Big Data over a 100G Network at Fermilab

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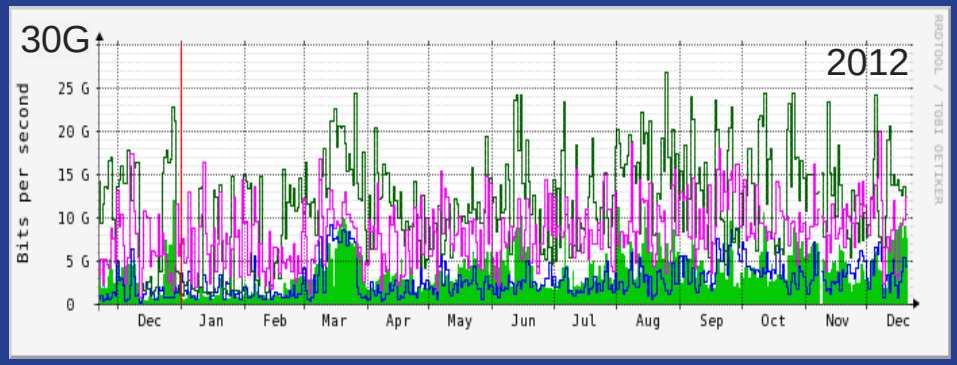
Overview

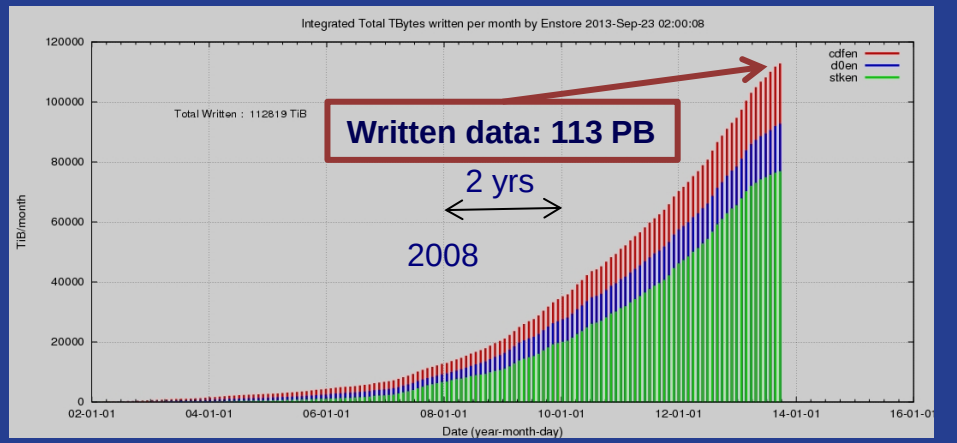
- Network R&D Program
  Motivations and Overview
- Network Infrastructure
  Production and R&D
- 100G Network R&D Program
  Results and Plans

Fermilab Users and 100G

- Using the network for decades in the process of scientific discovery for sustained, high speed, large and wide-scale distribution of and access to data
  - High Energy Physics community
  - Multi-disciplinary communities using grids (OSG, XSEDE)
- Figures of merit
  - 113 Petabytes written to tape, today mostly coming from offsite
  - 170Gbps peak LAN traffic from archive to local processing farms
  - LHC peak WAN usage in/out of Fermilab at 20-30 Gbps



Compact Muon Solenoid (CMS) routinely peaks at 20-30 Gbps for WAN traffic in/out of Fermilab.



