Performance and scalability comparison of disk IO protocols for LHC

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Outlook

- **Tests set-up:**
  - XRootD
  - dCache
  - CASTOR (already presented by Luca Dell'Agnello)
  - GPFS (already presented by Luca Dell'Agnello)
- **Client software:**
  - Description
  - Optimization
- **Test results** (CASTOR, dCache, GPFS, XRootD)
- **Conclusions**

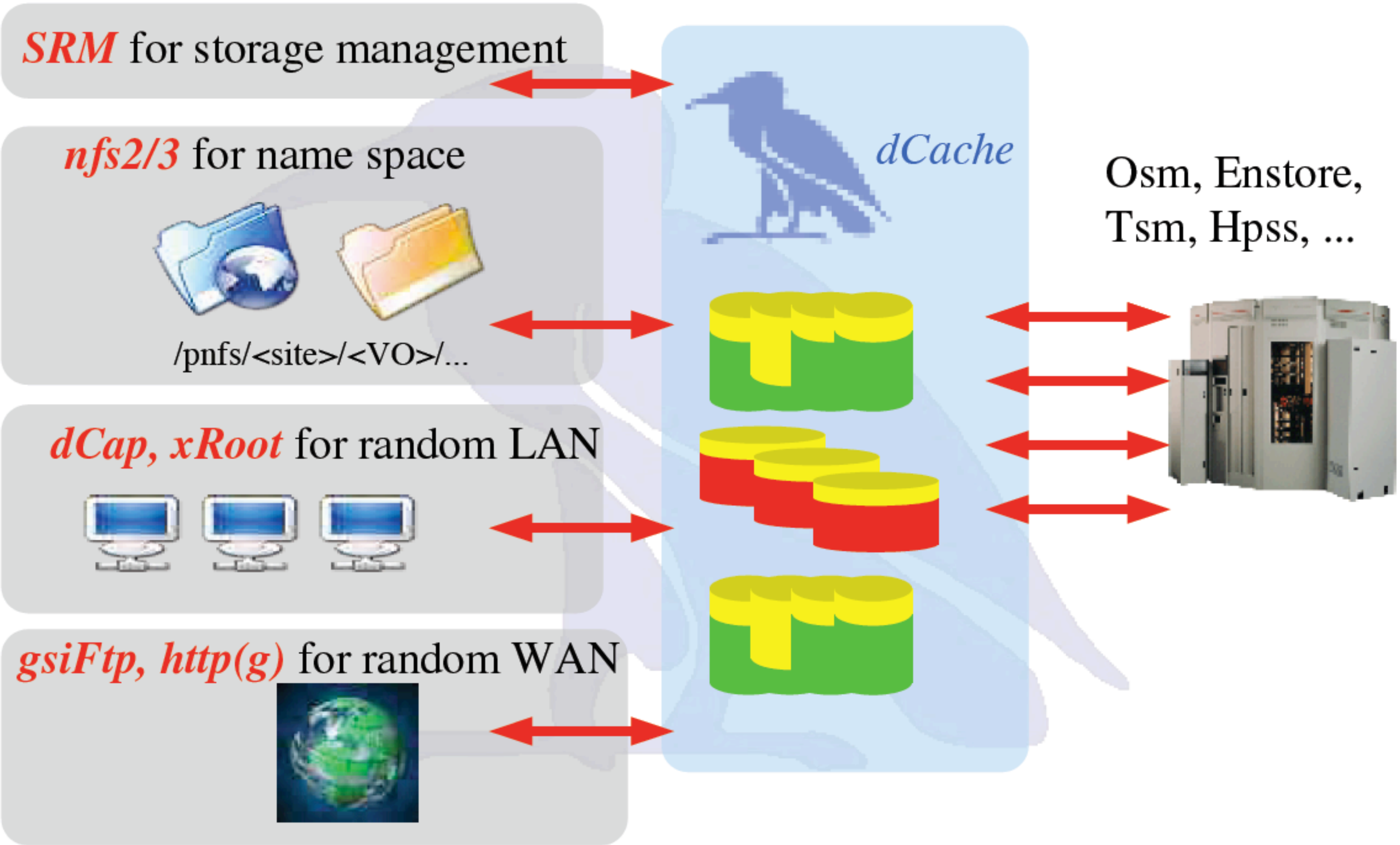
dCache overview

- It is developed in a large collaboration between Desy and FNAL (plus some other minor contributions)
- GOALS:
  - To make a distributed storage system to gain high performance and high-availability
  - To provide an abstraction of whole disk space under a unique NFS like file-system (just for metadata operations)
  - To possibly add the support for its own MSS system
    - They are needed only 2 or 3 scripts (put/get/remove)
- File access:
  - provides local and remote access (posix like) with many protocols (dcap, ftp, xrootd) both with and without authentication (gsi or kerberos)
- Access management: access priority and load balancing obtained trough the use of different queue
- Allows multiple copy of files spread over different pools to improve performance and HA
  - pool-2-pool automatic (or manually) transfers
- Allows dynamic "match-making" between pools
  - According to the parameters chosen by the administrator (they can be based on disk space, load, network, type of access etc.)

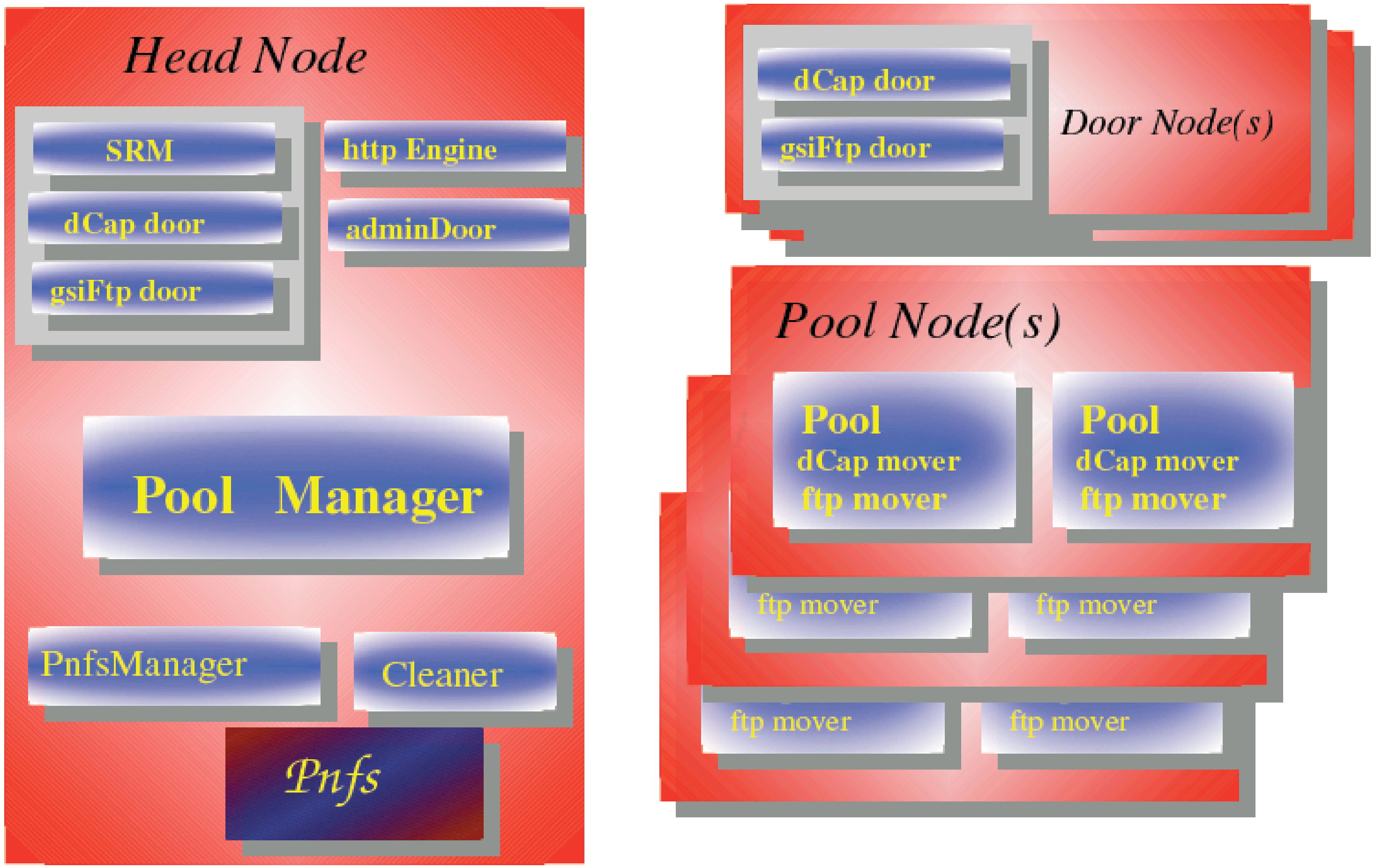
dCache overview (2)

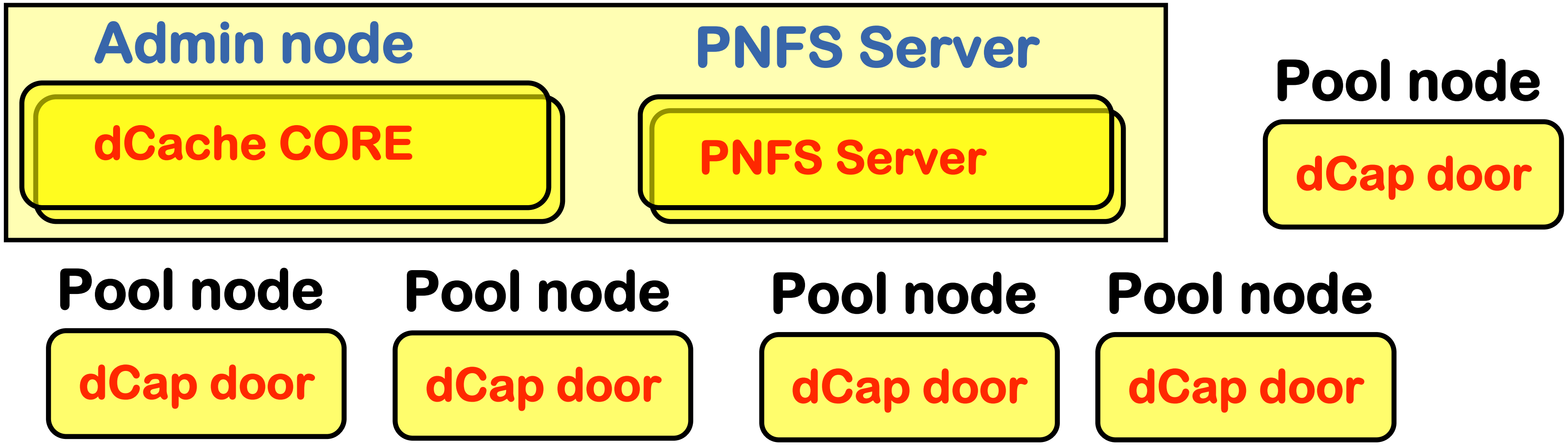
- It is possible to move all the files in a pool to put it in a "scheduled downtime"
  - Or just to choose which file you want to move and where.
- Also the "central services" can be split on different nodes to improve the scalability
- Pool management:
  - gives the possibility to create groups of pools named "storage class" (read, write, cache, or per VO and user bases or use bases)
  - Can be useful for quota management
- Web monitoring, statistical module (also with rate-plot)
- JAVA GUI for administration
- Both SRM v1 and v2 (in pre-production) is available
- Accounting system flat-files or DB based (not user friendly but there are many information) and space used per VO
- It is possible to use WN (or other "not reliable" space) disks to improve performance for local access

dCache overview (3)



dCache overview (4)



