Understanding Parallel I/O Performance Trends under Various HPC Configurations

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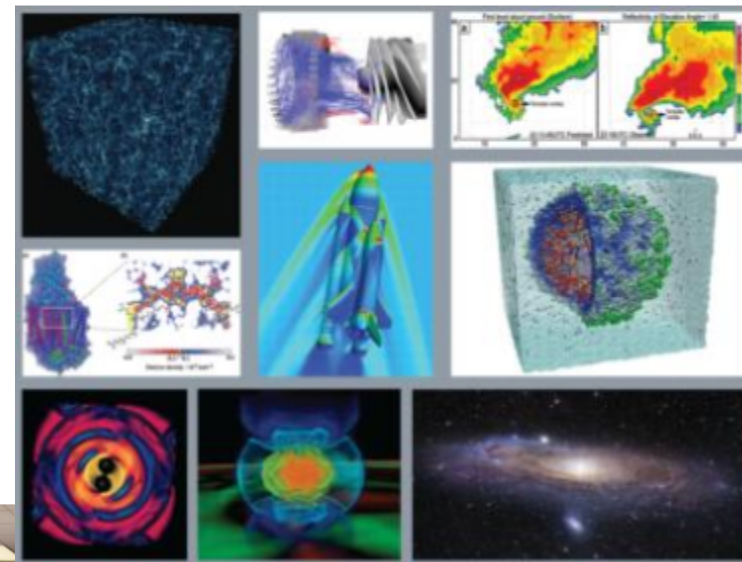
Table of Contents

- **Introduction**
- **Background**
  - Cori supercomputer
  - Parallel I/O operation
- **Parallel I/O Performance Trend**
  - Independent I/O
  - Collective I/O
- **Evaluation**
- **Conclusion**

Petascale Computing on Super Computer

- **Improving the importance of Distributed File System**



Petascale Computing on Super Computer

- **Improving the importance of Distributed File System**
  - Various tunable parameters
    - # of compute nodes, # of cores, # of OSTs and stripe size

Limitation of Super Computer Usage

- **HPC users are unfamiliar with their HPC environments**
  - They do not use HPC parameter settings properly

Limitation of Super Computer Usage

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  - They do not use HPC parameter settings properly

- **There are too many combinations of parameters to be considered for experiments**
  - I/O characteristics for each application is different
  - I/O performance differs depending on the HPC system

Limitation of Super Computer Usage

- **HPC users are unfamiliar with their HPC environments**
  - They do not use HPC parameter settings properly
- **There are too many combinations of parameters to be considered for experiments**
  - I/O characteristics for each application is different
  - I/O performance differs depending on the HPC system
- **Performance fluctuation is inevitable because hardware resource is shared by multiple users in HPC environment**
  - It is difficult to get expected or correct I/O performance in a single experiment per configuration

Parallel I/O Performance Trend

- **Motivation**
  - Easy way to get the best configuration with minimal efforts
    - For the highest I/O performance

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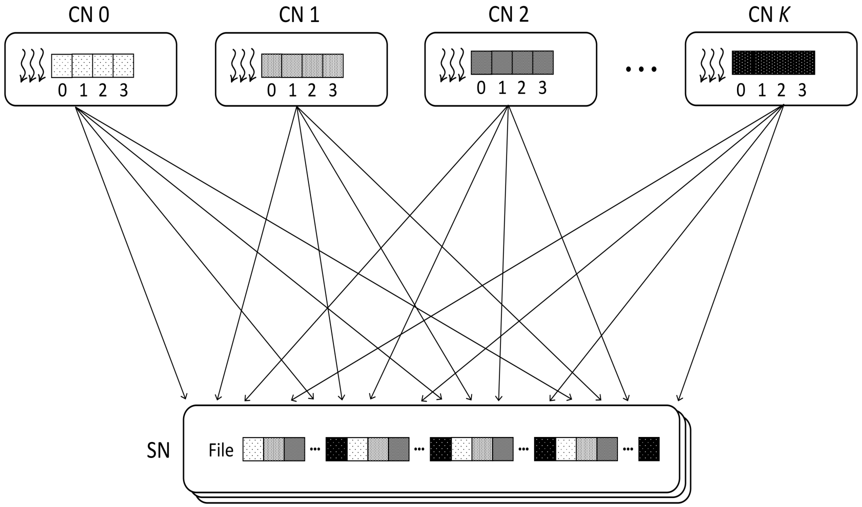
Parallel I/O Performance Trend

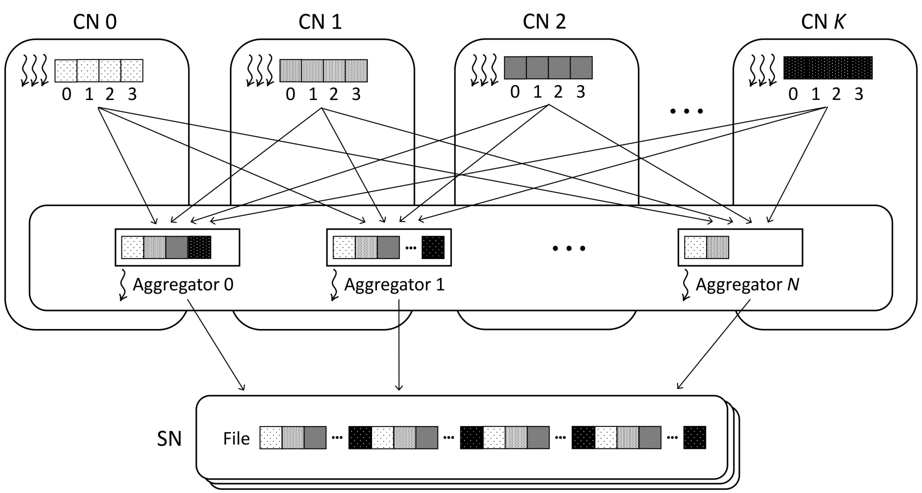
- **Motivation**
  - Easy way to get the best configuration with minimal efforts
    - For the highest I/O performance
- **Goal**
  - Analyzing performance trends by adjusting the tunable parameter settings in Cori system
- **Method**
  - Different HPC I/O characteristics
    - Independent I/O
    - Collective I/O
  - Tunable parameters
    - # of compute nodes
    - # of cores per compute node
    - # of OSTs

HPC I/O Characteristic

- **Independent I/O**
  - Each MPI processes handles I/O operations independently on its own data
- **Collective I/O**
  - Aggregators merge other processes' data and only participate in file I/O



