FEFS* Performance Evaluation on K computer and Fujitsu's Roadmap toward Lustre 2.x

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*: "FUJITSU Software FEFS"

Outline

- RIKEN and Fujitsu jointly developed "K computer"
  - Now in Public Operation, and still continuing system software tuning for more suitable.
- Outline of This Talk
  - K computer and FEFS Overview
  - Performance Evaluation
  - Issues towards Exascale
  - Fujitsu's Roadmap towards Lustre 2.x

System Overview of K computer

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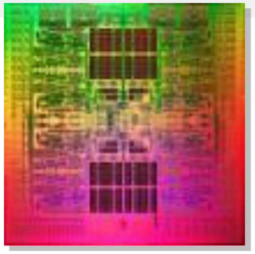
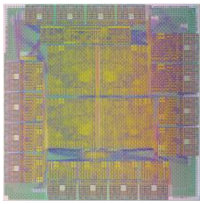




Processor: SPARC64™ VIIIfx

- Fujitsu's 45nm technology
- 8 Core, 6MB Cache Memory and MAC on Single Chip
- High Performance and High Reliability with Low Power Consumption

Interconnect Controller:ICC

- 6 dims-Torus/mesh (Tofu Interconnect)

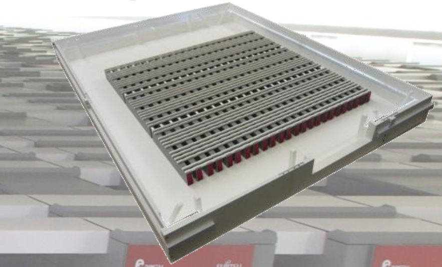
System Board: High Efficient Cooling

- With 4 Computing Nodes
- Water Cooling: Processors, ICCs etc
- Increasing component lifetime and reducing electric leak current by low temperature water cooling

Rack:High Density

- 102 Nodes on Single Rack
  - 24 System Boards
  - 6 IO System Boards
  - System Disk
  - Power Units

(10PFlops: 864 Racks)



Our Goals

- Challenging to Realize World's Top 1 Performance
- Keeping Stable System Operation over 88K Node System

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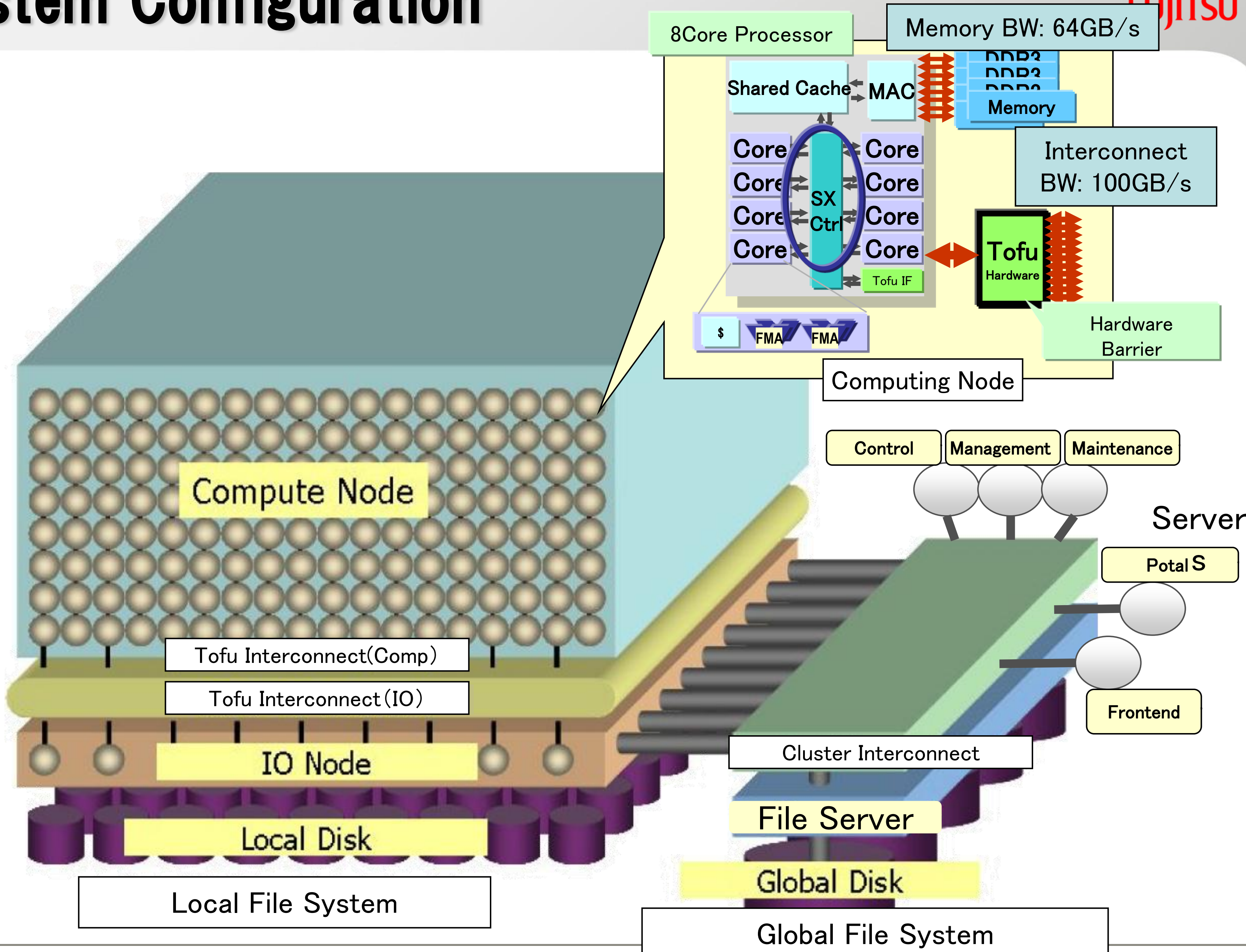
System Configuration



IO Architecture of “K computer”

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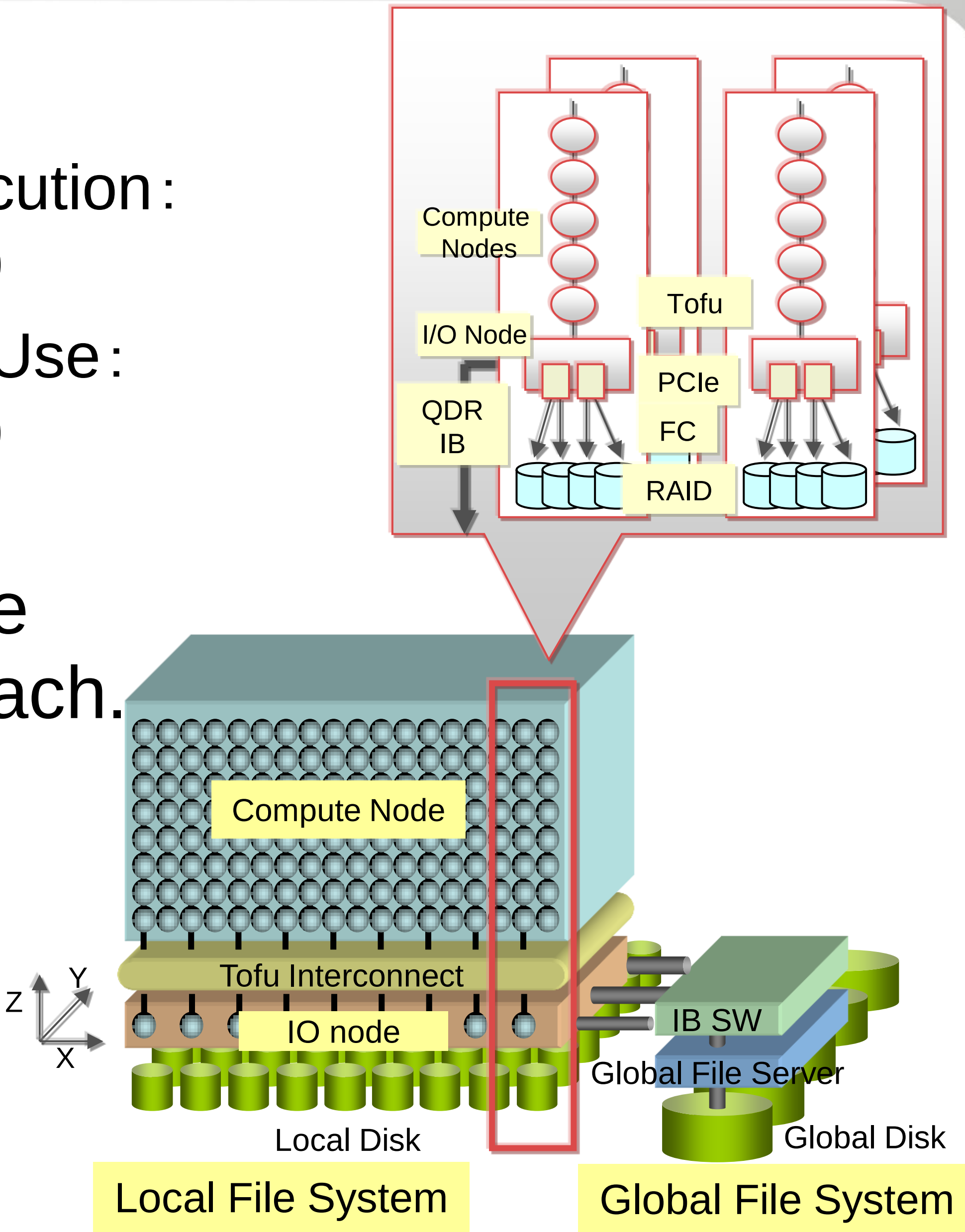
- IO System Architecture
  - Local Storage for JOB Execution : ETERNUS(2.5inch, RAID5)
  - Global Storage for Shared Use : ETERNUS(3.5inch, RAID6)
- Configurations of each file system is optimized for each.
  - Local File System : Over 2,400-OSS (for Highly Parallel)
  - Global File System : Over 80-OSS (for Big Capacity)



