Spare Node Substitution for Failure Nodes

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Background

- In the Exa-flops era, faults could happen more frequently than ever → System MTBF becomes shorter
- Important Issue : Recovery from faults

- Conventional method : System-level Checkpoint-Restart
  - Requires massive I/O
- Many mechanisms to survive failures have been proposed and investigated
  - Less I/O Size
  - One of the mechanisms is ULFM(User-Level Fault Mitigation).
    - User program handles failures
    - The program can survive from the failures and continue its execution
- But there is no discussion how a job should survive from node failures

Purpose of this Research

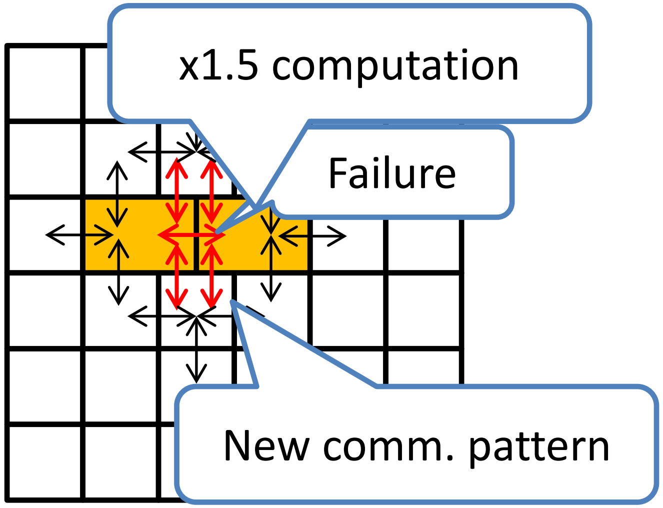
- **What is the best way to survive from node failures ?**
  - Assuming a job can survive from a node failure by using an existing fault mitigation software
  - Not to propose a new fault mitigation mechanism
  - Propose recovery strategy

Survival from Node Failure

- Applications with dynamic load balancing
  - e.g. Distributed Master-Worker model
  - Avoiding failure nodes method
  - Applications continue its execution only with healthy nodes after failure

- How about applications **without** dynamic load balancing?
  - e.g. Stencil Computation

Avoiding Failure Node(s) for Stencil Computation



- Stencil computation characteristics
  - Communication pattern is fixed
  - Load can be balanced
- When a recovery happens, above stencil computation characteristics must be preserved
- However,
  - Hard to balance loads
  - Impossible to preserve communication pattern
  - Every time a new failure happens, communication pattern can differ
- Hard to program !!!

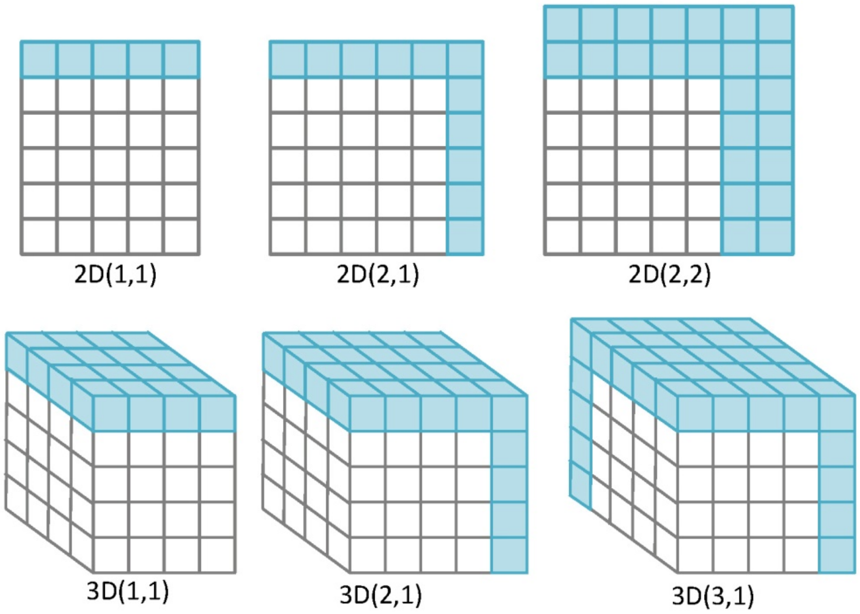
Using spare nodes to solve these problems