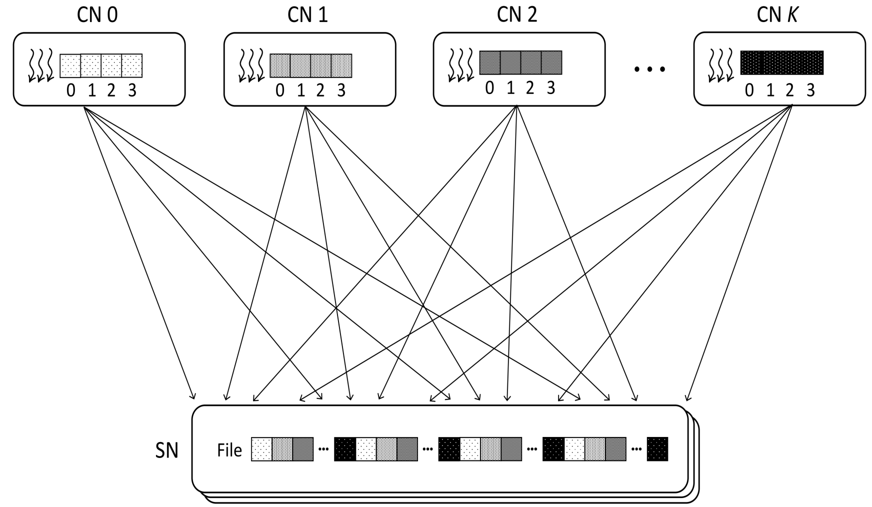
Independent I/O



Collective I/O

Independent I/O

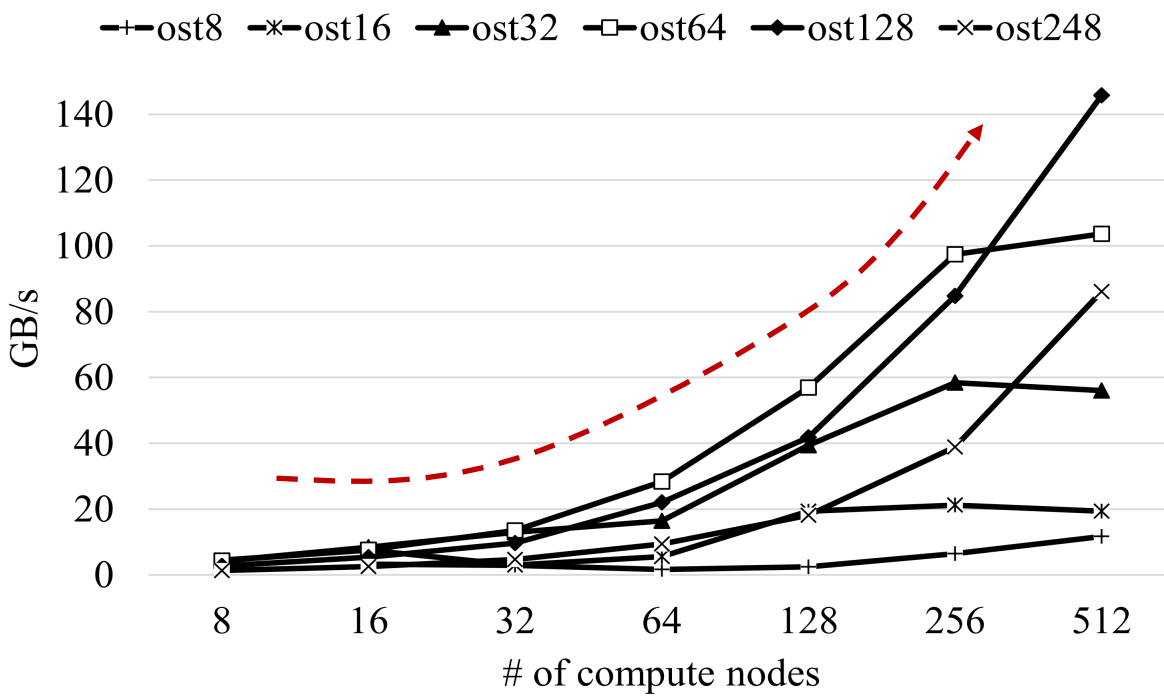
- **Analysis setting**
  - 8 to 512 KNL compute nodes
    - 8, 16, 32, 64, 128, 256, 512 compute nodes
  - 64 cores per compute node
  - 8 to 248 OSTs
    - 8, 16, 32, 64, 128, 248 OSTs
  - 512GB output size
  - 1MB stripe size



