Runtime Algorithm Selection of Collective Communication with RMA-based Monitoring Mechanism

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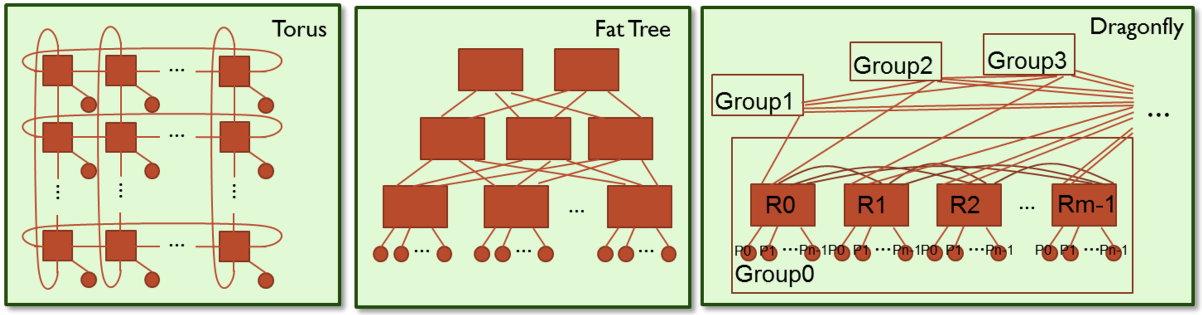
Background

- Difficulties in static optimization of parallel codes because:
  - Larger number of nodes
  - More complexed network topologies



  - Load imbalances
  - Congestions among jobs

  etc.

- Needs for efficient method of runtime optimization

Cycle of Runtime Optimization

Monitor

Gather information about current status

Analyze

Decide how to adjust the system

Apply

Change the system according to the decision

Motivation of this work

- Examine efficiency of using RMA (Remote Memory Access) interface of MPI in the Monitoring Phase of runtime optimization

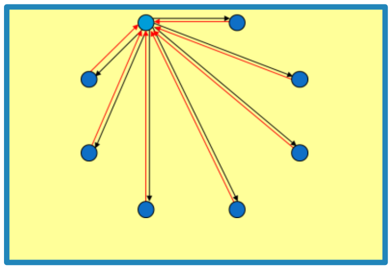
- Why RMA?
  - Asynchronous
  - Non-blocking

Enable low-overhead monitoring on parallel systems

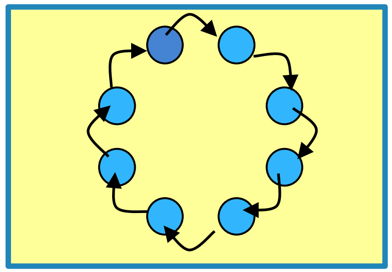
- Target in this work:
  Runtime algorithm selection of collective communication

Algorithms of Collective Communications

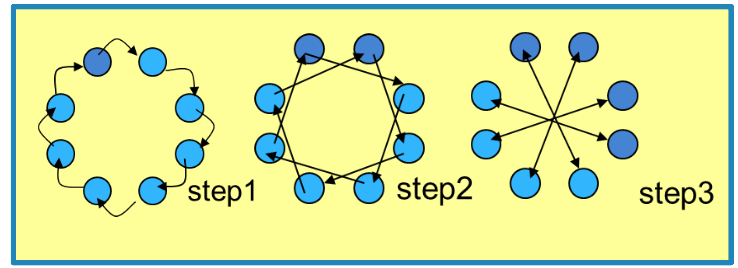
- Various candidates for each function:



Basic Linear



Ring



Bruck

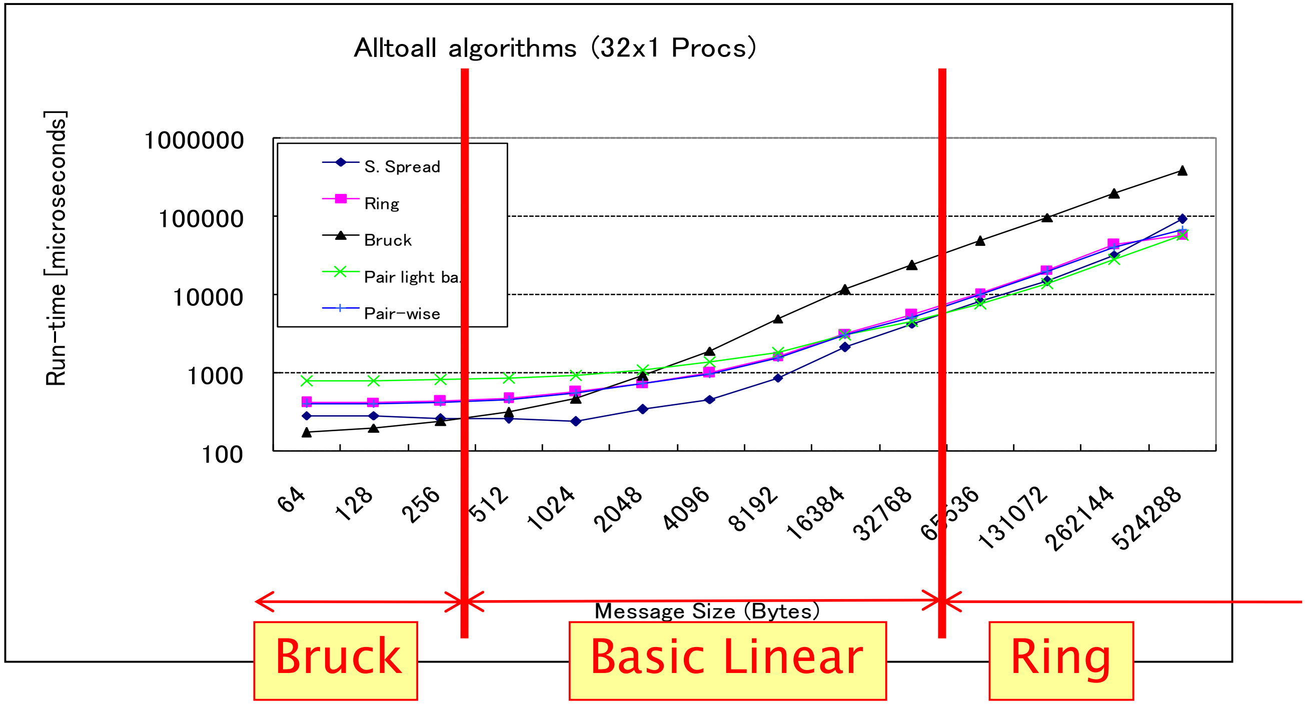
…

- Different characteristics:
  - Number of steps
  - Possibility of pipelining
  - Robustness against load imbalances

    etc.
- No champion algorithm that is fastest in any situations

Traditional, Static Algorithm Selection

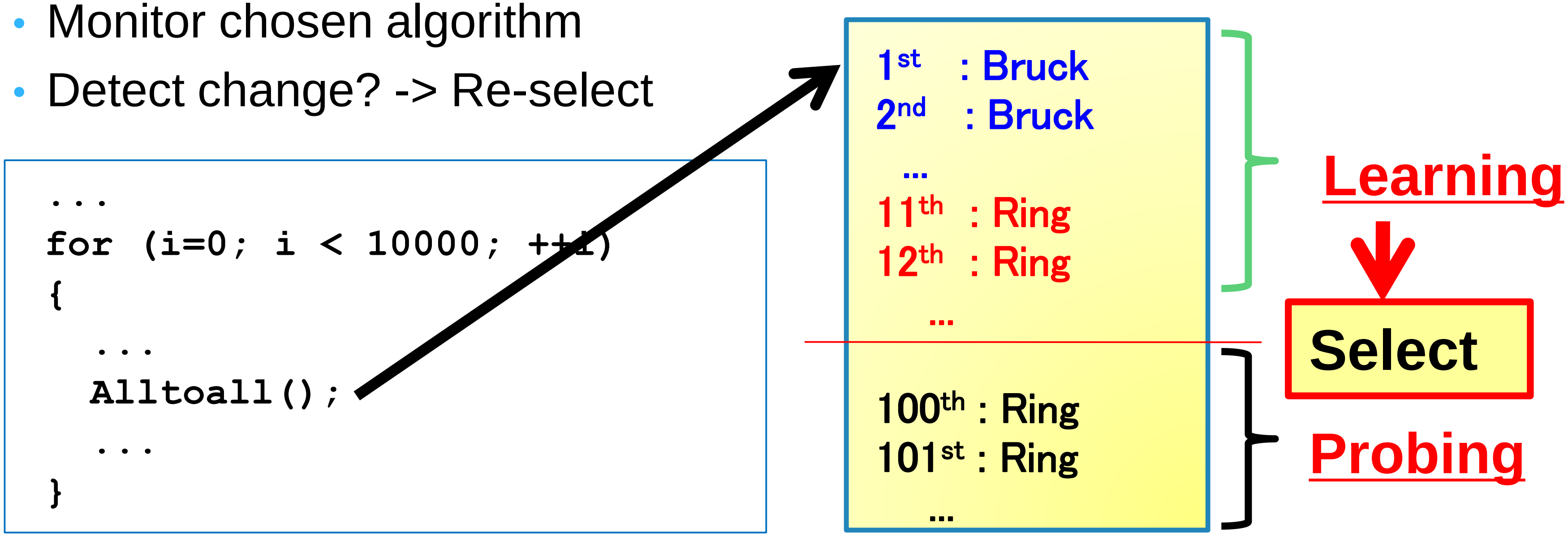
- Switch algorithm according to static thresholds
  - Message sizes and number of processes



