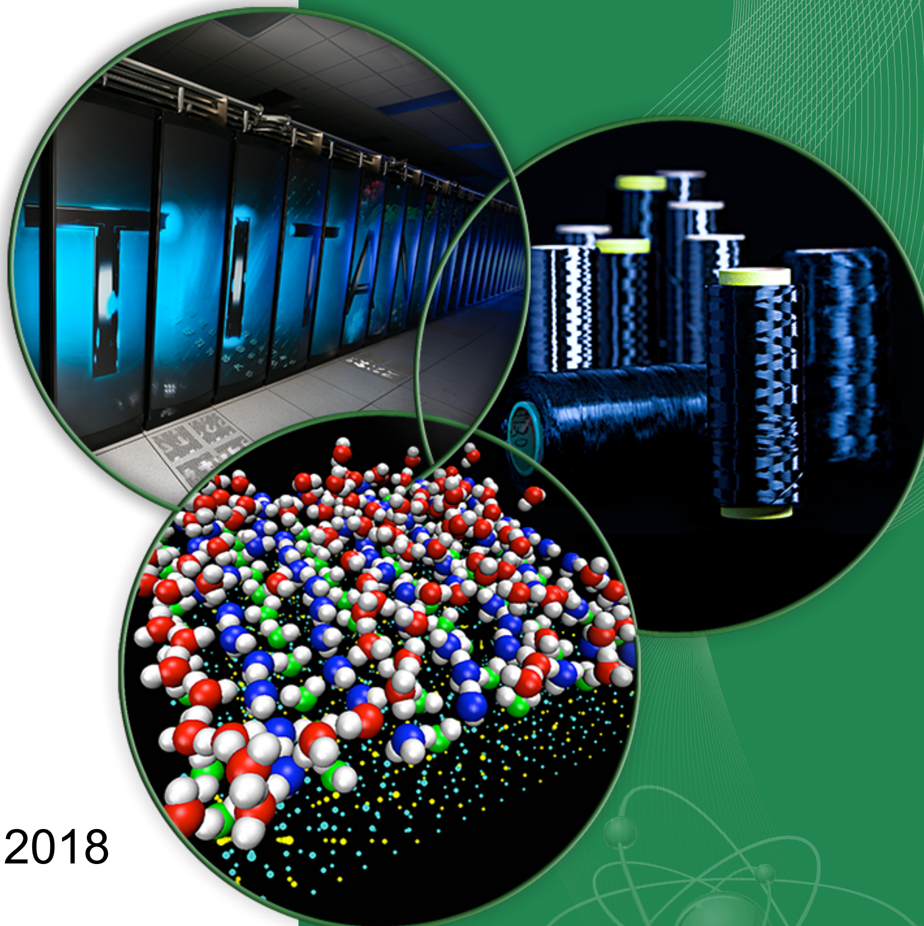
Analytics of Wide-Area Lustre Throughput Using LNet Routers



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Oak Ridge National Laboratory

Lustre User Group Conference – LUG 2018
April 24-26, 2018
Argonne National Laboratory
Argonne, IL

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Outline

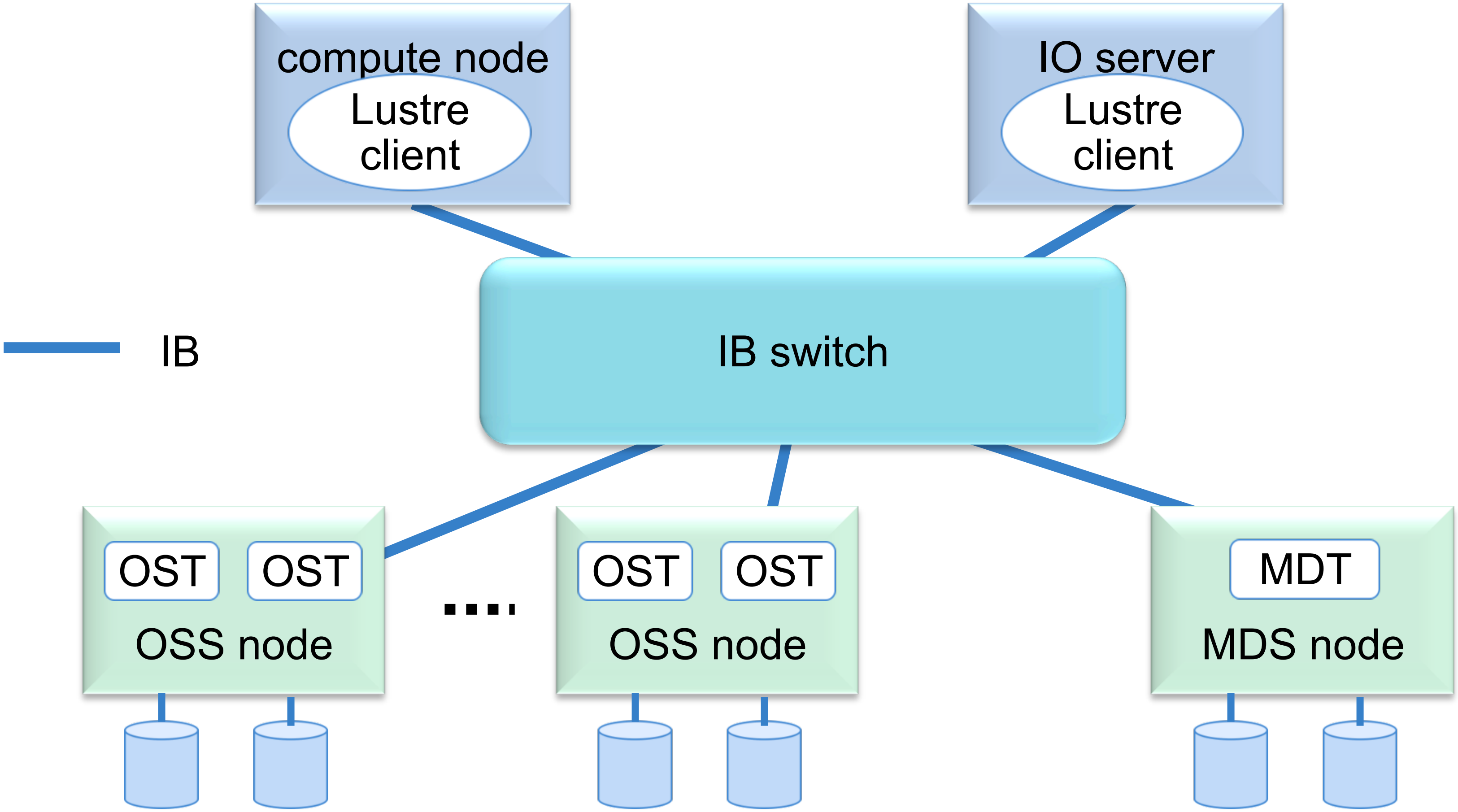
- Introduction
- Lustre Basic Configurations
- Luster Over Ethernet
- Test Configurations and Measurements
- LNet Buffers Impact
- Conclusions

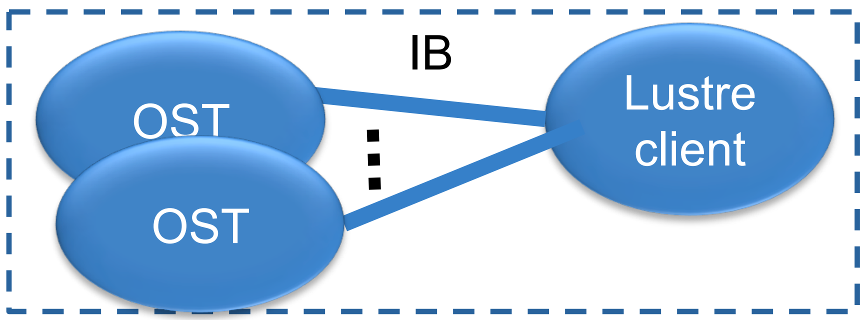
Lustre: Distributed File System

Lustre file system

- One or more Meta Data Server (MDS)
  - supported by Meta Data Targets (MDT)
- One or more Object Storage Servers (OSS)
  - supported by one or more Object Storage Target (OST)
- Mounted by Lustre clients on hosts (IO and compute)
  - over IB, Ethernet, and other networks
  - compute host: typically nodes in a cluster – computations with files accesses
  - IO or Data Transfer Node (DTN) hosts: typically used for bulk and storage operations
- Lustre achieves high performance by effectively parallelizing I/O from multiple clients to multiple OSTs
  - files striped over multiple OSTs per a pre-defined pattern

Lustre over IB: Basic Configuration

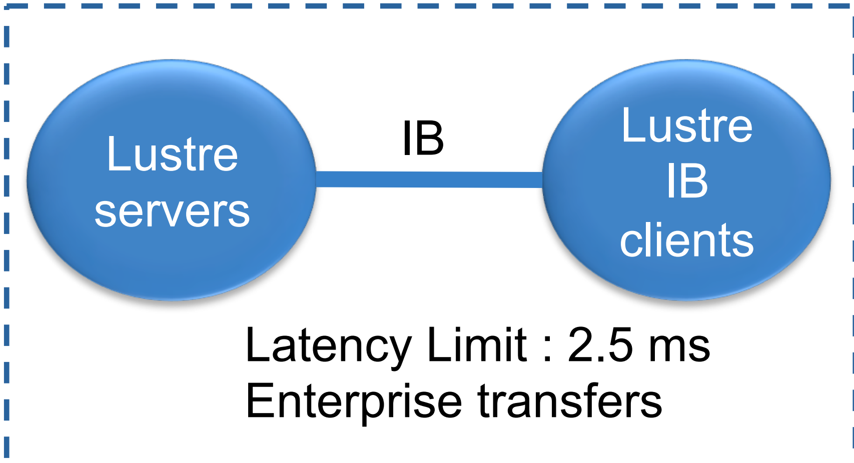


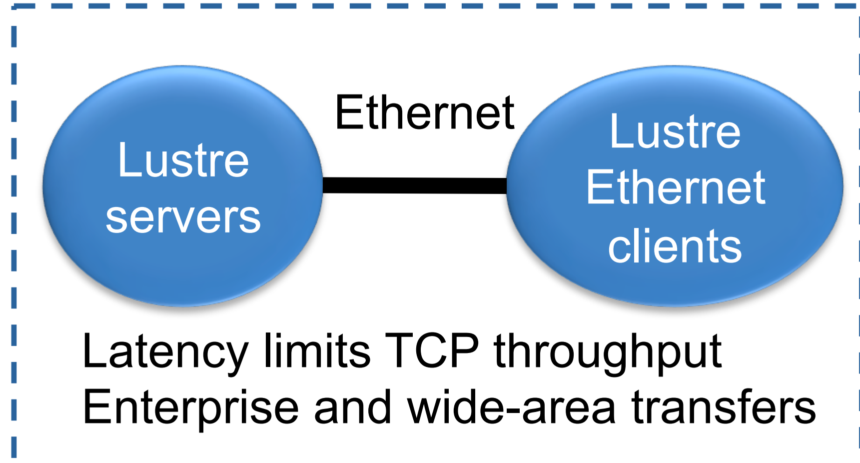


Lustre Over Wide-Area

- Desired features: Lustre mounted over wide-area
  - Obviates need for transfer services such as GridFTP, Aspera, XDD and others
  - Easier application integration with remote file operations: “super facility” with distributed HPC systems with containers – codes may be moved among the sites - currently files need to moved too
- Current Installations
  - Majority are supported over site IB networks
  - Time-out limitation: 2.5ms
  - IB WAN extenders: too expensive and not flexible
- Lustre over Ethernet (not as widely deployed)
  - TCP/IP implementation: uses existing networks
  - Very little infrastructure enhancements needed

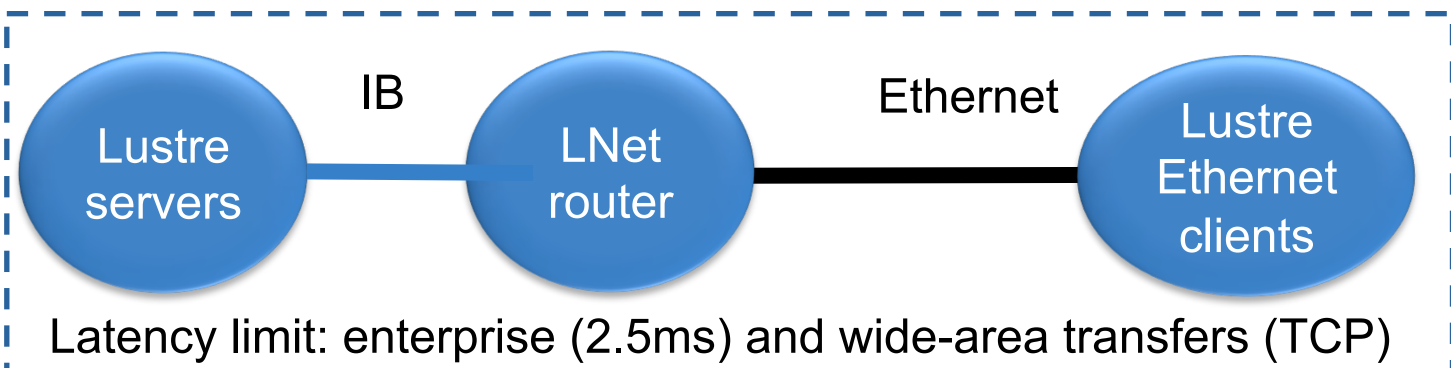
Basic IB and Ethernet Lustre Configurations





Lustre over IB: limited to enterprises – 2.5ms latency limit
Lustre over Ethernet for wide-area – TCP version limited by throughput

LNet routers: extent enterprise Lustre/IP to wide-area using Luster/Ethernet



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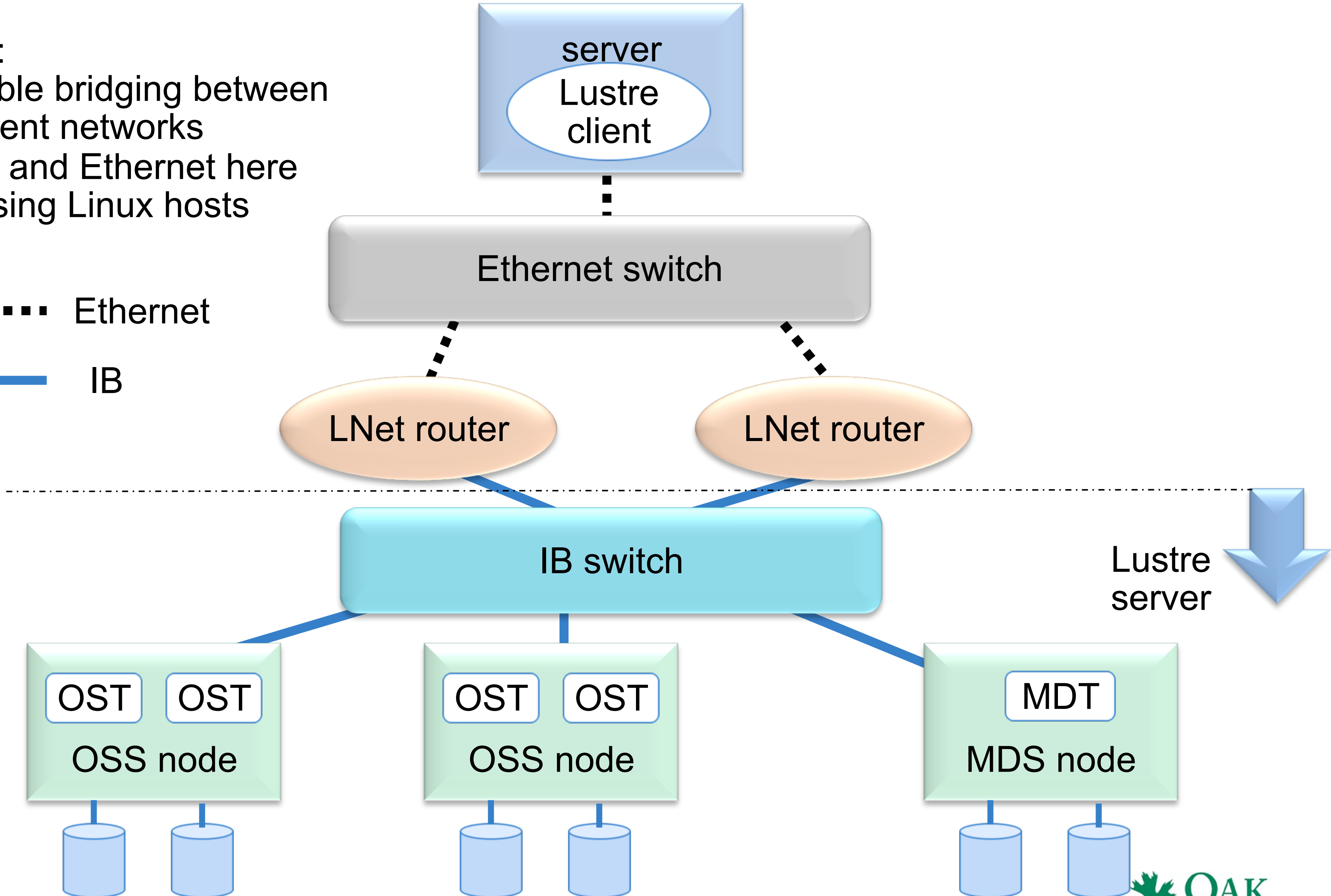
Lustre over IB-Ethernet: LNet routers