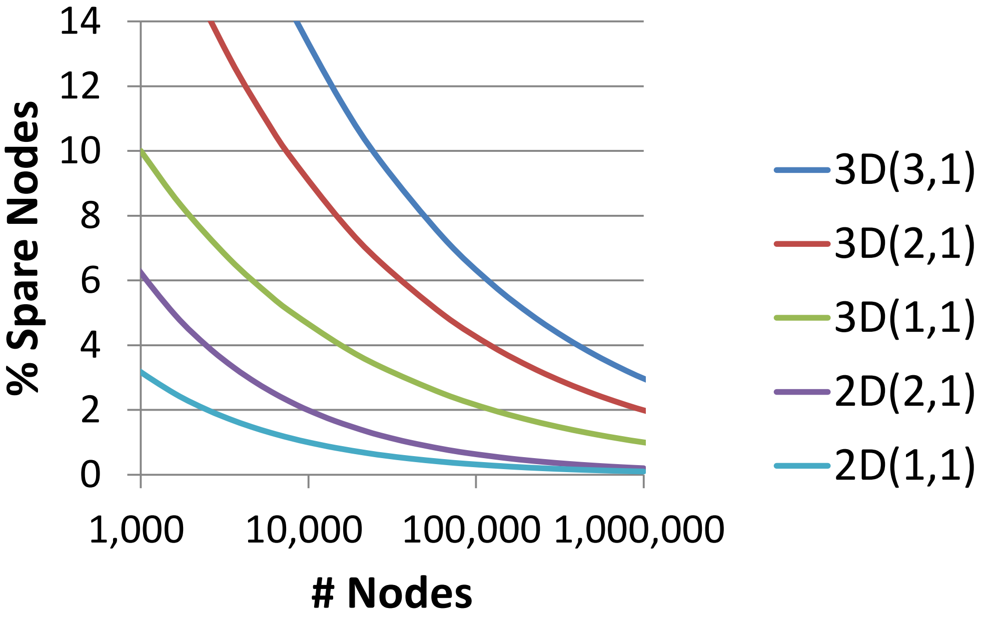
Using Spare Nodes

- An application runs with spare nodes
- If node failure happens, migrate the task running on failed node to the spare node
  - Loads are balanced (continues with the same # procs.)
  - Preserve logical communication pattern
  - No change in the kernel part of application
  - Some penalties

Spare Node Penalty-1
-System utilization Degradation-

- Spare node allocation
- System utilization is decreased





nD(α,β)

n: Dimensions of networks

α: # dimensions of spare nodes

β: spare nodes width

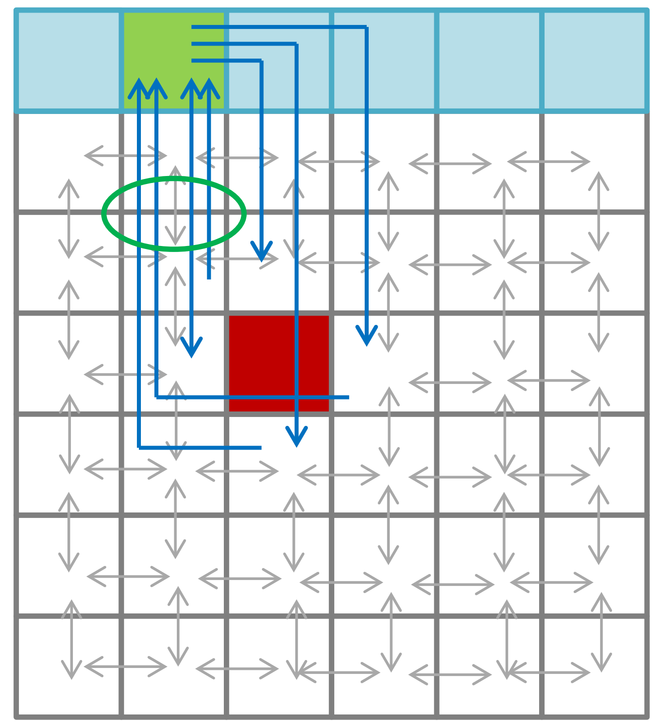
Spare Node Penalty-2
-Communication Performance Degradation-

- **Logical** communication pattern can be preserved
  - by creating a new MPI communicator to exclude the failed node and include a spare node.
- However, **physical** communication pattern is not the same, and communication performance(CP) can be degraded.
  - Larger hop counts (latency), and
  - Possible message collisions

Ex. CP Degradation of Spare Node Substitution

- Nodes on the topmost row work as spare nodes

- Up to 5 possible collisions after 1 node failure
  - Independent from the # nodes