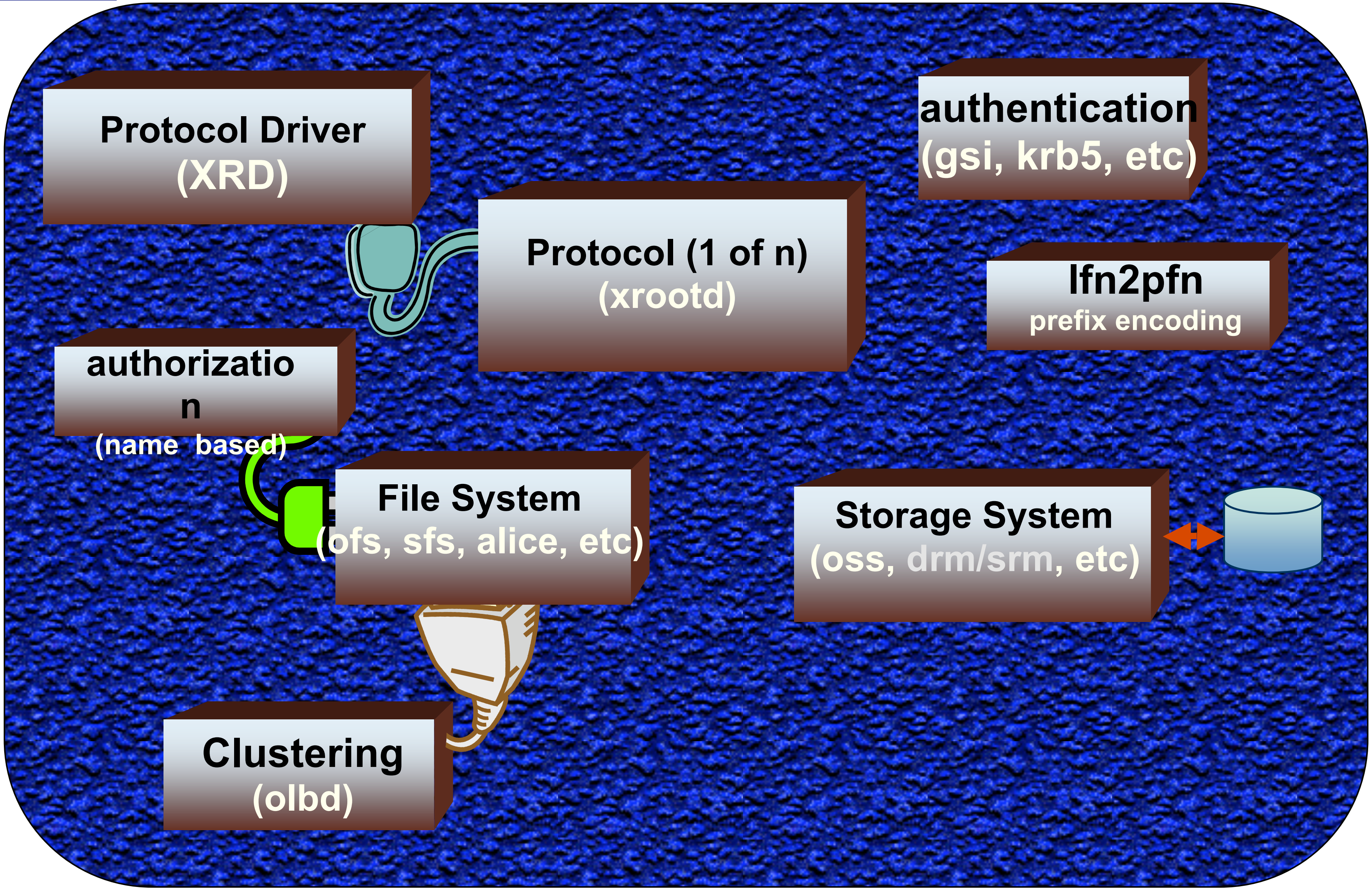


- The admin door is split in two machine: PNFS(Database) and dCache Admin-dcap door
    - The PNFS-server is on flat-files database (the lack in performance is not important since the number of files is small)
- On each machine we have a pool running with 2-3 partitions used
- Small tuning done in order to fit with the large requirements:
    - Number of allocable slots
    - Time-out in opening file

XRootD Overview

- Developed in a collaboration between SLAC, INFN, CERN, BNL and many other contributors
- Purpose:
  - to construct high performance data access systems by means of P2P-like clustering
  - develop a synergy between high performance, low latency servers, virtually unlimited clustering capabilities (up to 262K server nodes)
  - to build systems able to seamlessly ignore a server's failure, even through WANs
  - no central points of failure, no bottlenecks (e.g. file catalogs) except for the single disks performance
  - no 3rd party SW needed, no messy dependencies
  - to do it privileging simplicity, i.e. low admin cost

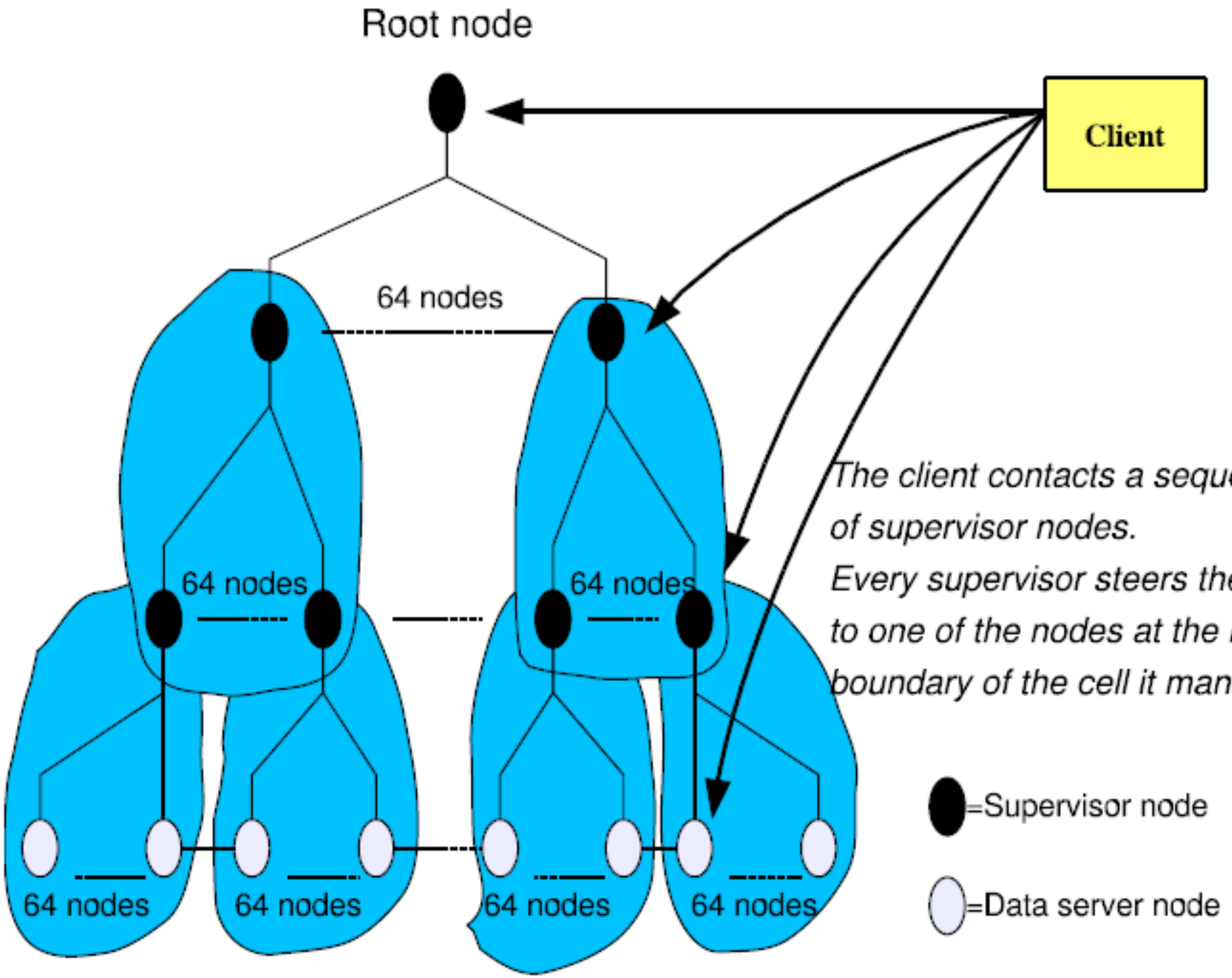
XRootD Overview (2)



XRootD Overview (3)

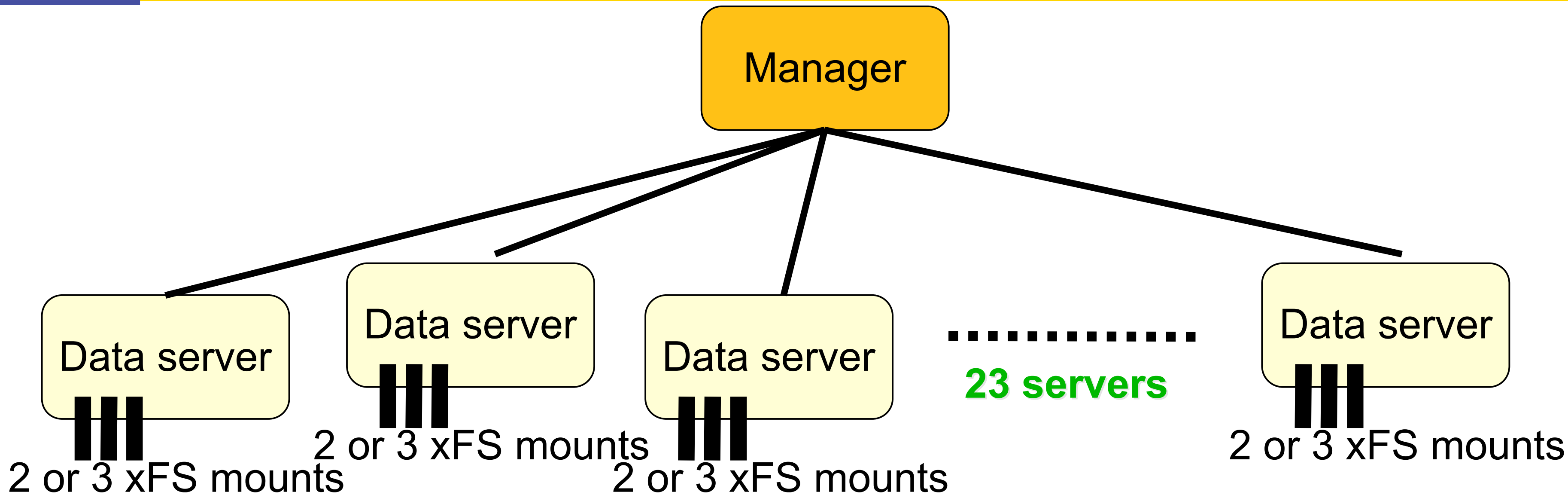
- File access: the storage granularity is at file level
- Plugin-based architecture, entirely POSIX and C++ based, many platforms available, very low dependencies on specific kernels, versions
- SRM compliance through external sw integrations (e.g. Castor), native SRM integration is on the way (STORM)
- Can aggregate different local namespaces into a global unique one
- Load balancing, resource allocation, access and fault tolerance achieved through
  - P2P-like mechanisms at the server side
  - An intelligent fault-detecting client which crawls the server clusters
  - In principle the app does not notice server failures
- Supports any number of file replicas to higher data availability and read performance
- Many interfaces (native, POSIX, ...) available through different sw layers
- Various MSS integrations (HPSS, CASTOR, ...)
- WAN-friendly, not limited to file copying
  - multiple clusters can cooperate through WAN
  - the client can be used to exploit high bandwidth WANs from the applications by hiding the data access latency

XRootD Overview (4)



The client contacts a sequence of supervisor nodes. Every supervisor steers the client to one of the nodes at the lower boundary of the cell it manages.