DCSLAB

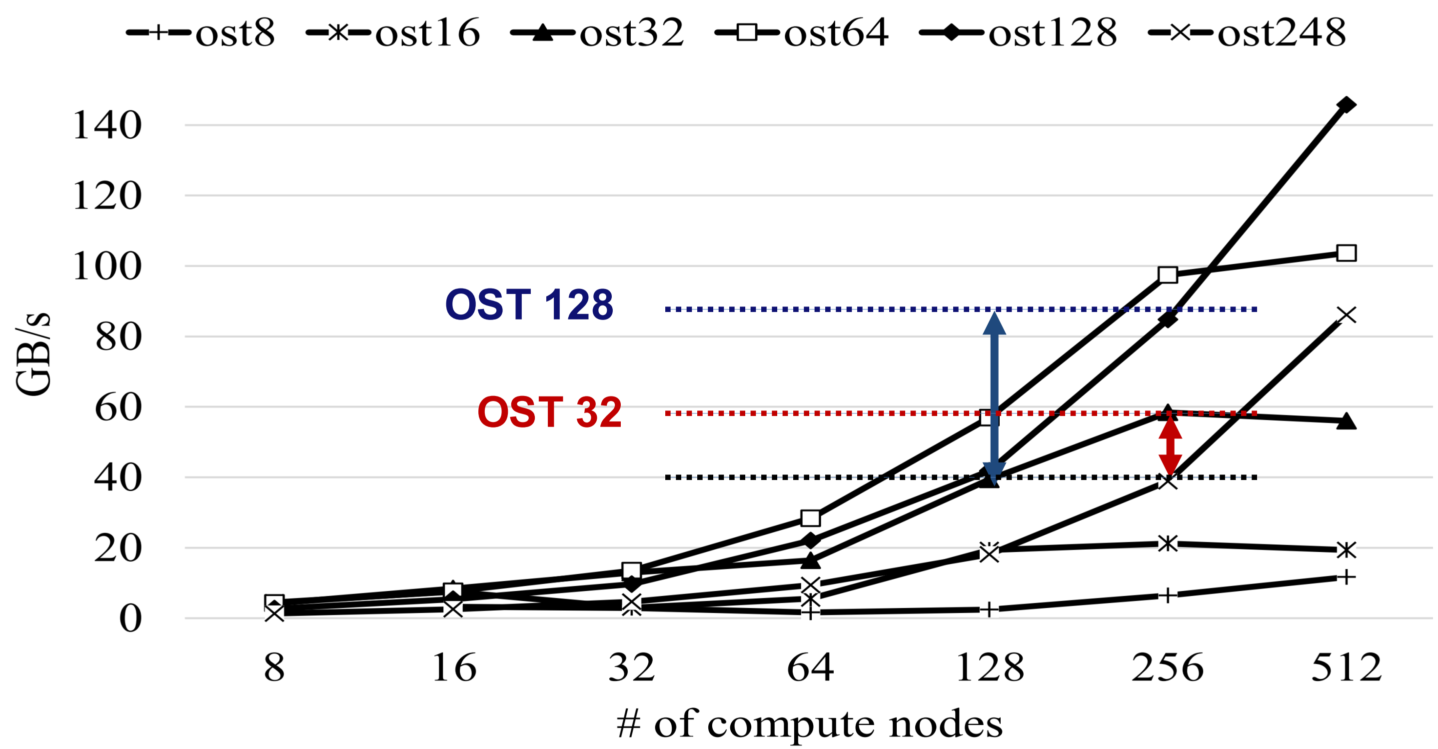
Independent I/O

- **# of compute nodes**
  - # of compute nodes ↑ ➡ MPI throughput ↑



Independent I/O

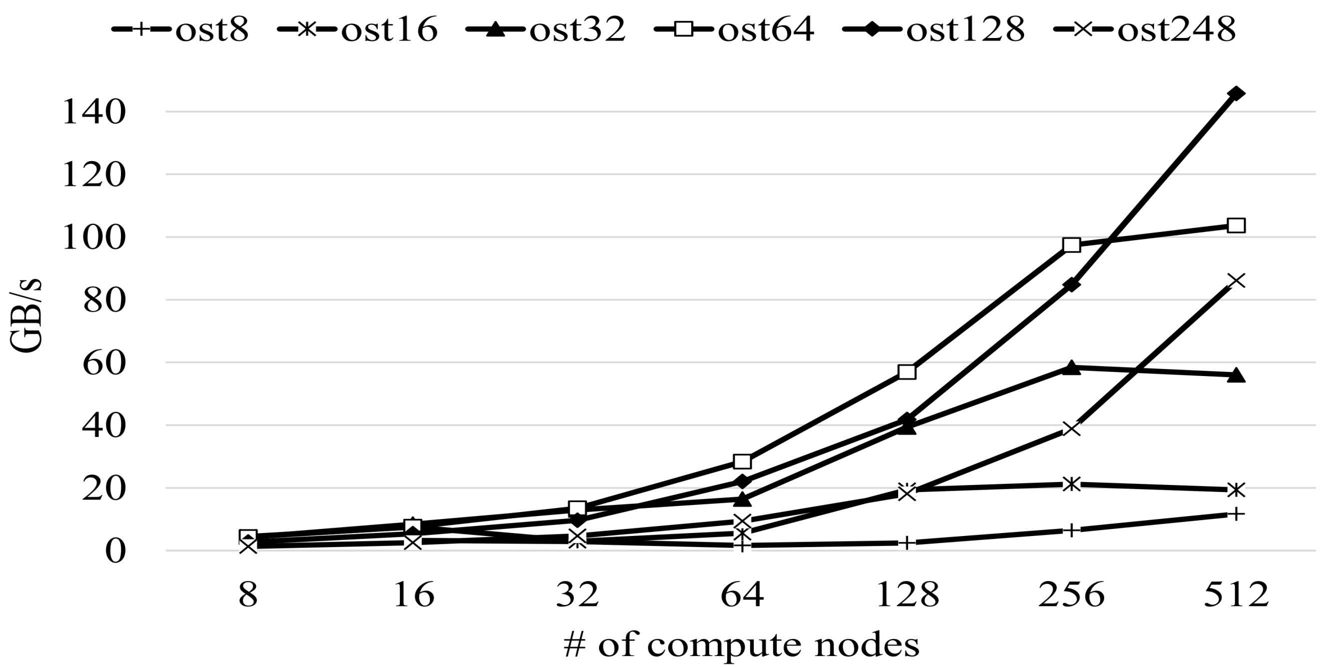
- **# of compute nodes**
  - # of compute nodes ↑ ➡ MPI throughput ↑
  - # of OSTs ↑ ➡ MPI throughput variation ↑



Independent I/O

- **# of compute nodes**
  - # of compute nodes ↑ ➡ MPI throughput ↑
  - # of OSTs ↑ ➡ MPI throughput variation ↑

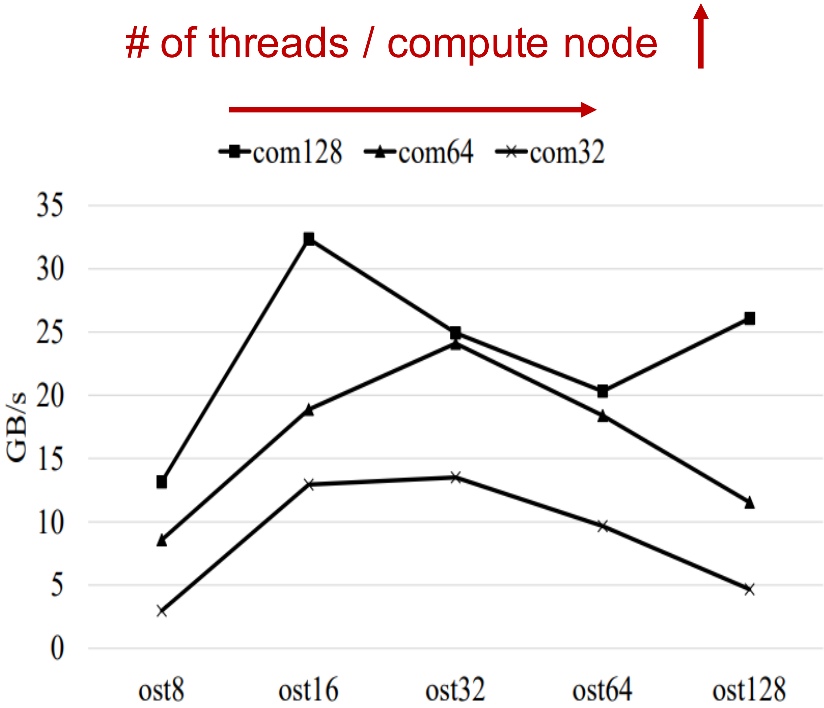
If the number of available OSTs is fixed, it is better to use as many compute nodes as possible for high performance



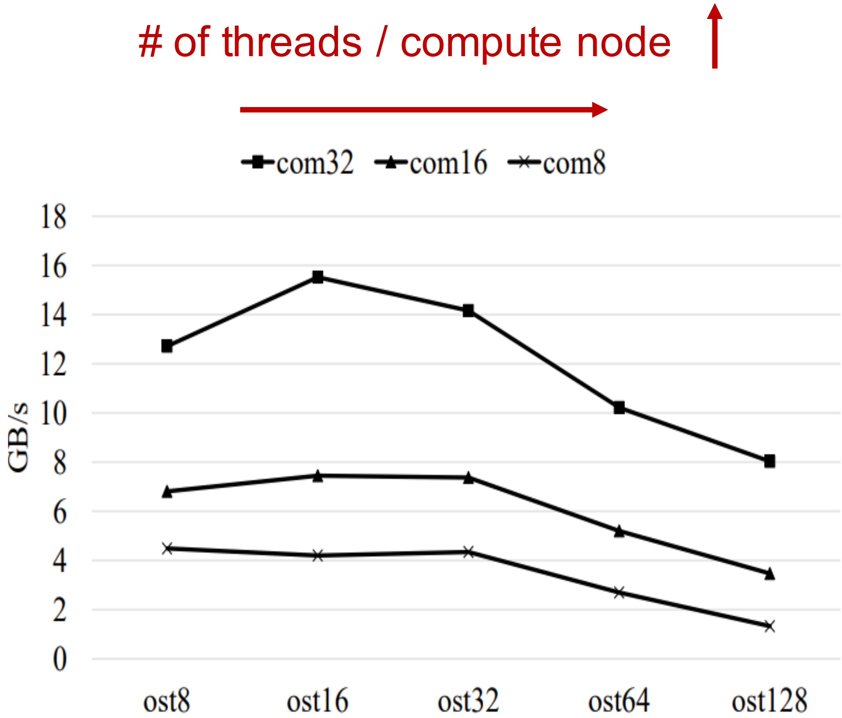
DCSLAB

Independent I/O

- **# of cores per compute node**
  - # of cores per compute node ↑ ➡ MPI throughput ↓



(b) 2048 threads

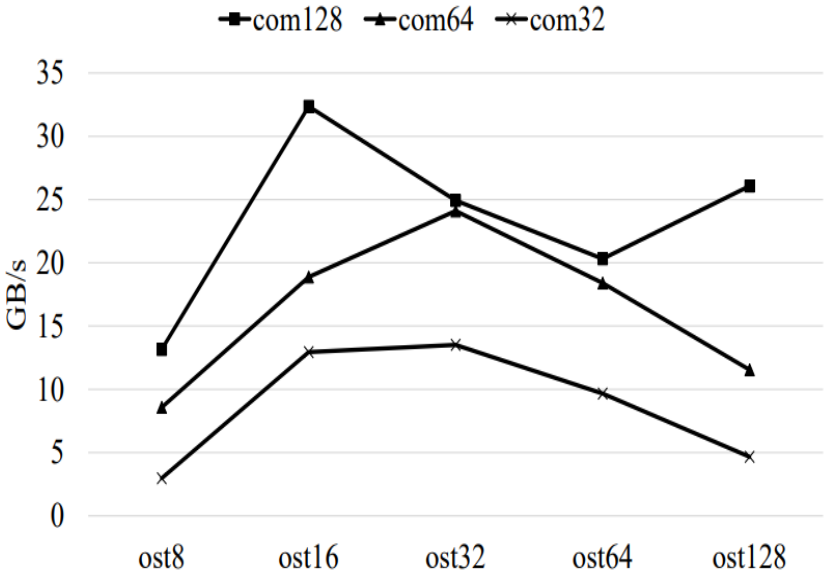


(c) 512 threads

Independent I/O

- **# of cores per compute node**
  - # of cores per compute node ↑ ➡ MPI throughput ↓

If there is enough number of compute nodes, it is better to use fewer cores per compute node for high performance