FEFS Requirement of K computer

- Extremely Large
  - Extra-large volume (100PB~1EB).
  - Massive number of clients (100k~1M) & servers (1k~10k)
- High Performance
  - Throughput of Single-stream (~GB/s) & Parallel IO (~TB/s).
  - Reducing file open latency (~10k ops).
  - Avoidance of IO interferences among jobs.
- High Reliability and High Availability
  - Always continuing file service against component failures
- Low Resource Usage
  - System Software including MPI runtime, file cache and OS limits its memory usage within 10% of physical memory.

Design Issues for Ultra Large Scale File System

- Keeping user's available memory over 90% of physical memory
  - Clients requires o(# of Servers) memory statically
- Minimizing impact of OS jitter to application performance
  - llpings among all clients and OSSs are terrible
- Parallel IO performance
  - Leveled I/O and Communication Performance among Servers and Network Links
- RAS
  - Recovery Performance

Keeping user's available memory over 90% of physical memory

- Strategy:
  - Limiting file buffer cache for dirty buffers
  - Minimizing local buffer usages
  - Minimizing Number of OSTs
- Issue:
  - System Software including MPI runtime and OS limits its memory usage within 10% of physical memory.
  - Basic Memory Allocation Policy of Lustre is pre-allocation for max size system.

Memory Issue: Request Buffer (1)

Issue

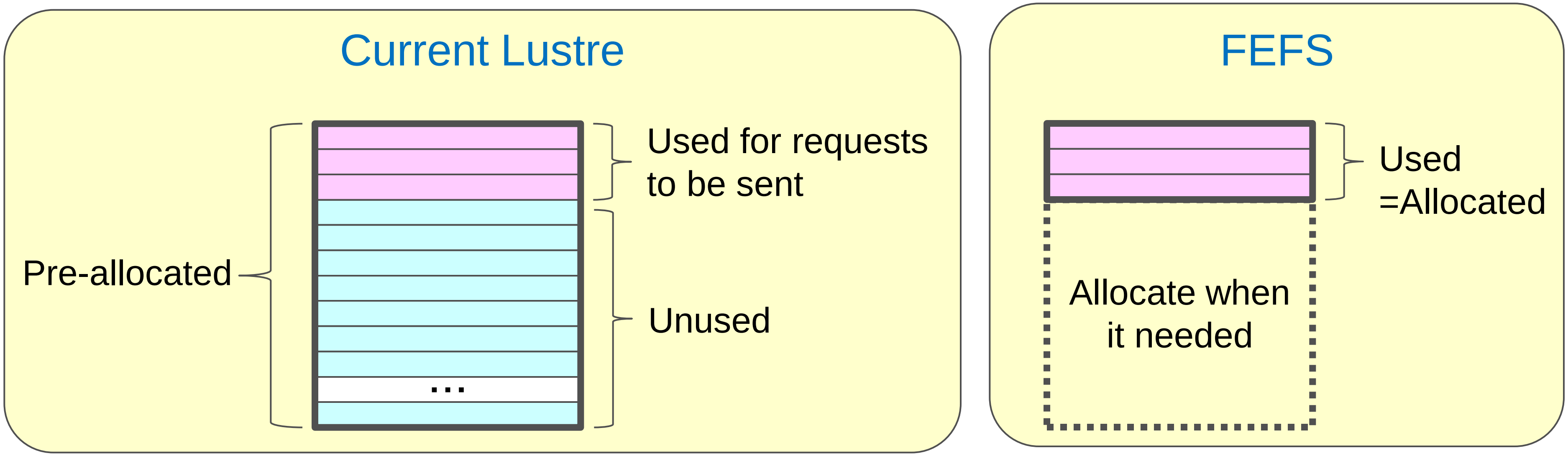
- Request buffer on client is **pre-allocated by #OSTs** in Lustre.
  - Buffer size = **8KB x 10 x #OSTs / request**

    #OST=1,000 ⇒ 80MB / request

    #OST=10,000 ⇒ 800MB / request

Our Approach

- On demand allocation: Allocate request buffer when it required.



Memory Issue: Request Buffer (2)

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Issue

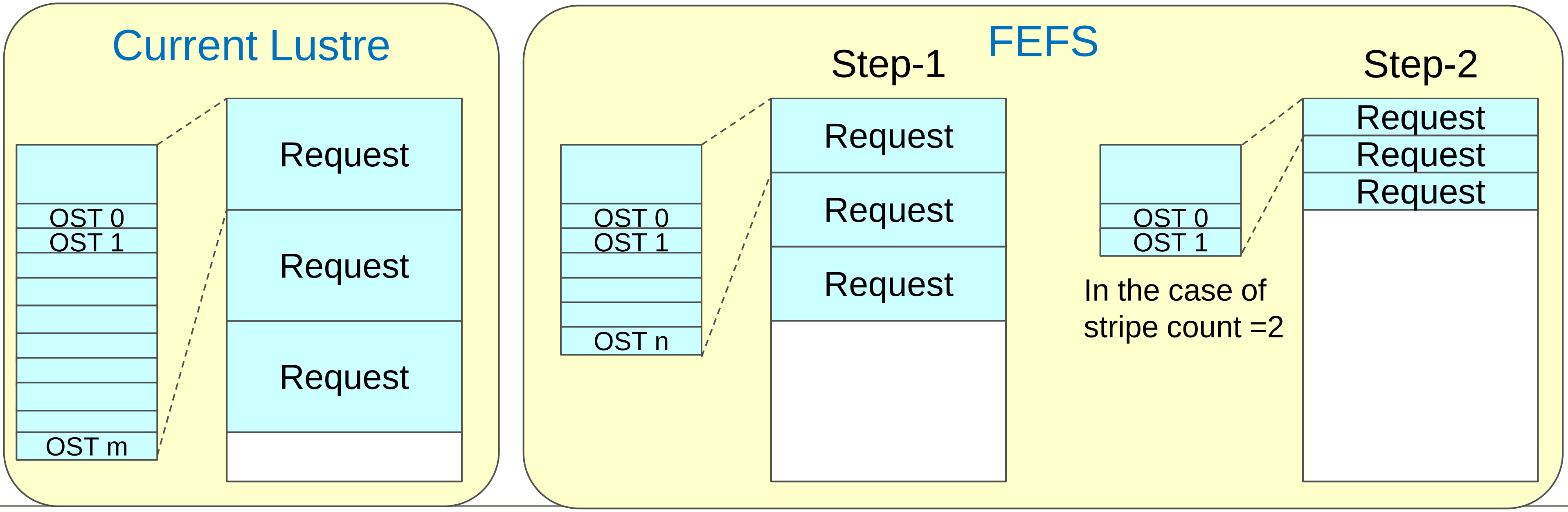
- When create a file, client allocates “**24B x Max. OST index**” size of request buffer. (to store message sent from MDS)

  OST index = 1,000 ⇒ 23KB / request

  OST index = 10,000 ⇒ 234KB / request

Our Approach

- Step-1: Reduce buffer size to “**24B x #Existing OSTs**”. (done)
- Step-2: Minimize to “**24B x #Striped OSTs**”.