XRootD: Test Installation Schema



- A total of 24 servers
- 1 Manager + 23 data servers
- No data redundancy, No server redundancy
- Plain default configuration
- 2 or 3 mounts per data server, everything mapped to /store namespace
- Files have been distributed in a round-robin fashion by just writing them to /store
- No server local storage
- Many external mountpoints, pointing to a few disk controllers in the SAN

Client software

- The goal is to simulate a typical analysis job
- The schema for all the client is always the same:
  - There were 4 different implementation: CASTOR, dCache, GPFS, XRootD
- The operation executed by the client is logically simple:
  - It reads the required number of bytes at a given offset for each specified file
  - The list of "read operations" (offset and number of bytes) is given with an input file (named "tracefiles")
  - The list of files to be read is given with an input file:
    - 5 different files are opened by each job
  - The "tracefile" is chosen random between 10 different files:
    - 5 are taken from real BaBar jobs
    - 5 are composed by a random list of offset and number of bytes in order to simulate the worst possible case
    - Each "tracefile" contains 5000 "read operation"
  - It is enough a single read-failure makes jobs fail

Client software (2)

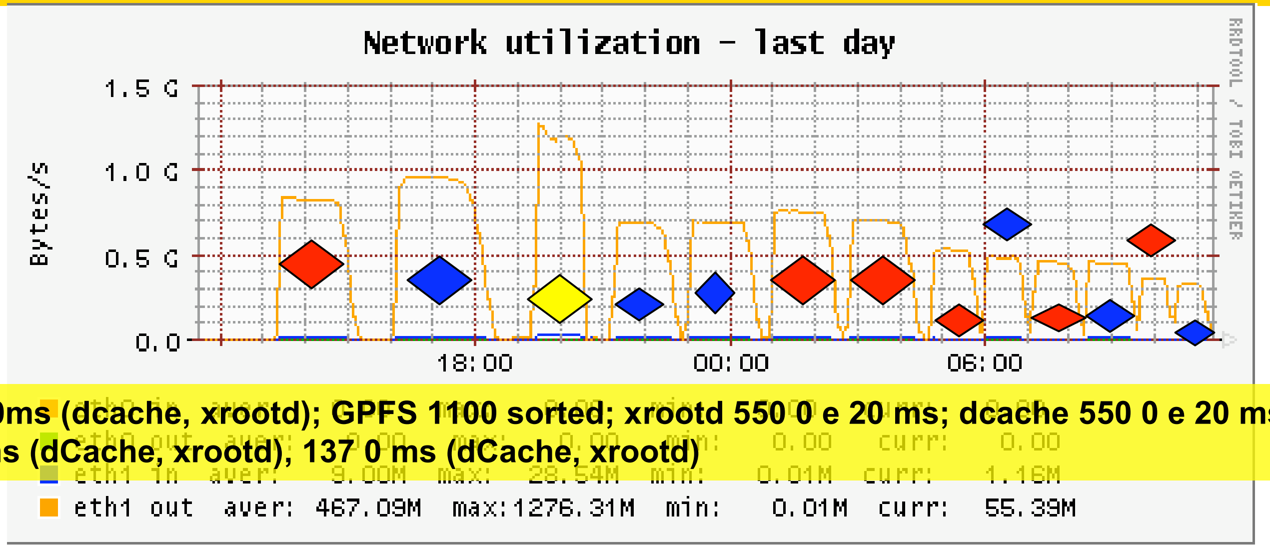
- Highlight on the tests:
  - All the jobs are synchronized in order to maximize the impact on the Storage Manager
    - This is a limit situation in order to simulate a higher number of concurrent jobs
  - All the files (5 file for each jobs) are opened before starting reading
    - Also 5 files per job are used in order to simulate a higher number of concurrent jobs
  - The access pattern is random in order to increase the stress on the storage system (both hardware and software)
  - It is possible to set a “think-time” in order to simulate the CPU time of a typical analysis-job (the CPU is really loaded)
  - Each file is red from several WN
  - Sorted “tracefiles” are used to reduce the load on the disk sub-system
  - A sequential access pattern is used in order to measure pick rate in case of concurrent file access
  - The client reports a lot of information useful for statistics:
    - open_elapsed, data_xfer_elapsed, close_elapsed, total_elapsed, totalbytesreadperfile, maxbytesreadpersecperfile, effbytesreadpersecperfile, throughputperfile, readscountperfile, openedokfilescount

Client side optimization

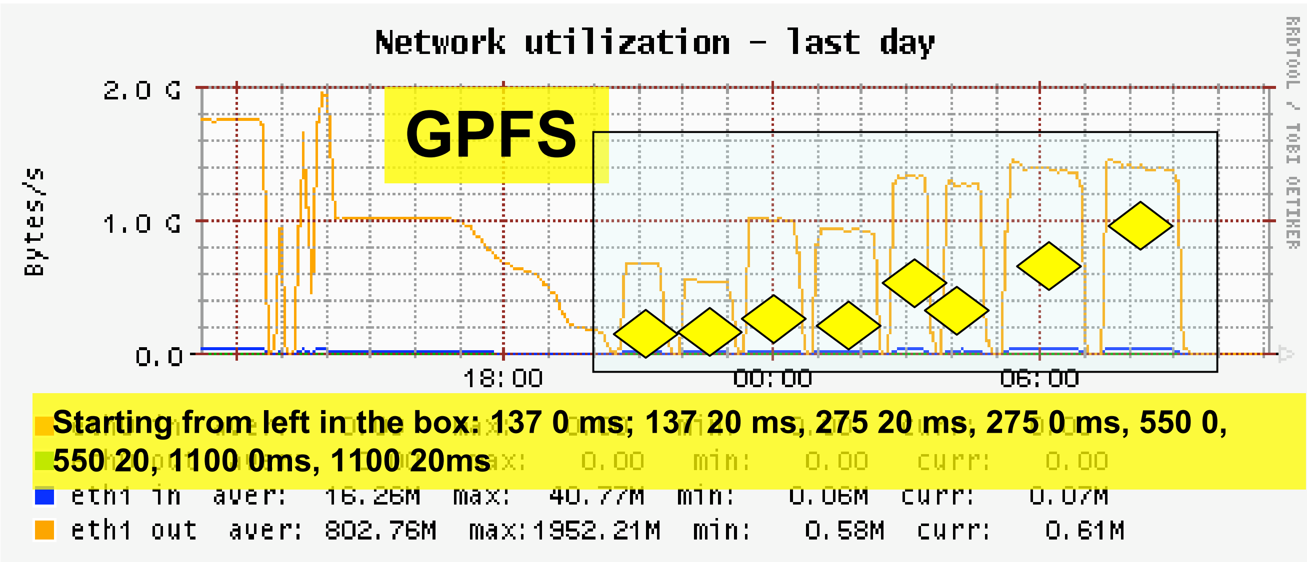
- dCache optimization:
  - Using ENV-Variables:
    - Reducing READHAED (export DCACHE_RA_BUFFER=1000)
      - Avoid overloading the system with data not used by the application
- GPFS optimization:
  - Using simple C “read” function
    - Avoid overloading the system with read action not needed (triggered automatically from C++ library)
- XRootD optimization:
  - Readahead switched OFF, using vectored asynchronous reads of 512 subchunks.
  - Set very high data xfer timeout (1200 secs) to efficiently deal with overloaded disk systems.

Results: Network views

- dCache
- Xrootd
- GPFS



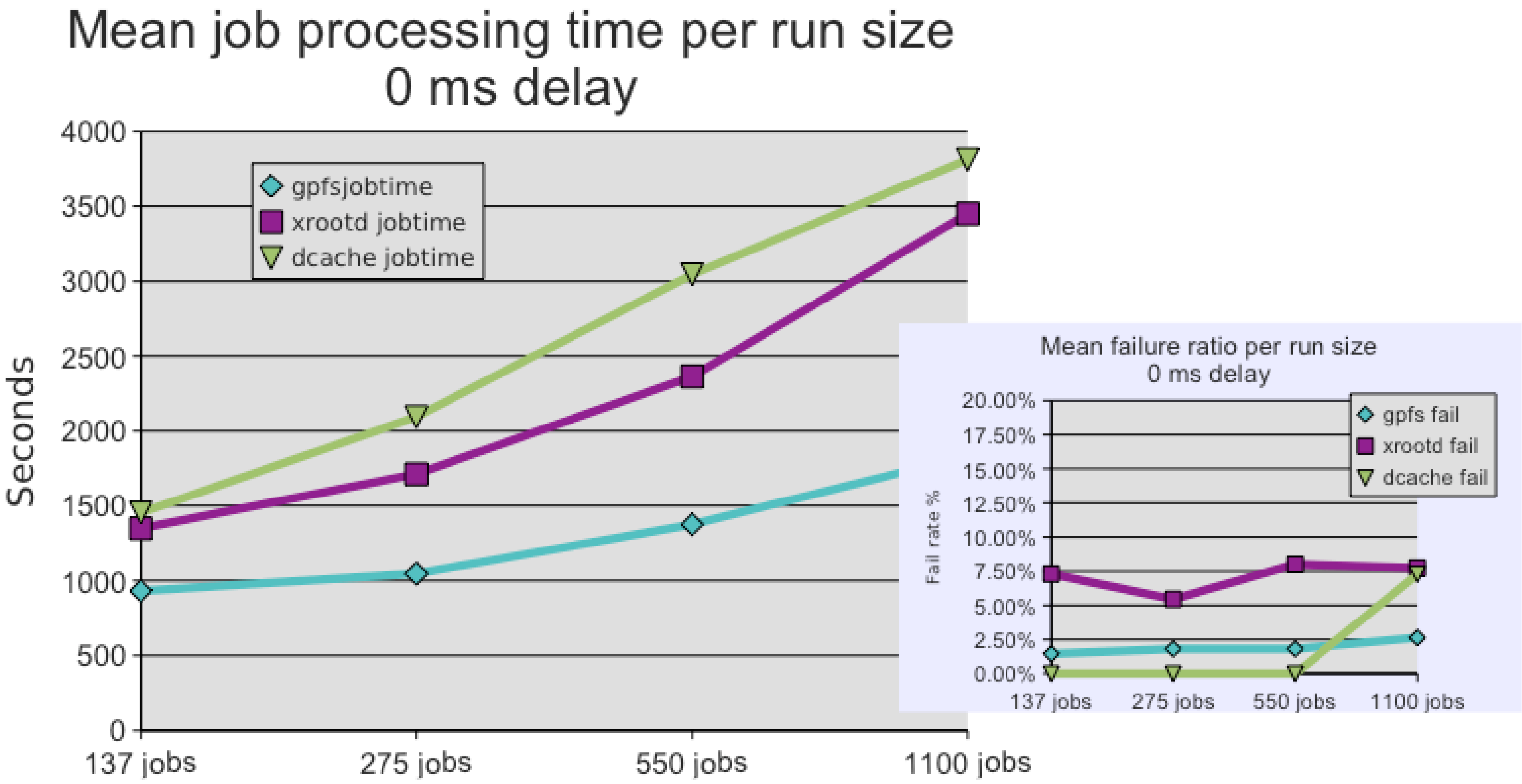
Starting from left: 1100 think-time 20ms (dcache, xrootd); GPFS 1100 sorted; xrootd 550 0 e 20 ms; dcache 550 0 e 20 ms; 275 0 ms (dCache, xrootd), 275 20 ms (dCache, xrootd), 137 0 ms (dCache, xrootd)



