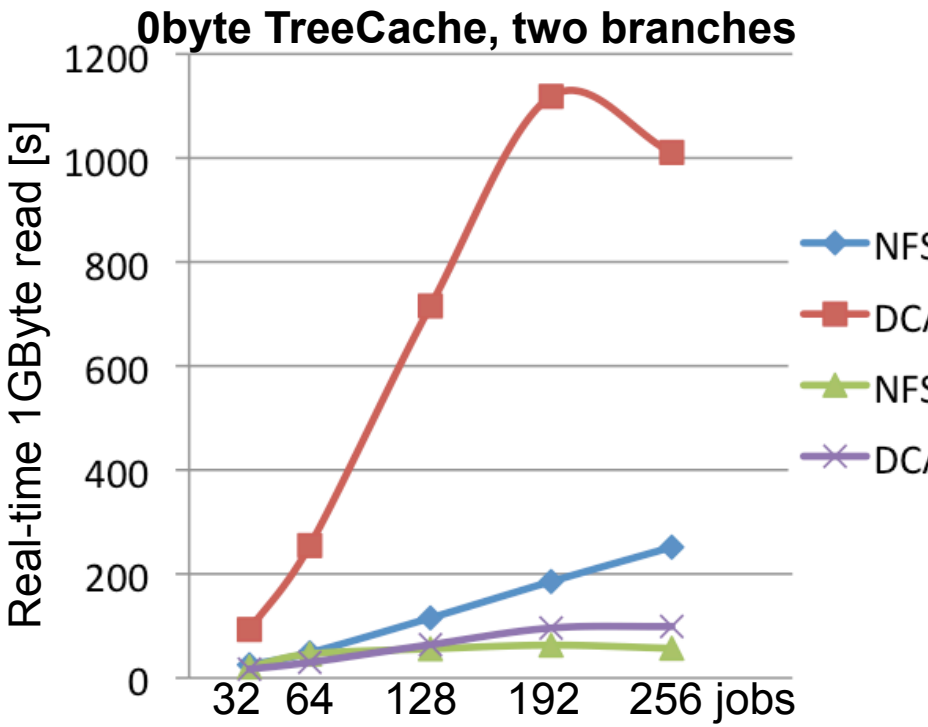
Half-Synthetic ROOT tests: Setup

- New ROOT version 5.27.06, compiled with dCap support
- Files provided by René Brun: `atlasFlushed.root` (re-organized files with optimized buffers) and `AOD.067184.big.pool_4.root` (some other original file) (flushed: 1GByte, original 1.3 GByte)
- Test script provided by René: simple script reading events: `taodr.C`
- Different test runs:
  - Reading via NFS or dCap
  - Reading with 60MByte TreeCache, or with 0Byte TreeCache
  - Reading all branches or only 2 branches
  - 32, 64, 128, 192 or 256 jobs running in parallel

- Last minute-result! Have not spoken with ROOT people!

Half-Synthetic ROOT tests: Results





- NFS better for original and flushed files than dCap
  - Flushed: not much difference, original: Large difference
- TreeCache helps, NFS adds additional speed
- Peak at 192 clients not understood
- Remember: Just going through events and doing nothing … not really representative for analysis

Kernel availability

- Kernel used for evaluation : 2.6.36_rc3
- NFS 4.1 (pNFS) kernels expected in SL6.(>2)
- 2.6.36 back-port to SL5 available from DESY
  - Plus 'mount tools' RPM.
  - Kernel will very likely not cover all hardware setups.
- With a Joined Effort (e.g. CERN, FNAL, DESY), we would be able to provide an SL5 with NFS 4.1 (pNFS) kernel within months. (If we really want)

Patrick Fuhrmann
@ GDB 10/13/2010

Summary

- Set up different use cases
  - Synthetic, ATLAS HammerCloud, CMS analysis, ROOT files
  - No change to experiments applications needed
  - Managed to be run and steered by non-experts (like me)
- Set up a test bed comparable to a small Grid site
  - **Underpowered w.r.t dCache storage**: Able to see bottlenecks
- Presented results
  - **Synthetic**: Provide general performance and stability measurements of NFS 4.1/pNFS
  - **ATLAS HammerCloud:** Stable and well-performing running over four days
  - **CMS analysis:** See effects of FS cache, excellent behavior of NFS up to some point
  - **ROOT files**: See effects of FS cache, better performance than dcap, even with most recent ROOT version and with TreeCache enabled

- **NFS 4.1/pNFS has advantages over traditional proprietary protocols**
- **We now know: Performance is one of them!**

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Future

- More tests needs to be done, some issues have to be understood and fixed
- Remember: NFS4.1 (pNFS) is not dCache only. NetApp have promised to give us a test storage a.s.a.p. (unfortunately not in CHEP timeline…)
  - DPM: Talk by Ricardo Rocha in Parallel Session 15
- No mentioning of security, authentication, authorization here. This needs to come next (and will!)
- Maybe it is time to think about a backport of NFS 4.1 (pNFS) into SL5 kernel? Could this be a combined effort? Would be a temporary effort!

Backup 1: Complete set of ROOT result plots