Request Size: OST data sent in close

Issue

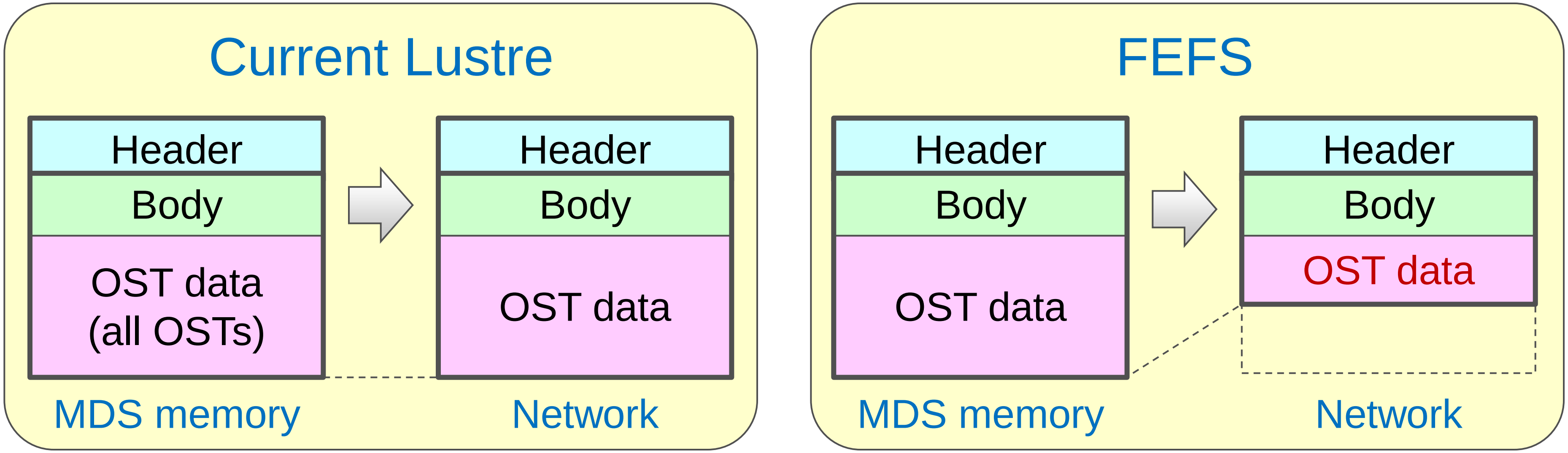
- When a client closes a file, OST data (including all OST information) is transferred from MDS to the client. ⇒Increase in proportion to #OSTs
  - OST data size = "**32B x #OST**".

  1,000 OSTs ⇒ 31KB / close

  10,000 OSTs ⇒ 312KB / close

Our Approach

- Only send striped #OST data instead of ALL OSTs.
  - ex. Stripe count=1 ⇒ 1 OST data is sent.



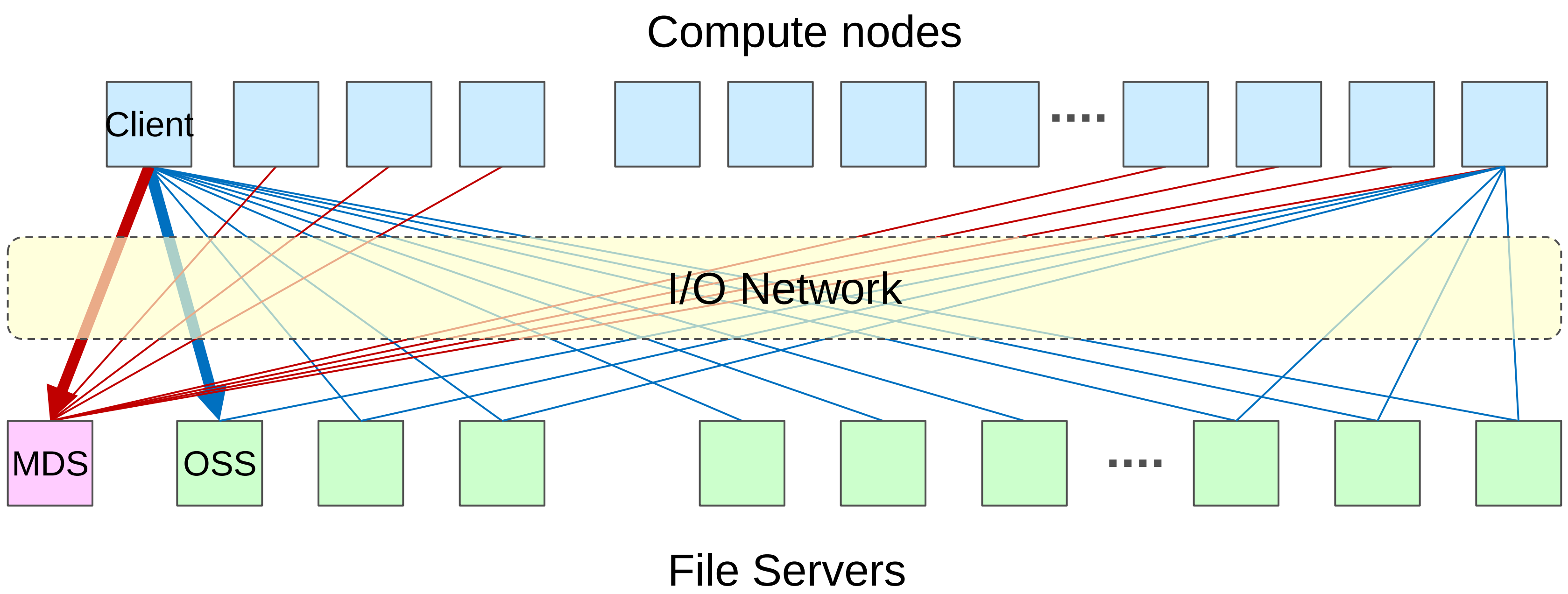
Improving Application Performance: Minimizing OS jitter

- ll_ping Problem:
  - All clients broadcast monitoring pings to all OSTs (not OSS) at regular intervals of 25 seconds. **100K Clients x 10K OSTs ⇒ 1M pings every 25 seconds.**
    - Vast amount of pings cause performance degradation of MPI and application.
  - Our Solution: Stopping broadcasting pings on clients.
    - Other pings, such as for recovery and for I/O confirmation, etc., are kept
- ldlm_poold Problem:
  - Operation time of *ldlm_poold* on client increases in proportion to the number of OSTs. *It* manages the pool of LDLM locks. It wakes up regular interval of 1sec.
  - Our Solution: Reduce the processing time per operation of *ldlm_poold* by divide the deamon's internal operation.