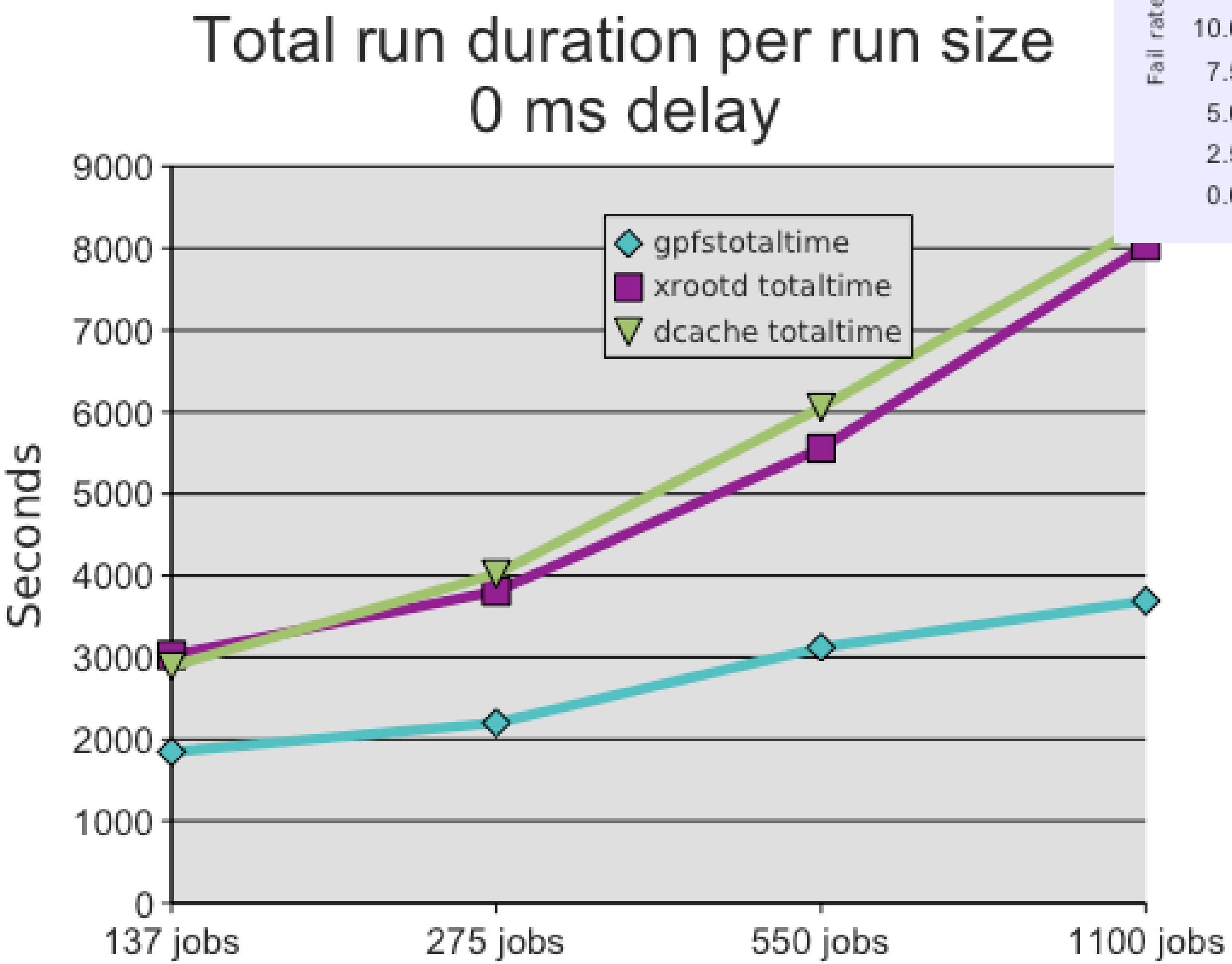
Starting from left in the box: 137 0 ms; 137 20 ms, 275 20 ms, 275 0 ms, 550 0, 550 20, 1100 0ms, 1100 20ms

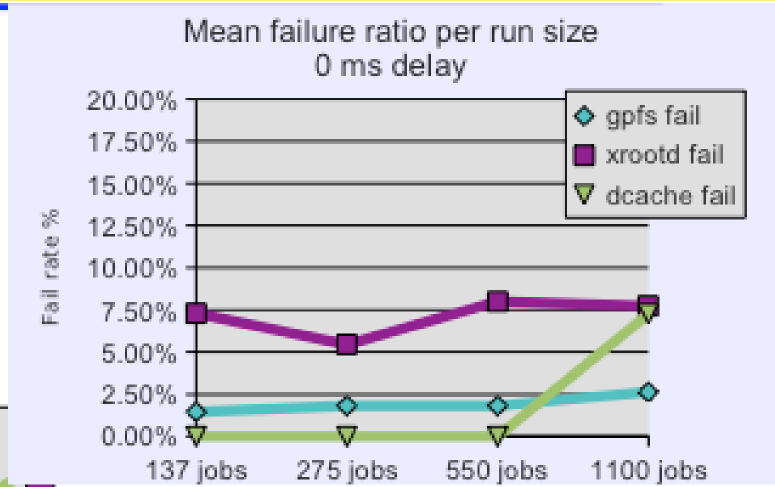
“APPLICATION” VIEWS

Results: JOBtime vs size vs failures - 0ms

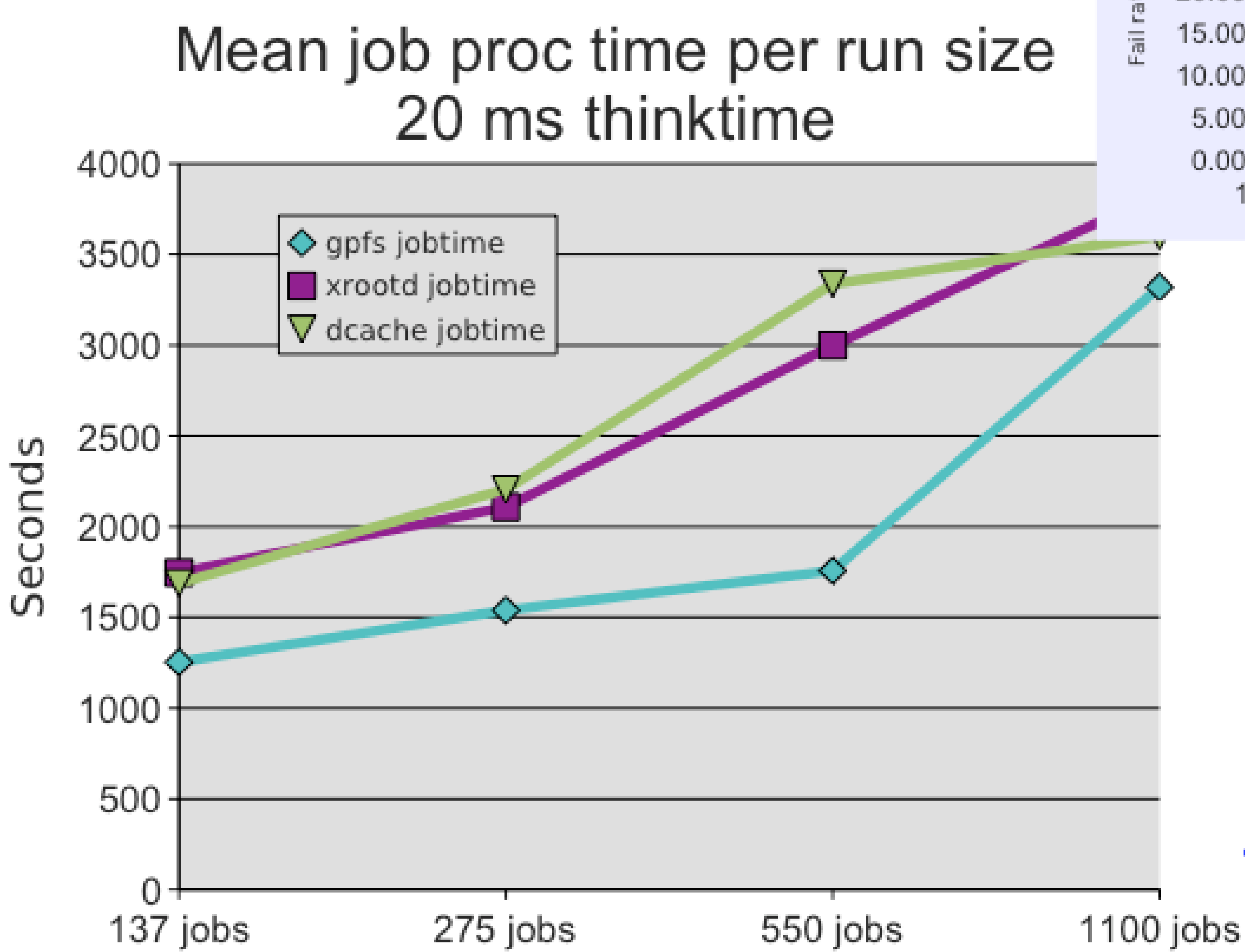


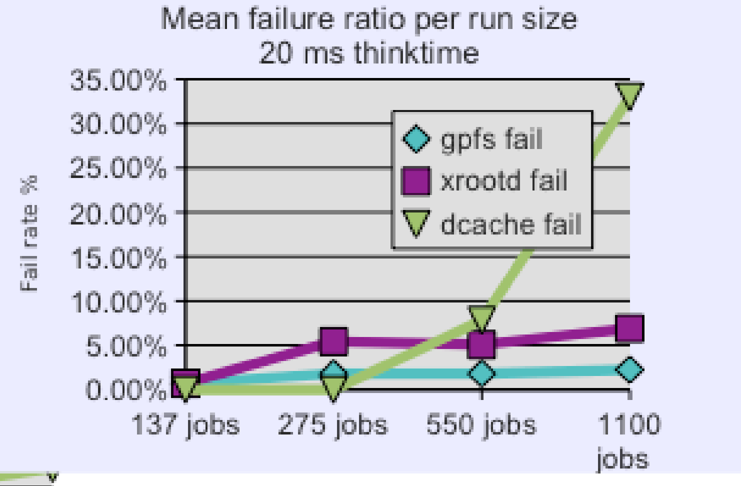
Results: RUNtime vs size vs failures - 0ms



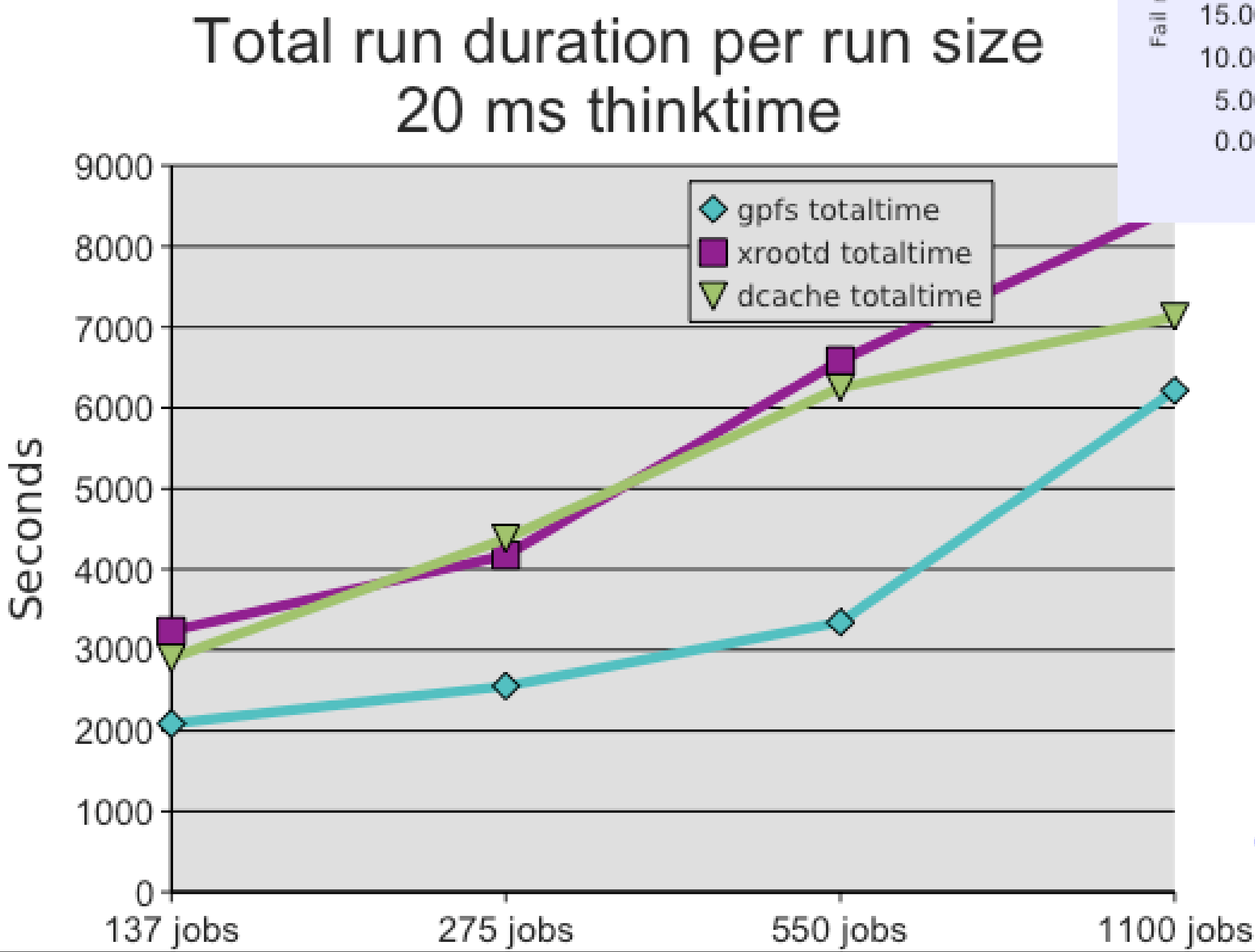


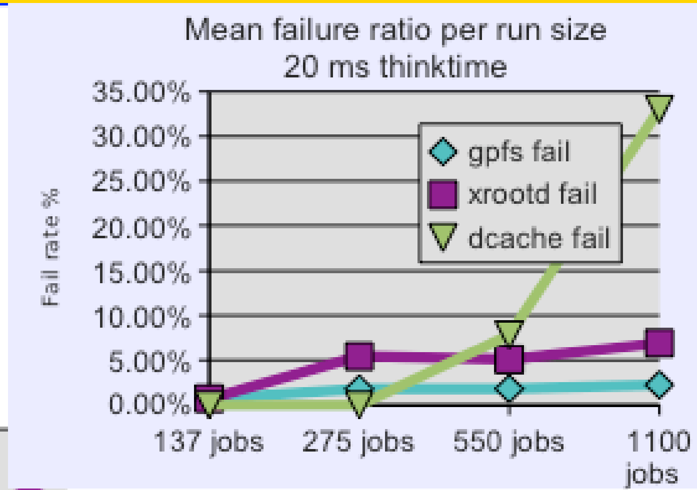
Results: JOBtime vs size vs failures - 20ms