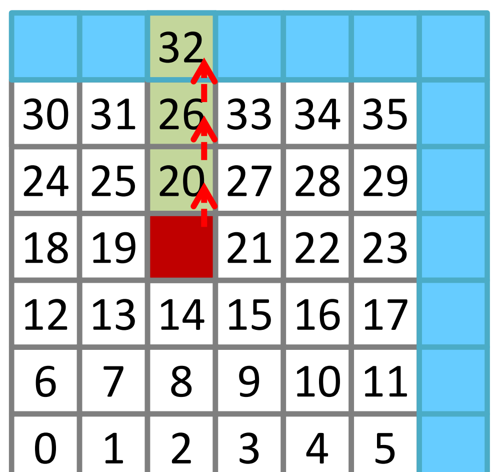
2D Cartesian network topology
(XY routing)
5-point Stencil Computation

How faulty nodes should be replaced by spare nodes?

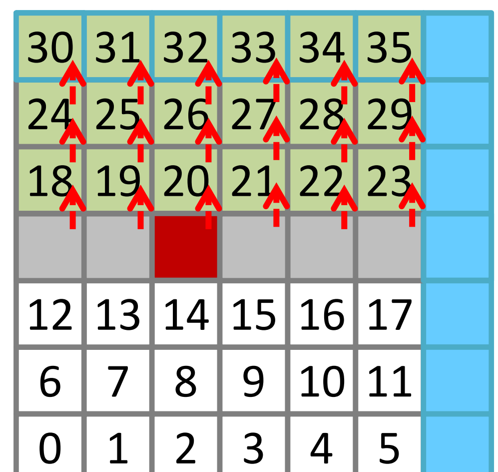
Sliding Substitution(1)

- We proposed "Sliding Substitution" methods
  - 0D Sliding (simple replace)
    - Failed rank is continued on an alternative node
  - 1D Sliding
    - Processes between the failure node and the spare node are shifted
  - 2D Sliding
    - Whole processes between the failure node's row(column) and the spare node's row(column) are shifted
  - 3D Sliding, 4D , 5D…