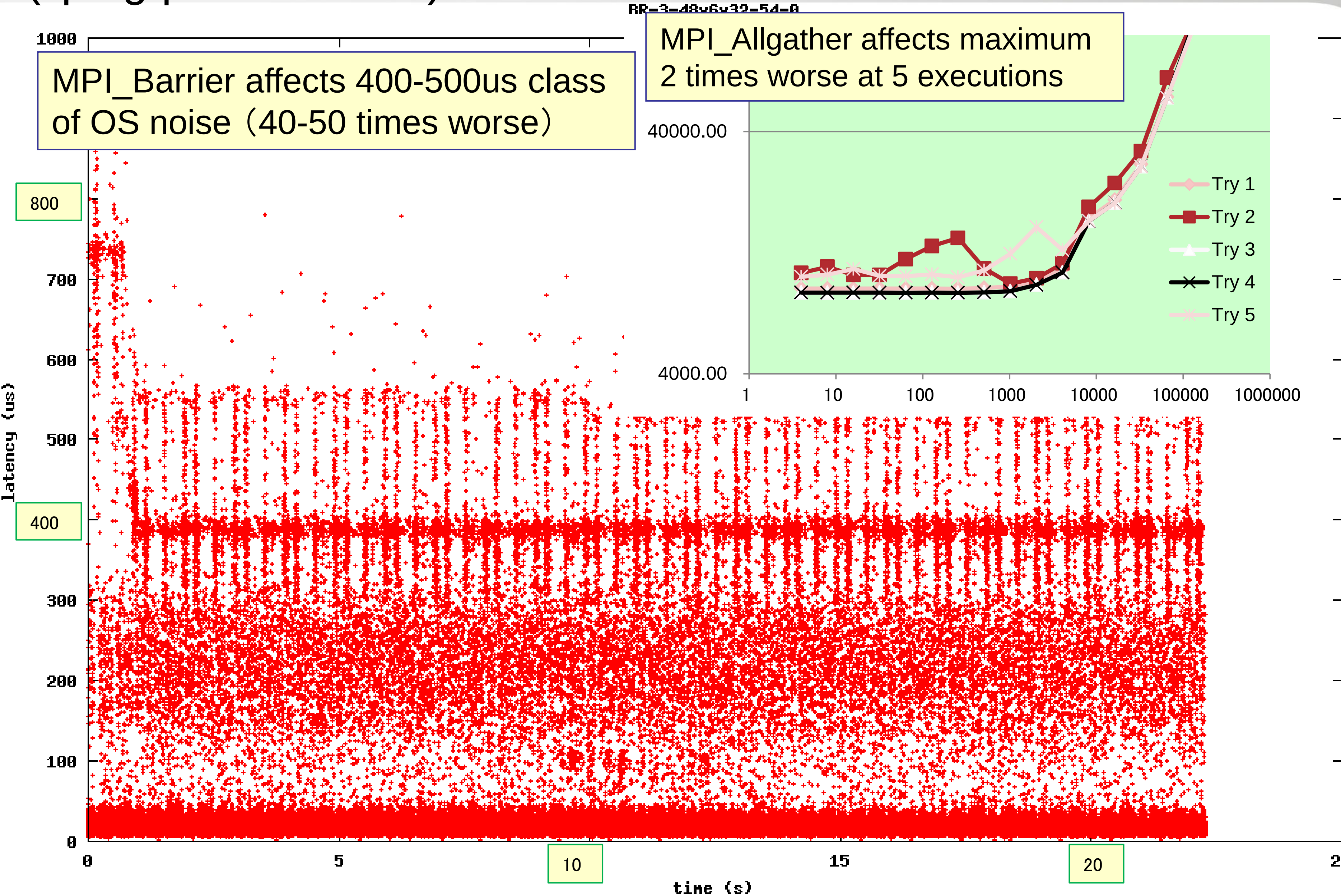
Improving Application Performance: Minimizing Network Traffic Congestion by ll_ping

- ll_ping Problem: Network congestion and request timeout cause: #of monitoring pings ∝ "#of clients x #of servers"
  - MPI and file I/O communication degradation.
  - Application performance degradation by OS jitter.

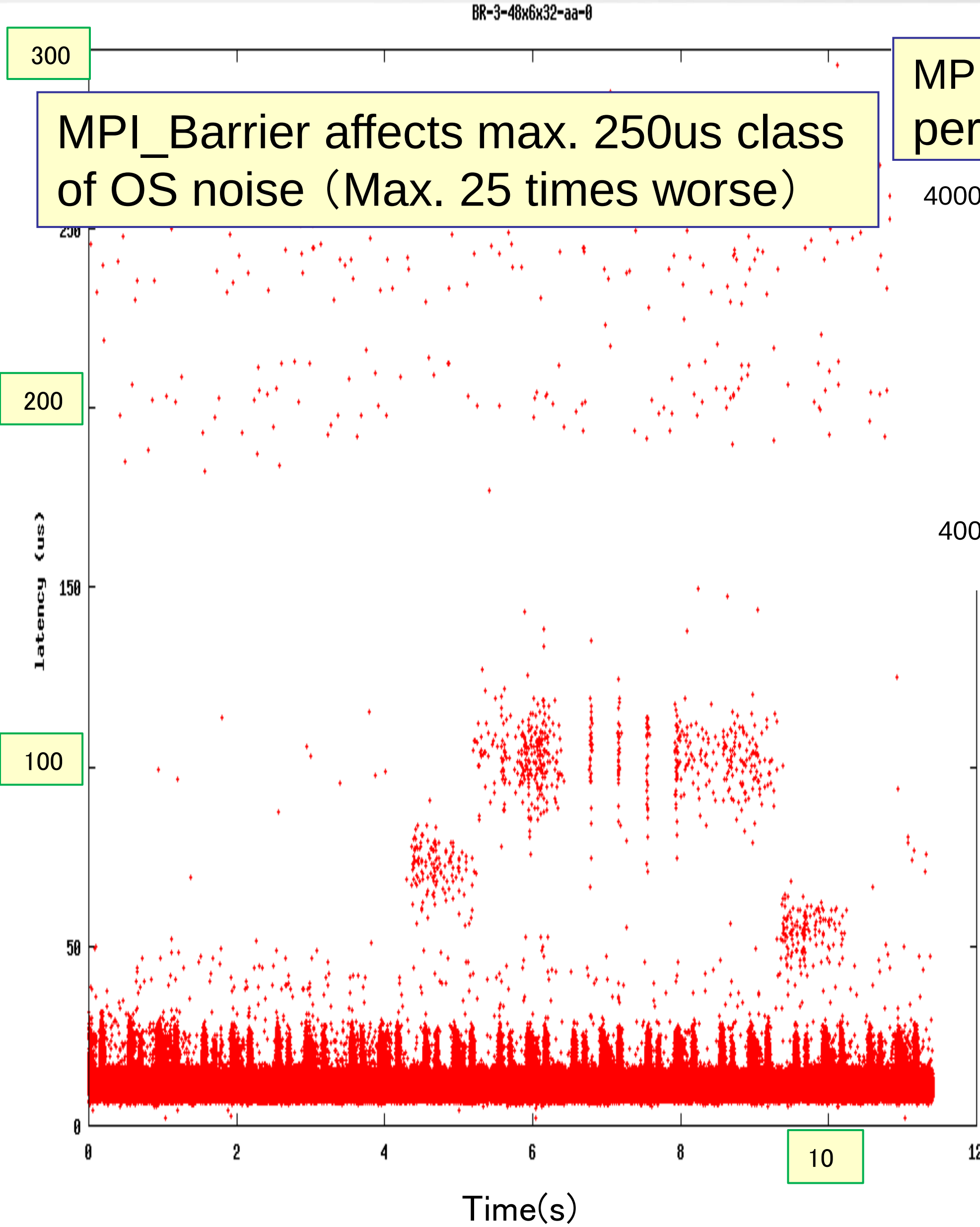
- Our Solution: Stopping interval ll_ping

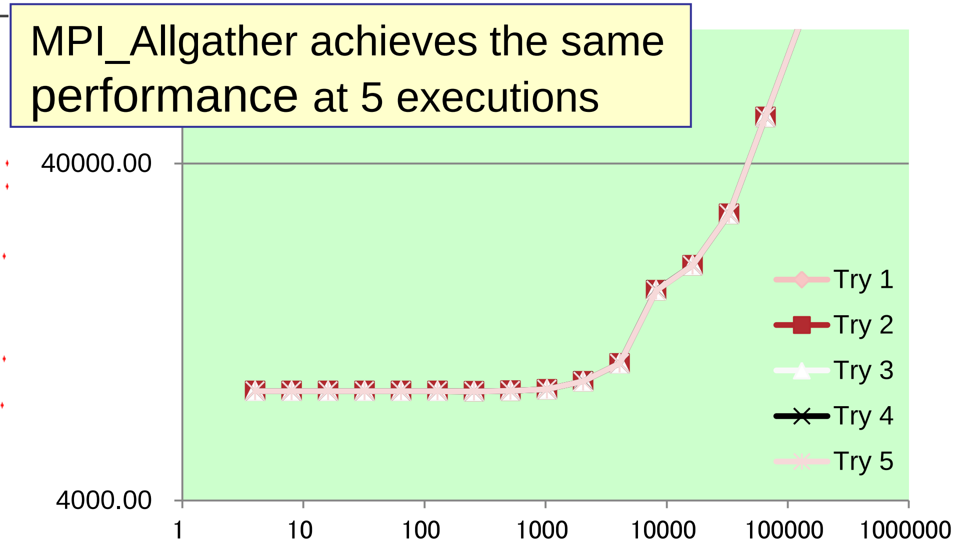


llping Impacts for MPI Performance on 1PF System (llping period 20min)



Removing llping Affects for MPI Performance on 1PF System





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I/O Zoning: I/O Separation among Jobs