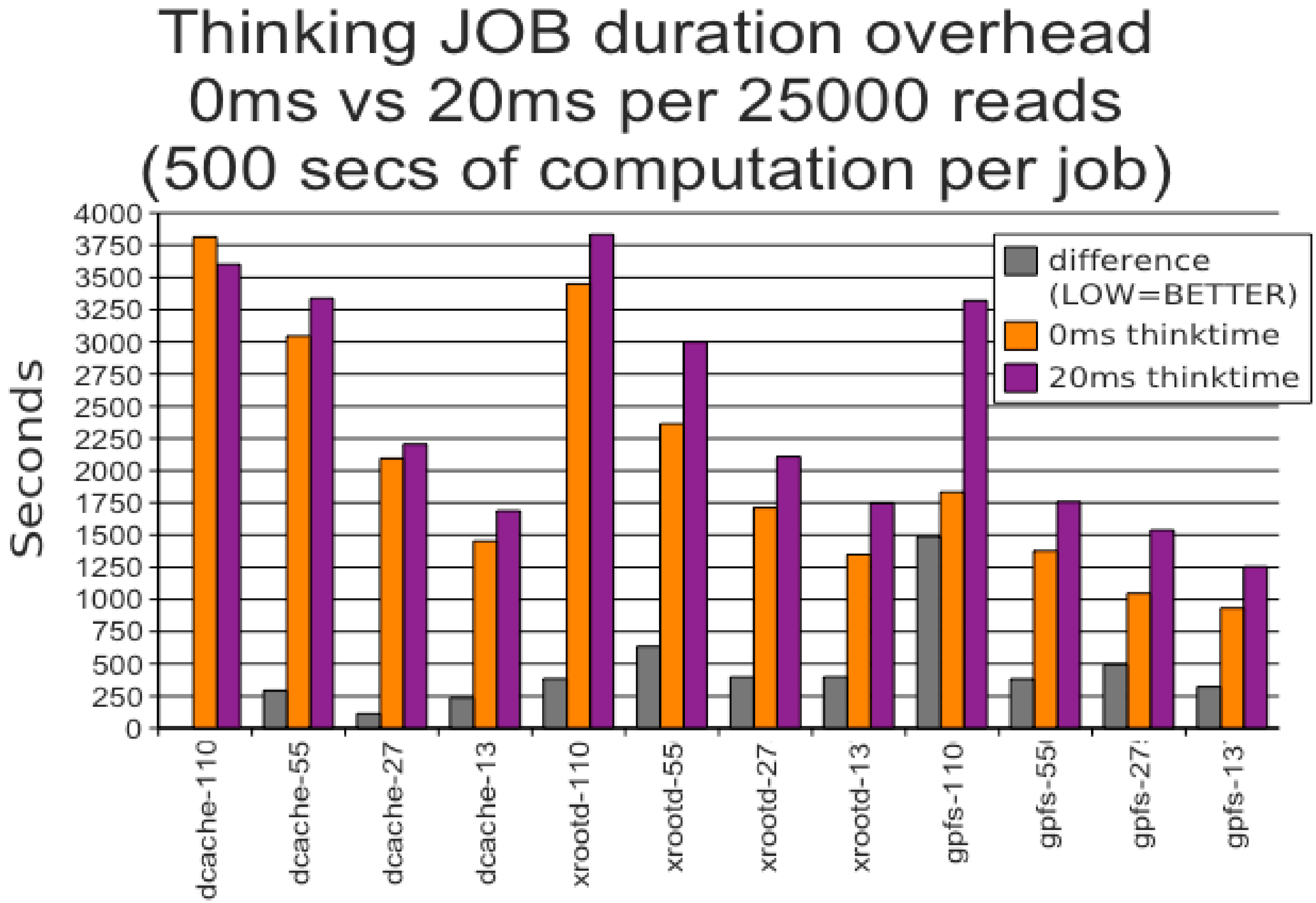


Results: RUNtime vs size vs failures - 20ms

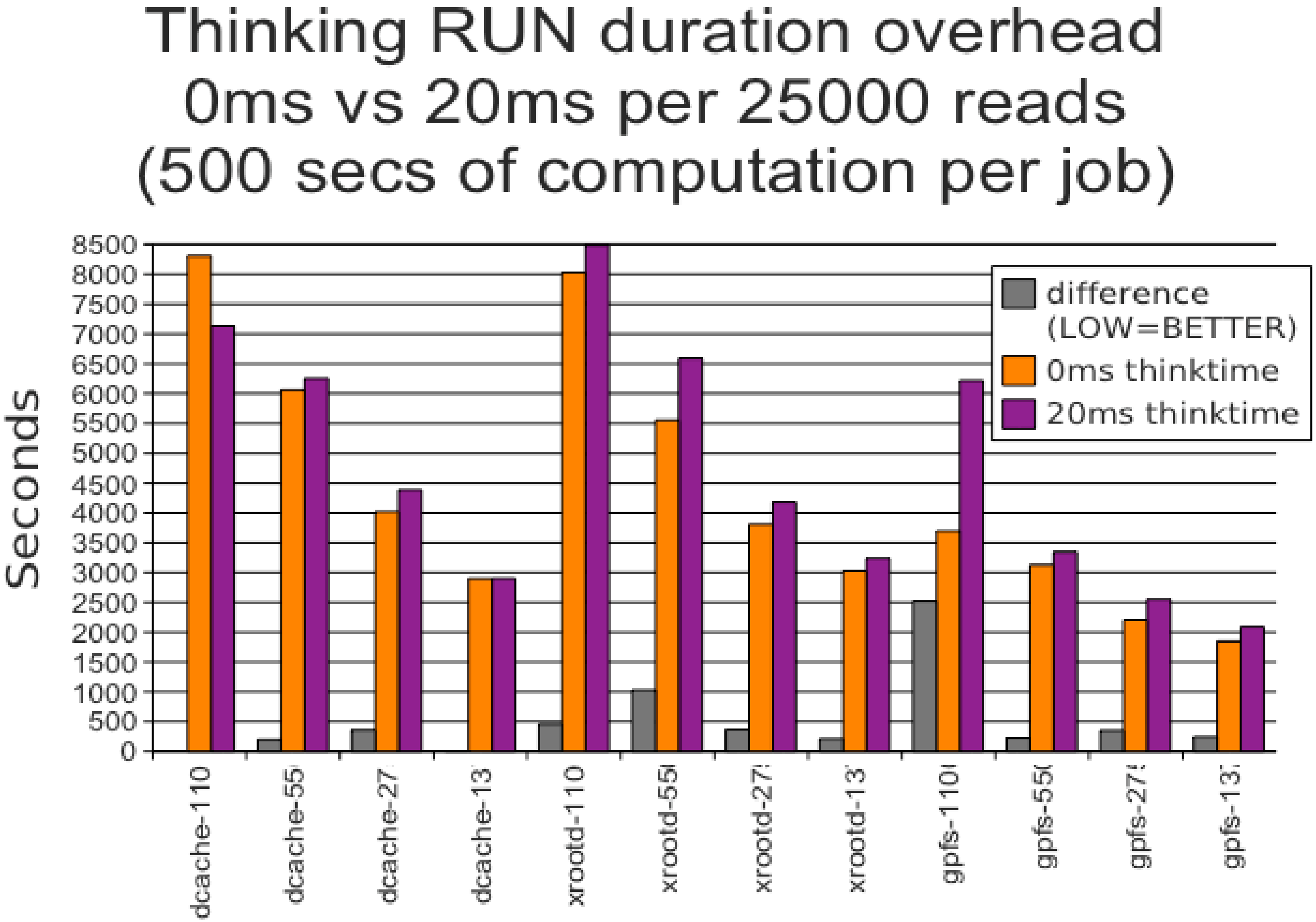




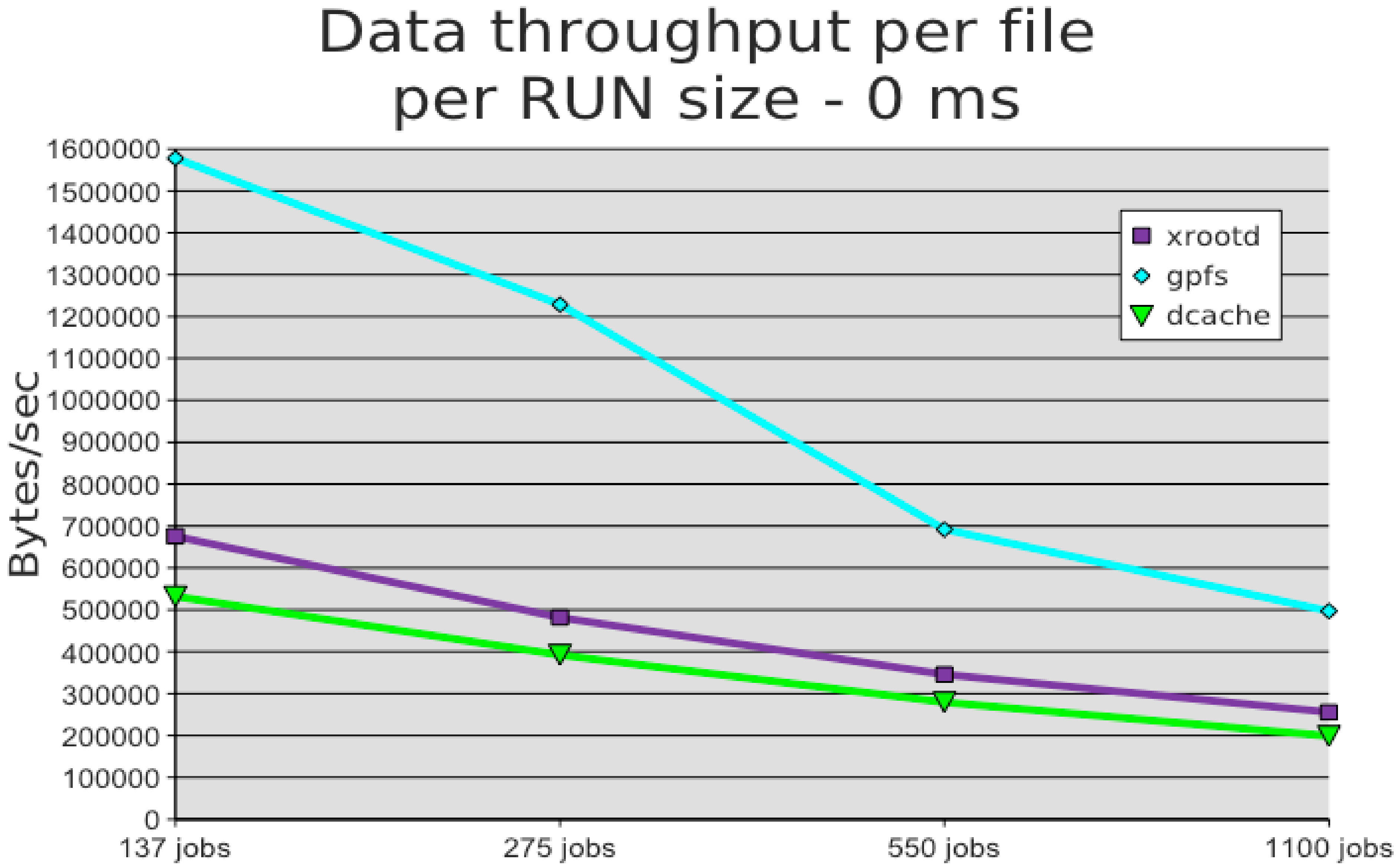
Computation impact on JOBtime