LNet:
Flexible bridging between different networks

- IB and Ethernet here
- Using Linux hosts

Ethernet

IB



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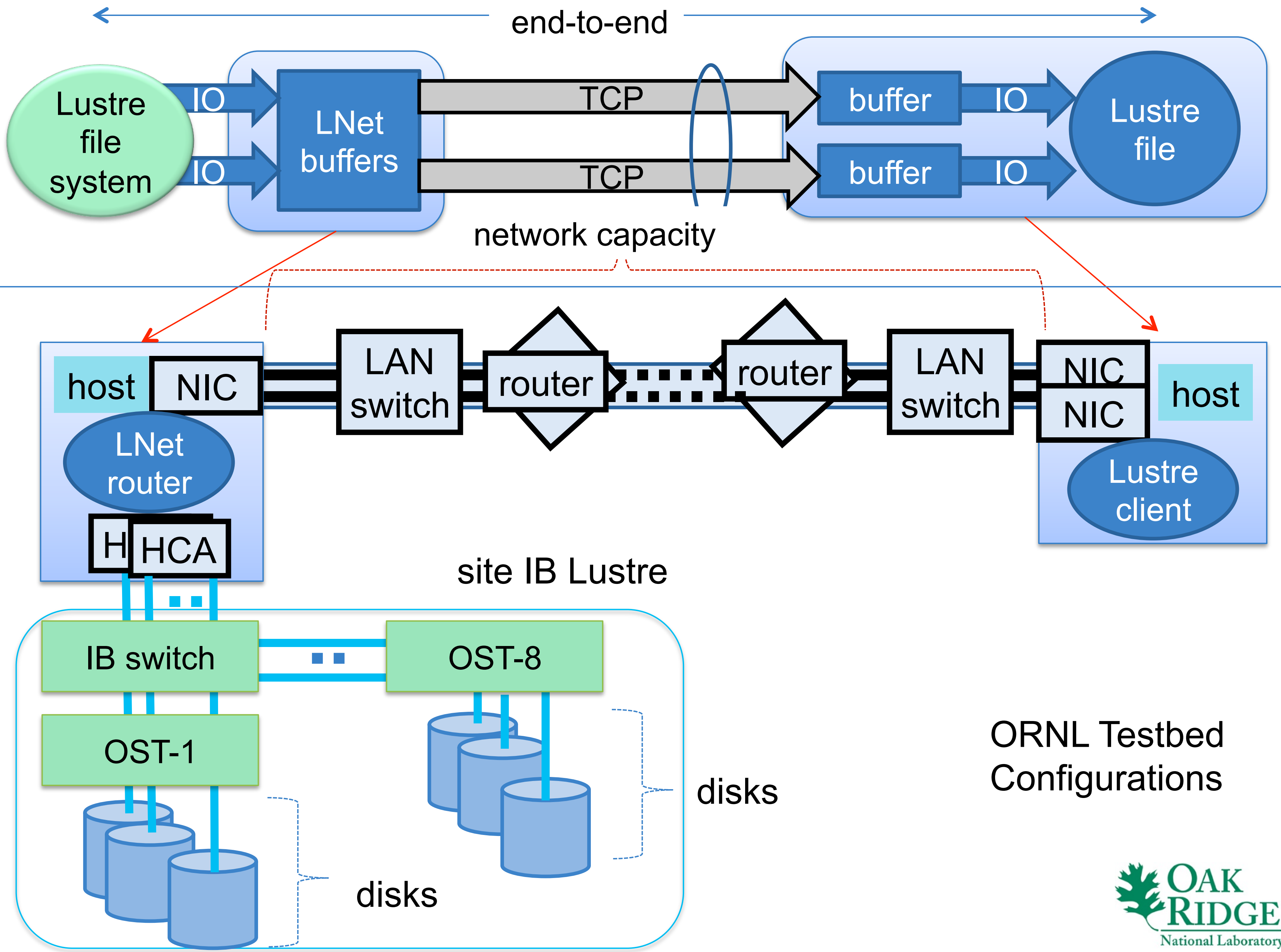
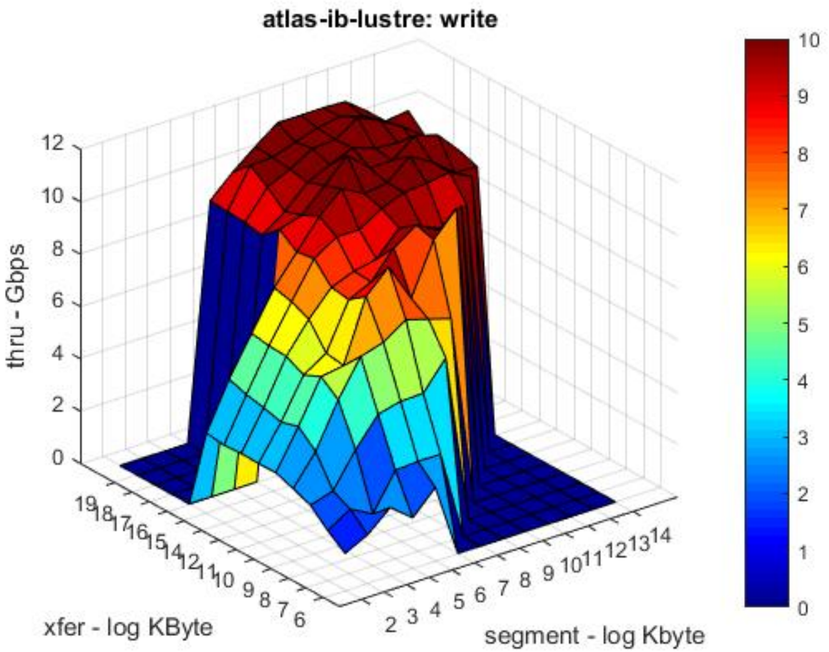

end-to-end
Lustre file system
IO
IO
LNet buffers
TCP
TCP
buffer
buffer
IO
IO
Lustre file
network capacity
host
NIC
LNet router
H
HCA
LAN switch
router
router
LAN switch
NIC
NIC
host
Lustre client
site IB Lustre
IB switch
OST-8
OST-1
disks
disks
ORNL Testbed Configurations

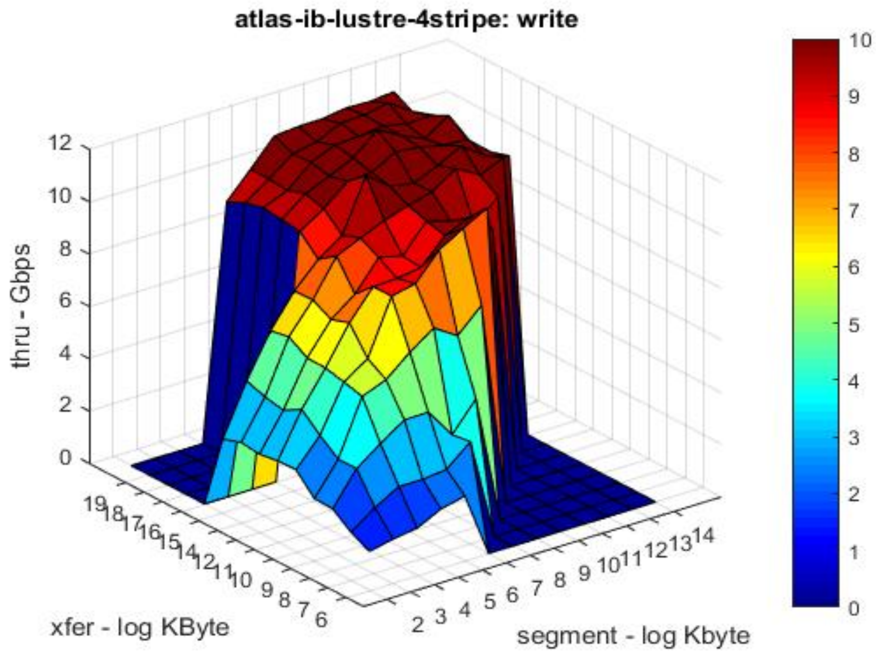
Lustre and LNet Parameter Setup

- Lustre parameters:
  - Client-level: lustre_ctrl
    - number of credits: default:8; current 256
  - File/Directory Level:
    - number of stripes: 2,8
    - stripe size: default
- LNet parameters
  - Base parameters: lnetctl
  - ksocklnd.conf: LNet buffer-size range: 50K – 2G; default 65K
- TCP parameters
  - Congestion-control modules: CUBIC and Hamilton TCP
  - Buffer sizes: 200ms recommended values, largest allowed

Lustre Throughput: IOZone (IB - Reference)

- ORNL OLCF
  - Atlas/Spider Lustre system: 2K OSSs
  - Data Transfer Node (DTN) server
  - Write throughput: stable ~10Gigabits/sec (Gbps) =~1.25GigaBytes/sec(GBps)





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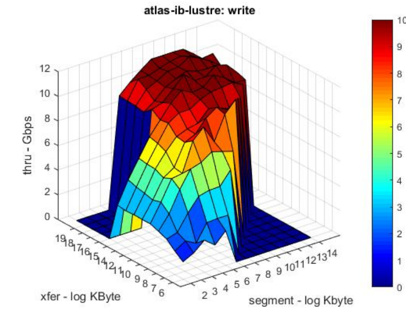
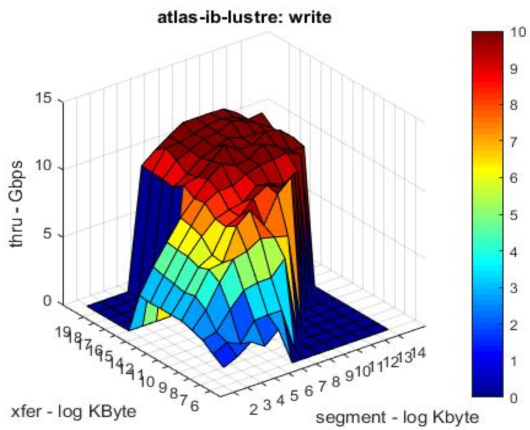
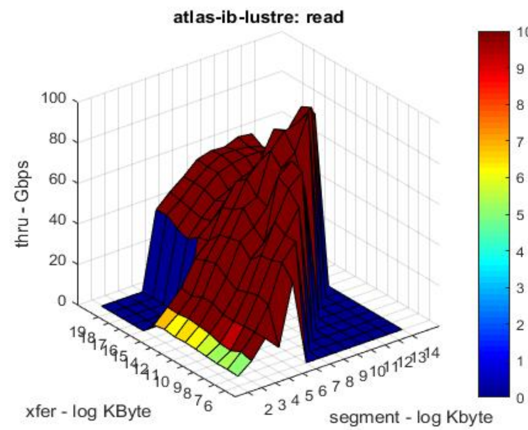
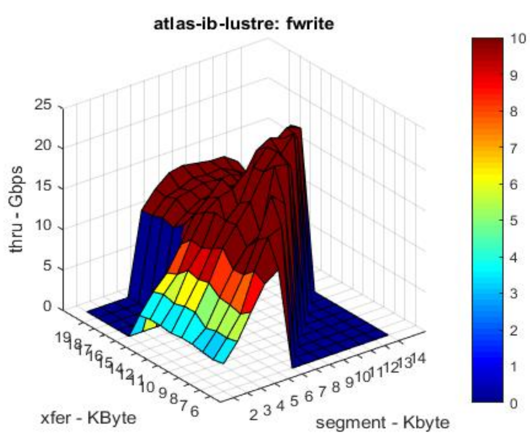
IO Zone: Lustre Throughput

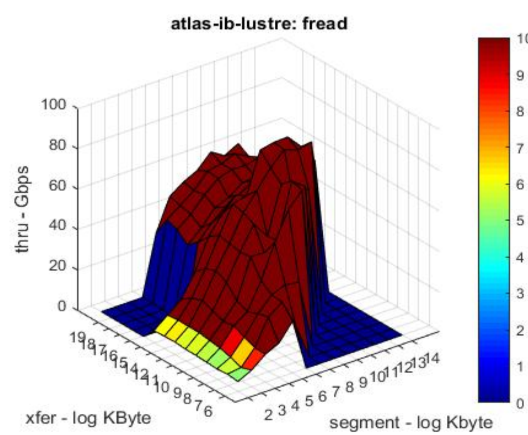
- ORNL OLCF
  - Write throughput: stable ~10Gbps











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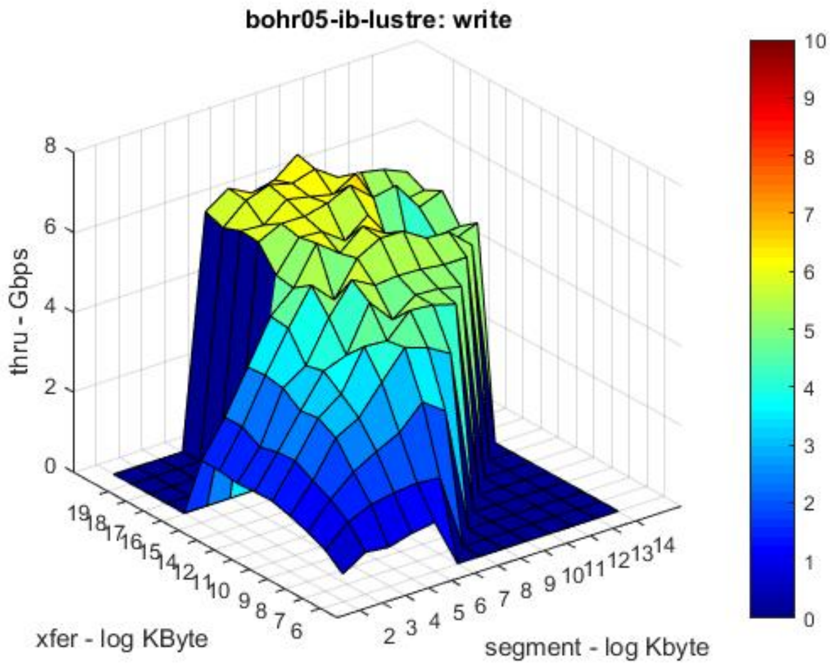
Site Lustre over IB: ORNL Testbed