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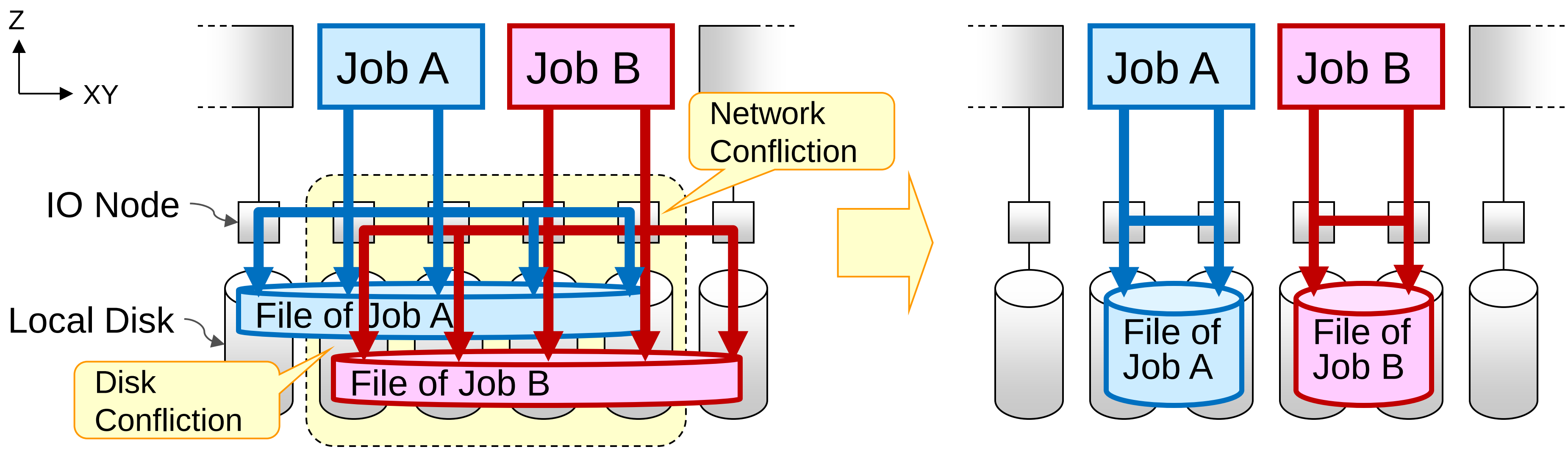
- Issue: Job's I/O conflicts on hardware.
  - Sharing disk volumes, network links among jobs cause I/O performance degradation because of their confliction.
- Our Approach: Separate hardware among jobs.
  - Separating of disk volumes, network links among jobs as much as possible.



No-good: w/ I/O Confliction

Good: w/o I/O Confliction

FEFS Performance Evaluation on K computer

- Environment: Full system of K computer 864 Racks
- Target: Local File System:
  - OSS：IO Node（Memory 16GB） x 2,592
    - OST：ETURNUS（RAID5+0{（4D+1P）x2} x2 set） x 2,592 （5,184 OST）
  - MDS： Xeon 2.00 GHz x2，Memory 64GB
    - MDT：ETRUNUS（RAID1+0（4D+4M） x4 set） x1
- Benchmark Programs:
  - IOR： w/,w/o IO Zoning
  - mdtest: MDS Performance Evaluation

Local FS I/O Performance on 10PF without I/O Zoning

- IOR Results using 2,575 OSSes (w/o slow 17 OSSes)

	POSIX File/Proc	POSIX Shared File	MPI-IO Shared File
Write	965 GB/s	929 GB/s	659 GB/s
Read	1,486 GB/s	983 GB/s	847 GB/s

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- Two Issues
  - POSIX shared file: Slow Read Performance
  - MPI-IO shared file: Slow Read/Write Performance

IOR Performance Statistics Analysis by Collectl

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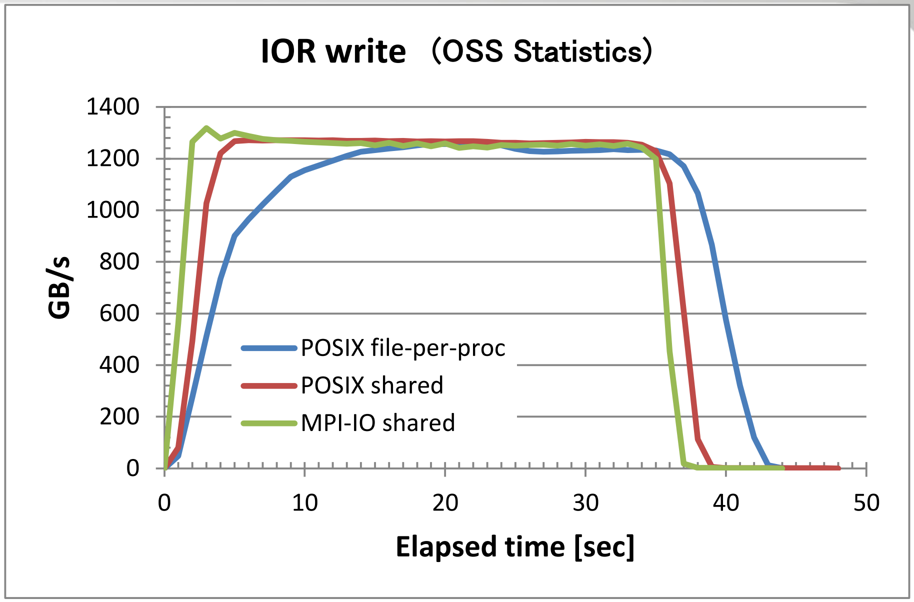
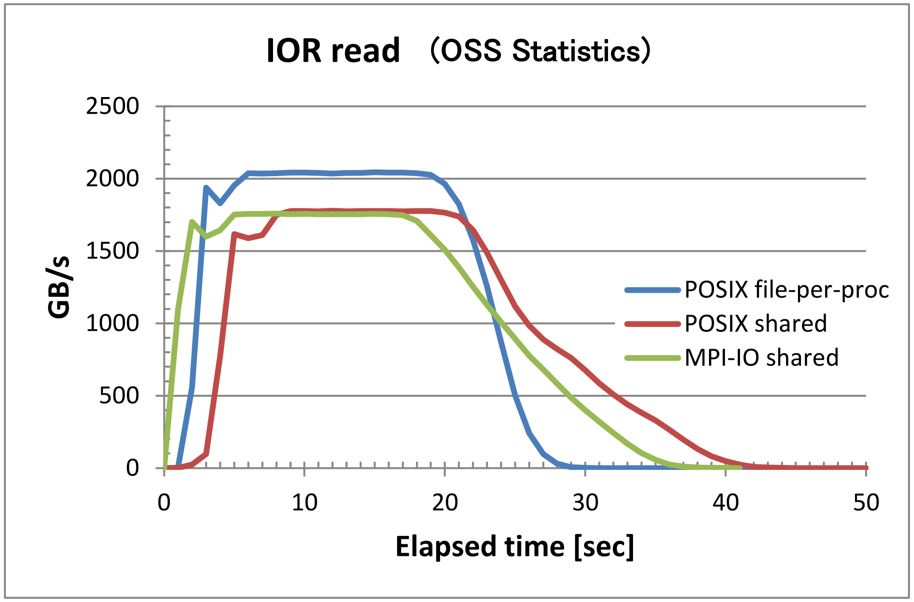
- Write:
  - 1.2 TB/s Sustained Performance
  - No reason for slow MPI-IO
- Read:
  - Sustained Over 2.0 TB/s Performance on File/Proc
  - Sustained 1.75 TB/s on Shared/MPI-IO
    - Shared: Slow Startup/Ending
    - MPI-IO: Fast Startup/ Slow Ending

      Seems to be serialized by something.