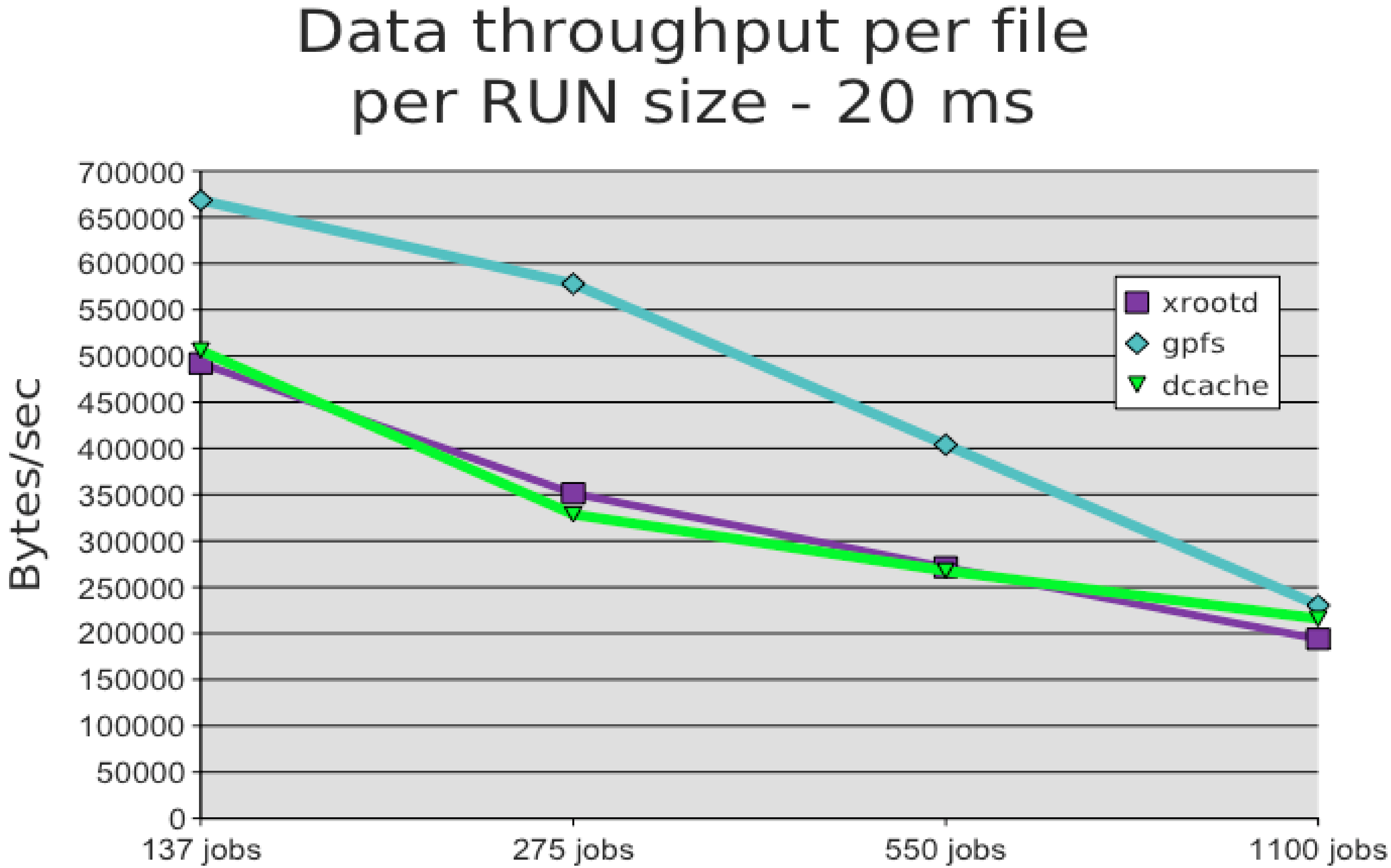
Computation impact on RUNtime



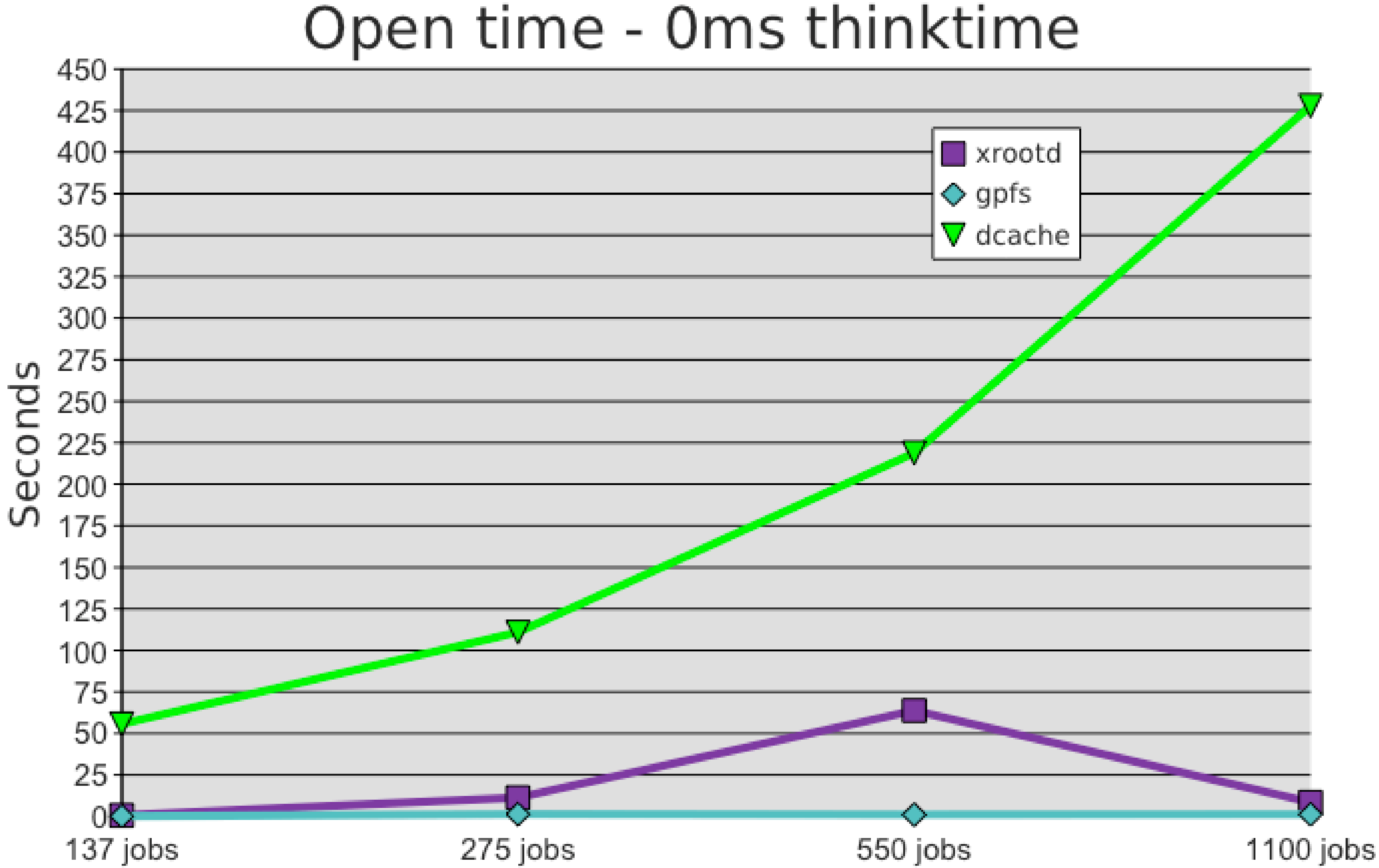
Performance degradation?



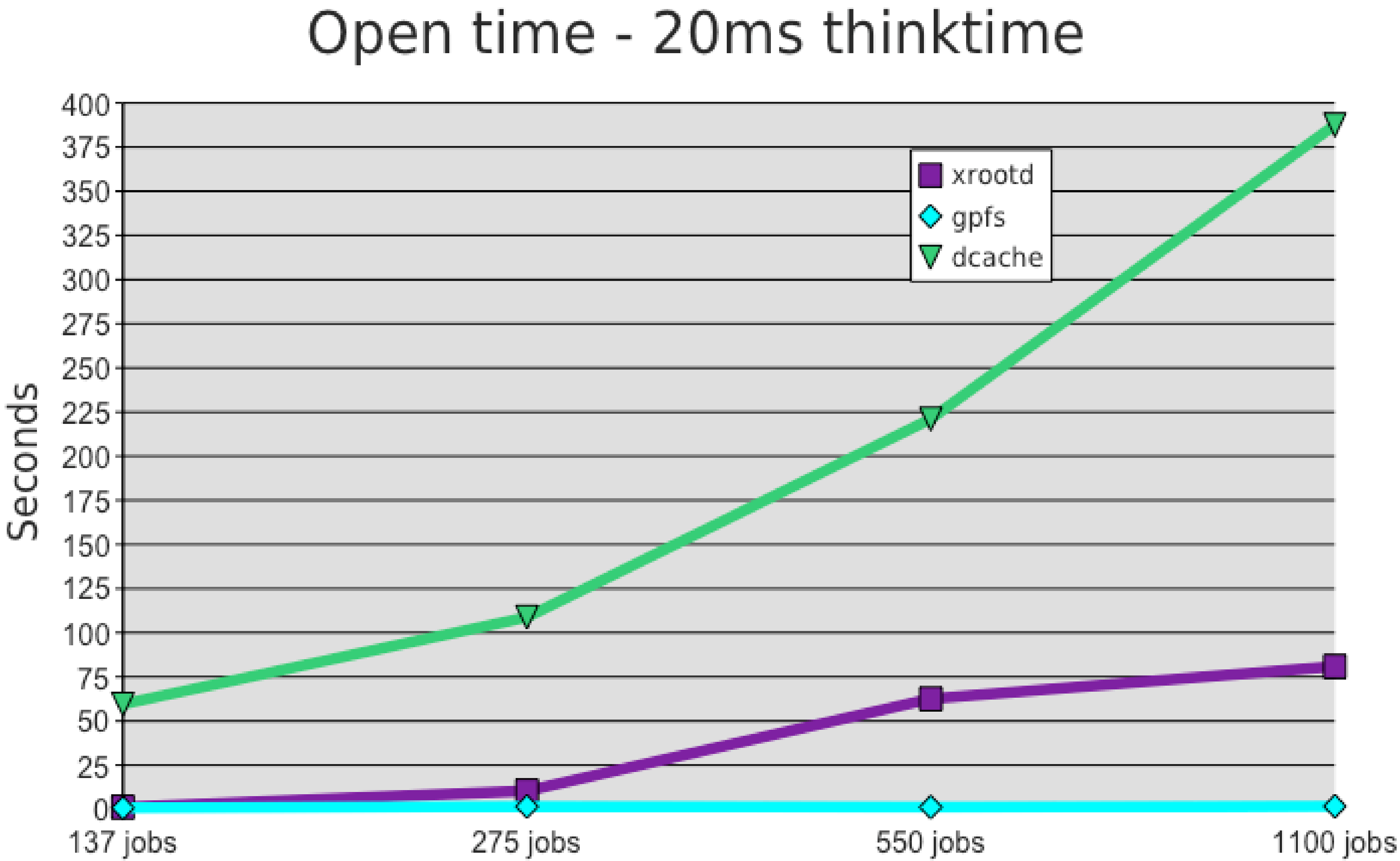
Performance degradation?