- Cannot adapt to the different situations at runtime:
  - topological location, load balance, network traffic, etc.

STAR-MPI (A. Faraj, et al., 2006)

- A framework for runtime selection of collective communication algorithms
- Learning phase:
  - For each invocation, examine one candidate
  - All candidates are examined -> Choose the fastest
- Probing phase:
  - Monitor chosen algorithm
  - Detect change? -> Re-select



In this work

- Apply RMA-based monitoring to the Probing Phase of STAR-MPI
  - Instead of using Allreduce
- Use "Persistent Collective"-like interface
  - Instead of specifying "Call Site ID" argument in STAR-MPI
    - "Call Site ID":
      Extra argument to represent position of collective call in the program
      - Choose best algorithm for each invocation

Persistent Collective

- Currently discussed in the "Persistent WG" of MPI Forum
  - ex)

```
MPI_Allgather_init( ..., &request1);
MPI_Allgather_init( ..., &request2);

for (...) {
  ...
  MPI_Start(request1);
  ...
  MPI_Wait(request1);
  ...
  MPI_Start(request2);
  ...
  MPI_Wait(request2);
}
```

- Requests can represent the position of invocation in a program

Overview of Runtime Algorithm Selection

Init
- Prepare collective and create a request

Start
- Start clock
- Start collective(req)

Wait
- Complete collective(req)
- Stop clock
- if (Learning Phase)
    - record time for the algorithm
    - if (all algorithms are examined?)
        - choose the fastest
        - go to probing phase
- else
    - Monitor
    - Analyze
    - Apply

Probing Phase

```
MPI_Allgather_init( ..., &request1);
MPI_Allgather_init( ..., &request2);

for (...) {
  ...
  MPI_Start(request1);
  ...
  MPI_Wait(request1);
  ...
  MPI_Start(request2);
  ...
  MPI_Wait(request2);
}
```

Probing Phase with Allreduce (STAR-MPI)