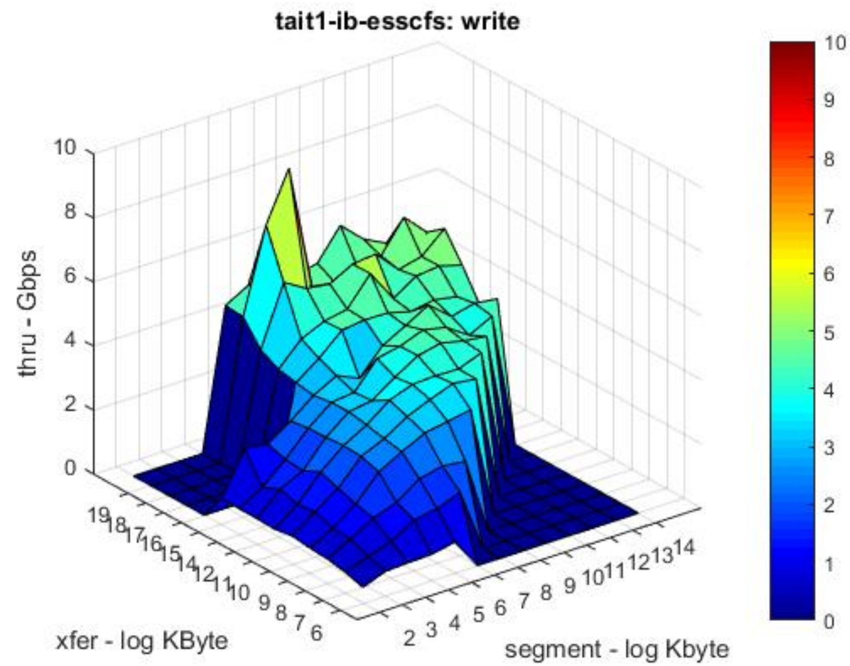
bohr **data servers** - centos 6.8

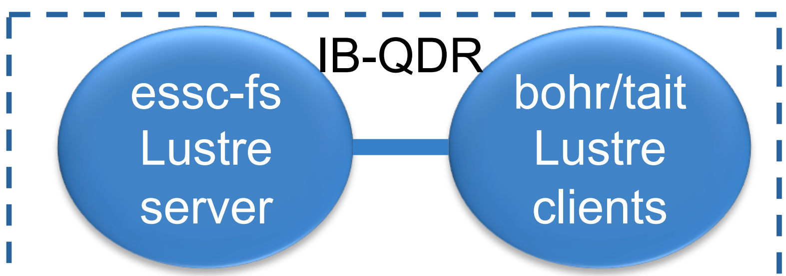
- 48core, opteron, 2.2 GHz
- write peak throughput: ~6Gbps



tait **compute nodes** – centos 6.8

- 24 core, xeon 2.6GHz
- Write peak throughput: ~5Gbps





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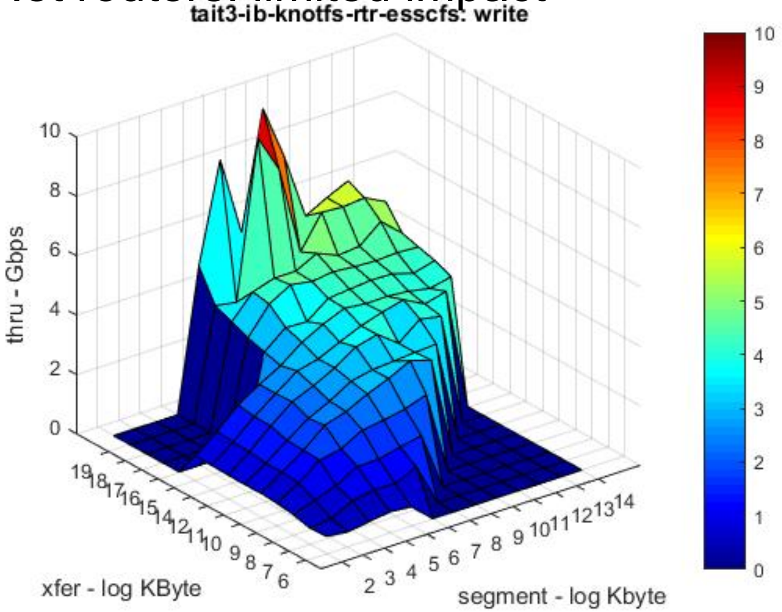
Site Lustre over IB: Test Hosts

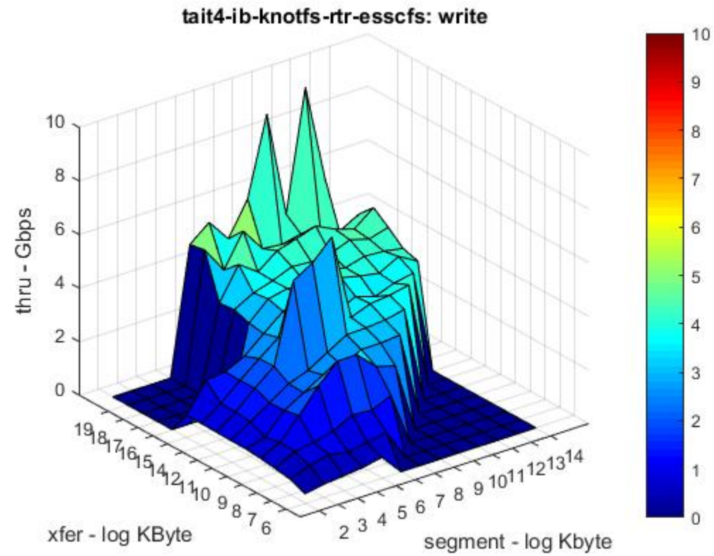
- bohr specs – primarily used for file transfers
  - HP ProLiant DL585 G7
  - AMD Opteron(tm) Processor 6176 SE: 48 cores and two sockets
  - 48x 8GB DDR3 1066MHz DIMMs
  - InfiniBand: Mellanox Technologies MT26428 [ConnectX VPI PCIe 2.0 5GT/s - IB QDR / 10GigE] (rev b0): MT26428
  - Ethernet: Mellanox Technologies MT27700 Family [ConnectX-4]: MT4115
- tait specs – node on compute clusters
  - Dell PowerEdge R720
  - Dual Intel(R) Xeon(R) CPU E5-2630 v2 @ 2.60GHz: 24 cores
  - 8x Micro Technology 16GB DDR3 1600MHz DIMMs
  - InfiniBand: Mellanox Technologies MT27500 Family [ConnectX-3]: MT4099
  - Ethernet: Mellanox Technologies MT27700 Family [ConnectX-4]: MT4115