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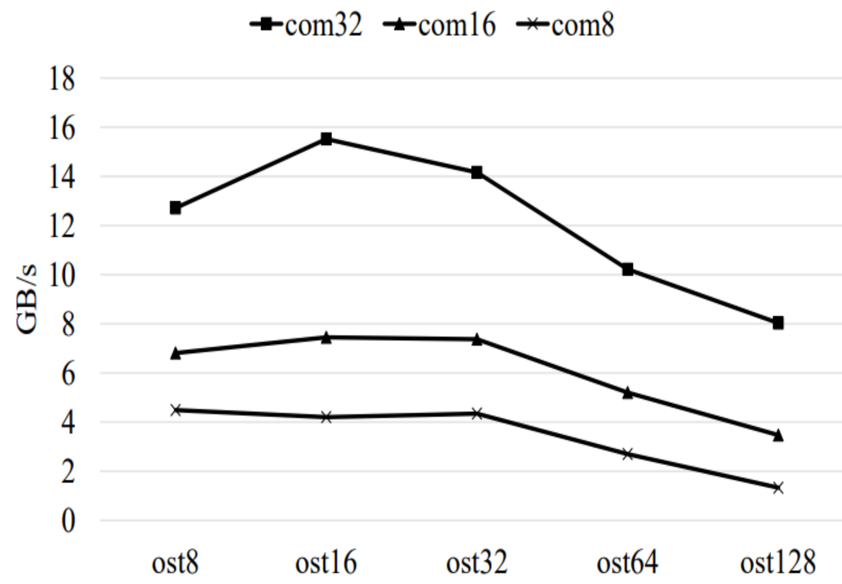

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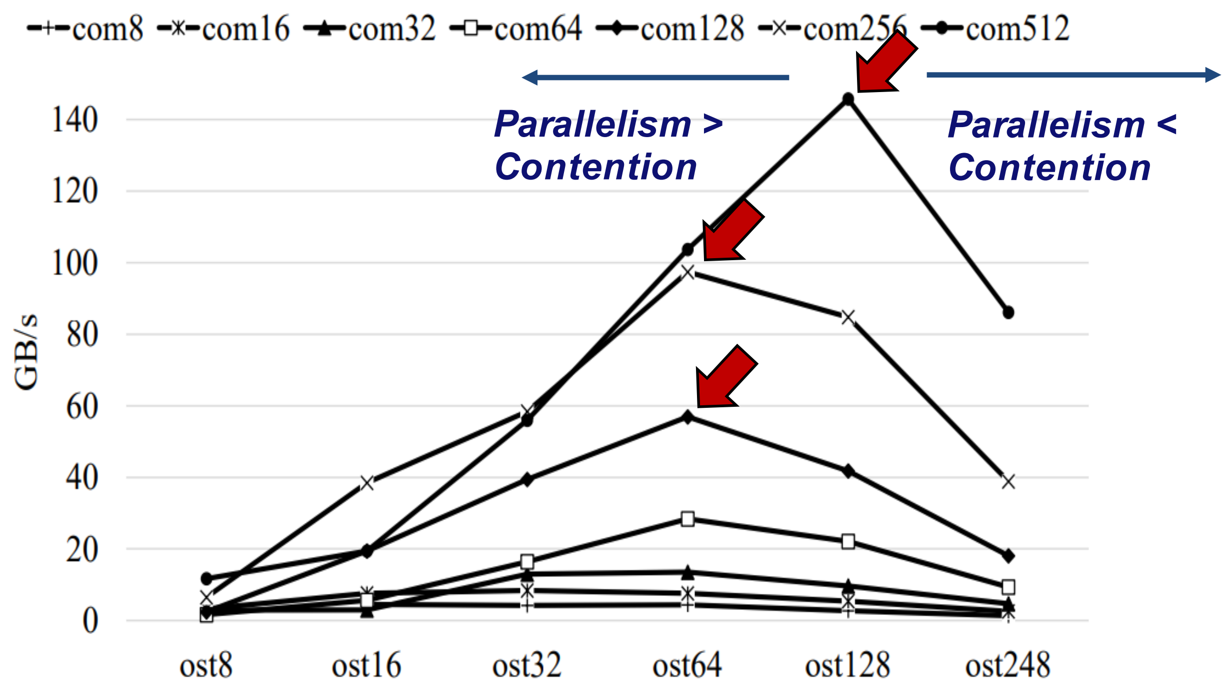
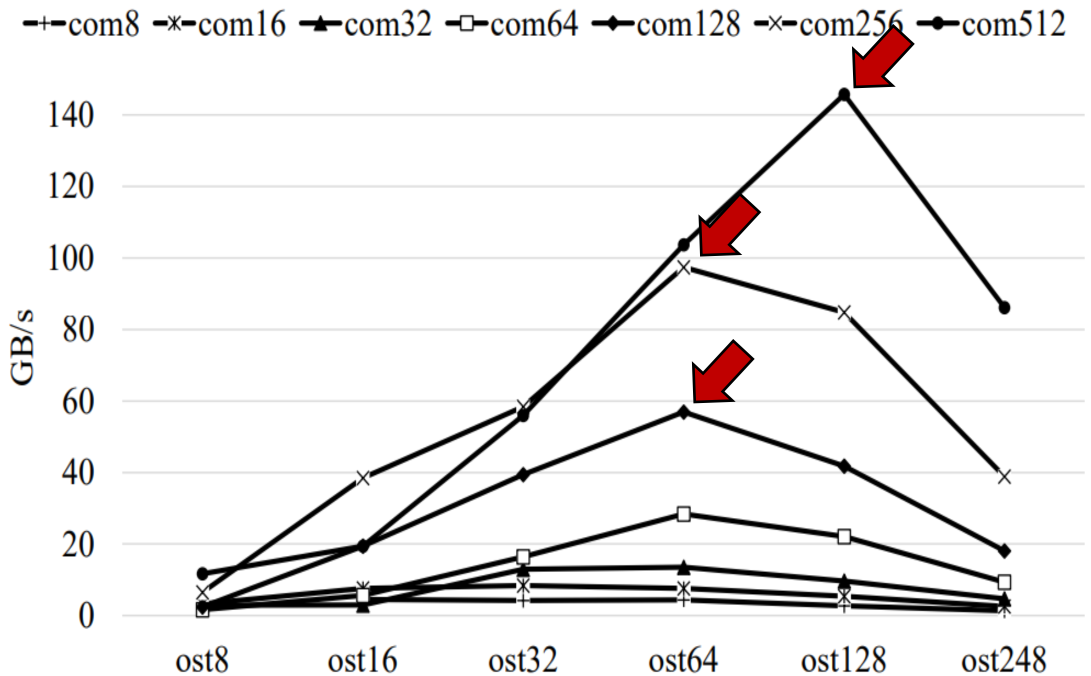
Independent I/O

- **The number of OSTs**
  - # of OSTs ↑ ➡ MPI throughput ↑ until certain point
    - Parallelism vs Contention in shared OSTs



Independent I/O

- **The number of OSTs**
  - # of OSTs ↑ ➡ MPI throughput ↑ until certain point
    - Parallelism vs Contention in shared OSTs
  - # of OSTs giving the best performance differs depending on the number of compute nodes