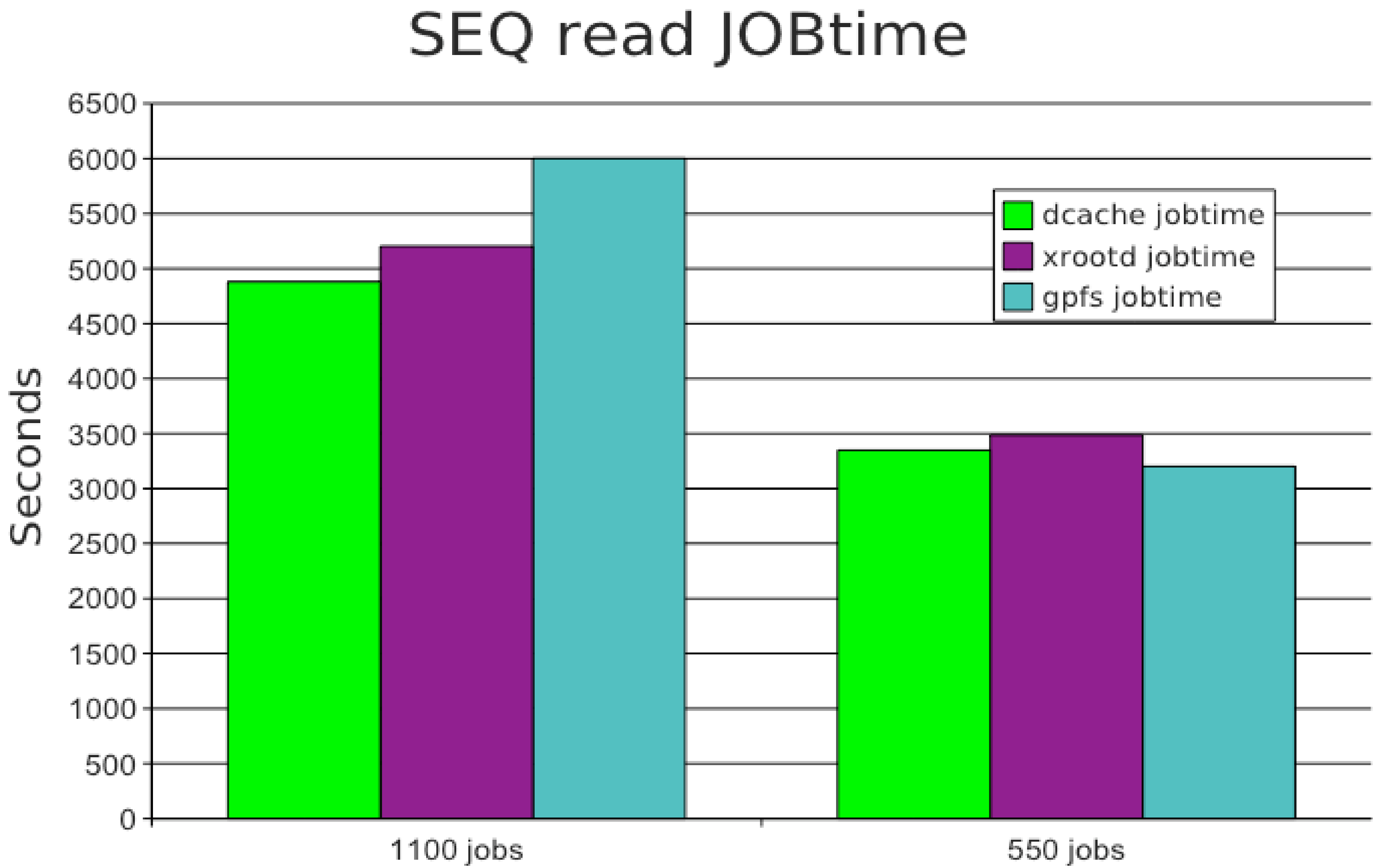
Access to the data



Access to the data



Pure sequential pattern, 2GB per job



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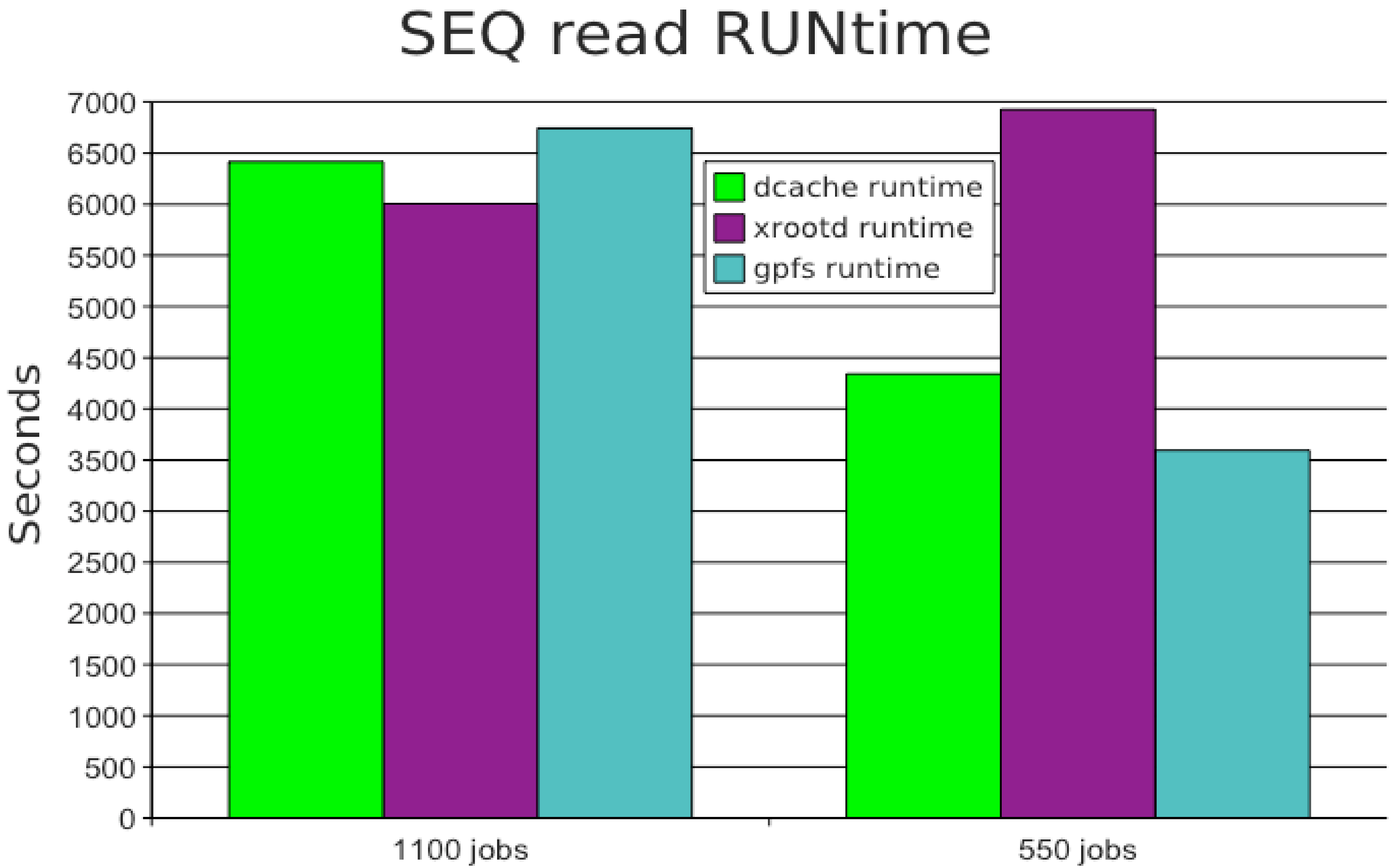
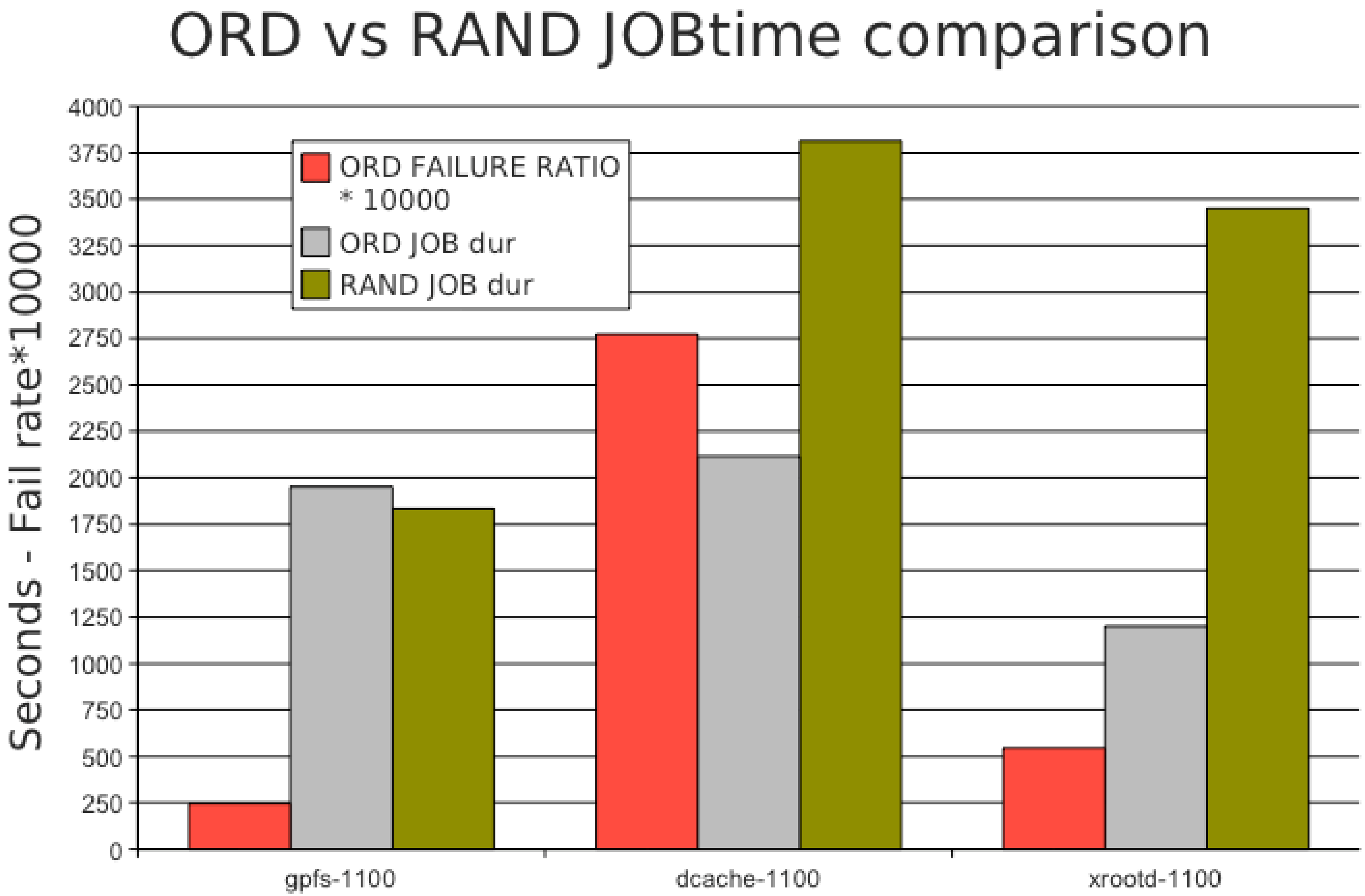
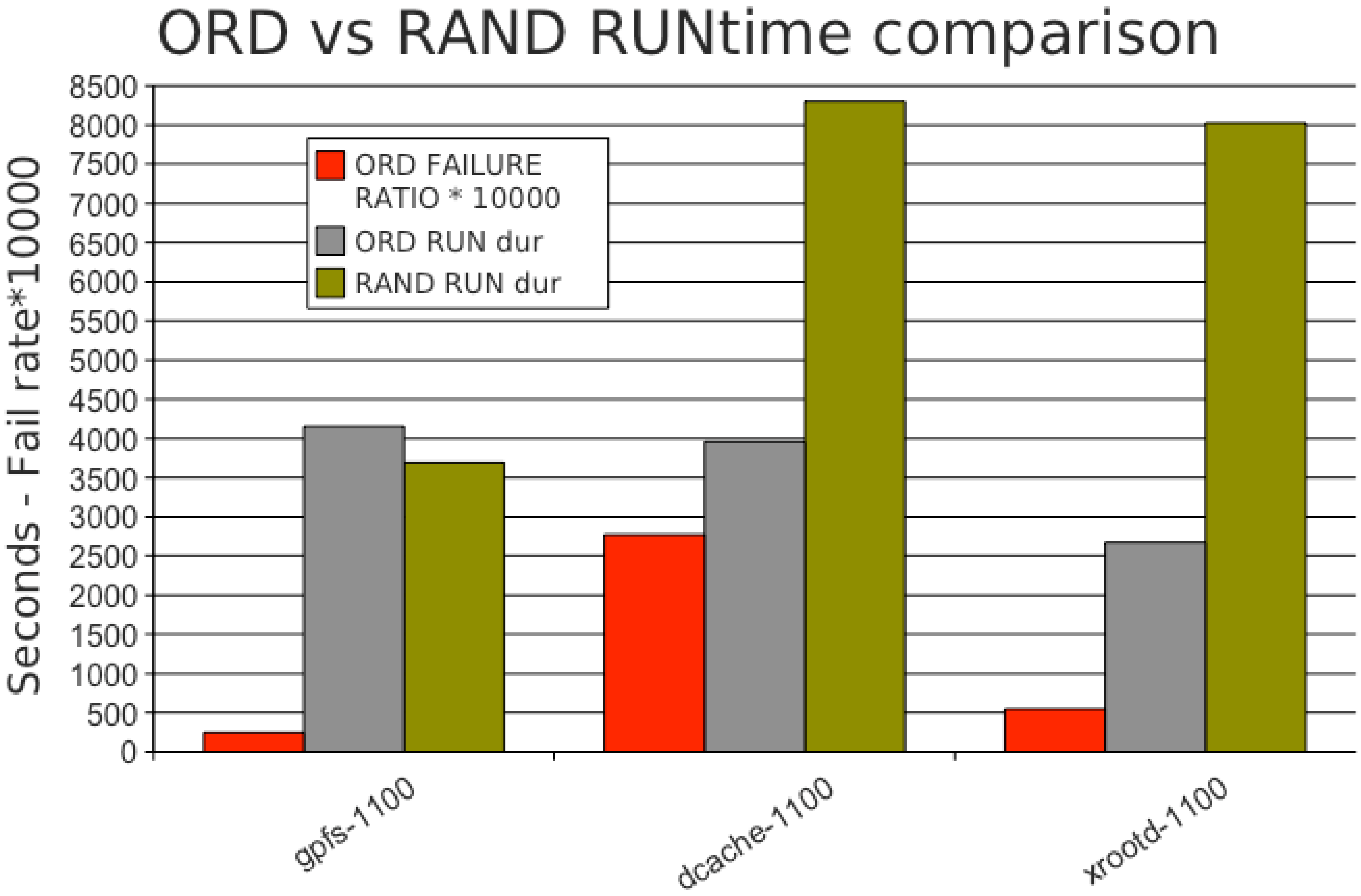