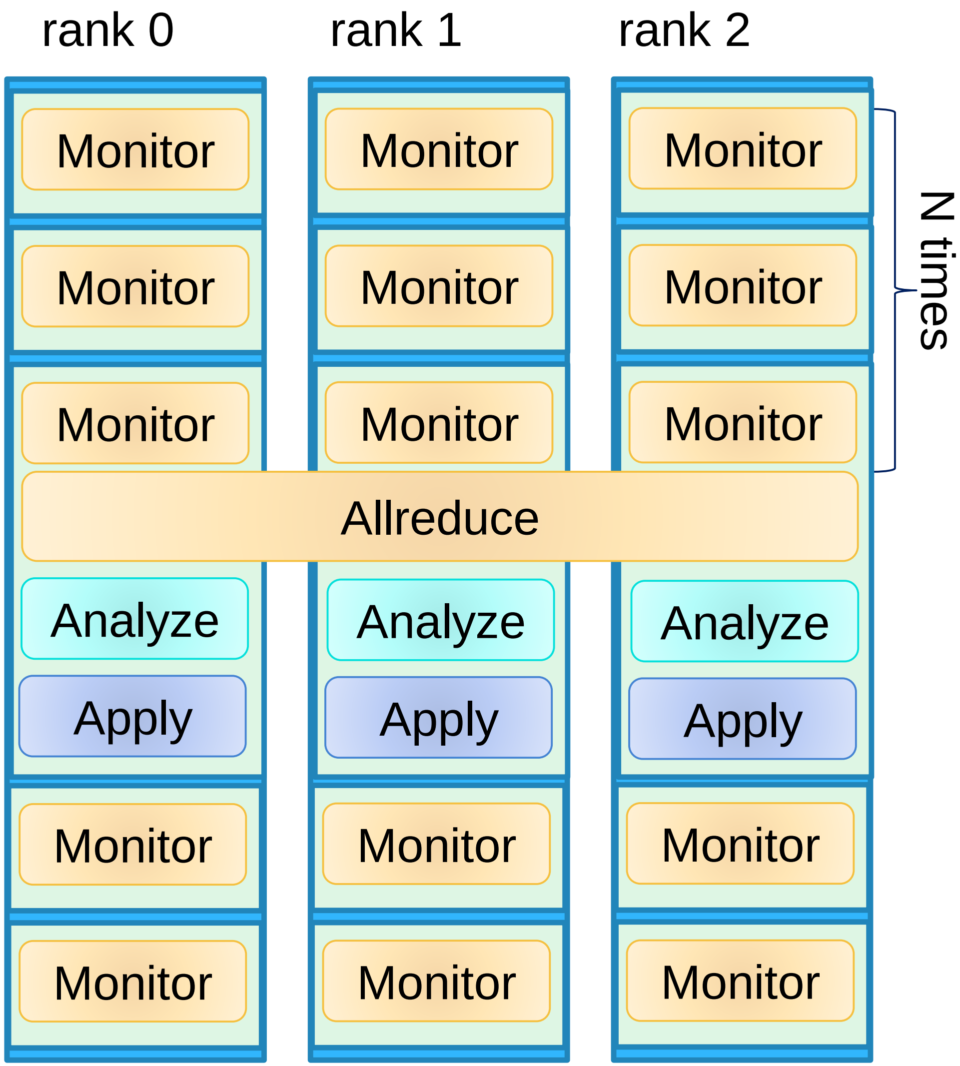
- Monitor

- Record time
- if (N-th monitor)
  - AVE = total(Recorded Times) / N
  - **MPI_Allreduce (AVE)**

Call MPI_Allreduce every N times of Probing Phase

- Analyze + Apply

  - if (AVE changed)
    - go back to Learning Phase



Probing Phase with RMA-based Monitoring

- Monitor (all ranks)