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Independent I/O

- **The number of OSTs**
  - # of OSTs ↑ ➡ MPI throughput ↑ until certain point
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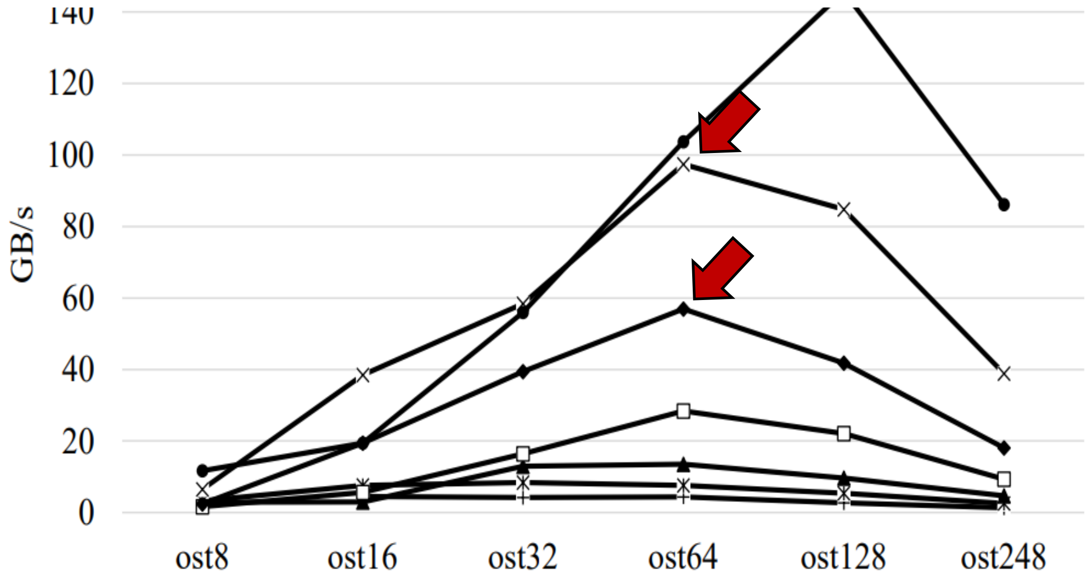
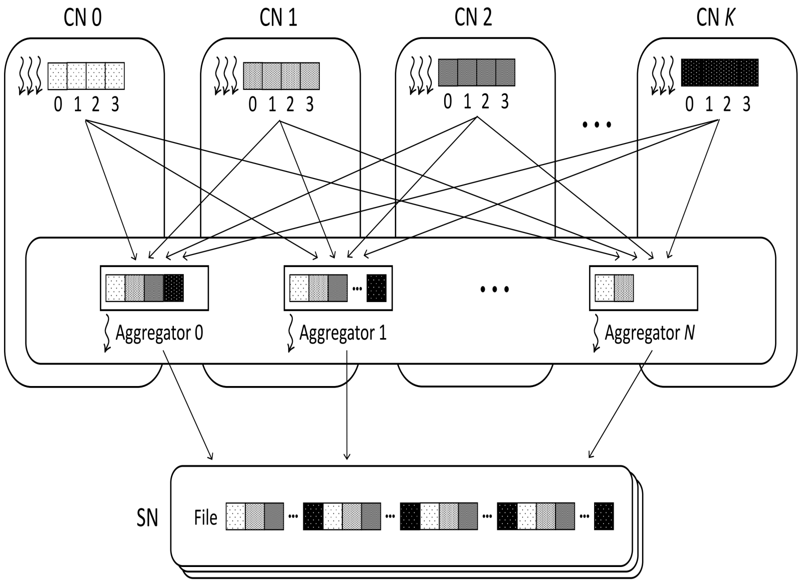
The number of OSTs showing the best performance gets larger as the number compute nodes increases



Collective I/O

- **Analysis setting**
  - 8 to 512 KNL compute nodes
    - 8, 16, 32, 64, 128, 256, 512 compute nodes
  - 32 cores per compute node
  - 8 to 248 OSTs
    - 8, 16, 32, 64, 128, 248 OSTs
  - 512GB output size
  - 16MB stripe size



  - $\# \, of \, aggregators = \# \, of \, OSTs$
  - $\# \, of \, aggregators \, per \, compute \, node = \dfrac{\# \, of \, OSTs}{\# \, of \, compute \, nodes}$

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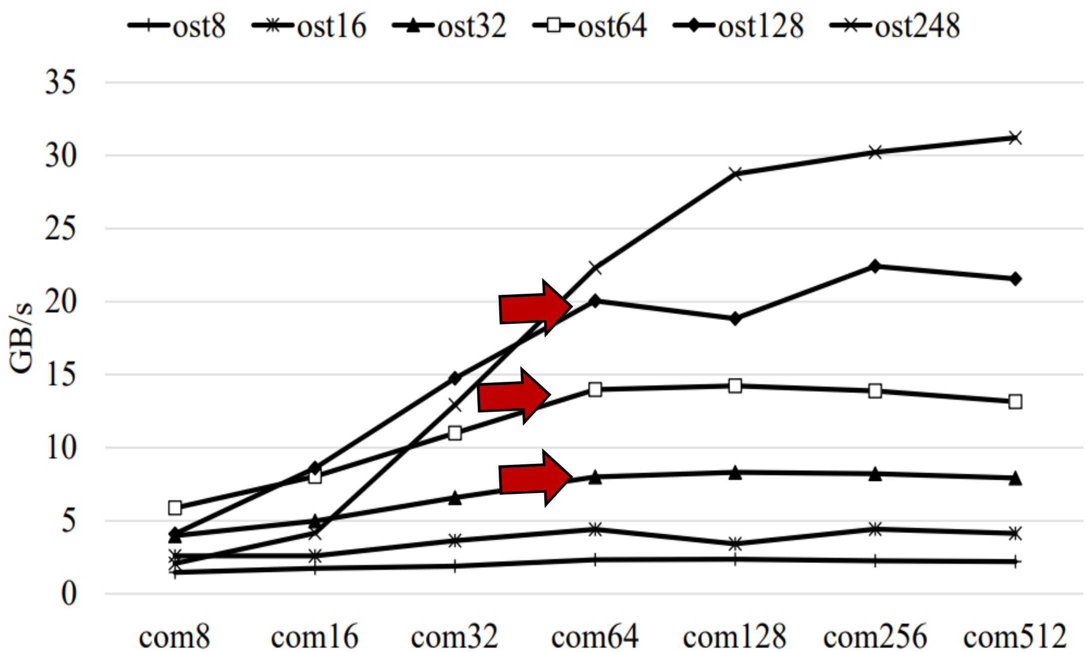
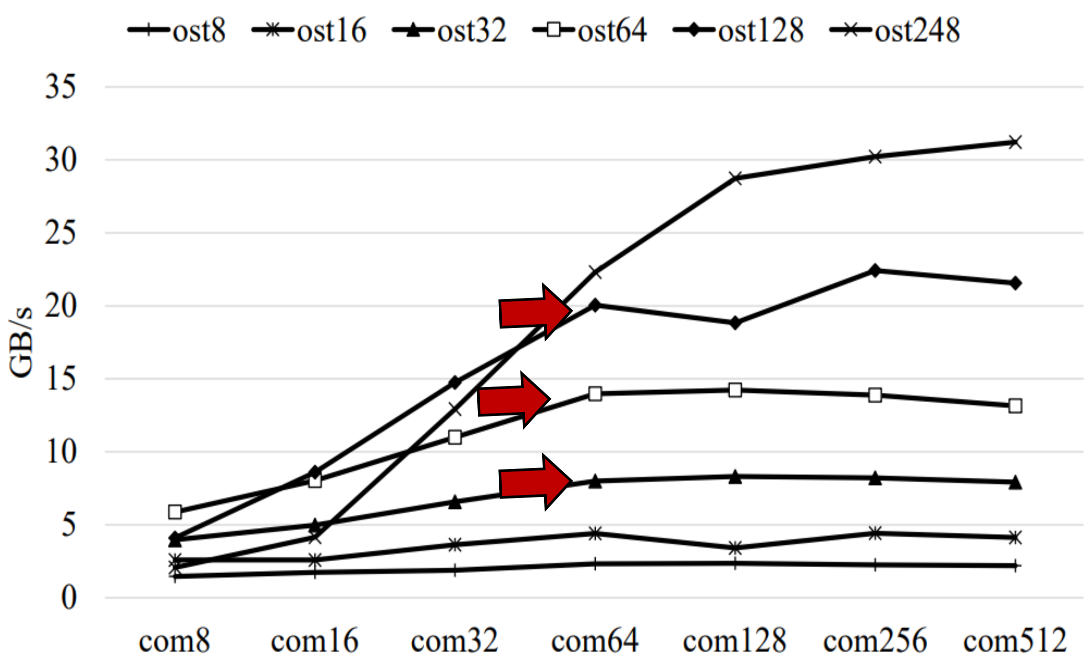
Collective I/O

- **The number of compute nodes**
  - # of compute nodes ↑ ➡ MPI throuhgput ↑ and saturates from the a certain point