0D Sliding

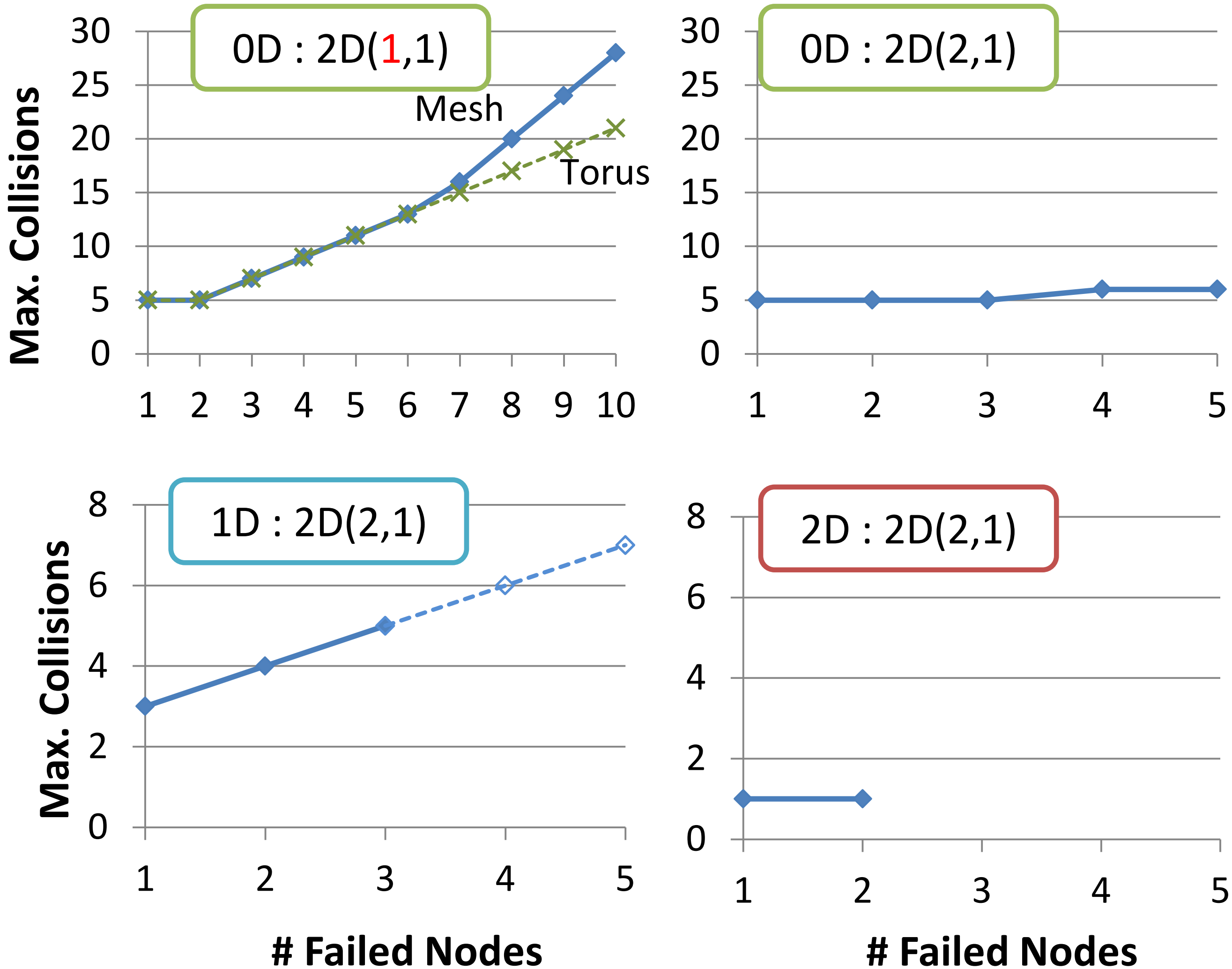


1D Sliding



2D Sliding

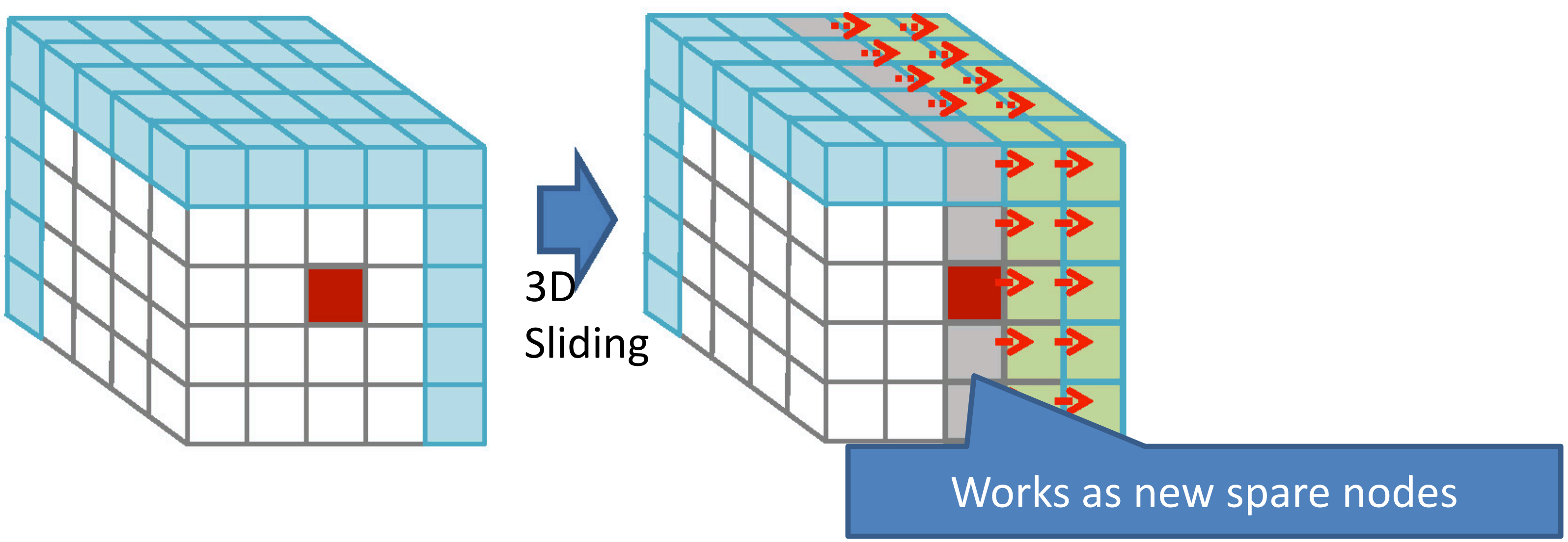
Preliminary Evaluation
-5D stencil on 2D network-