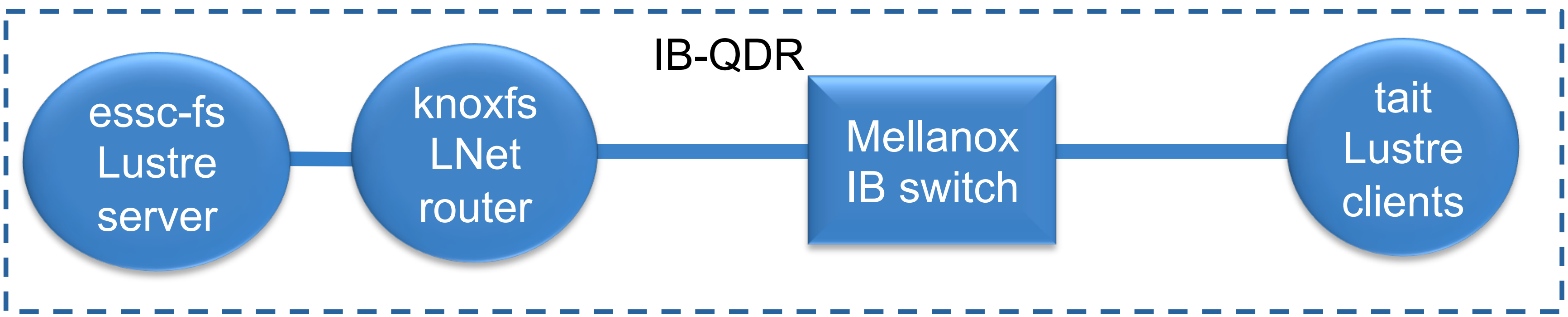
Site Lustre: LNet over IB Networks

tait compute servers – centos 6.8: write peak throughput: ~5Gbps

LNet routers: limited impact



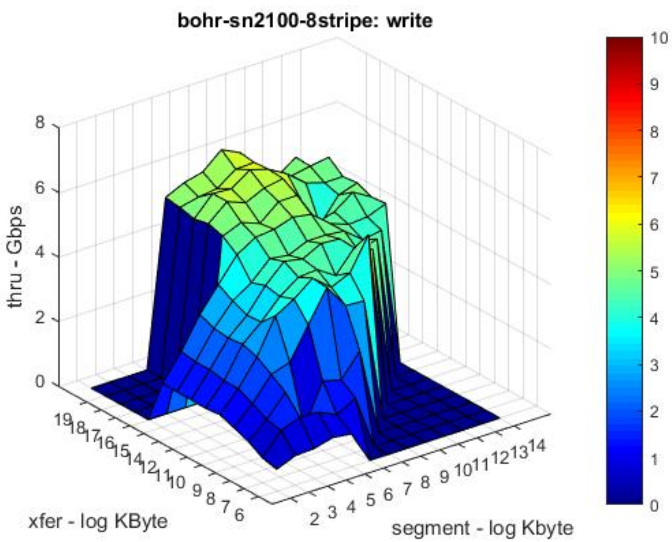


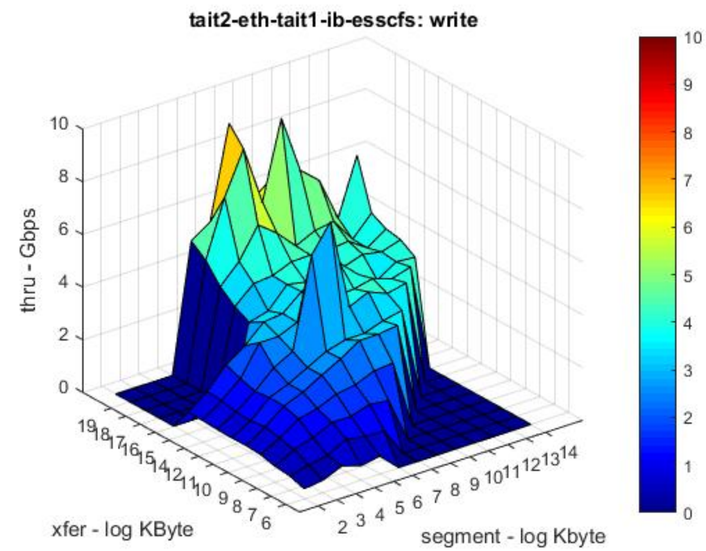


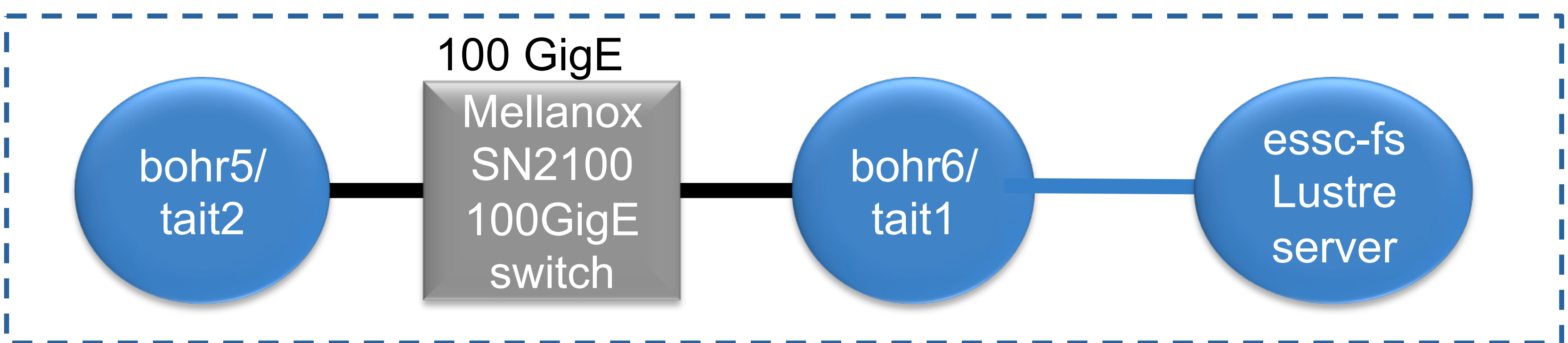
Site Lustre with LNet over IB-Ethernet

bohr and tait servers (6.8): write peak throughput: ~6 and 4 Gbps

LNet router and Ethernet switch: limited impact

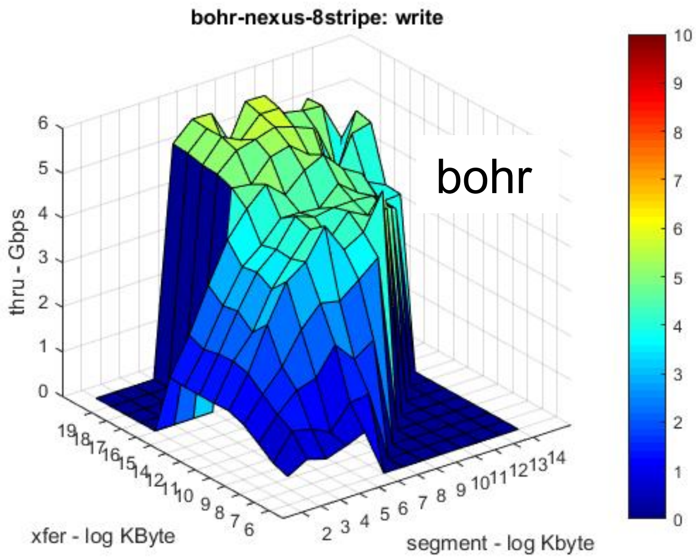


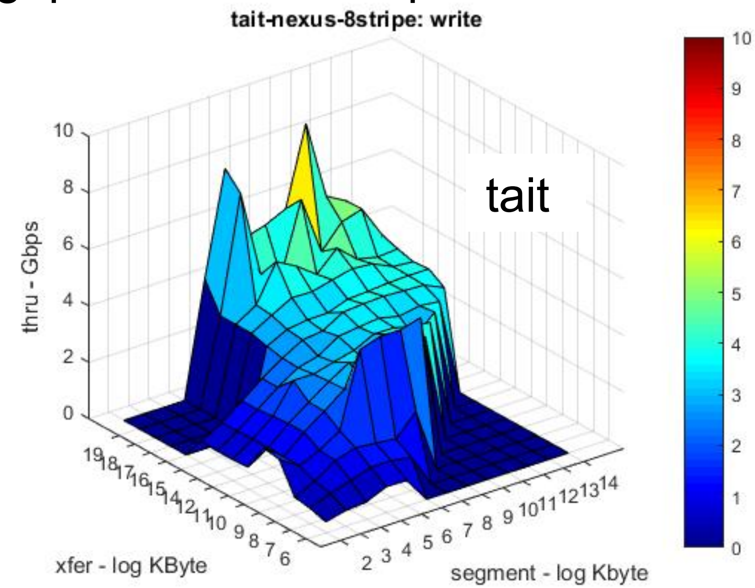


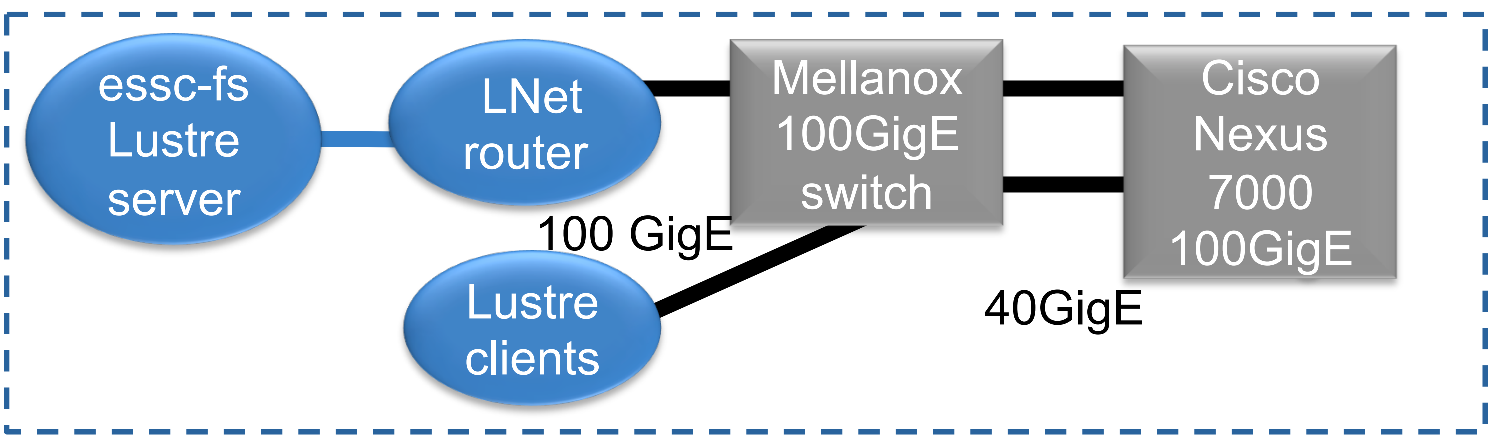


Site Lustre with LNet over IB-Ethernet

bohr and tait servers (6.8): write peak throughput: ~6 and 4 Gbps

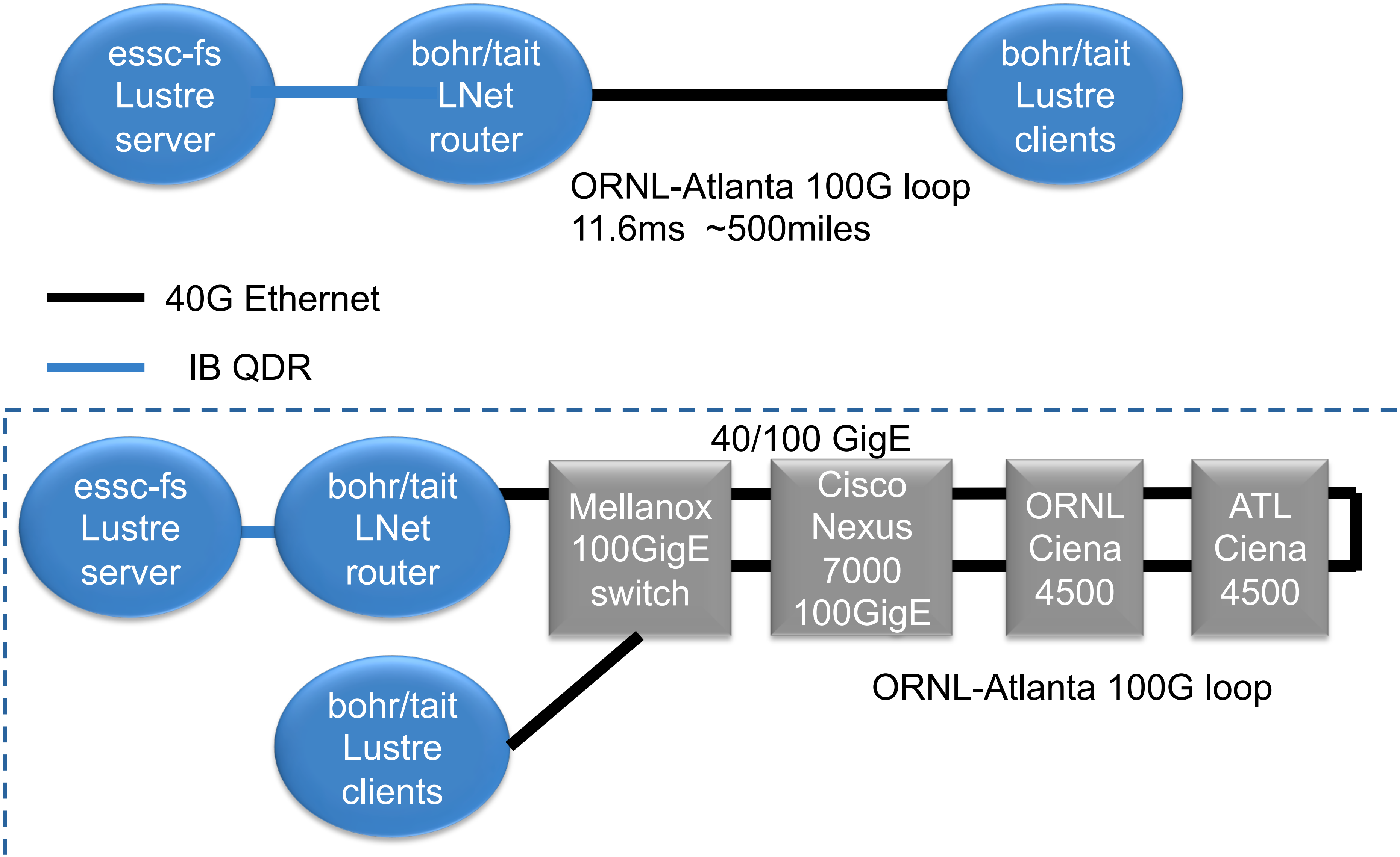






Testbed configuration: complex with several “firsts” – IB, LNet, Lustre and n/w

Wide-Area Lustre: ORNL-Atlanta: 11.6ms



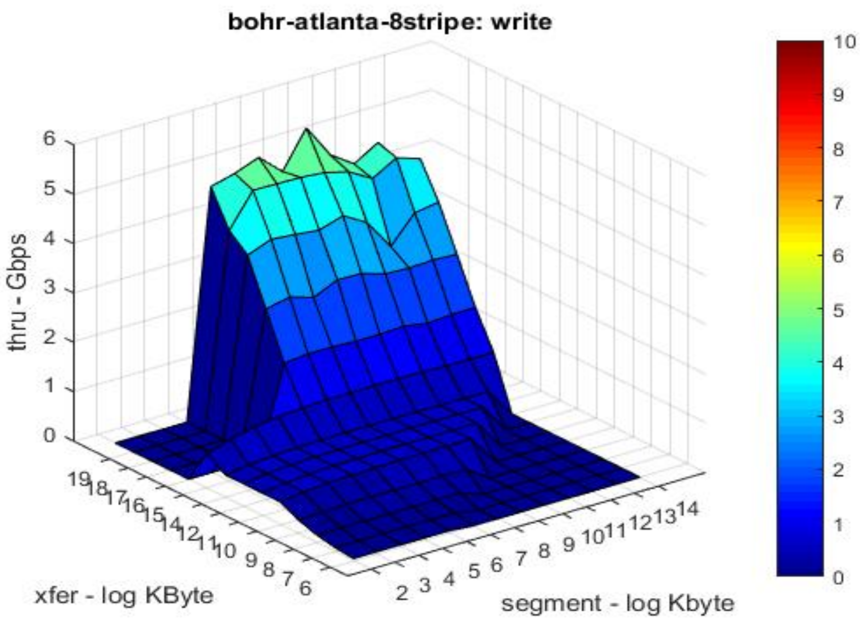
Wide-Area Lustre: ORNL-Atlanta: 11.6ms

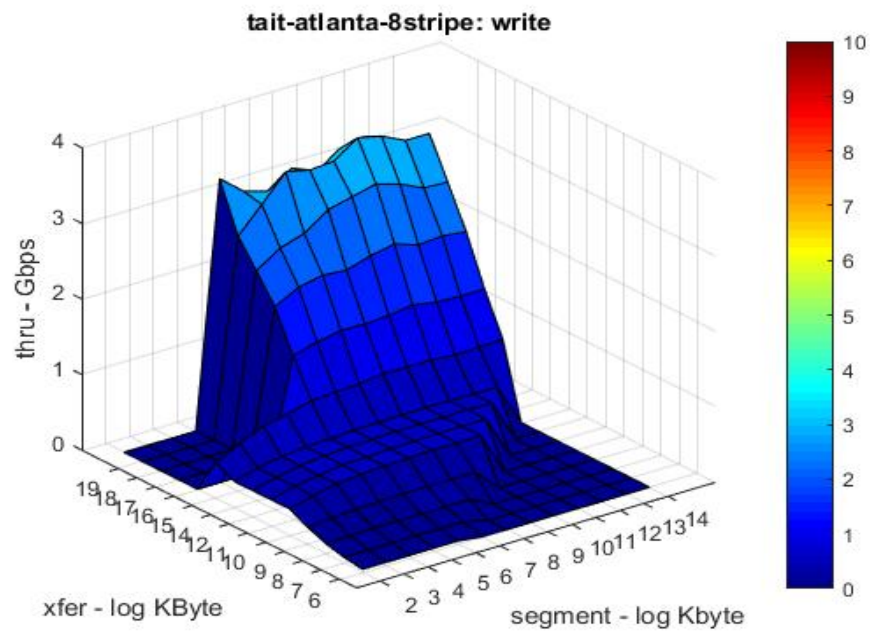
bohr IO servers: write peak throughput:

- wide-area: ~5Gbps
- local: ~6Gbps

tait compute servers: write peak throughput:

- wide-area:~3Gbps
- local:~5Gbps





Need deeper examination of networking: buffers and congestion control

This default throughput is for centos 6.8

Default is lower ~10% when upgraded to centos 7.2

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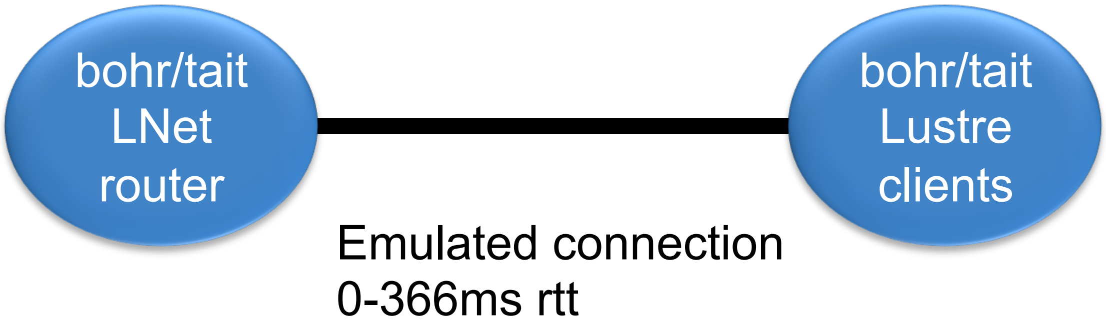
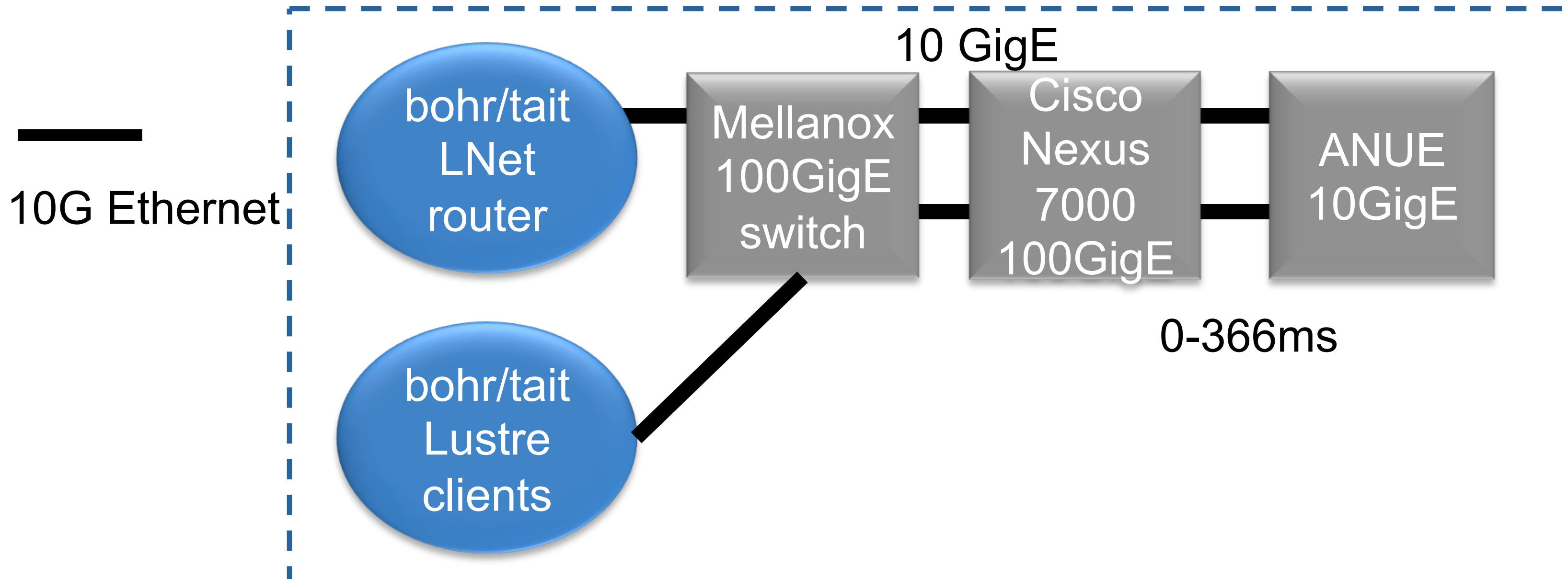
Network Emulation: 0-366 ms

ANUE 10GigE hardware emulator:

- sufficient since local throughput is below 10Gbps

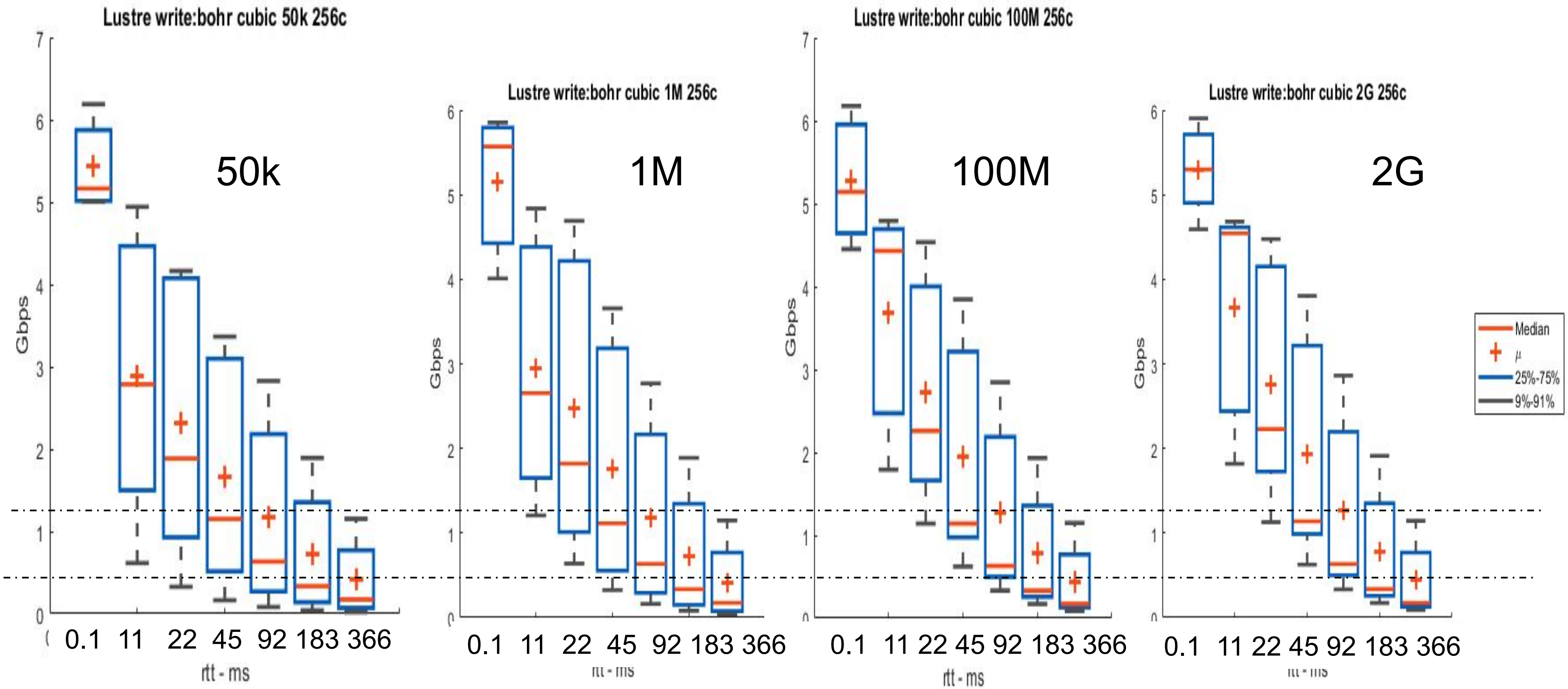




Lustre wide-area: bohr – cubic – LNet

Overall Summary: TCP and Lustre tuned

Increasing Lnet router buffers: 50k-2G: improves throughput within 1%



bohr IO servers – TCP tuned

- 48core, opteron, 2.2 GHz, Centos 7.2
- write peak throughput: ~6Gbps

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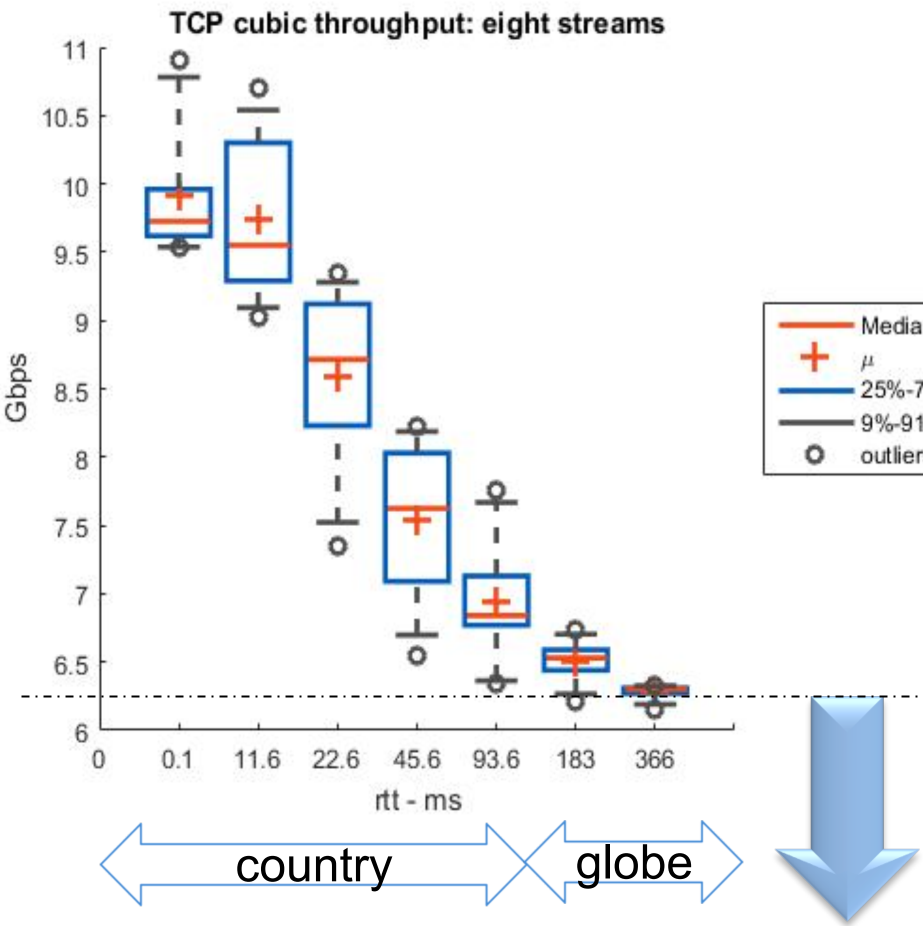
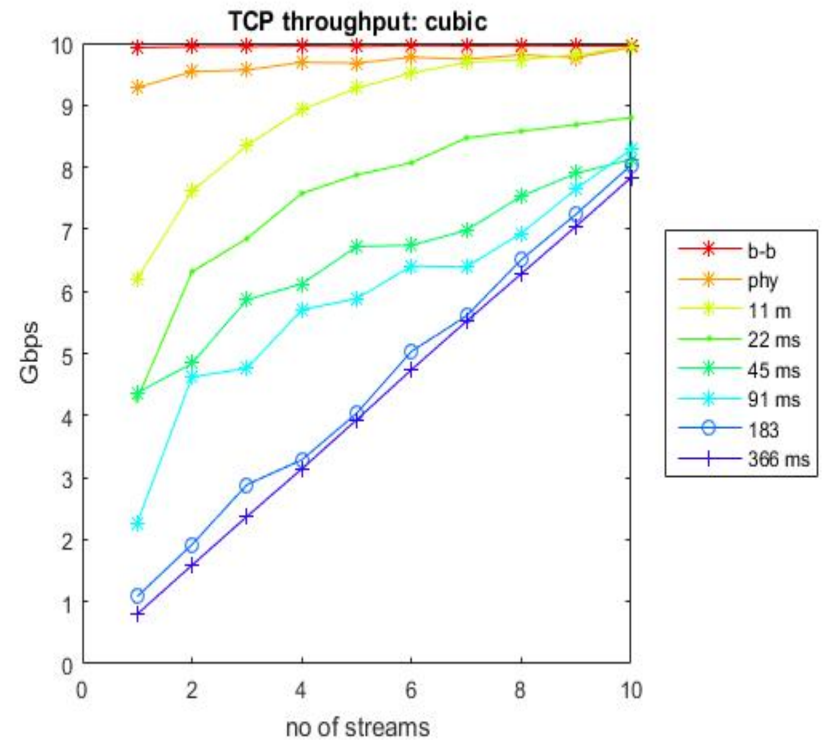
Network Throughput - CUBIC

bohr IO servers – TCP tuned

- 48core, opteron, 2.2 GHz
- write peak throughput: ~6Gbps





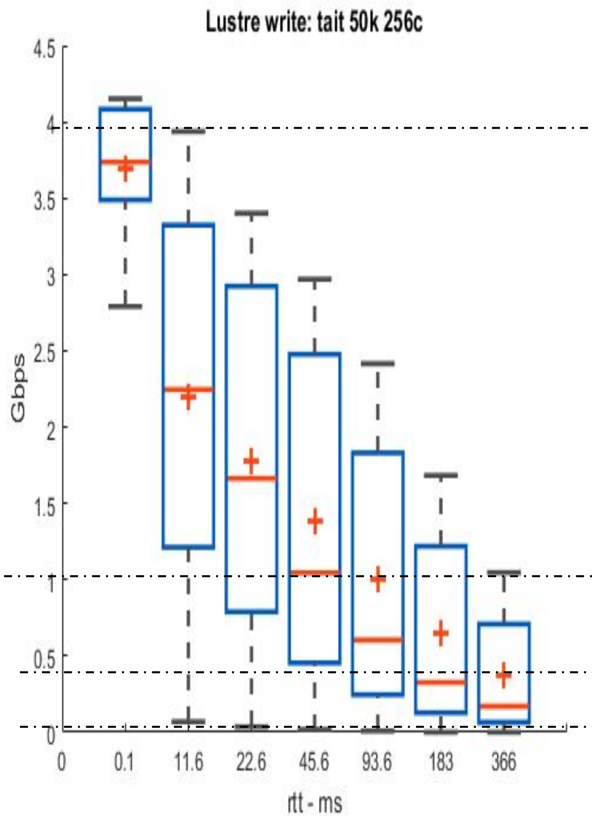
Lustre throughput peak ~6Gbps

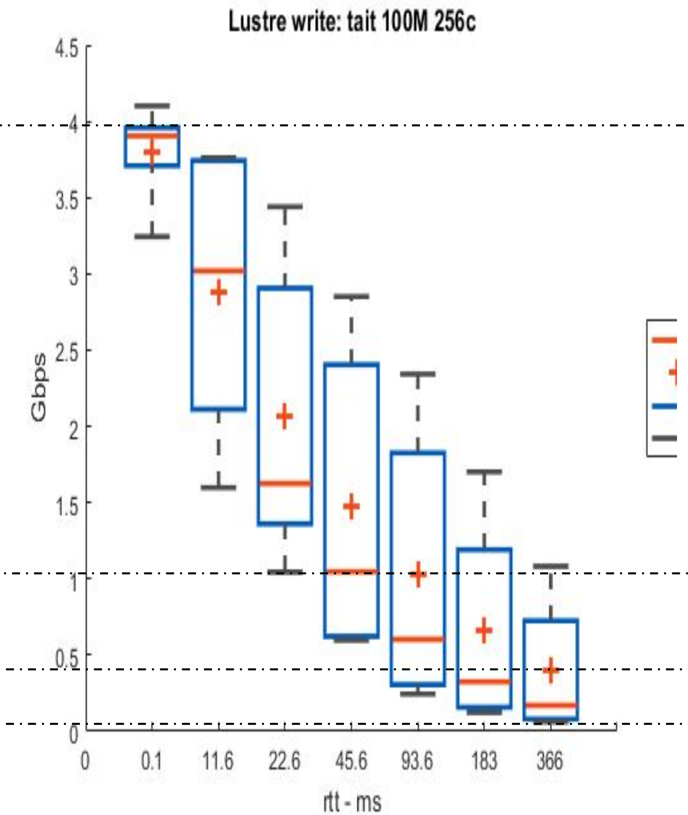
Lustre wide-area: tait – cubic – LNet

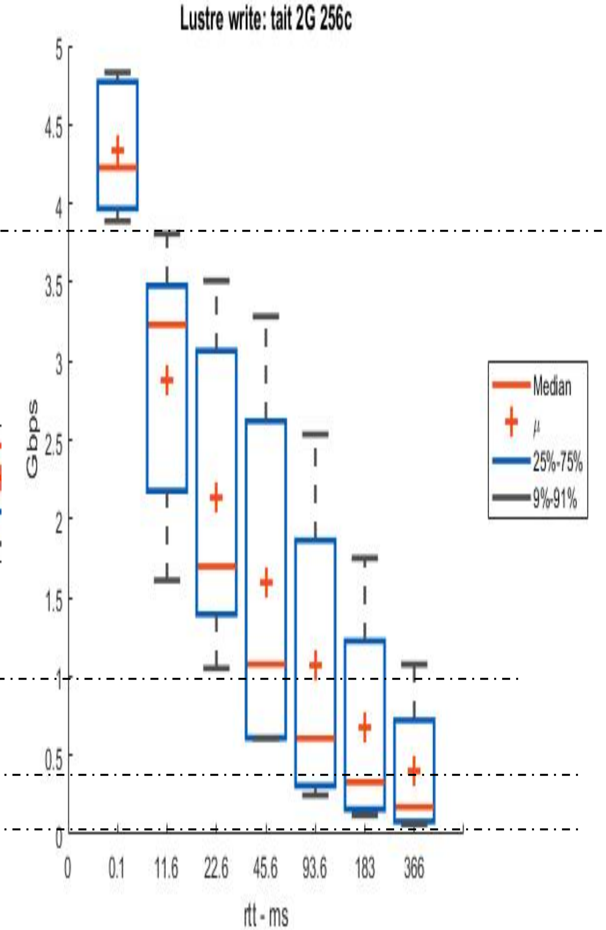
Overall Summary: TCP and Lustre tuned

Increasing Lnet router buffers: improves throughput 10% with 2G buffer

More significant than bohr nodes



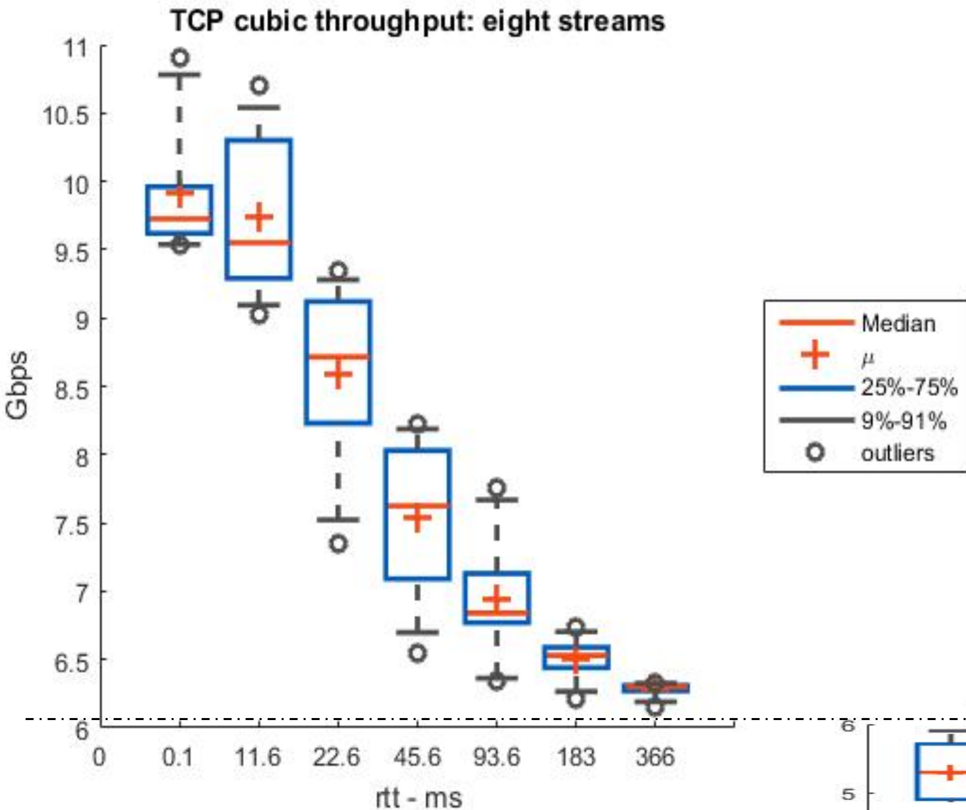




tait compute-cluster servers – centos 7.2

- 24 core, xeon 2.6GHz

Lustre wide-area: bohr - cubic

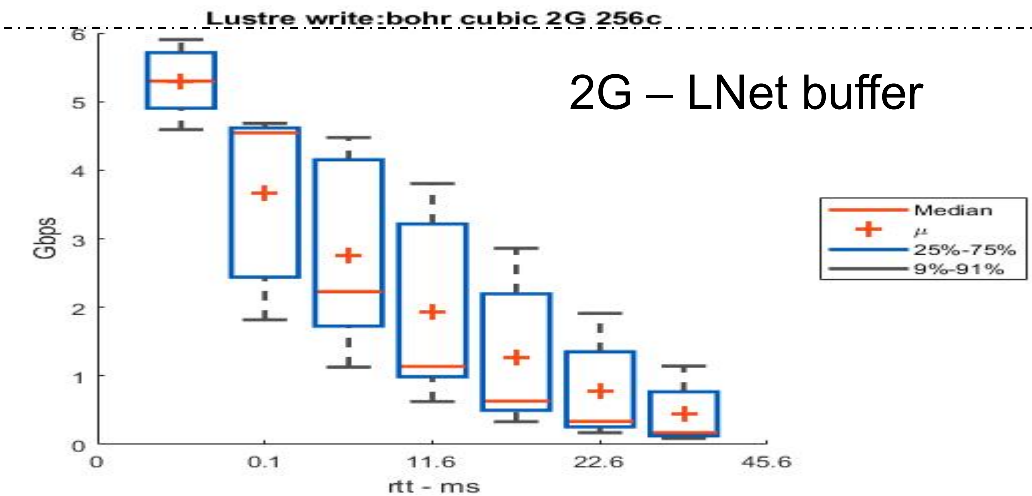


bohr IO servers – centos 7.2

- 48core, opteron, 2.2 GHz
- write peak throughput: ~6Gbps

Lnet router 2G buffers:

Lustre throughput is much below TCP memory throughput



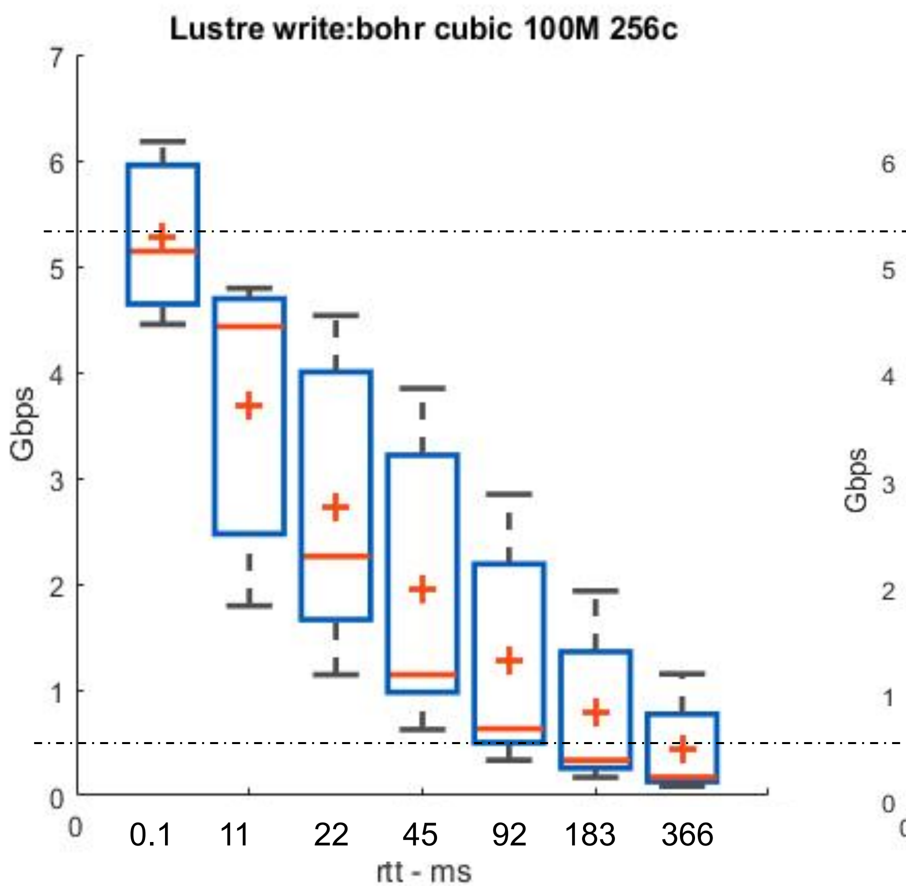
2G – LNet buffer

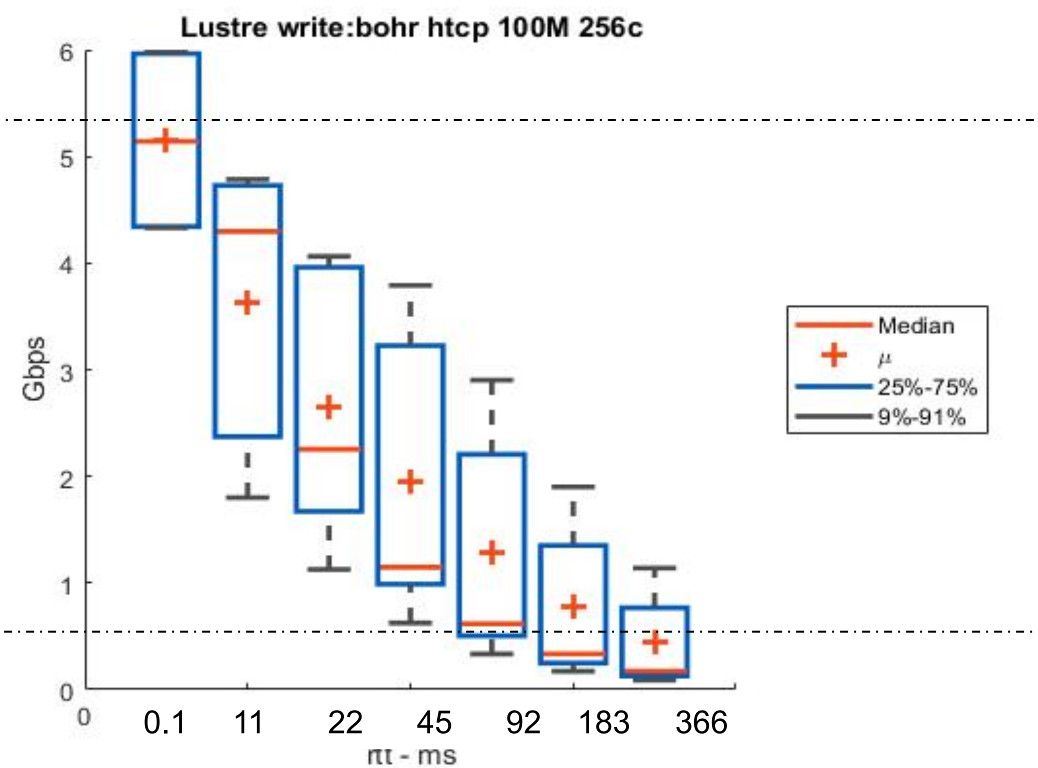
Lustre wide-area: bohr – cubic and htcp

Lustre throughput: cubic and htcp almost same

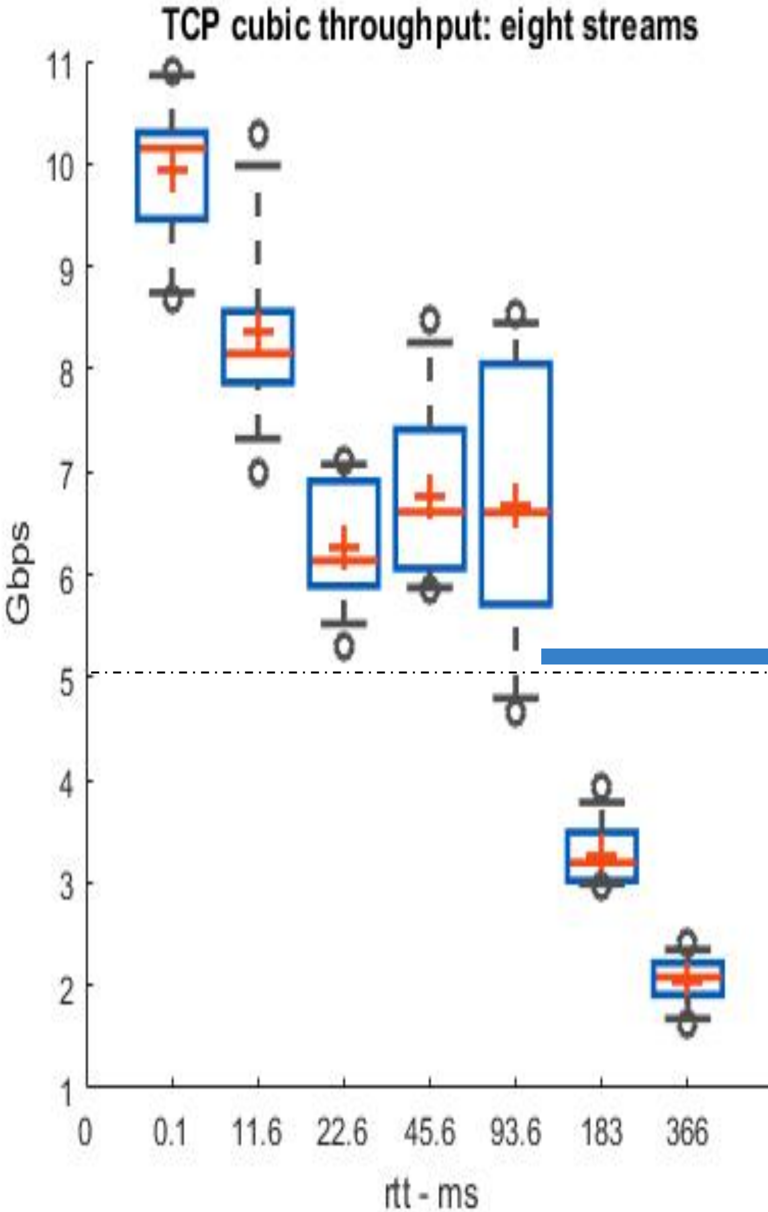
bohr IO servers – centos 7.2

- 48core, opteron, 2.2 GHz
- write peak throughput: ~6Gbps



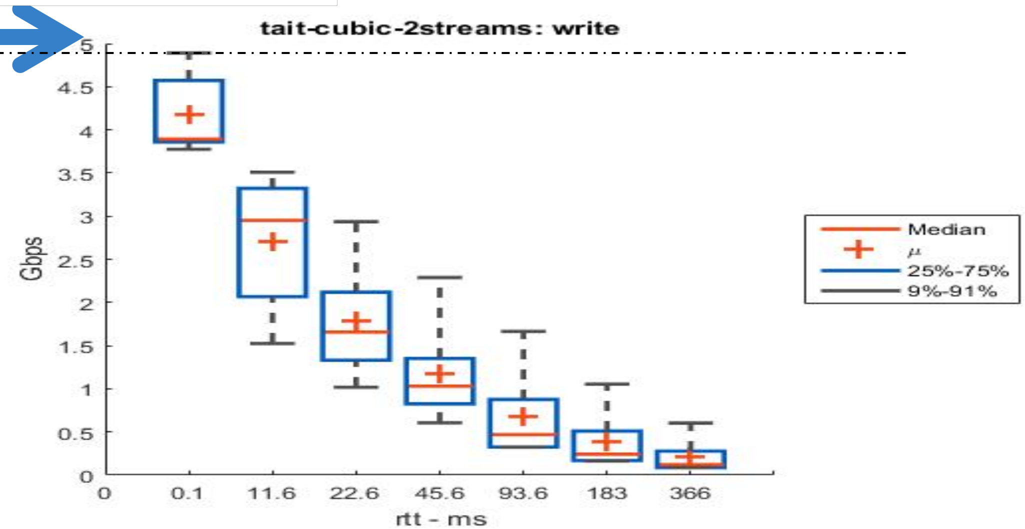


Lustre wide-area: tait - cubic



tait compute servers – centos 6.8

- 24 core, xeon 2.6GHz
- write peak throughput: ~5Gbps
- lower than corresponding iperf throughput



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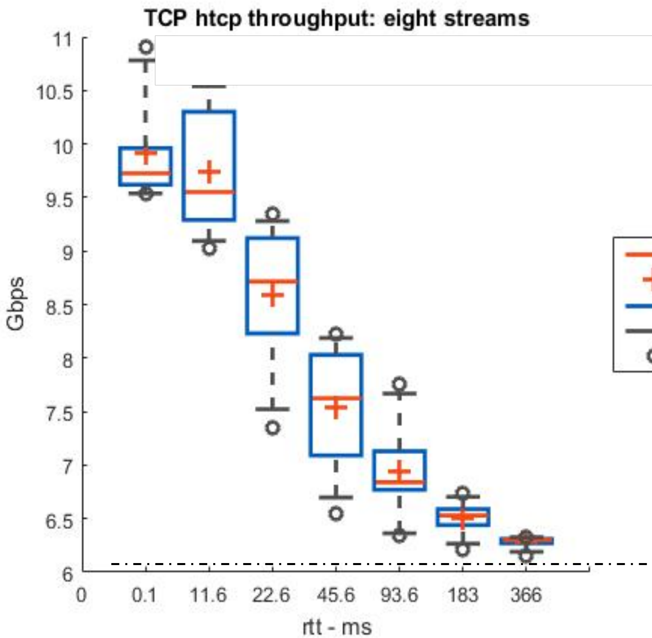
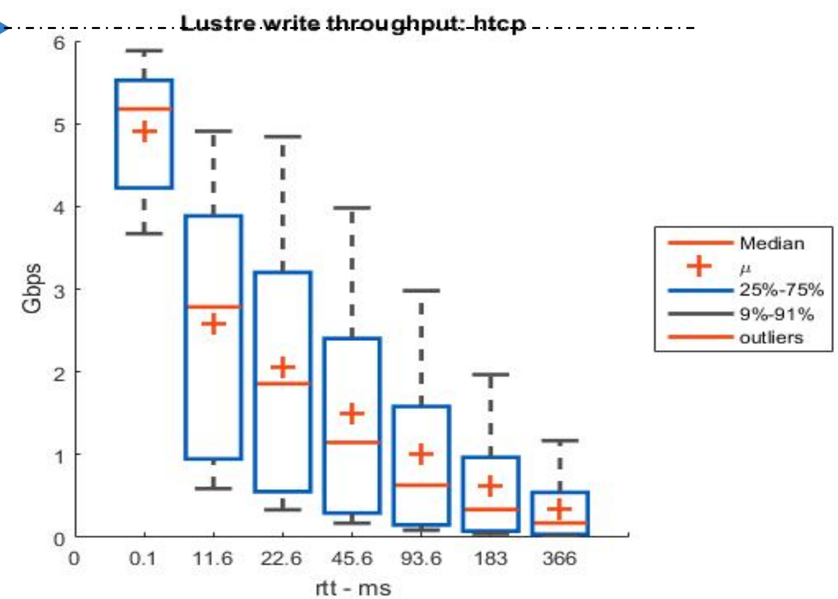
Lustre wide-area: bohr – Hamilton TCP



bohr IO servers – TCP tuned

- 48core, opteron, 2.2 GHz
- write peak throughput: ~6Gbps
- lower than lowest iperf throughput
- Centos 6.8



Hamilton TCP: Not much difference

Recommended for large transfers over long (cross-country and inter-continental) distances

- Used in DOE Data Transfer Nodes (DTNs)
- CUBIC is default in Linux

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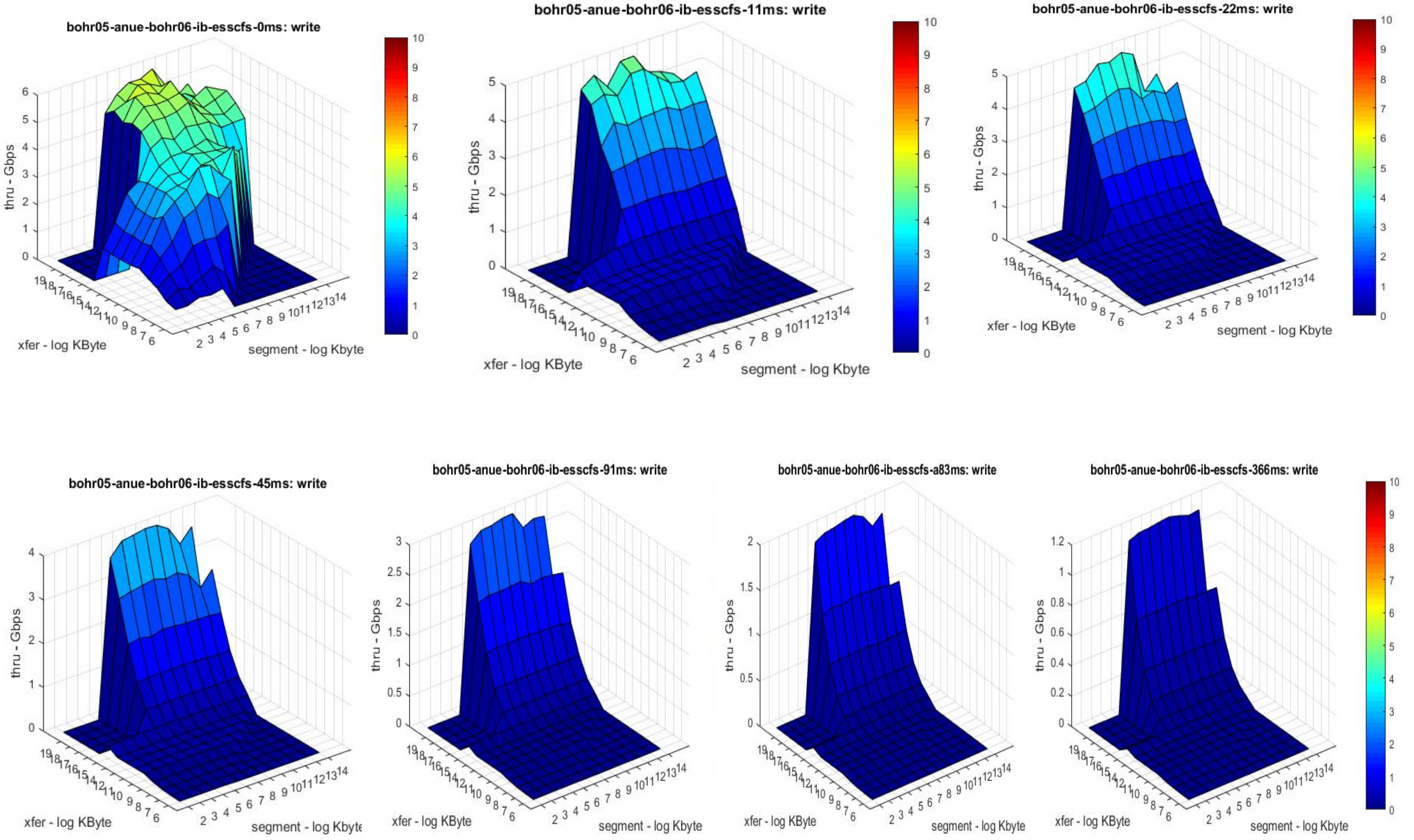
Lustre wide-area: bohr - htcp