Collective I/O

- **The number of compute nodes**
  - # of compute nodes ↑ ➡ MPI throuhgput ↑ and saturates from the a certain point
  - # of OSTs ↑ ➡ MPI throughput variation ↑

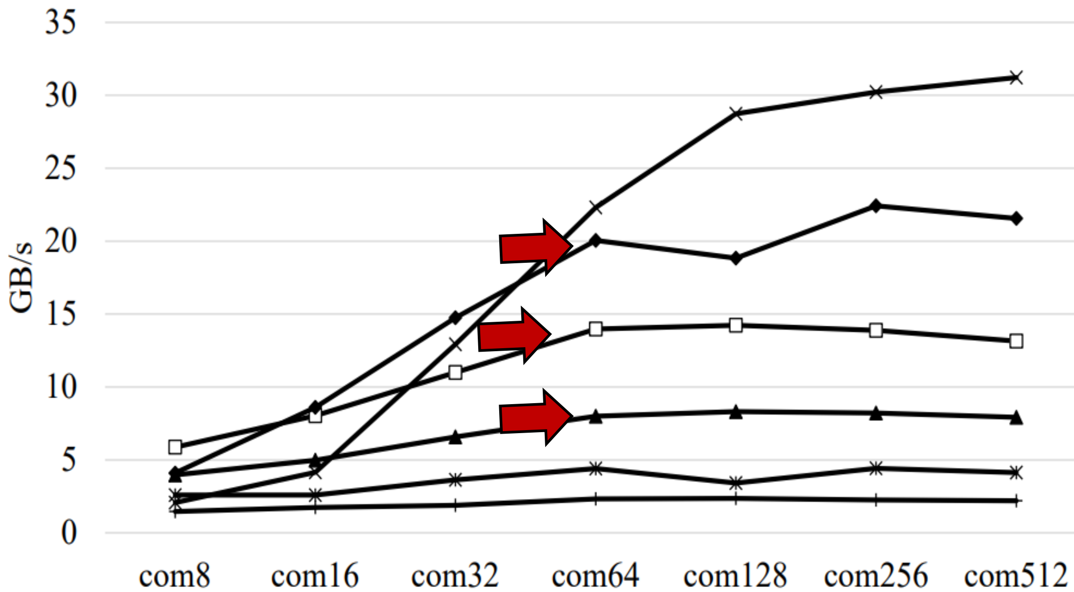


DCSLAB

Collective I/O

- **The number of compute nodes**
  - # of compute nodes ↑ ➡ MPI throuhgput ↑ and saturates from the a certain point
  - # of OSTs ↑ ➡ MPI throughput variation ↑

If the number of available OSTs is large enough, the greater the performance improvement can be achieved with more compute nodes



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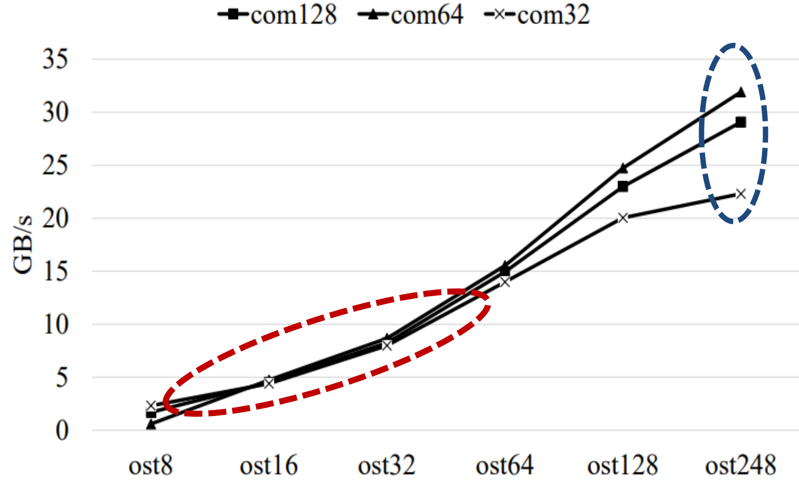
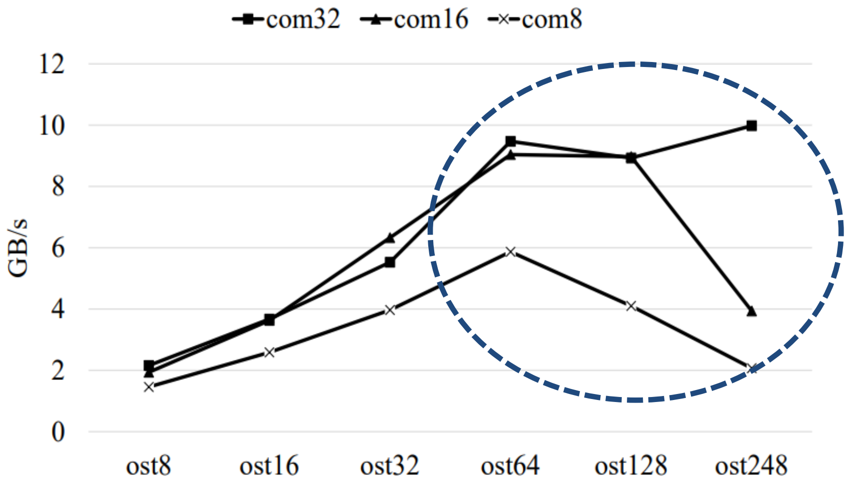
Collective I/O

- **The number of cores per compute node**
  - Few aggregators per compute node ➡ Similar I/O throughput
  - Larger aggregators per compute node ➡ I/O throughput variation ↑



(b) 2048 threads

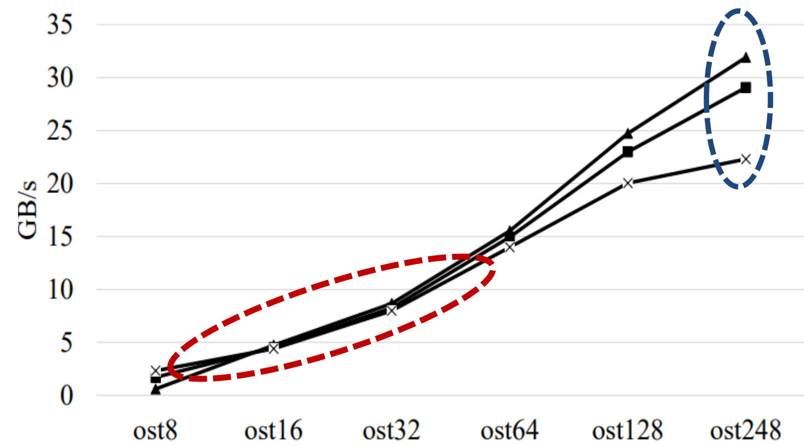


(c) 512 threads

Collective I/O

- **The number of cores per compute node**
  - Few aggregators per compute node ➡ Similar I/O throughput
  - Larger aggregators per compute node ➡ I/O throughput variation ↑

The larger the number of aggregators in the single compute node, the better performance can be achieved by spreading the aggregators to more compute nodes