113 PB of data ever written to the Enstore tape archive

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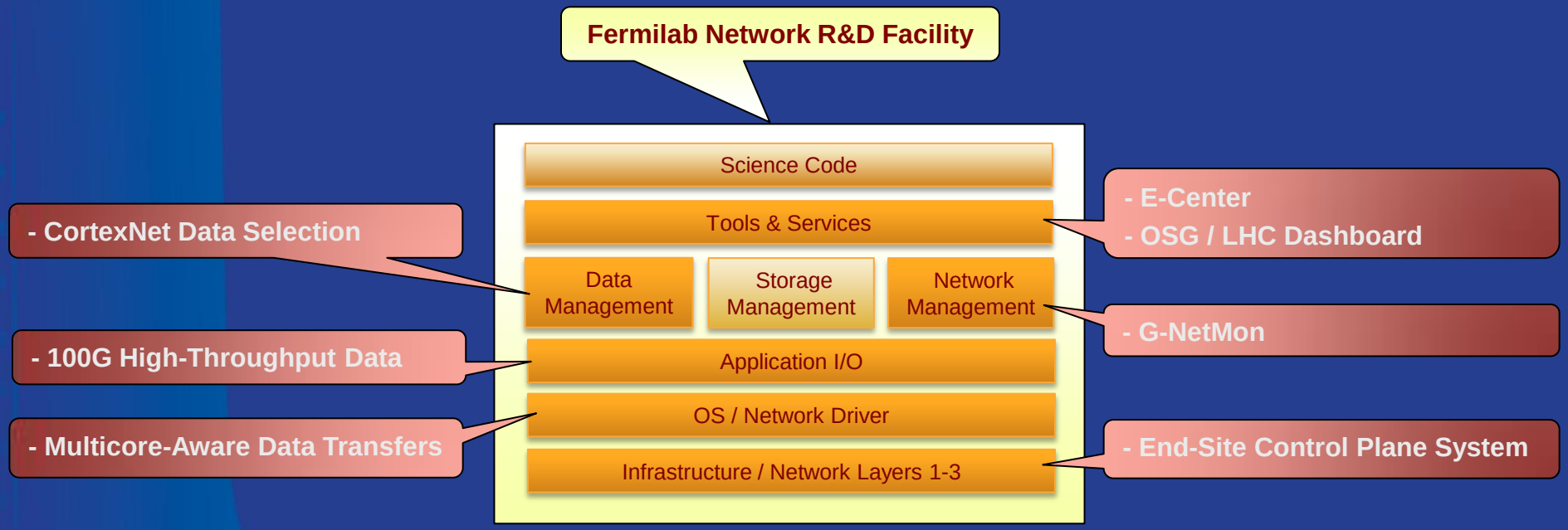
Network R&D at Fermilab



- A collaborative process part of the national program on network involving multiple research organizations (ESNet, I2, LBL, UNL, ANL, NERSC, UFL, UCSD, …)
- Builds on core competencies on Big Data inheriting from RunII and CMS expertise
- A diverse program of work that spans all layers of computing for scientific discovery

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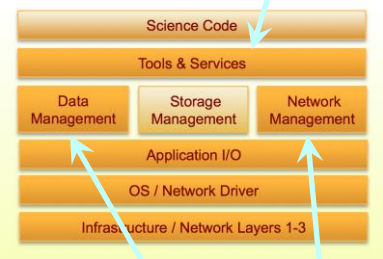
Pulling all R&D effort together from the top layers…



- Providing tools & services to enable users / apps to optimize use of the network
  - Collaborating with the OSG Network Area for the deployment of perfSONAR at 100 OSG facilities
  - Aggregating and displaying data through E-Center and the OSG Dashboard for end-to-end hop-by-hop paths across network domains
- Developing tools to monitor real-time 100G network traffic through multicore & manycore architectures
- Proposed integration with Data Management through network-aware data source selection – CortexNET

Pulling all R&D effort together from the bottom layers…

- Application-level R&D through the High Throughput Data Program
  - R&D on 100G for production use by CMS & FNAL high-capacity high-throughput Storage facility
  - Identifying gaps in data movement middleware for the applications used for scientific discovery – GridFTP, SRM, Globus Online, XRootD, Frontier / Squid, NFS v4
- OS-level R&D to improve data transfer performance
  - Optimizing network I/O for 40/100G environments
  - Multicore-aware data transfer middleware (MDTM)
- Integrating local network infrastructure with WAN circuit technologies through policy-driven configuration (ESCPS)