Access pattern impact



Access pattern impact



Final thoughts

- These test are focused only on a specific (and very important) feature
  - Each of these complex software has many other aspect to be evaluated
  - The condition in which we tested the system is high loading
    - 5430 Files opened (concurrently)
    - 2 GB/sec of network bandwidth
    - 1.6 GB/sec of disc bandwidth
  - We surely reach the limit of the underline disk sub-system

Proposed Conclusions

- GPFS:
  - ✓ Excellent performance in all tests
  - ✓ Low failure rate in all tests
  - ✓ SRM available from INFN (StoRM: not usable in production at this moment because only SRMv2.2 is available)
  - ✗ Reduced performance when WN load is high (should be solved increasing the priority of GPFS daemon on WN)
  - ✗ Failure rate constant also with few concurrent jobs
- XRootD:
  - ✓ Good performance
  - ✓ Low failure rate in all tests
  - ✓ Installation and management quite easy
  - ✓ INFN is involved in developing
  - ✗ Failure rate constant also with few concurrent jobs (the problem should be fixed in next client release)
  - ✗ Better performance if client is well tuned
  - ✗ SRM and gridftp not available yet.

Proposed Conclusions

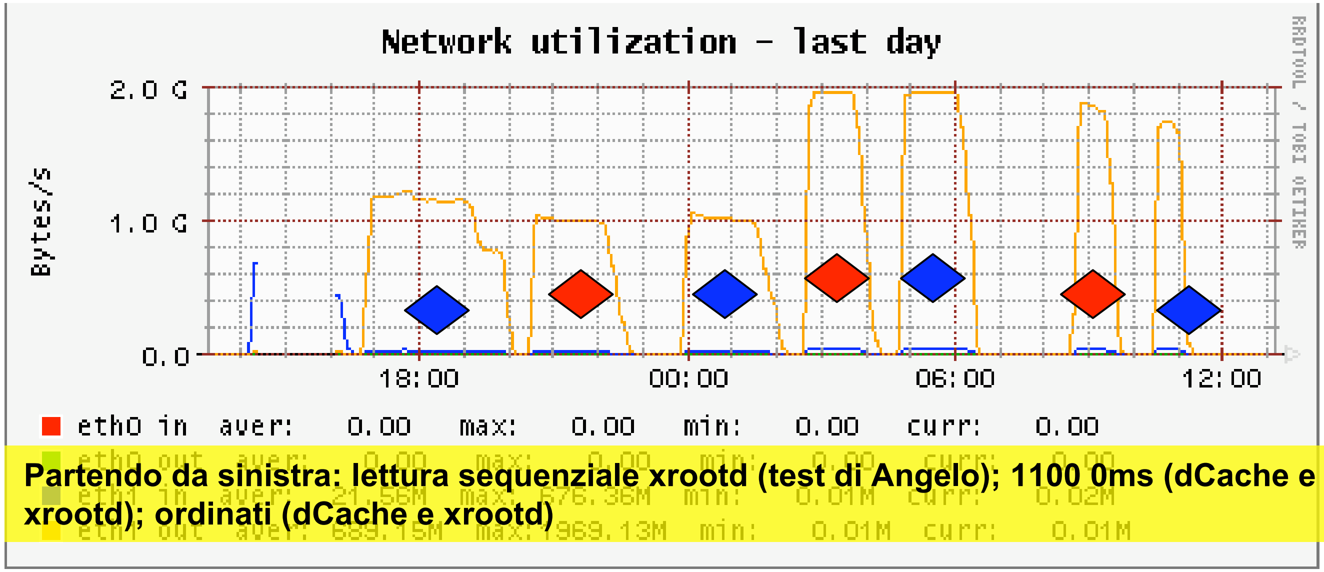
- dCache:
  - ✓ Good stability with few concurrent jobs (0 failure)
  - ✓ Complete and widely distributed solution for LHC T1/2 (with SRMv1/2, gsiftp, xrootd, tape management, etc)
  - ✓ The system is highly configurable to fit with the site needes
  - ✗ Large Failure rate when the load is too high (It is needed a large number of dcap doors to scale at this level of parallelism)
  - ✗ The default set-up is not always a good choice (can be changed at site-level)
  - ✗ Open time greater than the other system (intrinsic limit: “chimera” should solve this in next release)
- CASTOR:
  - ✗ The release in production is not able to pass this test: the next release will solve this problems

Credits

- **Network setup:** M. Bencivenni, D. Degirolamo, R. Veraldi, S. Zani
- **Farm setup:** A. Italiano, D. Salomoni
- **Monitoring setup:** F. Rosso, D. Vitlacil
- **Storage hw setup:** A. D'apice, PP. Ricci, V. Sapunenko
- **Storage systems setup:** G. Donvito, A. Fella, F. Furano, G. Lore, V. Sapunenko ,D. Vitlacil
- **Storage systems tests:** A. Carbone, L. dell'Agnello, G. Donvito, A. Fella, F. Furano, G. Lore, V. Sapunenko, V. Vagnoni

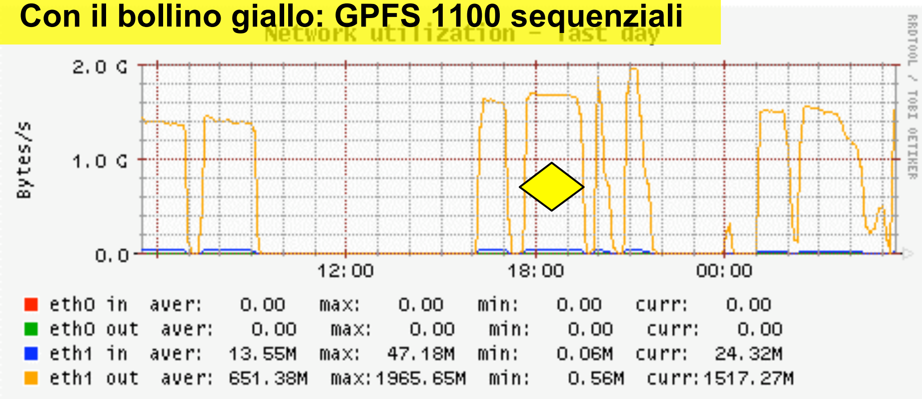
- **Storm development team:** A. Forti, L. Magnoni, R. Zappi
- **Storm tests:** E. Lanciotti, R. Santinelli, V. Sapunenko

Back-up Slides



Partendo da sinistra: lettura sequenziale xrootd (test di Angelo); 1100 0ms (dCache e xrootd); sequenziali (dCache e xrootd); ordinati (dCache e xrootd)

Con il bollino giallo: GPFS 1100 sequenziali



GPFS, nei sequenziali va peggio degli altri per un effetto dovuto alla cache del Sistema operativo che gli altri due sistemi possono usare a differenza di GPFS.

(quindi il risultato va preso un po' con le molle)

	Seq	Prot	Owner	Proc	Pnfsld	Pool	Host
in	1	dcap-3	cms032	23269	000100000000000000873D28	gridse03_3	gridfirb7.ba.infn.it
in	13	dcap-3	cms032	23269	000100000000000000874000	gridse03_3	gridfirb7.ba.infn.it
in	1	dcap-3	cms032	24912	00010000000000000086FF98	gridse03_3	gridfirb7.ba.infn.it
in	12	dcap-3	cms032	24912	000100000000000000870858	gridse03_1	gridfirb7.ba.infn.it
in	2	dcap-3	cmsprd	15937	0001000000000000009AF598	gridse03_3	pccms12.cmsfarm1.ba.infn.it
in	2	dcap-3	cms022	20913	0001000000000000008B86F0	gridse02_2	alicegrid09.ba.infn.it
in	8	dcap-3	cms022	20913	0001000000000000008B8808	gridba6_2	alicegrid09.ba.infn.it
in	2	dcap-3	cms022	15709	0001000000000000008D6E70	gridse03_3	alicegrid10.ba.infn.it
in	8	dcap-3	cms022	15709	0001000000000000008D6B80	gridba6_2	alicegrid10.ba.infn.it
in	2	dcap-3	cms022	15708	0001000000000000008C11D8	gridba6_2	alicegrid10.ba.infn.it
in	8	dcap-3	cms022	15708	0001000000000000008C1220	gridse01_2	alicegrid10.ba.infn.it
in	2	dcap-3	cms022	14096	0001000000000000008F4D80	gridse03_1	pccms32.ba.infn.it
in	2	dcap-3	cms022	15192	0001000000000000008F4D80	gridse03_1	pccms32.ba.infn.it
in	20	dcap-3	cms022	15192	0001000000000000008F4D60	gridse03_3	pccms32.ba.infn.it
in	2	dcap-3	cms022	24870	0001000000000000008F4D80	gridse03_1	alicegrid09.ba.infn.it
in	20	dcap-3	cms022	24870	0001000000000000008F4D60	gridse03_3	alicegrid09.ba.infn.it
in	2	dcap-3	cms022	16231	000100000000000000904720	gridse01_2	pccms32.ba.infn.it
in	2	dcap-3	cms022	17257	000100000000000000904720	gridse01_2	pccms32.ba.infn.it
in	10	dcap-3	cms022	17257	000100000000000000907AD8	gridse01_3	pccms32.ba.infn.it
in	2	dcap-3	cms022	13664	000100000000000000904720	gridse01_2	alicegrid08.ba.infn.it
in	8	dcap-3	cms022	13664	0001000000000000009006E0	gridse02_2	alicegrid08.ba.infn.it