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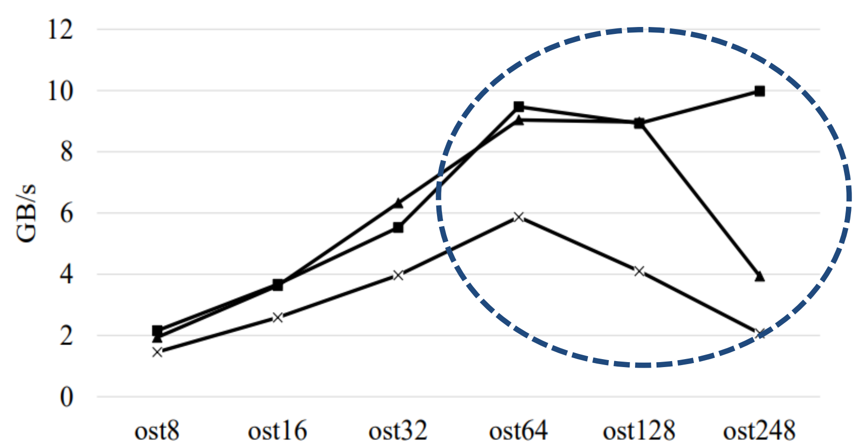
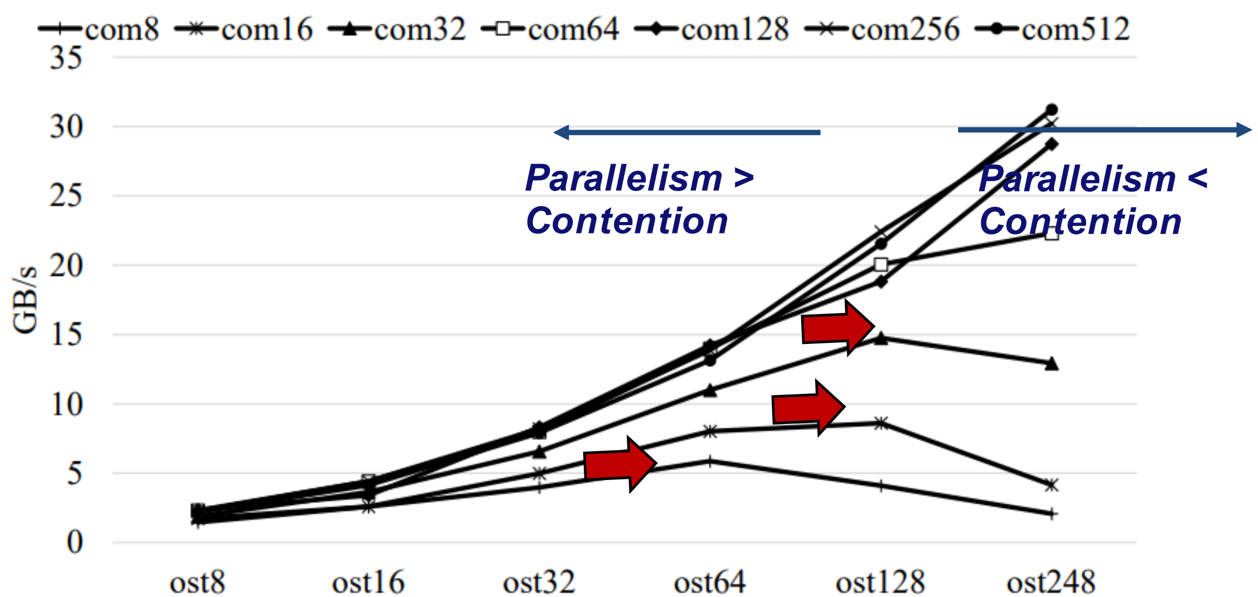


(c) 512 threads

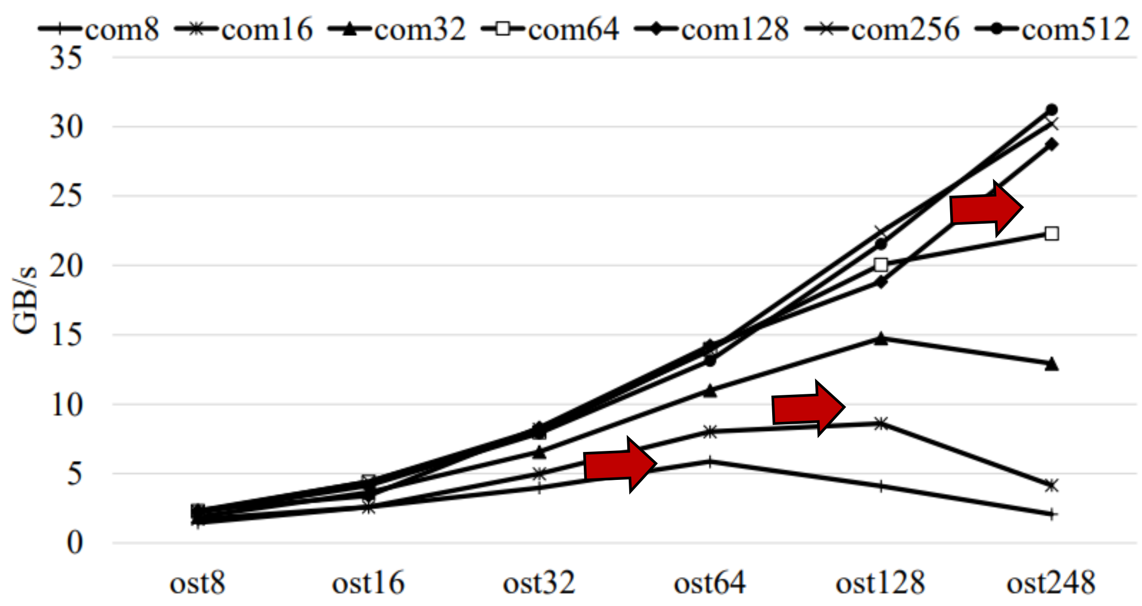
Collective I/O

- **The number of OSTs**
  - # of OSTs ↑ ➡ MPI throughput ↑ until a certain point



Collective I/O

- **The number of OSTs**
  - # of OSTs ↑ ➡ MPI throughput ↑ until a certain point
  - # of OSTs showing the best performance is different depending on the # of compute nodes



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Collective I/O

- **The number of OSTs**
  - # of OSTs ↑ ➡ MPI throughput ↑ until a certain point
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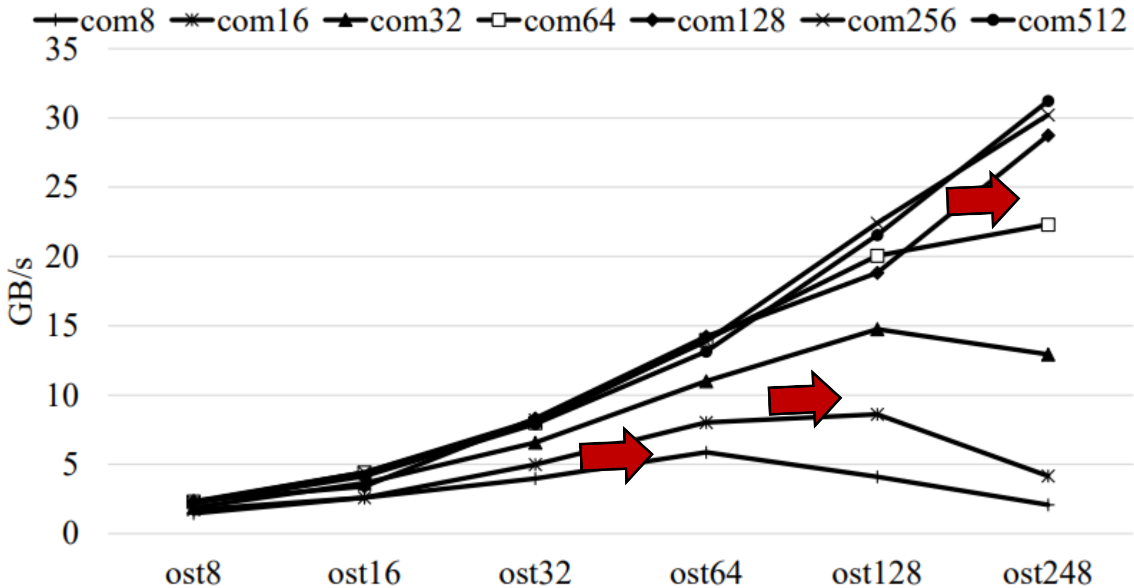
When the number of aggregators in each compute nodes is small, it is better to use more OSTs for better performance