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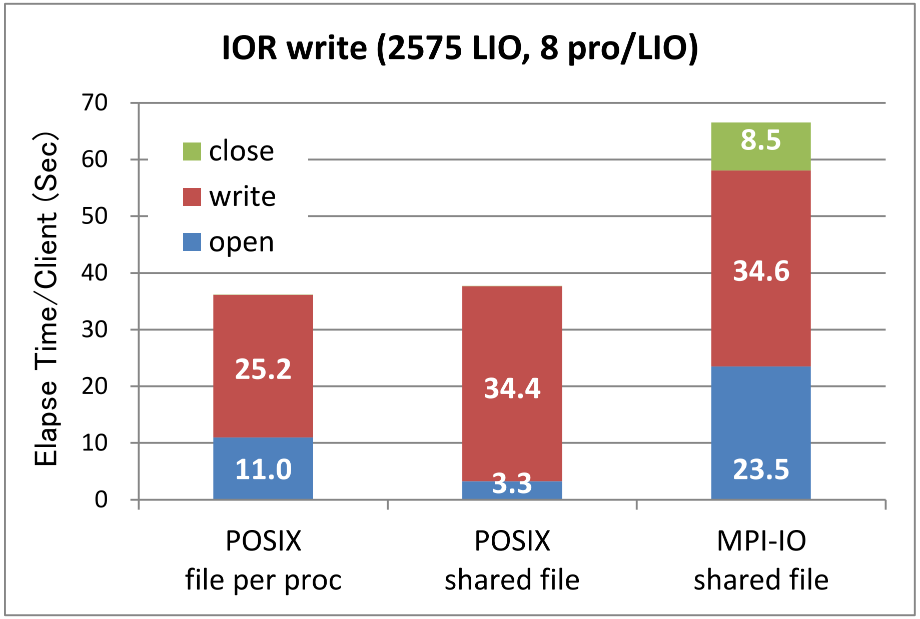
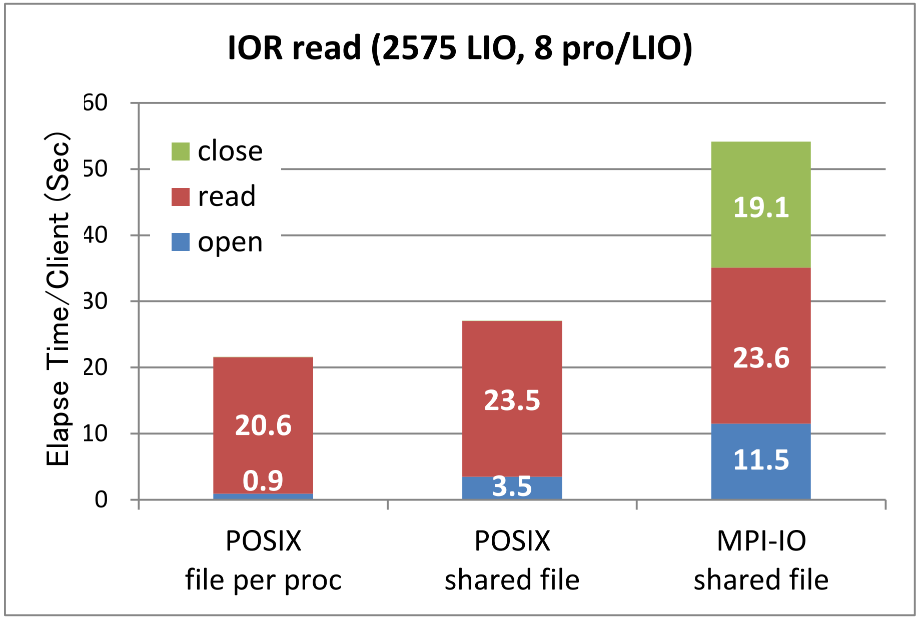
MPI-I/O：Performance Degradation Analysis

- Measured Elapsed Time of Open-Read/Write-Close
  - The same level time of POSIX File/Proc and Shared File
  - The open and close time of MPI-IO are the reason for performance degradation.





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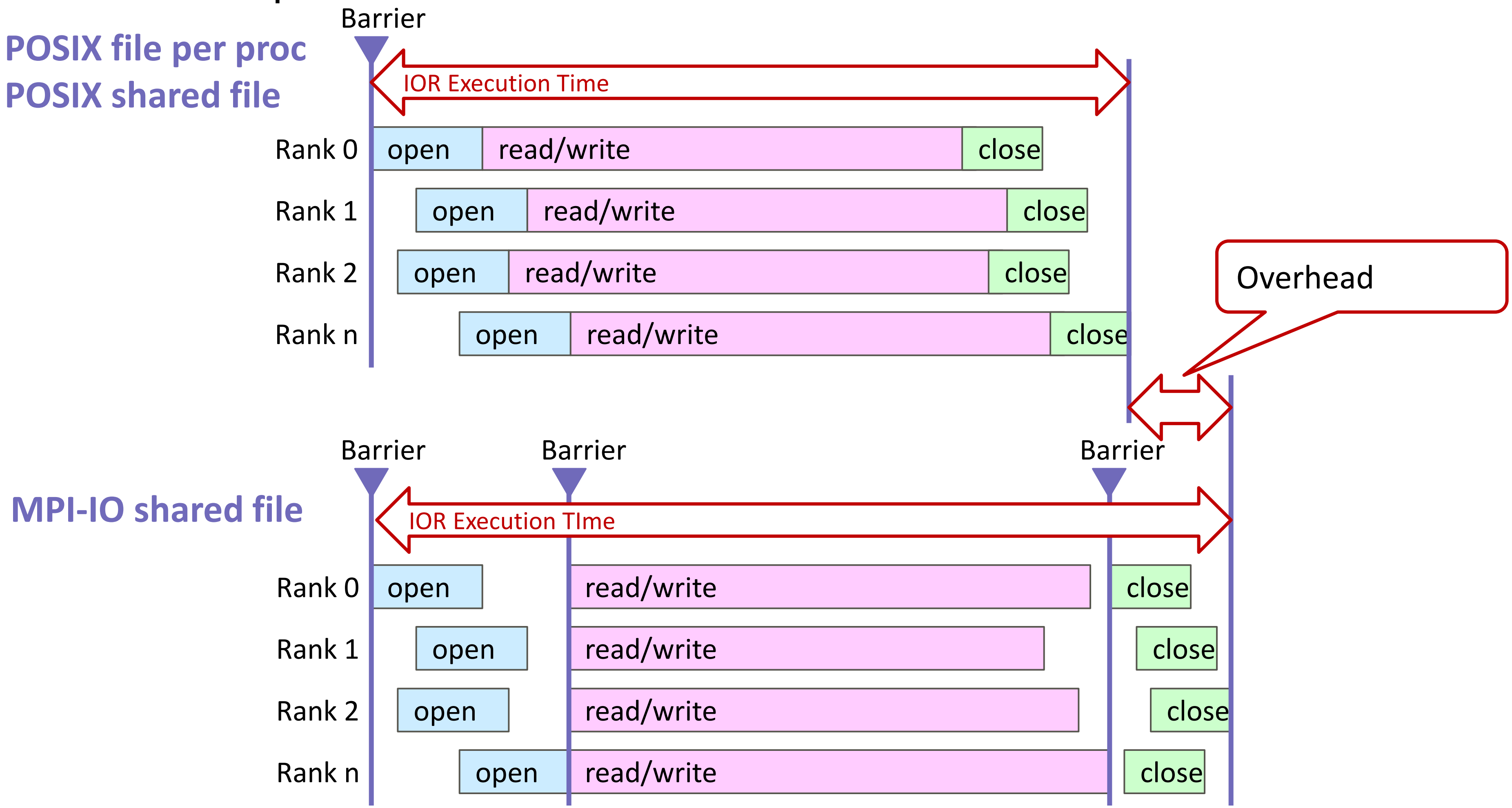
MPI-IO: The Reason for Performance Degradation

- MPI-IO library uses barrier on open and close file
  - This means 2GB I/O is too small to realize enough bandwidth for K computer.



Local FS MPI I/O Performance on 10PF with I/O Zoning

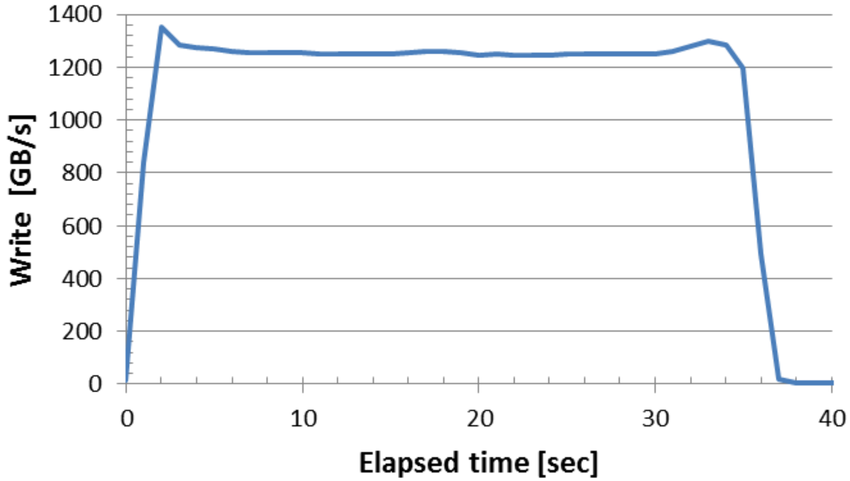
- Same Level Performance to File/Proc on Read Performance
  - I/O and Network Congestion Reduces IOR Performance
  - POSIX Shared File Performance will also speed up w/ I/O Zoning.