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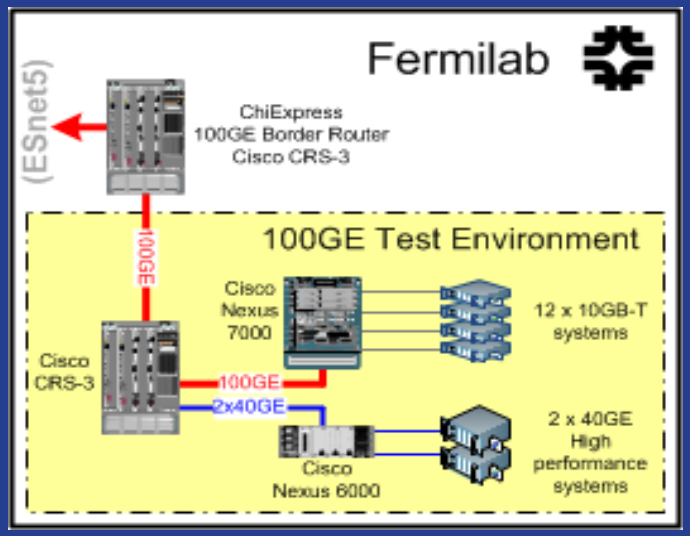
A dedicated R&D Network facility

- 100G R&D
- Production-like env for tech eval
- Testing of firmware upgrades

- Nexus 7000 w/ 2-port 100GE module / 6-port 40GE module / 10GE copper module
- 12 nodes w/ 10GE Intel X540-AT2 (PCIe) / 8 cores / 16 GB RAM



* Diagram courtesy of Phil DeMar

- Nexus 6000E for 40GE systems
  - IPv6 tests / F5 load balancer / Infoblox DNS, Palo Alto firewall
- 2 nodes w/ 40GE Mellanox ConnectX®-2 (PCIe-3) / 8 cores w/ Nvidia M2070 GPU

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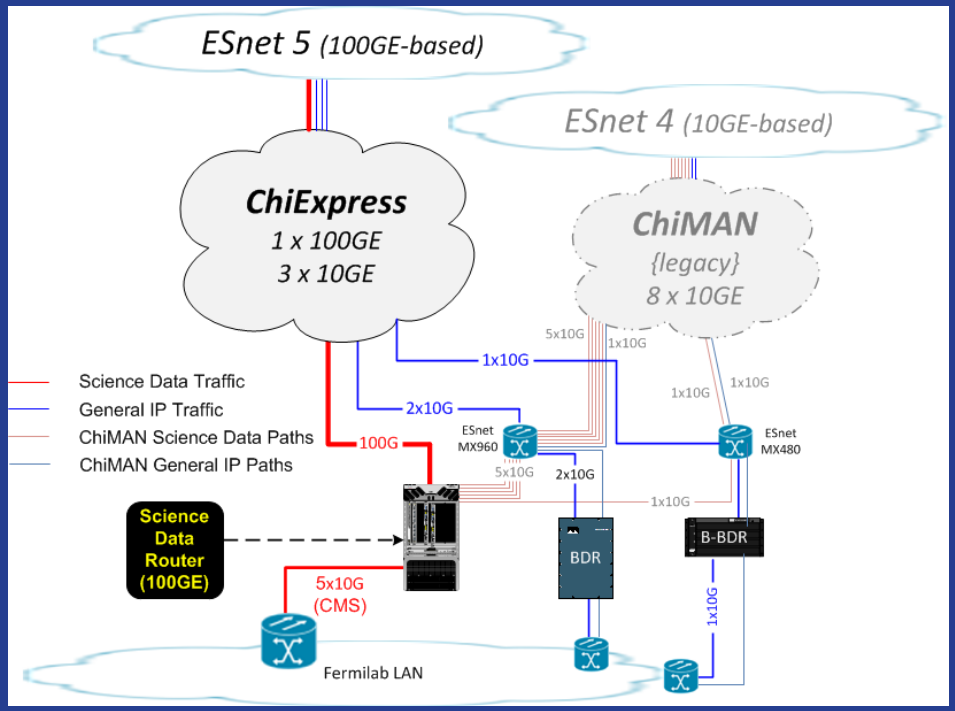
Fermilab WAN Capabilities: In Transition from n x 10GE to 100GE