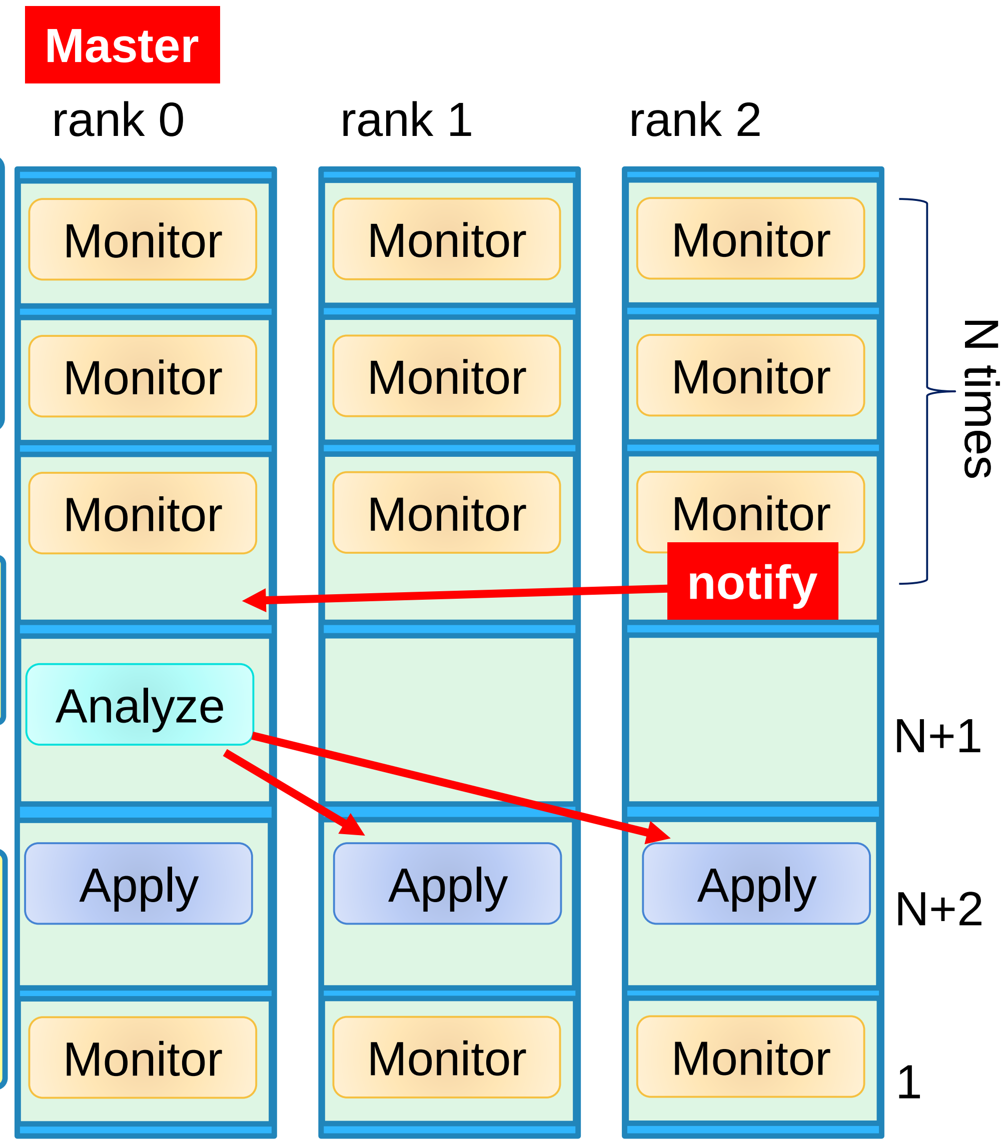
  - Record time
  - if (N-th monitor)
    - if (Change is determined)
      - **Notify to Master**

- Analyze (at Master rank)

  - if (Num. of notify exceeds limit)
    - **Notify to all**

- Apply (all ranks)

  - check notify from Master
  - if (Notify arrived)
    - go back to Learning Phase



Notify to Master with RMA

- A window is prepared and "lock-all"ed in Init function
  - Passive target

```
- if (rank == Master)
    - MPI_Win_create(counter, ..., win)
- else
    - MPI_Win_create(NULL, ..., win)
- MPI_Win_lock_all(0, *win)
```

- Remote atomic operation to increment a counter in Master **only when notification is required**

```
- if (N-th monitor)
    - if (Change is determined)
        - MPI_Fetch_and_op( ..., ..., MPI_INT, Master, ...,
                                          MPI_SUM, win)
        - MPI_Flush(Master, win)
```

Notify from Master to All with Send + Probe

- Master sends notification with MPI_Isend

```
- if ((N+1)-th monitor)
    - if ((rank == Master) && (counter > threshold))
        - FLAG = 1
        - for i = 0 to procs - 1
            MPI_Isend(FLAG, rank + i)
```

- Others check arrival of FLAG at (N+2)-th monitor
  - Depends on (N+2)-th collective to make sure that MPI_Isend(FLAG)s by Master have been completed already

```
- if ((N+2)-th monitor)
    - if (rank != Master)
        - MPI_Iprobe(Master, &arrived)
        - if (arrived)
            - MPI_Recv(FLAG)
    - if (FLAG) Go back to Learning Phase
```

Asynchronous Notification: RMA vs Send+Probe

- Notification with RMA (atomic, passive mode)
  - Latency may be higher than Send + Probe
  - Receiver does not have to perform any MPI function

Suitable for gathering notifications to Master
(as far as the frequency of notification is low enough)

- Notification with Send+Probe
  - Receiver needs to call MPI_Iprobe for every possible senders
  - Latency of Send/Recv is lower for short messages than MPI_Put