IOR MPI-I/O	w/ I/O Zoning	w/o I/O Zoning
Write	0.67 TB/s ⇐	0.66 GB/s
Read	1.46 TB/s ⇐	0.85 GB/s

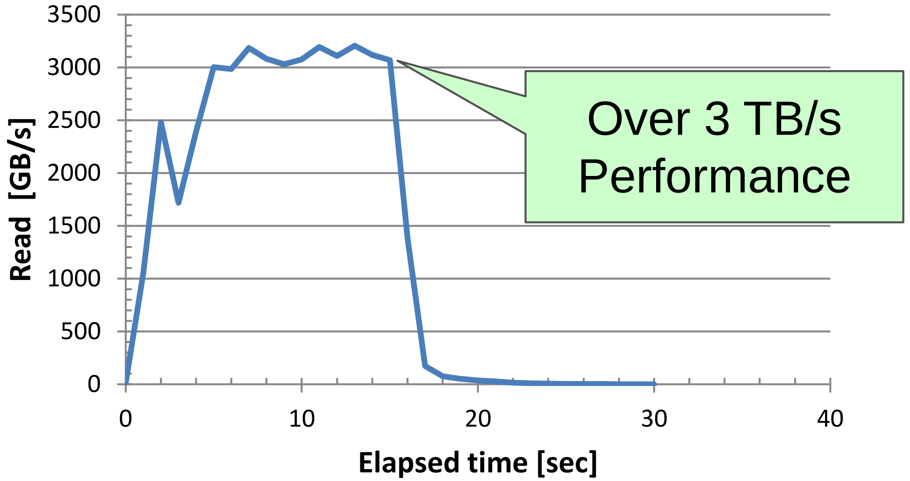
1.35 TB/s Peak

3.2 TB/s Peak

OSS Disk Statistics Write



OSS Disk Statistics Read



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Global FS IOR Performance

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- System Configuration:
  - OSS：Xeon 2.00 GHz x 2（Memory 192GB）90 Units
    - OST： ETURNUS（RAID6（6D+2P）x4 set）2800 OSTs
  - MDS： Xeon 2.00 GHz x2, Memory 64GiB
    - MDT：ETURNUS（RAID1+0（4D+4M）x4 set）2 Units

	IOR File/Proc
Write	207 GB/s
Read	235 GB/s

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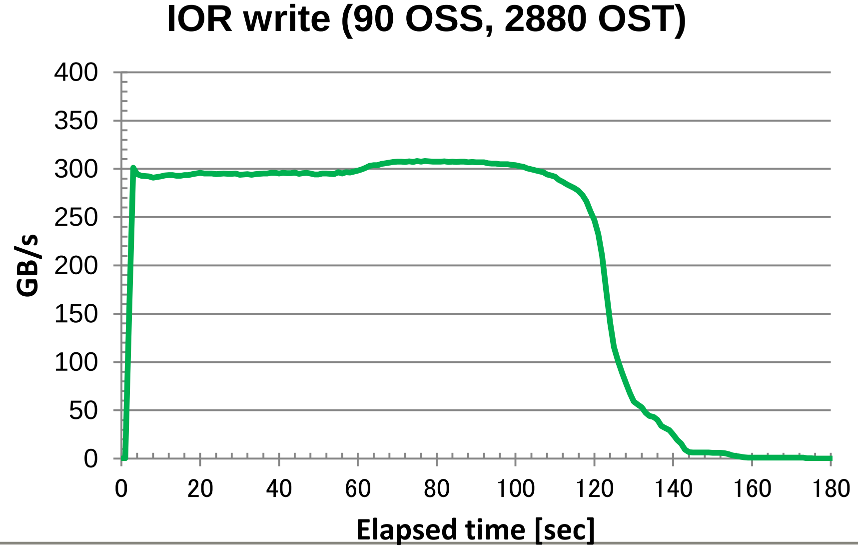

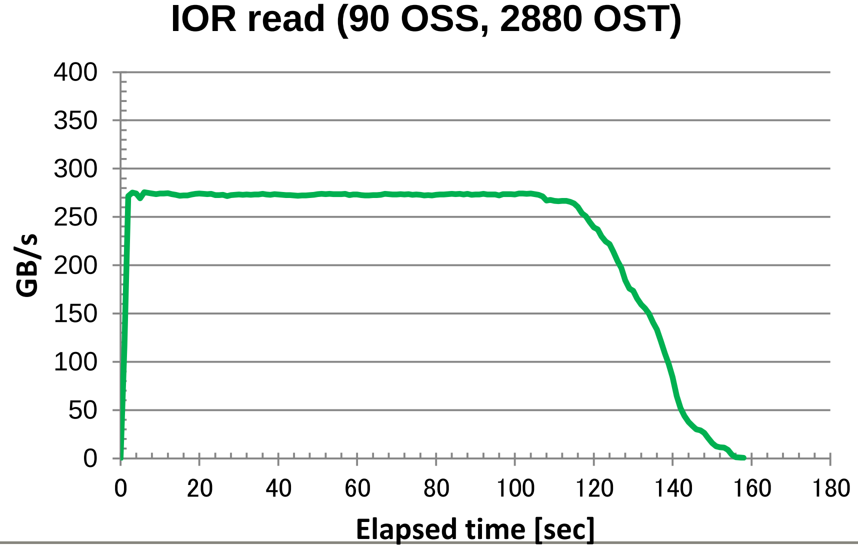

Mdtest: Metadata Processing Performance

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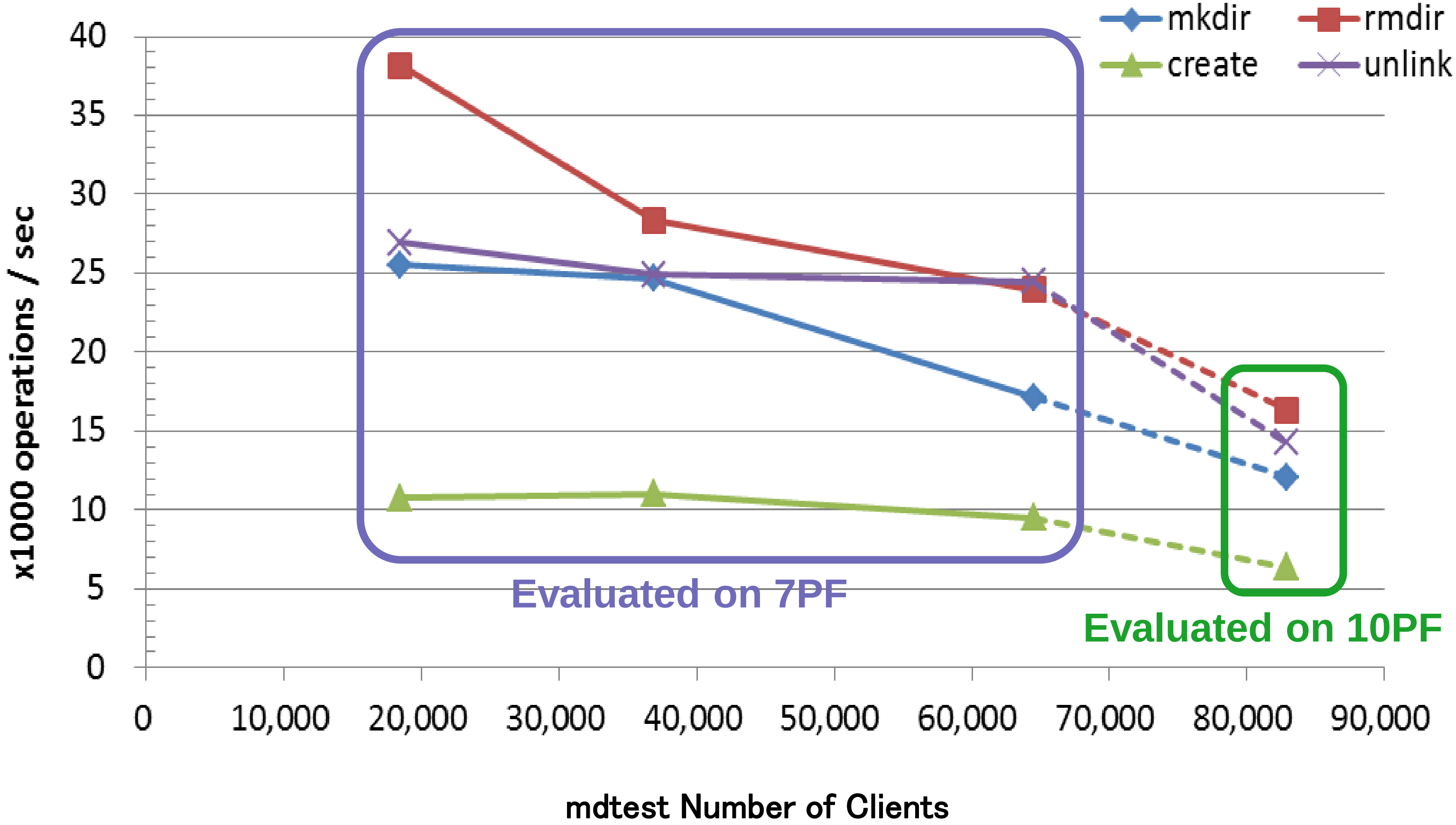