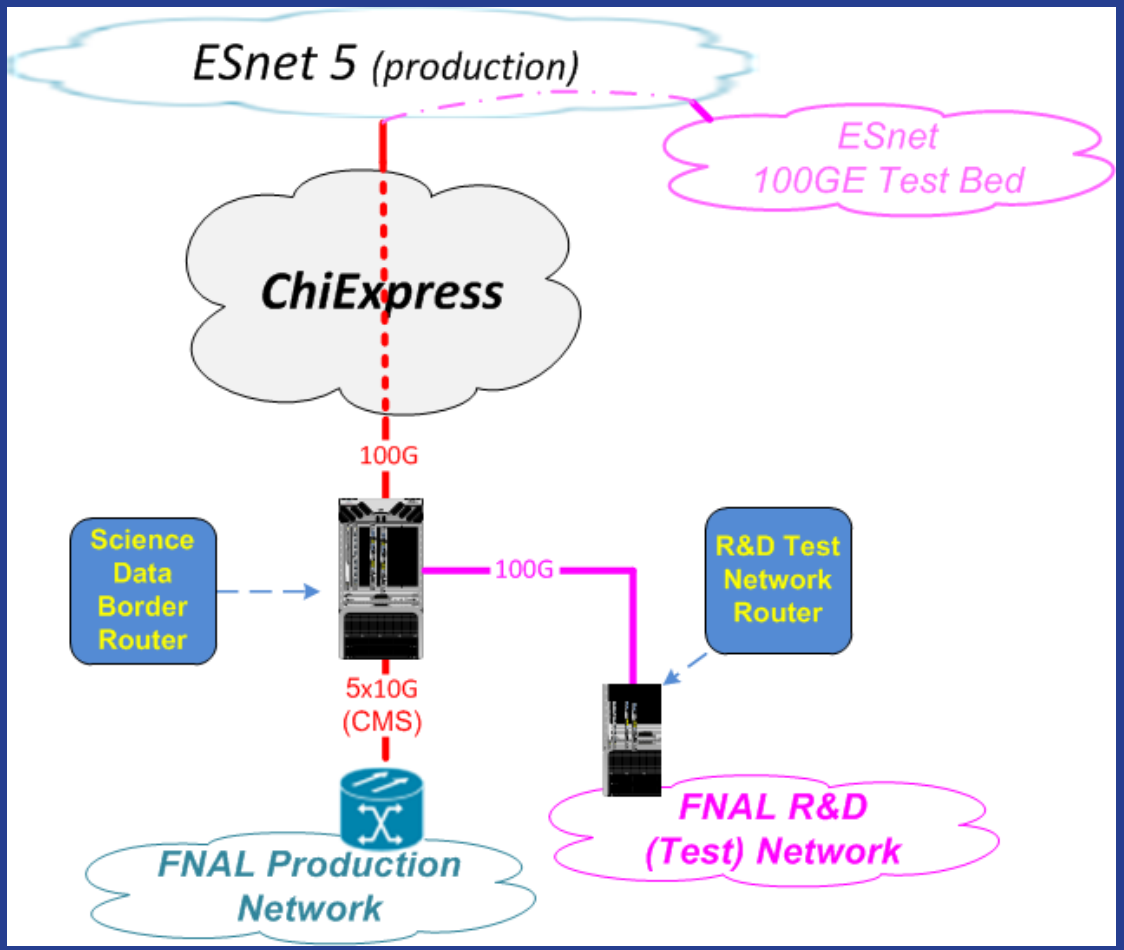
- Legacy 10GE-based MAN being phased out:
  - Eight 10GE channels
  - Six used for science data
- New 100GE-based MAN being phased in:
  - One 100GE channel and three 10GE channels
  - 100GE channel is for science data movement
  - 10GE channels for general IP traffic and redundancy for science data



* Diagram courtesy of Phil Demar

Using 100G Channel for R&D As Well

- CMS needs 50G of data traffic from the 100G channel
- Remaining ~50G for FNAL R&D network
  - Potentially higher when CMS traffic levels are low
  - LHC in shutdown until 2015
- Planning WAN circuit into ESnet 100G testbed
  - Potential for circuits to other R&D collaborations