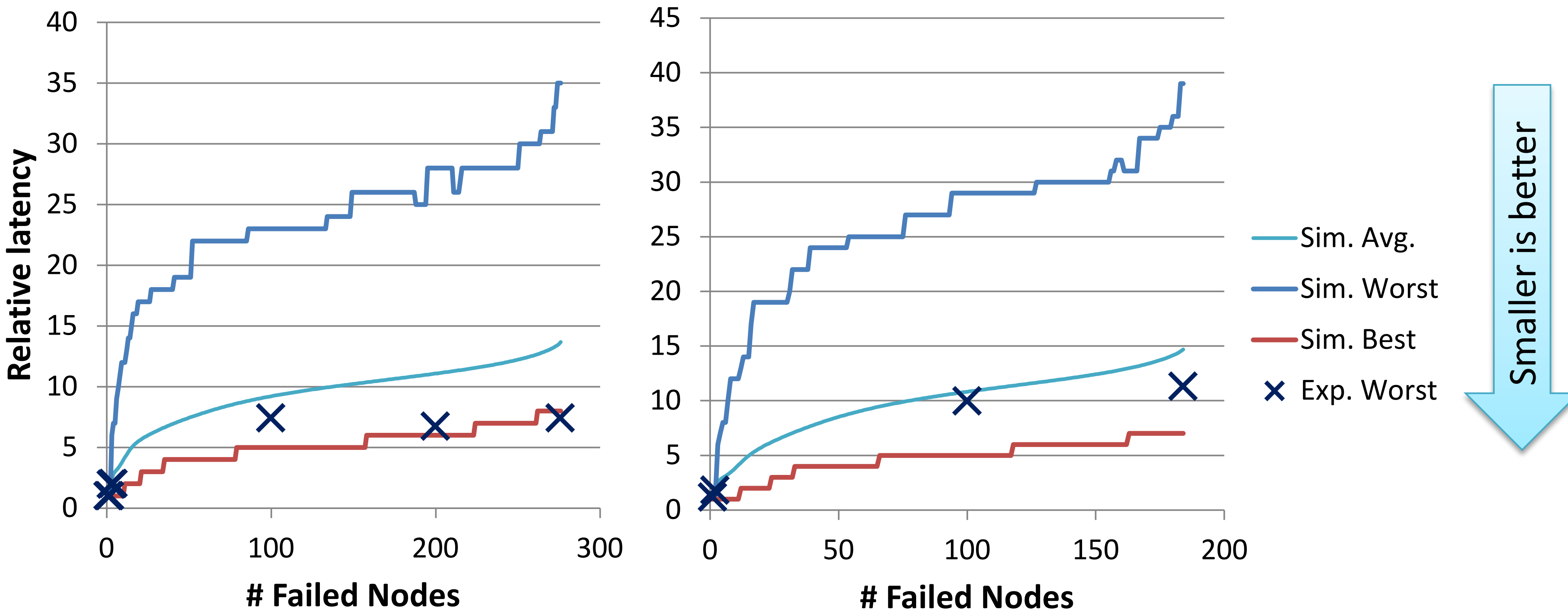
- Spare Allocation
  2D(2,1) > 2D(1,1)
- Max. Failure
  - 0D: up to # Spare
  - 1D: 3 (or more)
  - 2D: up to 2 (2D Cart. Topo.)
- Comm. Perf.
  2D > 1D > 0D

Sliding Substitution(2)

- The higher the dimension
  - The better the performance
  - The smaller the number of the failure nodes it can handle
- 2D or higher dimension Sliding
  - Migrate tasks running on healthy nodes
  - Free nodes works as new spare nodes
- Hybrid Sliding
  - 3D → 2D → 1D → 0D (on 3D network)



Evaluation : 7P-Stencil on the K and BG/Q (Hybrid, 3D(2,1), 4MiB)