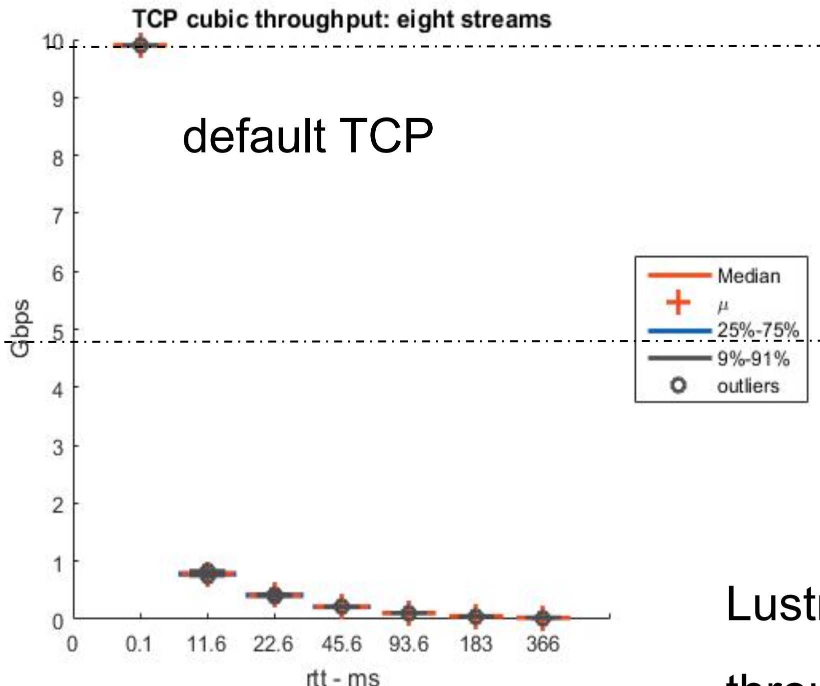
Throughput rates need to be interpreted with rtt

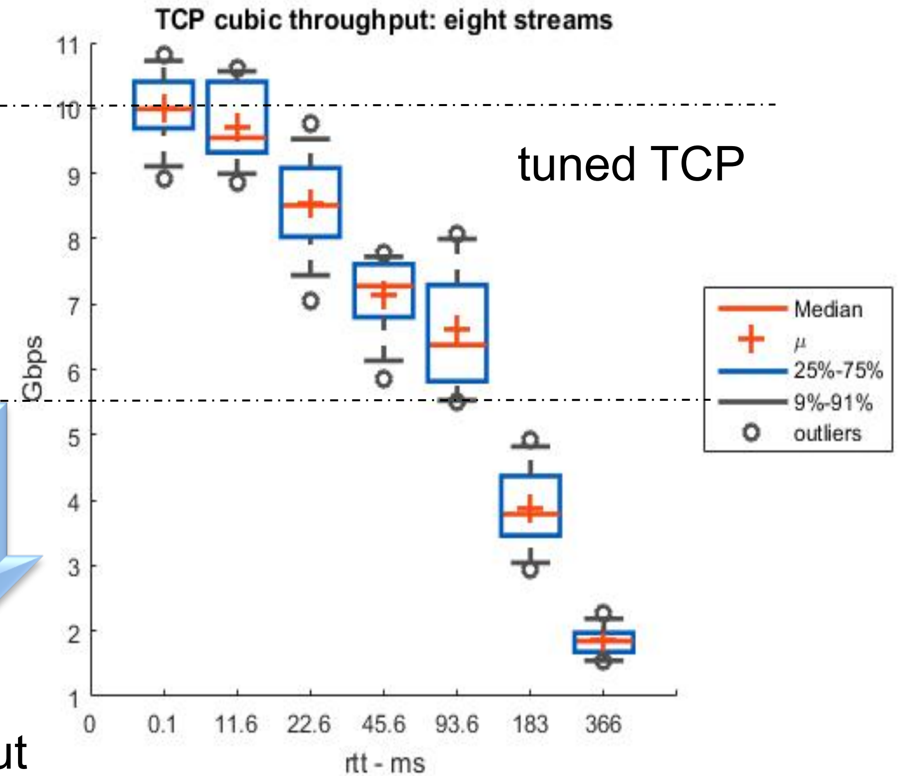
Network Throughput: Cluster Nodes

tait compute servers – centos 6.8

- 24 core, xeon 2.6GHz
- write peak throughput: ~5Gbps

Compute nodes are not tuned well for wide-area data transfers





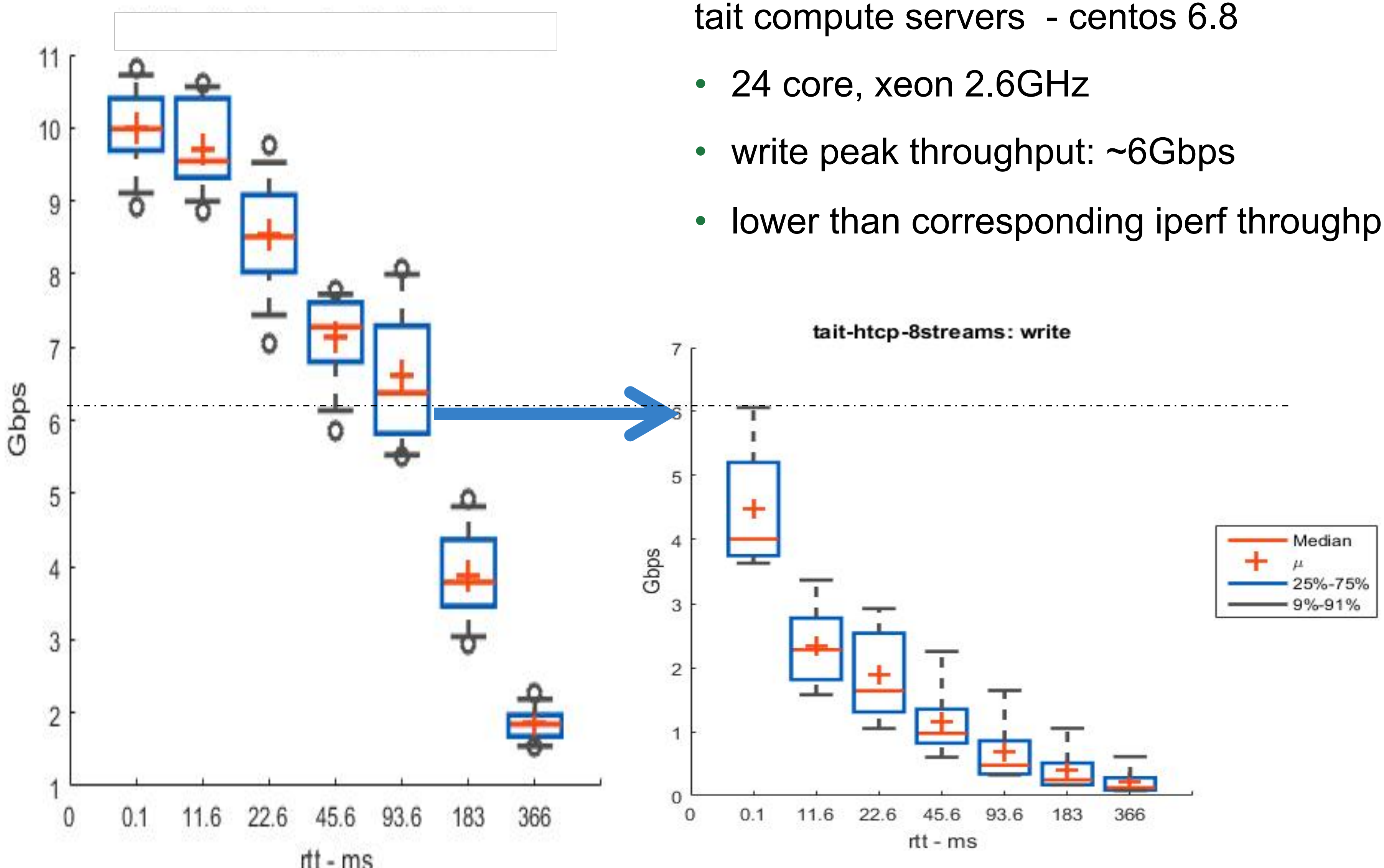
Lustre

throughput
peak ~5Gbps

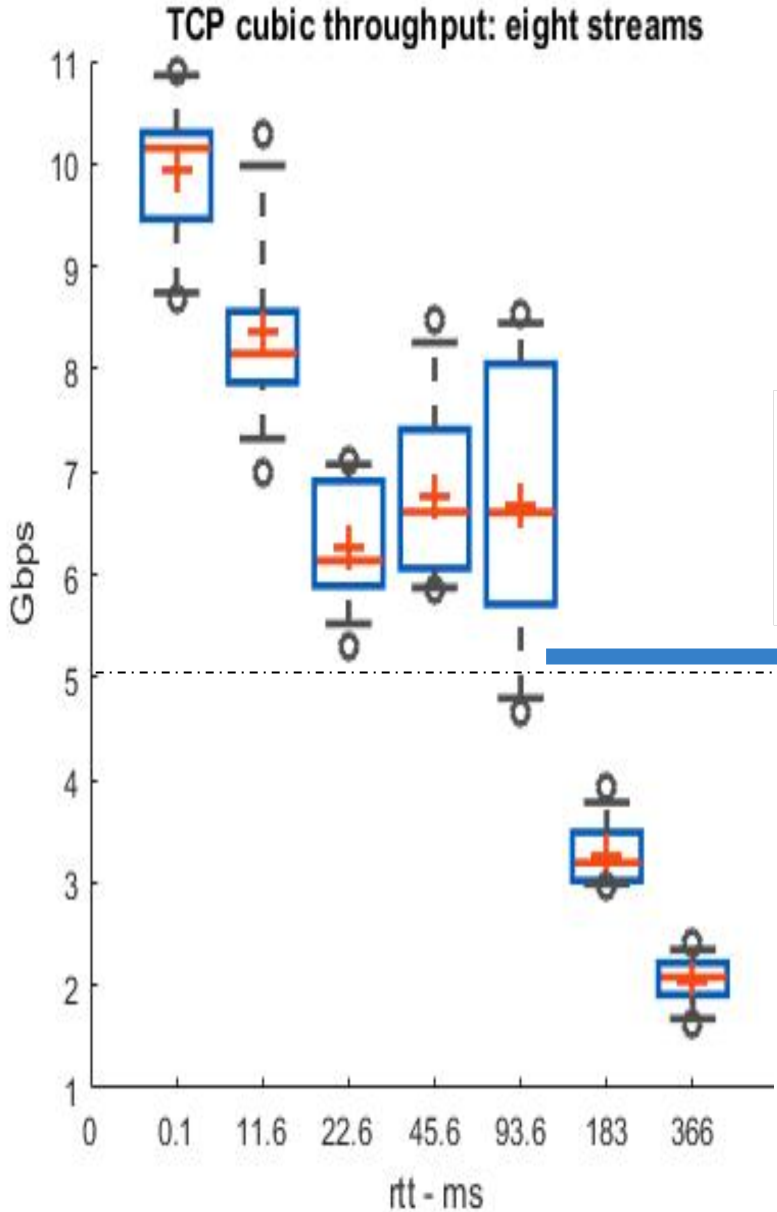
Lustre wide-area: tait - htcp

tait compute servers - centos 6.8

- 24 core, xeon 2.6GHz
- write peak throughput: ~6Gbps
- lower than corresponding iperf throughput

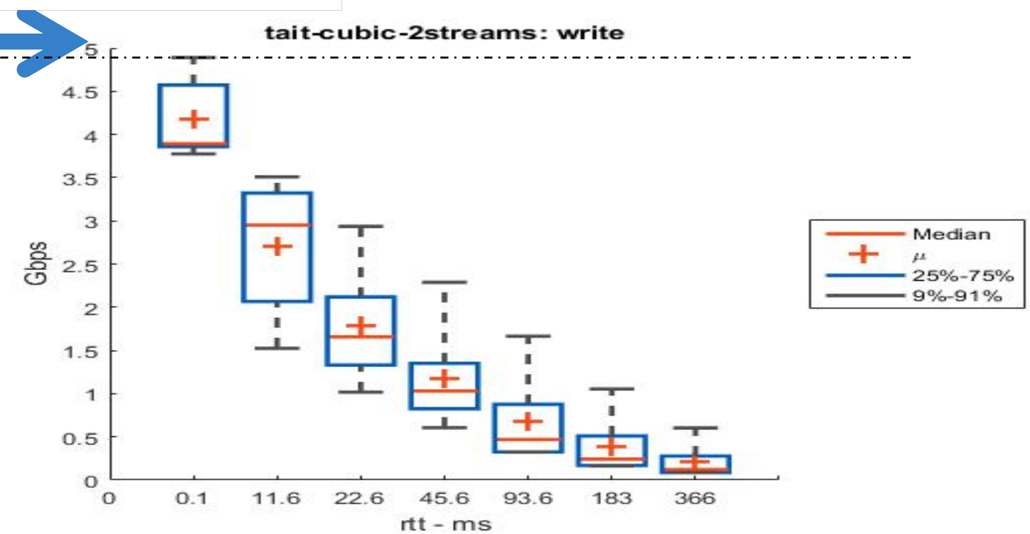


Lustre wide-area: tait - cubic



tait compute servers –centos 6.8

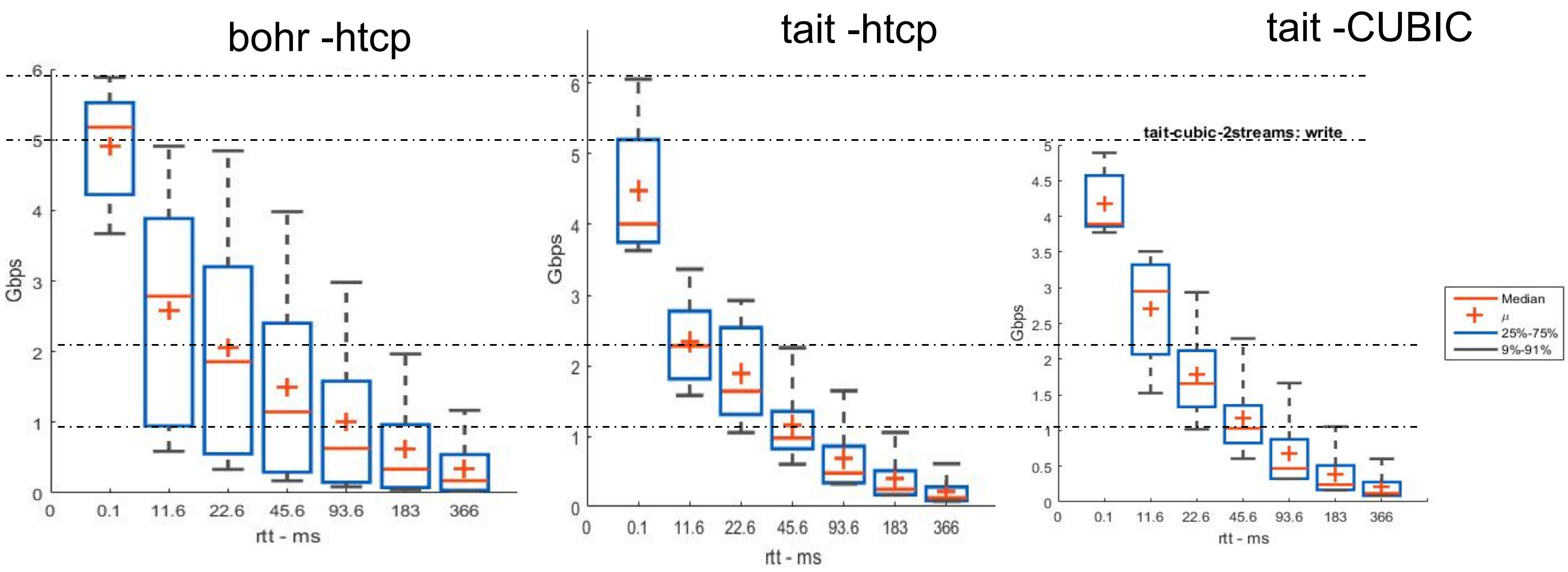
- 24 core, xeon 2.6GHz
- write peak throughput: ~5Gbps
- lower than corresponding iperf throughput