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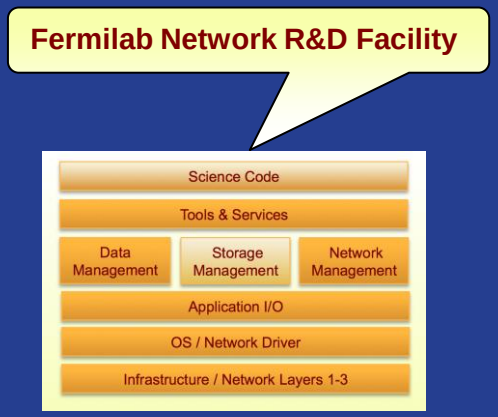
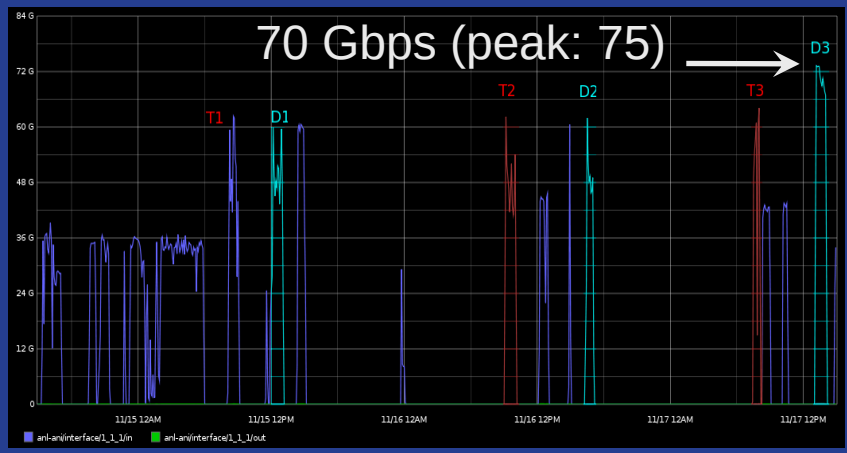
Goals of 100G Program at Fermilab

- Experiment analysis systems include a deep stack of software layers and services.
- Need to ensure these are functional and effective at the 100G scale end-to-end.
  - Determine and tune the configuration of all layers to ensure full throughput in and across each layer/service.
  - Measure and determine efficiency of the end-to-end solutions.
  - Monitor, identify and mitigate error conditions.



100G High Throughput Data Program

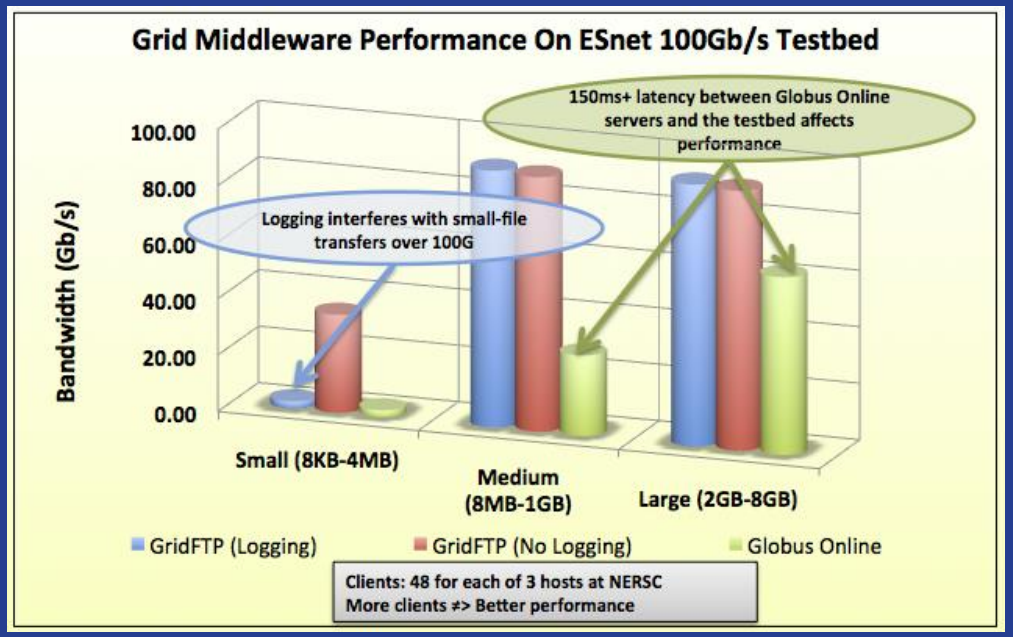
- 2011: Advanced Network Initiative (ANI) Long Island MAN (LIMAN) testbed.
  - GO / GridFTP over 3x10GE.
- 2011-2012: Super Computing ’11
  - Fast access to ~30TB of CMS data in 1h from NERSC to ANL using GridFTP.
  - 15 srv / 28 clnt – 4 gFTP / core; 2 strms; TCP Win. 2MB