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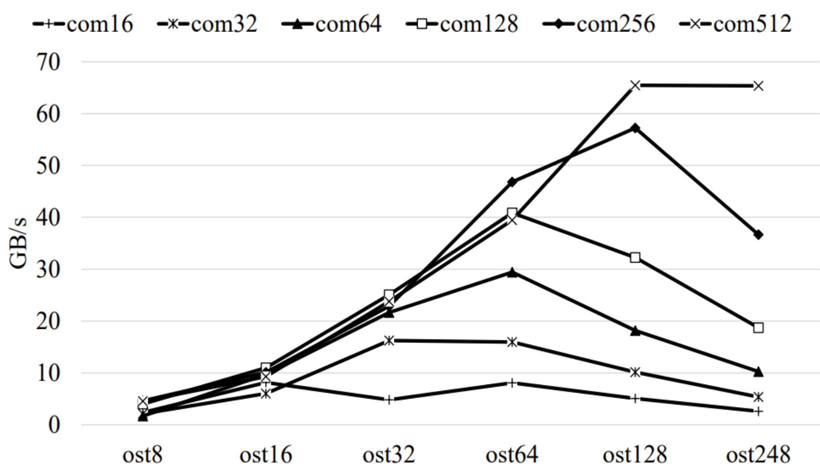
Prediction Accuracy

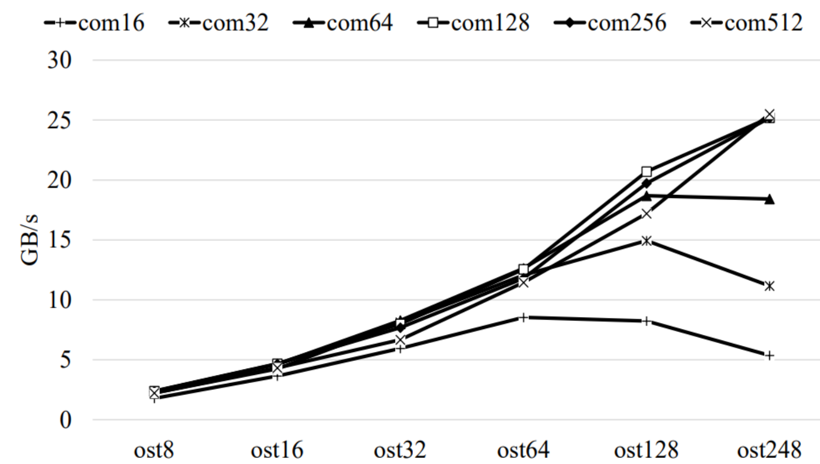
- **Comparing the performance trends with other HPC workloads under similar evaluation setting**
  - VPIC-IO for independent I/O
    - Plasma physics simulation's particle data write phase
  - Chombo for collective I/O
    - Adaptive mesh refinement scientific applications

Performance Trends of HPC Applications

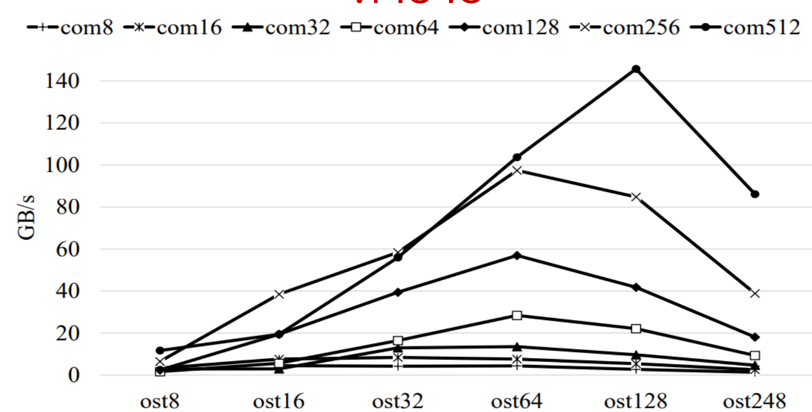
- **Result**
  - Both VPIC-IO and Chombo show similar performance trends as that of analysis using IOR

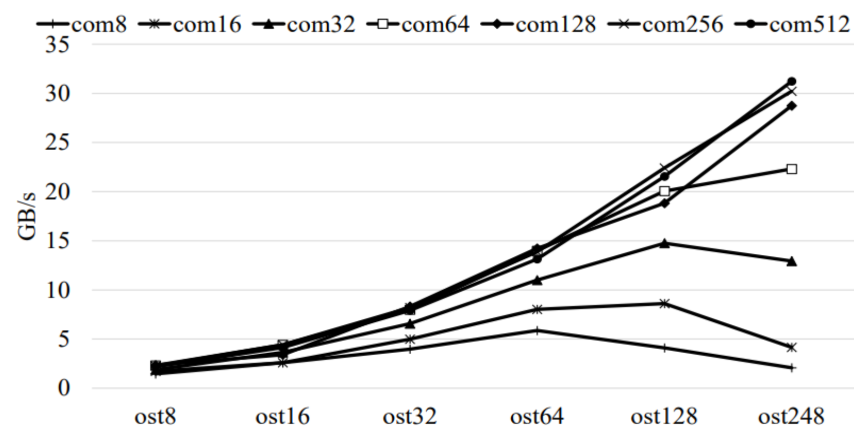


VPIC-IO



Chombo



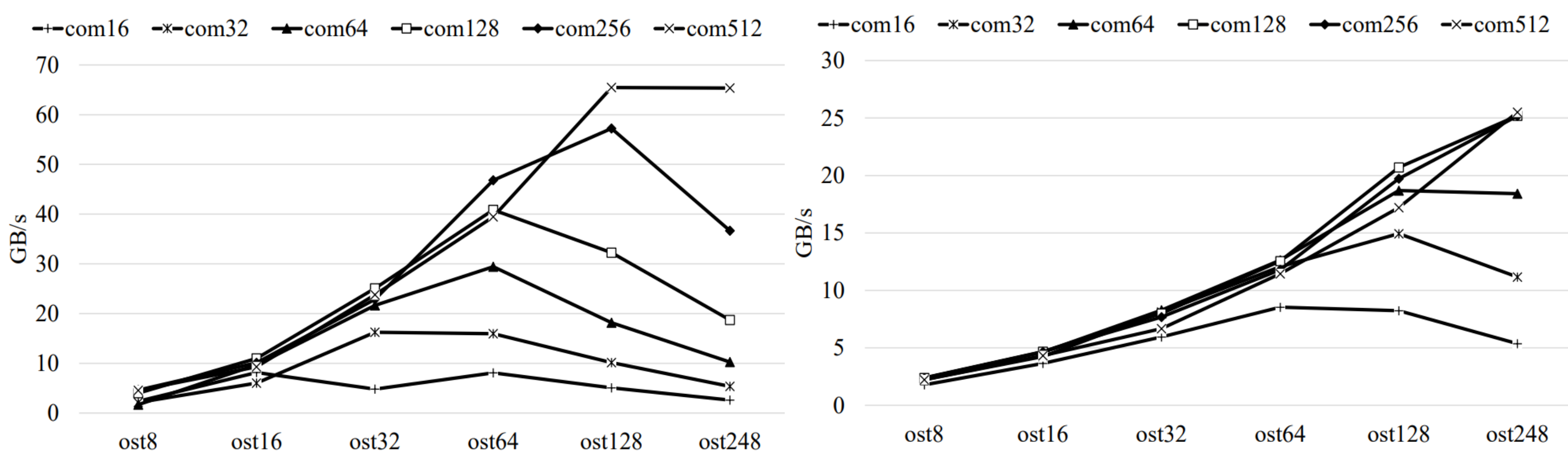


IOR with Collective I/O

IOR with Indenpend I/O

Performance Trends of HPC Applications

- **Result**
  - Both VPIC-IO and Chombo show similar performance trends as that of analysis using IOR
  - Performance trends of the other HPC workloads can be predicted by the analysis through the synthetic workload IOR
  - It is expected to be able to predict the best configuration that gives the highest performance



(a) VPIC-IO (b) Chombo

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Conclusion

- **Summary**
  - We analyzed the performance trends by changing the tunable parameters using the synthetic workload IOR
  - The different I/O characteristics show different performance trends depending on the configurations
  - The performance trends change due to the parallelism and the contention for the shared resource
  - Other HPC workloads, VPIC-IO and Chombo, showed similar performance trends to that of IOR
- **Future work**
  - Considering other I/O characteristics
  - Creating a recommend platform