Lustre wide-area: bohr - tait default LNet

Throughput is somewhat higher for bohr servers – centos 6.8

- their network and local Lustre throughputs are higher

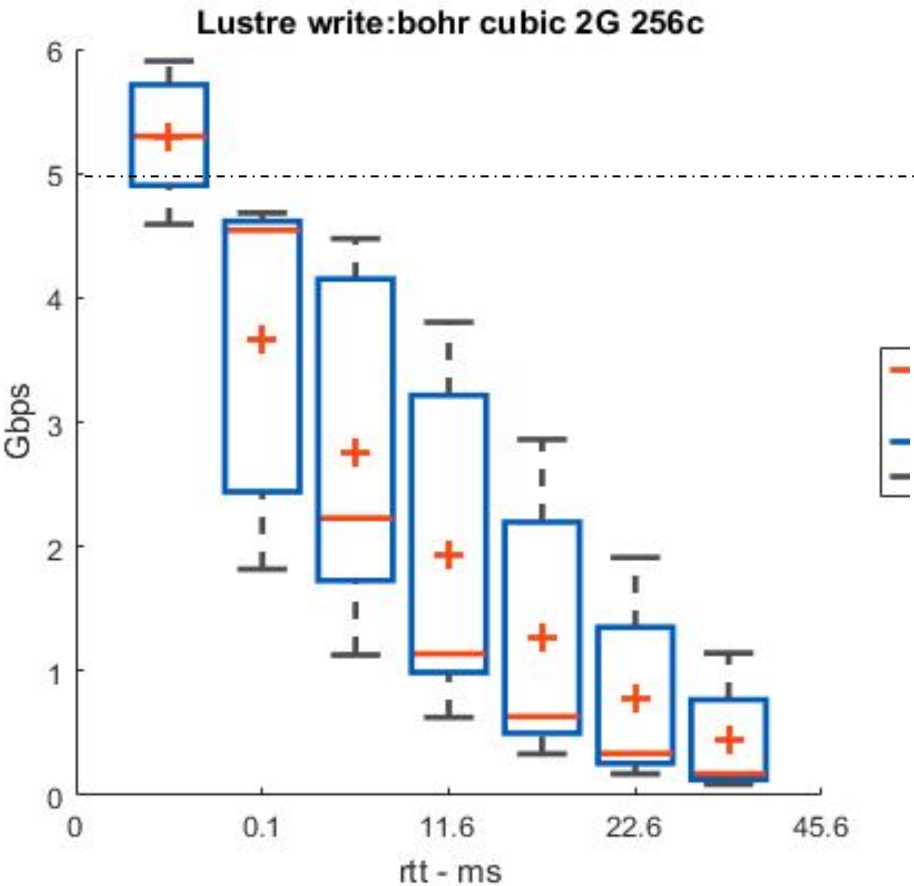


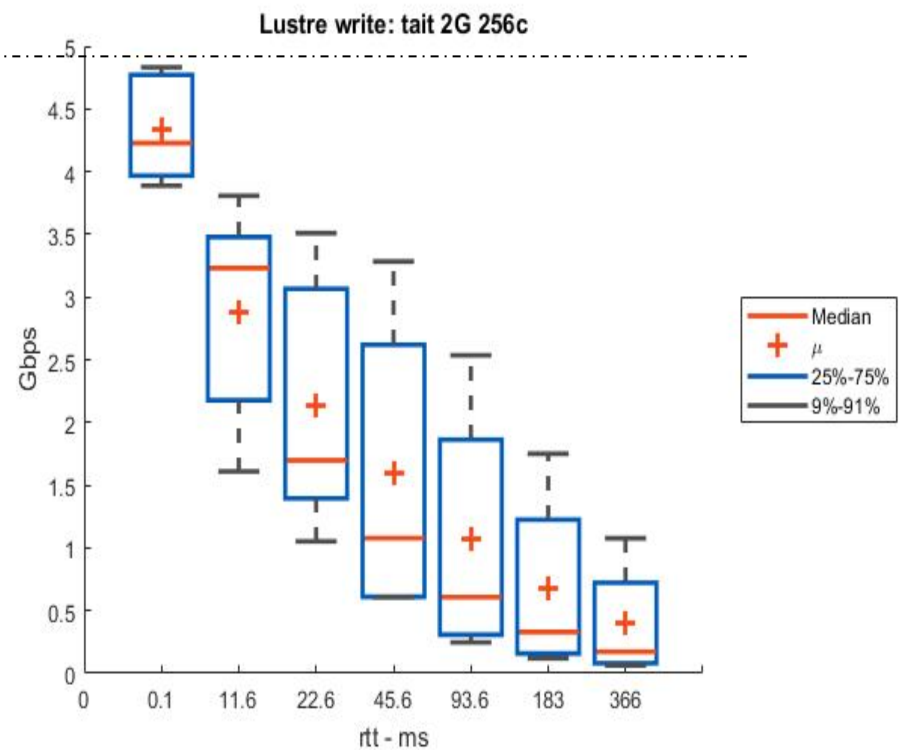
Throughput is similar for Hamilton TCP and CUBIC for tait

- network throughput is higher for Hamilton TCP but does not make much difference for Lustre

Lustre wide-area: bohr - tait 2G LNet

Throughput is somewhat higher for bohr servers (7.2) – similar to default case





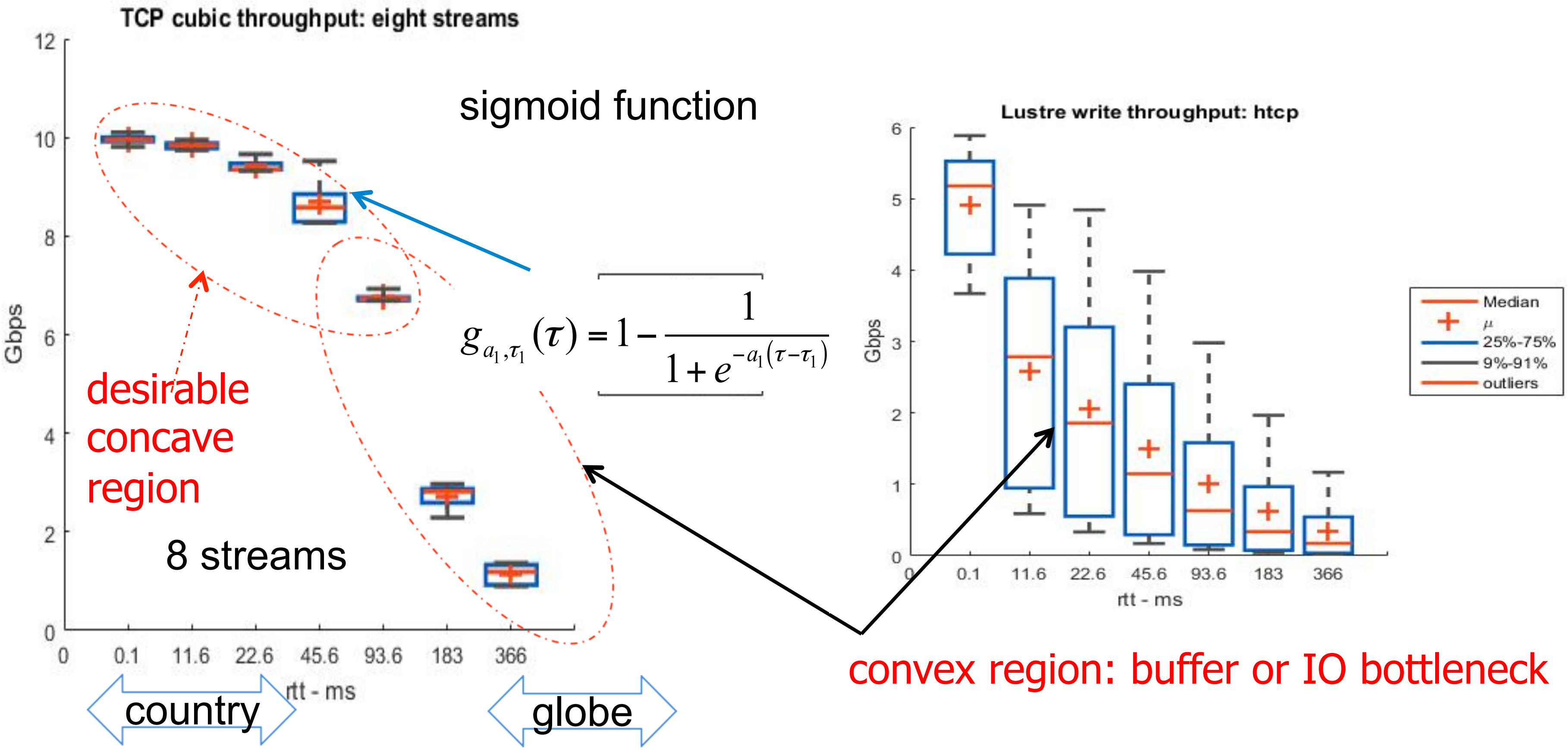
IO or Network Bottleneck?

TCP memory transfers: concave-convex regions

10Gbps: CUBIC TCP buffers tuned for 200ms rtt

Concave region: indicates buffer, IO bottleneck

Our Lustre configuration indicates IO limit



$$g_{a_1,\tau_1}(\tau) = 1 - \frac{1}{1 + e^{-a_1(\tau - \tau_1)}}$$

RTT: cross-country (0-100ms), cross-continents (100-200ms), across globe(366ms)

Generic Model for Data, Disk and File Transfers

Buffer size, IO throughput or available processing power limit data in transit:

connection capacity (bps): C

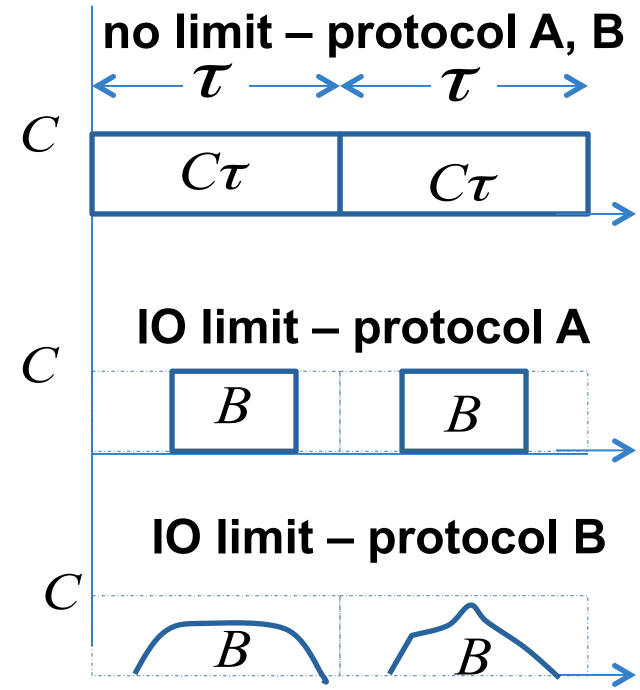
RTT: τ

data unacknowledged within a slot of period: τ

no IO or processor limit: $C\tau$

under IO or processor limit: $B < C\tau$

example: limited buffer size



Throughput averaged over each slot of width τ**:**

$$\theta^{\tau}(t) = \frac{B}{\tau}$$

Throughput profile: $$\Theta_O(\tau) = \frac{1}{T_O}\int_0^{T_O} \theta^{\tau}(t)dt = \frac{B}{\tau}$$

Throughput derivative: $$\frac{d\Theta_O}{d\tau} = -\frac{B}{\tau^2}$$

increasing function of τ **implies convexity of** $\Theta_O(\tau)$

Transport methods may have different shapes of B – but subject to convexity

- **convex profile indicates disk or file throughput limit**
- **due to peer credits on IB and Ethernet sides of LNet**

Conclusions

Summary

- Demonstrated Luster mounted over long-haul connections
  - file transfers do not require specialized solutions, e.g. XDD, Aspera, GrifFTP
  - distributed applications with file accesses are supported transparently
- LNet-based solution
  - extends local IB-based Lustre (no changes to file servers)
- Measurements over 0-366ms connection suites
  - provided insights for performance: configurations constrained by IO throughput

Future Work

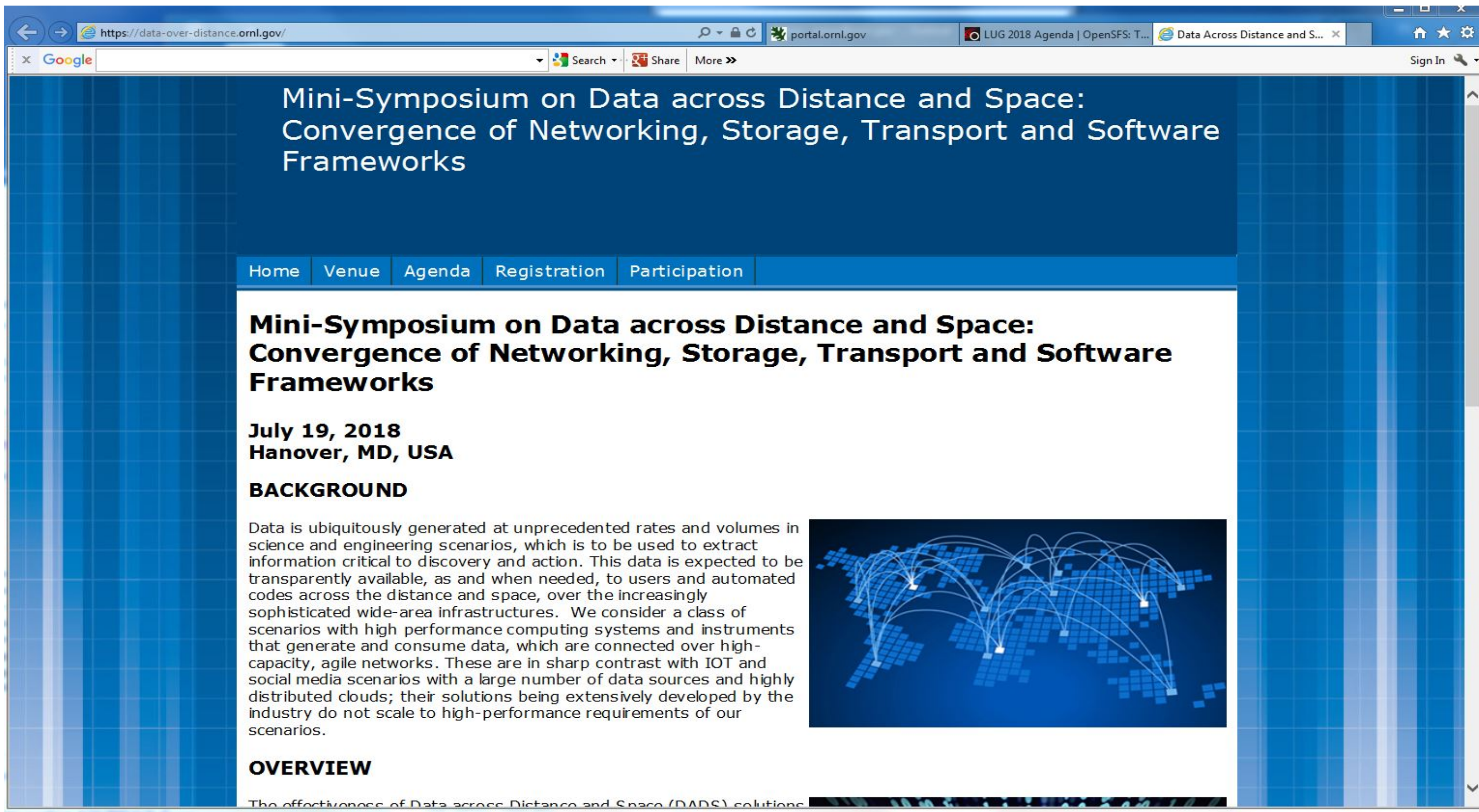
- Comprehensive tests and analysis
  - other TCP congestion control methods – Scalable TCP, BBR, …
- Continued analysis and performance tuning
  - host and Lustre performance parameters and tuning
- Comparative Analysis and Analytics:
  - TCP, ROCE(RDMA over Converged Ethernet) and IB Lustre solutions

Mini-Symposium on Data across Distance and Space:

Convergence of Networking, Storage, Transport and Software Frameworks

July 19, 2018
Hanover, MD, USA

https://data-over-distance.ornl.gov/



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BACKGROUND

Data is ubiquitously generated at unprecedented rates and volumes in science and engineering scenarios, which is to be used to extract information critical to discovery and action. This data is expected to be transparently available, as and when needed, to users and automated codes across the distance and space, over the increasingly sophisticated wide-area infrastructures. We consider a class of scenarios with high performance computing systems and instruments that generate and consume data, which are connected over high-capacity, agile networks. These are in sharp contrast with IOT and social media scenarios with a large number of data sources and highly distributed clouds; their solutions being extensively developed by the industry do not scale to high-performance requirements of our scenarios.

OVERVIEW

The effectiveness of Data across Distance and Space (DADS) solutions

OAK RIDGE
National Laboratory

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Questions?

Computational Research &
Development Programs

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