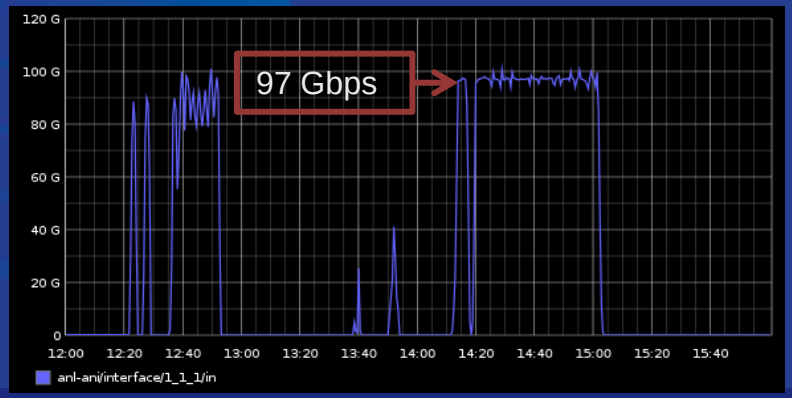


- 2012-2013: ESnet 100G testbed
  - Tuning parameters of middleware for data movement: xrootd, GridFTP, SRM, Globus Online, Squid. Achieved ~97Gbps
    - Rapid turn around on the testbed thank to custom boot images
  - Commissioning Fermilab Network R&D facility: 12 nodes at 8.5 Gbps per 10G node
  - Test NFS v4 over 100G using dCache (collab. w/ IBM research)
- Fall 2013 / Winter 2014: 100G Endpoint at Fermilab
  - Validate hardware link w/ data transfer apps with UFL and others. Talk to me if you want to participate in these activities.
  - Demonstrate storage-to-storage 100G rates

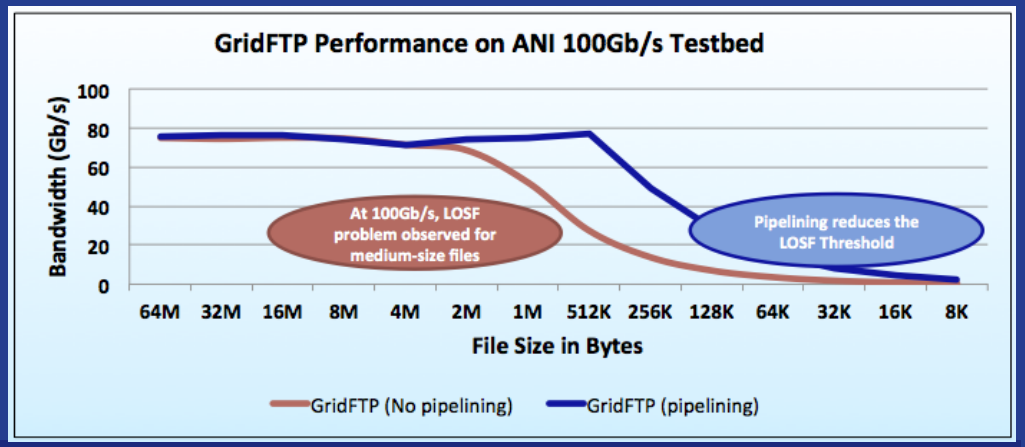
GridFTP / SRM / GlobusOnline Tests

- Data Movement using GridFTP
  - 3rd party Srv to Srv trans.: Src at NERSC / Dest at ANL
  - Dataset split into 3 size sets
- Large files transfer performance ~ 92Gbps
- GridFTP logging was through NFS on 1GE link: file transfers blocked on this.
- Lot of Small Files (LOSF) transfer performance improved with pipelining