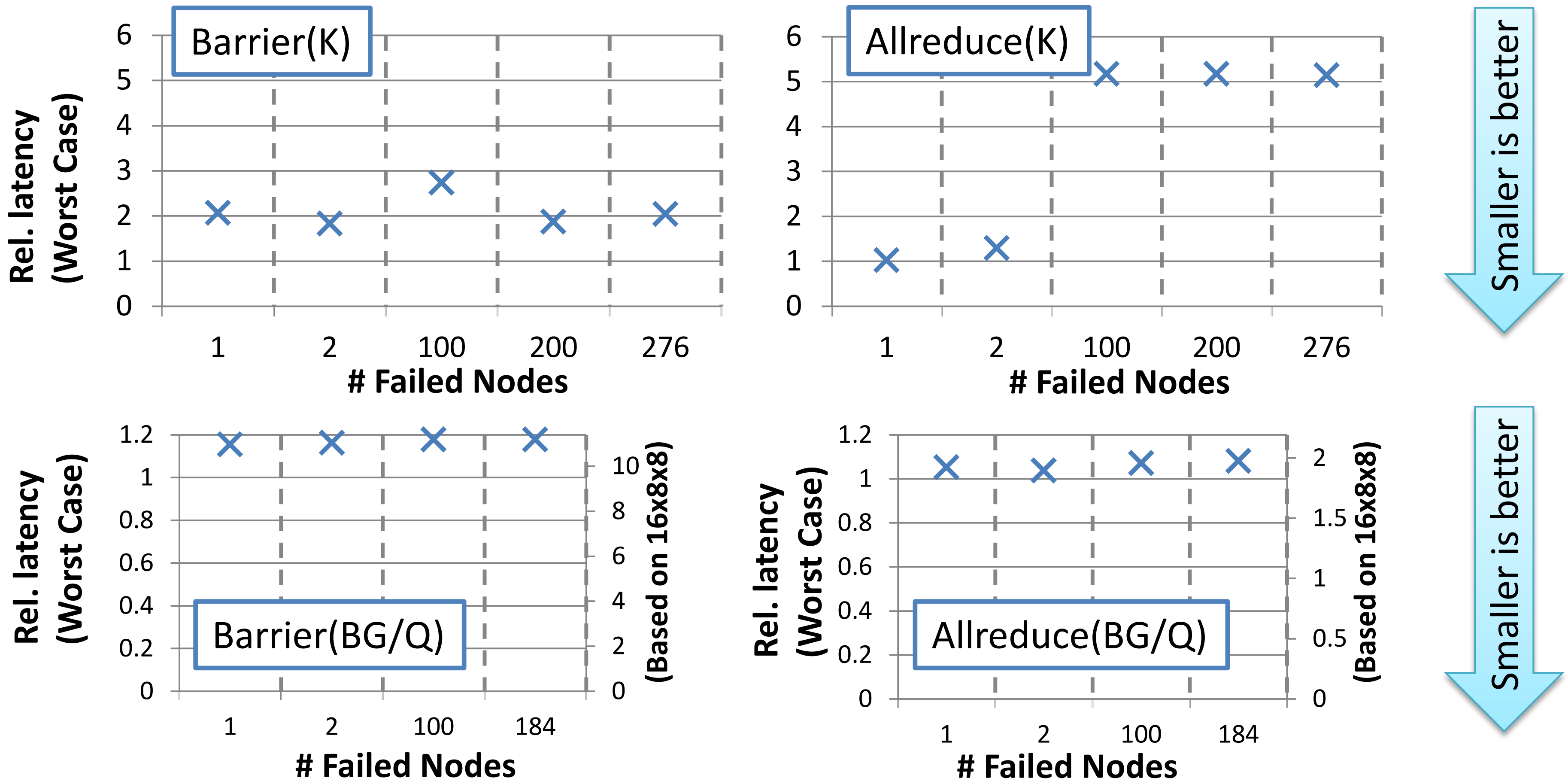


The K Computer
12x12x12 Nodes (calc. 11x11x12)

BG/Q
16x8x8 Nodes (calc. 15x7x8)

- K computer : up to 8 times slower
- BG/Q : up to 12 times slower

Evaluation: Collectives on the K and BG/Q (Hybrid, 3D(2,1))



- On the K and BG/Q, collective operations are optimized for their network
- Having spare nodes makes the optimization very difficult
- BG/Q's optimization works only with MPI_COMM_WORLD

Summary

- We proposed and compared “Sliding Substitution” methods.
- Communication performance degradation is observed
  - 7P-Stencil :
    - Simulation results: up to 40 collisions
    - Experimental results: up to 12 times larger latency
  - Collective communications:
    - up to 12 times lager latency (BG/Q, Barrier)

Future Work

- Evaluations with real applications
- Node-Rank re-mapping algorithms, or better substitution methods
- Discussion on the other network topology
  - Experiments using Tsubame 2.5 (Fat-tree) is scheduled