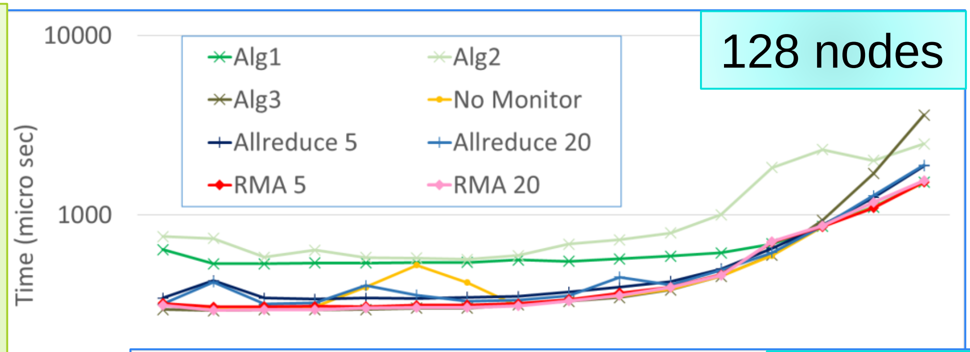
Suitable for propagating notifications from Master
(since there is only one possible sender per rank)

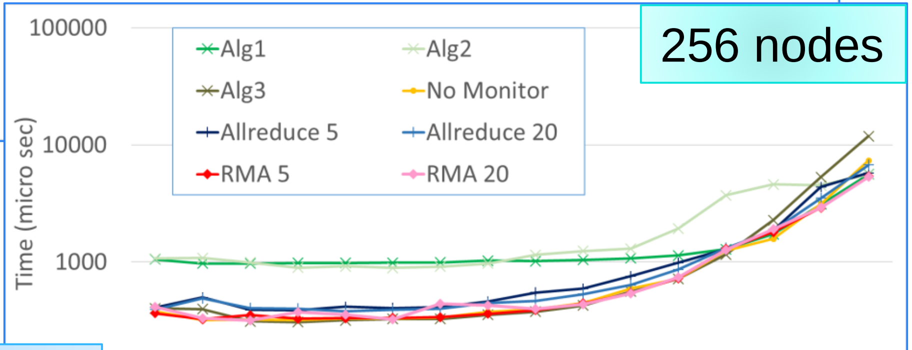
Experiments

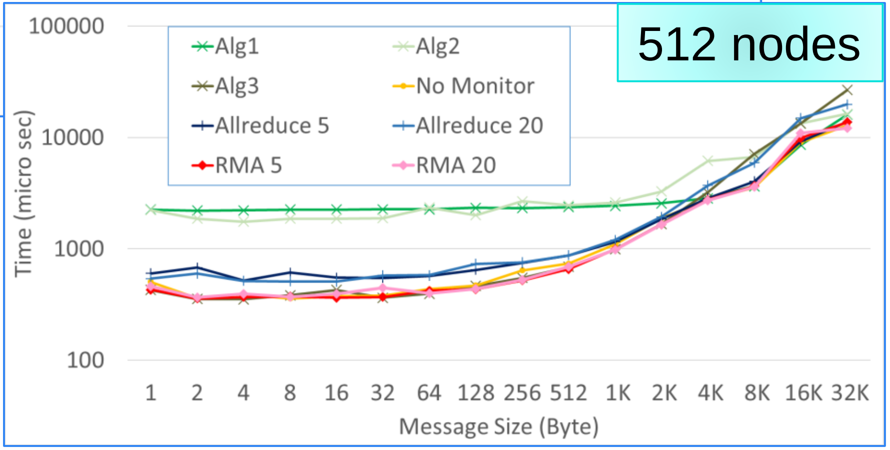
- Examine overhead of monitoring
  - RMA vs Allreduce vs No Monitor
- Study effects of runtime optimization
- Experimental platform: PC Cluster (Fujitsu CX400)
  - Intel Xeon E5-2680 x 2, 128GB, RedHat 6.1
  - up to 512 nodes / 1476, one process / node
  - InfiniBand FDR, Mellanox MT4099
  - MVAPICH2-2.2rc1 + GCC 4.4.6
- Benchmark program: OSU Benchmarks 5.1
  - Modified "osu_iallgather.c":
    - Use "persistent collective"-like interface
    - Fixed amount of dummy computation