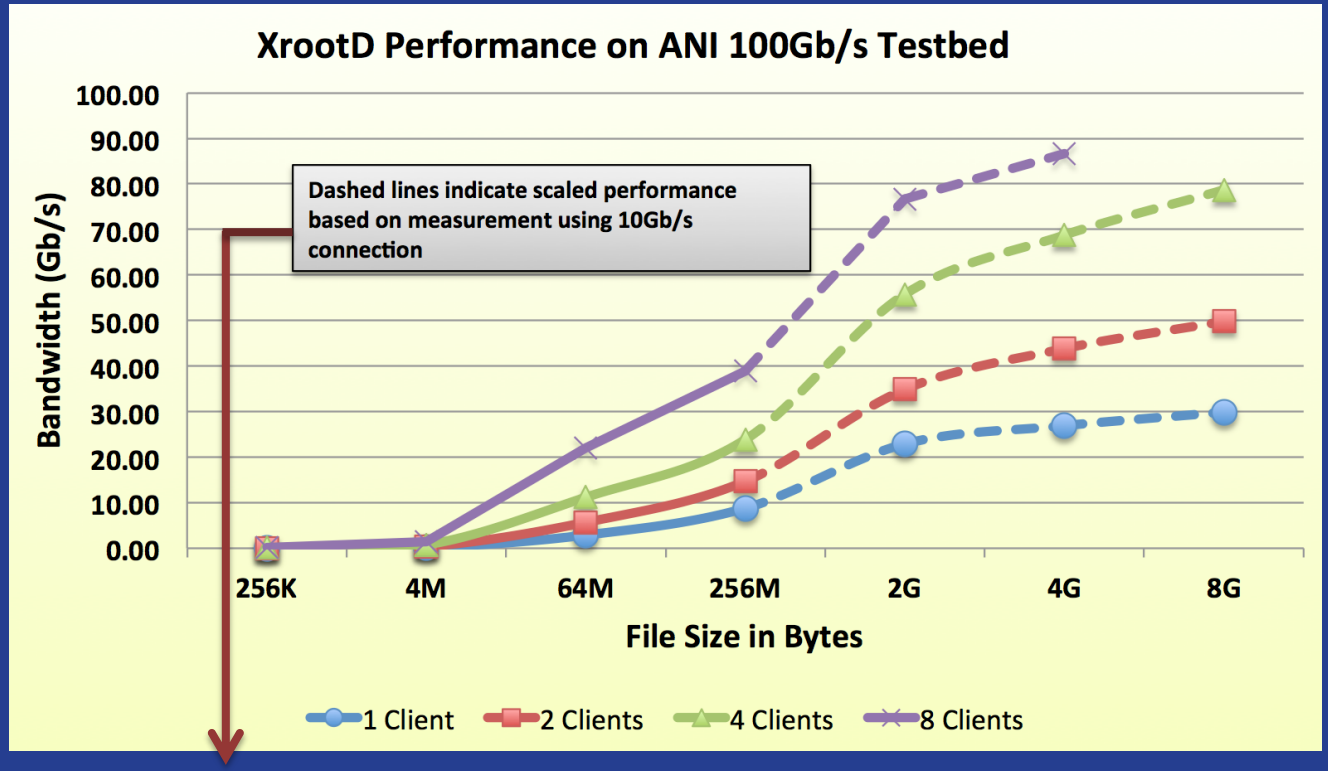
Optimal performance: 97 Gbps w/ GridFTP
2 GB files – 3 nodes x 16 streams / node