- Metadata performance degradation occurs by increasing number of clients

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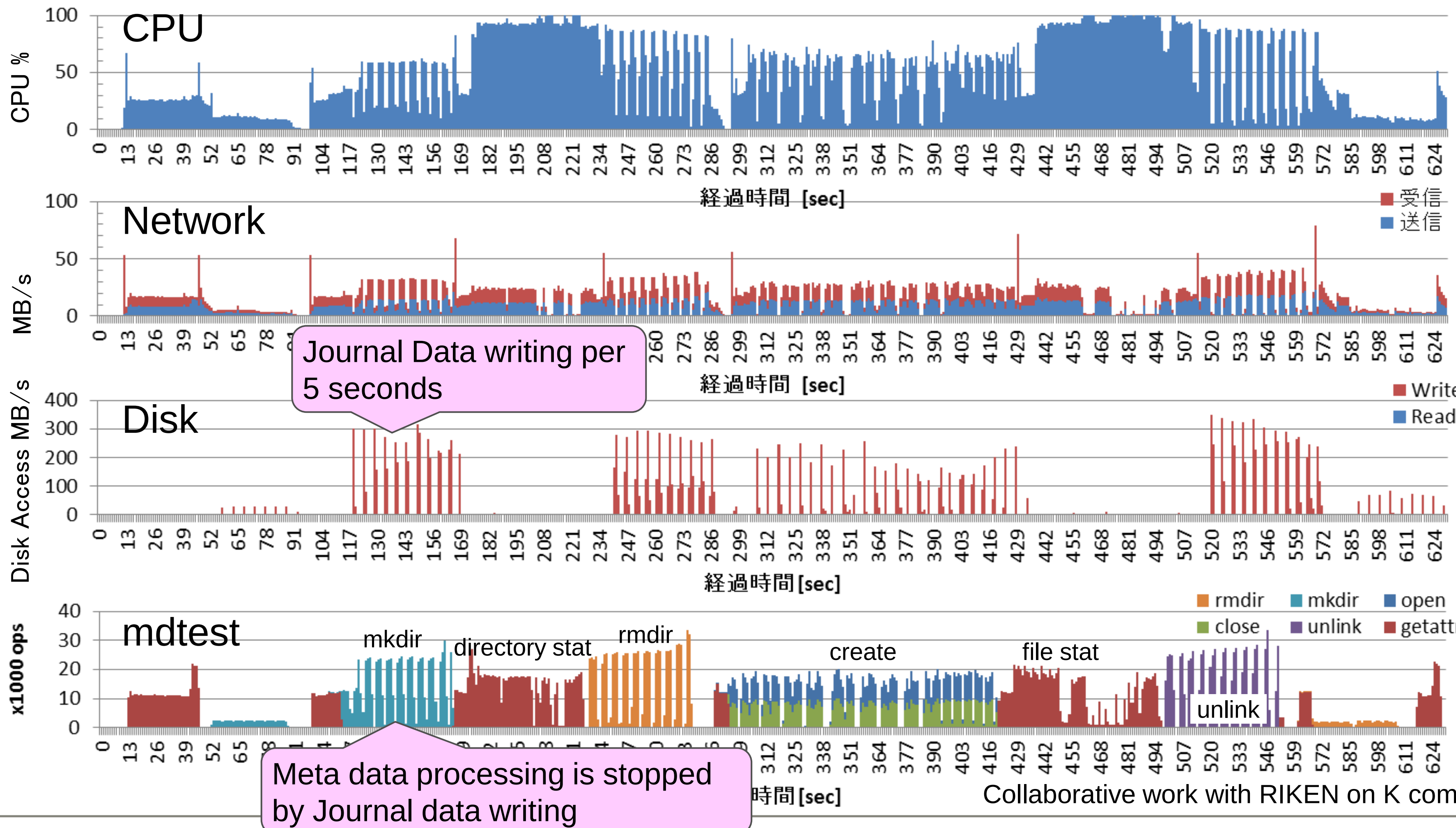
Reason for Degradation of mdtest Performance

- Journal data write processing per 5 seconds is the reason for mdtest performance degradation.
  - Ex: 20K ops create performance without journal writing



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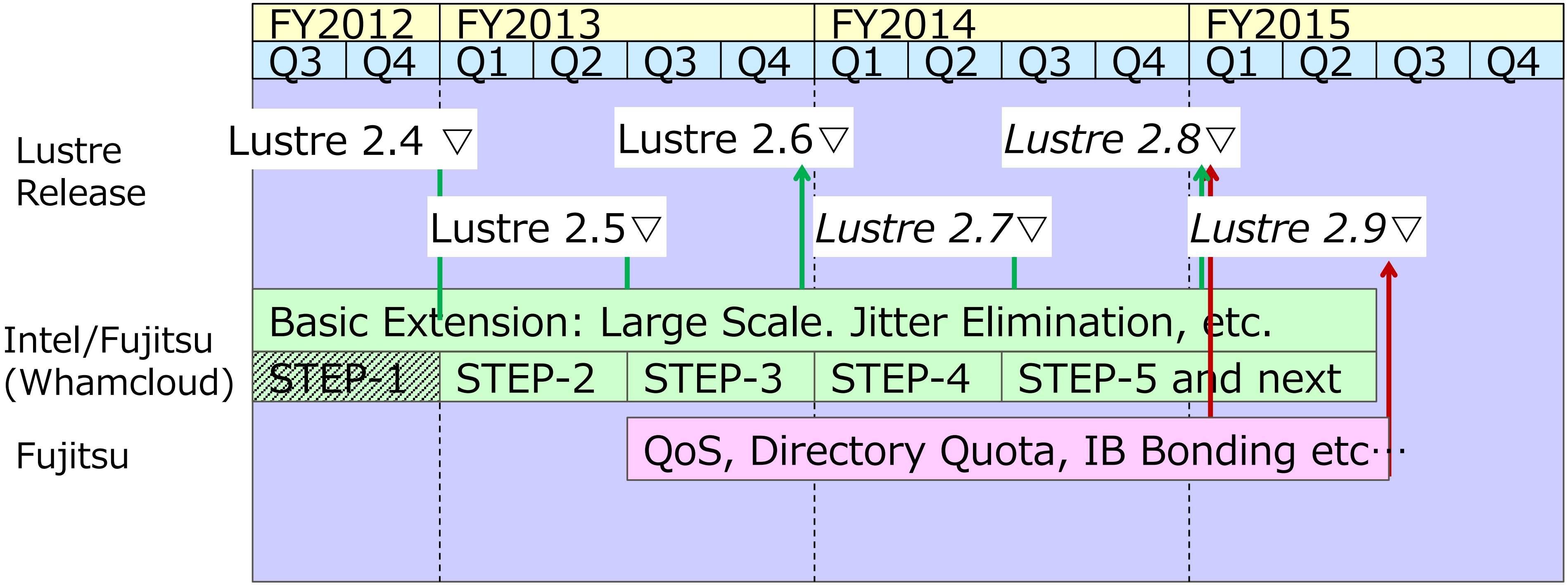
Issues Towards Exascale File System

- FEFS already has exa-byte level functions, however several problems for extra large file system.

- Resource Usage: Especially Memory
  - Client must mount whole of OSTs statically, however in MPI-IO case, a client only does file I/O into single OST. Needs to be dynamically mounted
  - Still needs to reduce memory consumption
  - Number of OSTs was reduced to half for Local FS compared with design phase
- OS Jitter
  - llping does not fit to thousands of OSTs system
- Performance Leveling among OSTs and Network Links
  - Keeping OST performance stable is very important to keep storage performance

Fujitsu's Roadmap towards Lustre 2.x

- Already started with Intel applying FEFS extension to Lustre 2.x, and will plan to finish by mid FY2015
  - Fujitsu will implement the rest of functions.



Summary and Future Work

- We described performance evaluation of FEFS on ‘K computer’ developed by RIKEN and Fujitsu.
  - Over 1.4 TB/s performance (Over 3TB/s Read Performance except starting up and ending time)

- Future Work
  - Rebase to newer version of Lustre (2.x)
  - Continue to Contribute our extensions to Lustre Community

shaping tomorrow with you