Average time of Comm + Dummy-Comp

- Alg1 ~ 3: each algorithm
- No Monitor:
- Allreduce 5, 20:
  perform allreduce every 5 or 20 times of monitoring
- RMA 5, 20:
  check changes every 5 or 20 times of monitoring



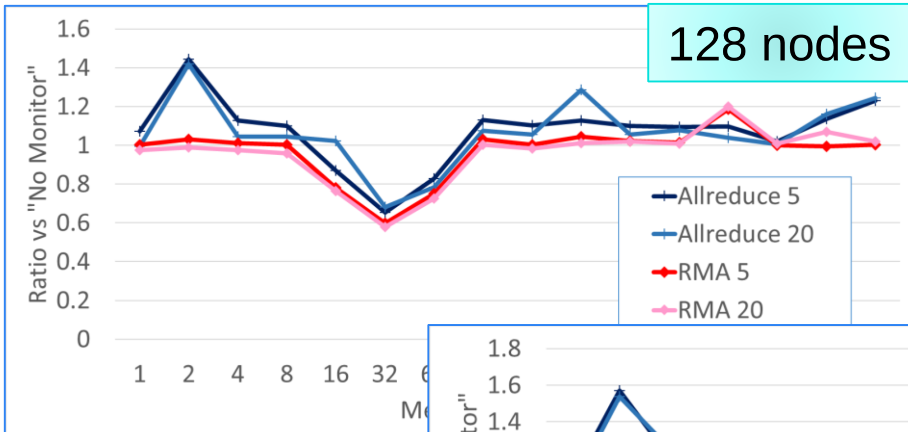


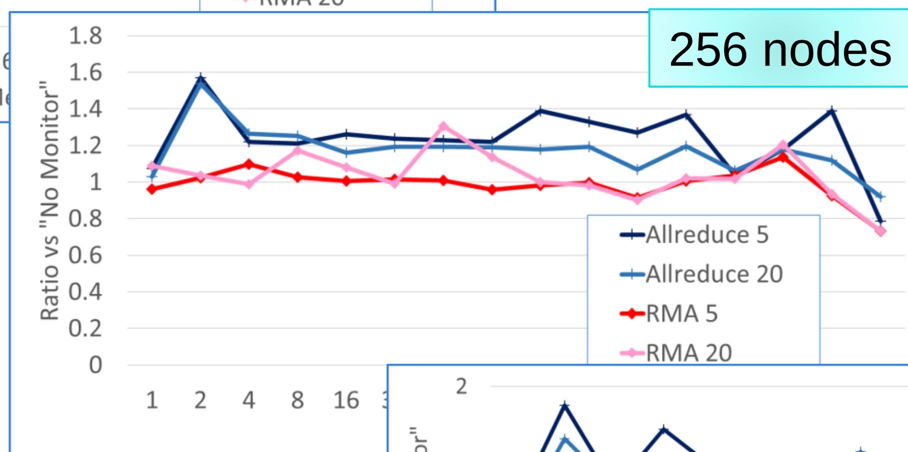


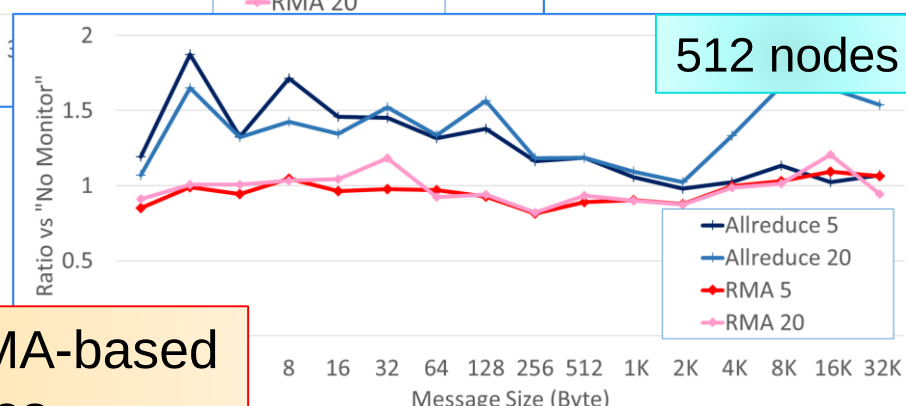
These are measured in stable situation. With dummy notification every 200 times in RMA5 and 20.