Pipelining ("FTP cmd in-flight") mitigates the negative effects of high-latency on transfer performance

XRootD Tests

- Data Movement over XRootD, testing LHC experiment (CMS / Atlas) analysis use cases.
  - Clients at NERSC / Servers at ANL
  - Using RAMDisk as storage area on the server side
- Challenges
  - Tests limited by the size of RAMDisk
  - Little control over xrootd client / server tuning parameters

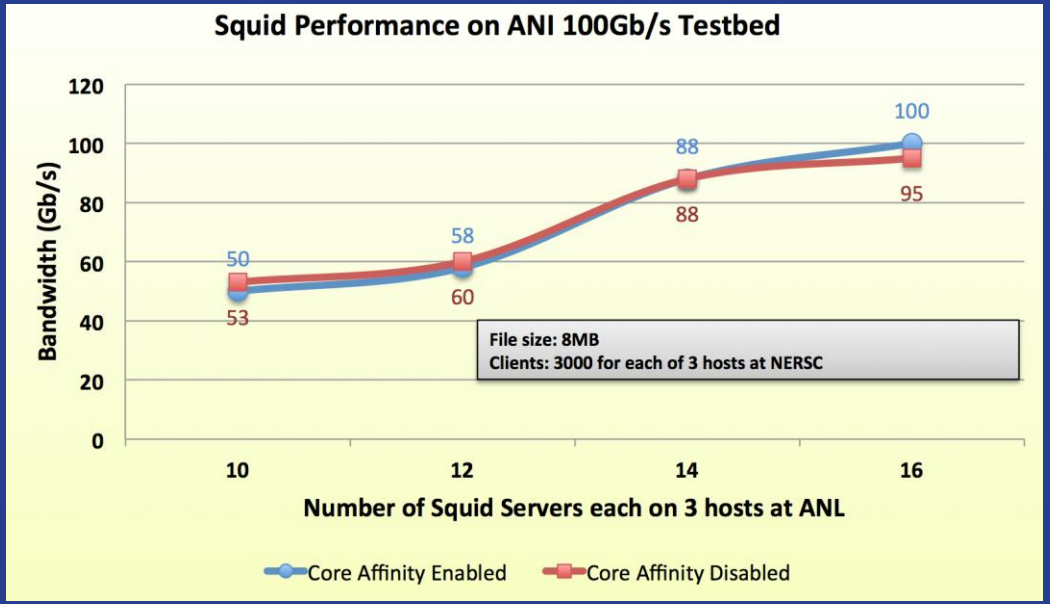


Dataset (GB)	1 NIC measurements (Gb/s)	Aggregate Measurements (12 NIC) (Gb/s)	Scale Factor per NIC	Aggregate estimate (12 NIC) (Gb/s)
0.512	4.5	46.9	0.87	–
1	6.2	62.4	0.83	–
4	8.7 (8 clients)	–	0.83	86.7
8	7.9 (4 clients)	–	0.83	78.7

Calculation of the scaling factor between 1 NIC and an aggregated 12 NIC for datasets too large to fit on the RAM disk

Squid / Frontier Tests

- Data transfers
  - Cache 8 MB file on Squid – This size mimics LHC use case for large calib. data
  - Clients (wget) at NERSC / Servers at ANL
  - Data always on RAM
- Setup
  - Using Squid2: single threaded
  - Multiple squid processes per node (4 NIC per node)
  - Testing core affinity on/off: pin Squid to core i.e. to L2 cache
  - Testing all clnt nodes vs. all servers AND aggregate one node vs. only one server



- Results
  - Core-affinity improves performance by 21% in some tests
  - Increasing the number of squid processes improves performance
  - Best performance w/ 9000 clients: ~100 Gbps

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Summary

- The Network R&D at Fermilab spans all layers of the communication stack
- Science discovery by HEP and Astrophysics drive the program of work
- Fermilab is deploying a Network R&D facility with 100G capability
- ESnet 100G Testbed has been fundamental for our middleware validation program
- Fermilab will test the 100GE capability in the Fall 2013 – Winter 2014