RMA-based Monitoring shows lower overheads than Allreduce-based

Ratio over "No Monitor"







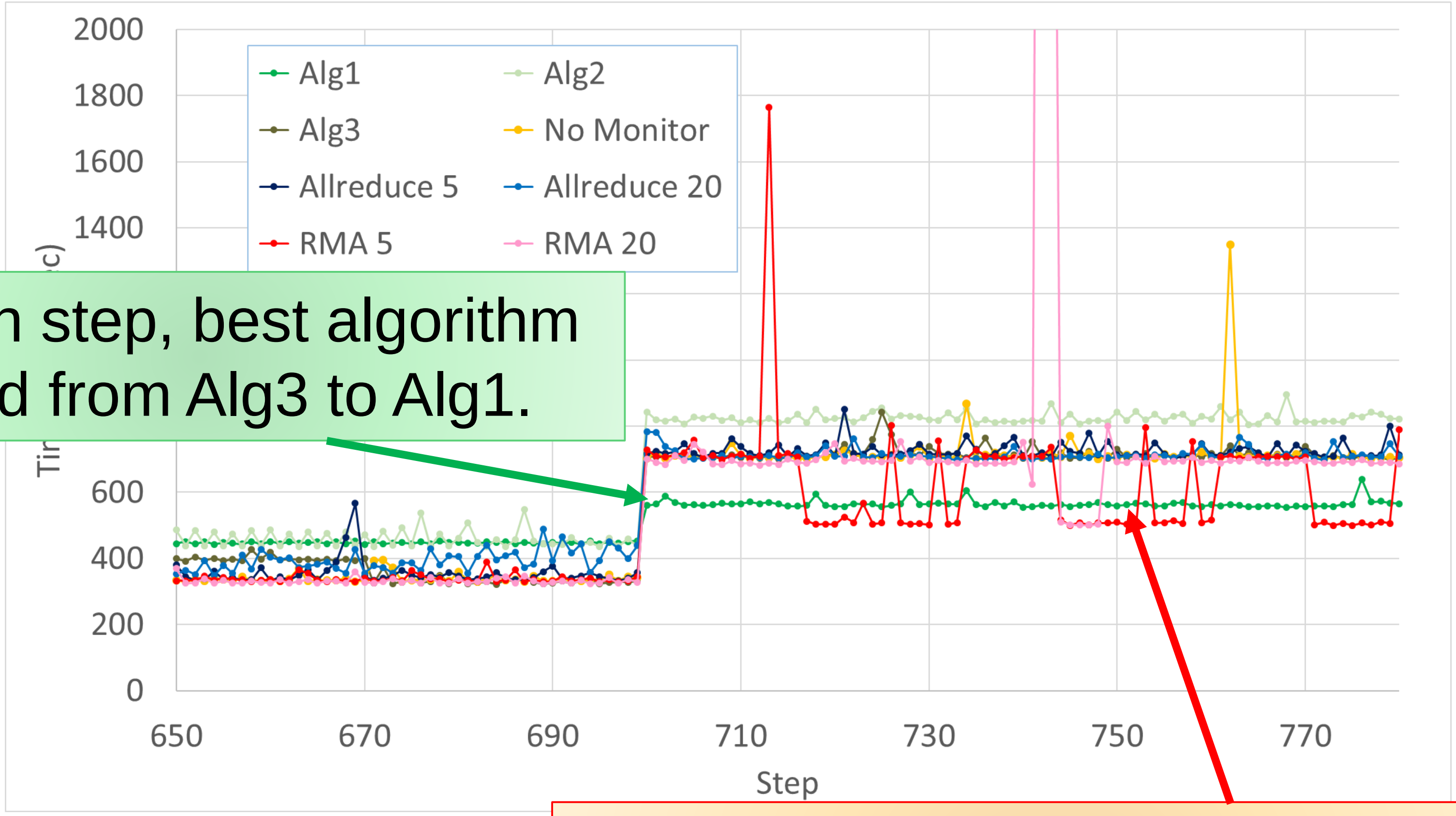
Gap between Allreduce-based and RMA-based glows according to the number of nodes

Effect of Runtime Optimization

- Scenario:
  Change load-balance of computation "before" collective communication at 250th, 400th, 550th and 700th iteration of "osu_iallgather.c"

- Check if the framework can detect the change and re-select the best algorithm.

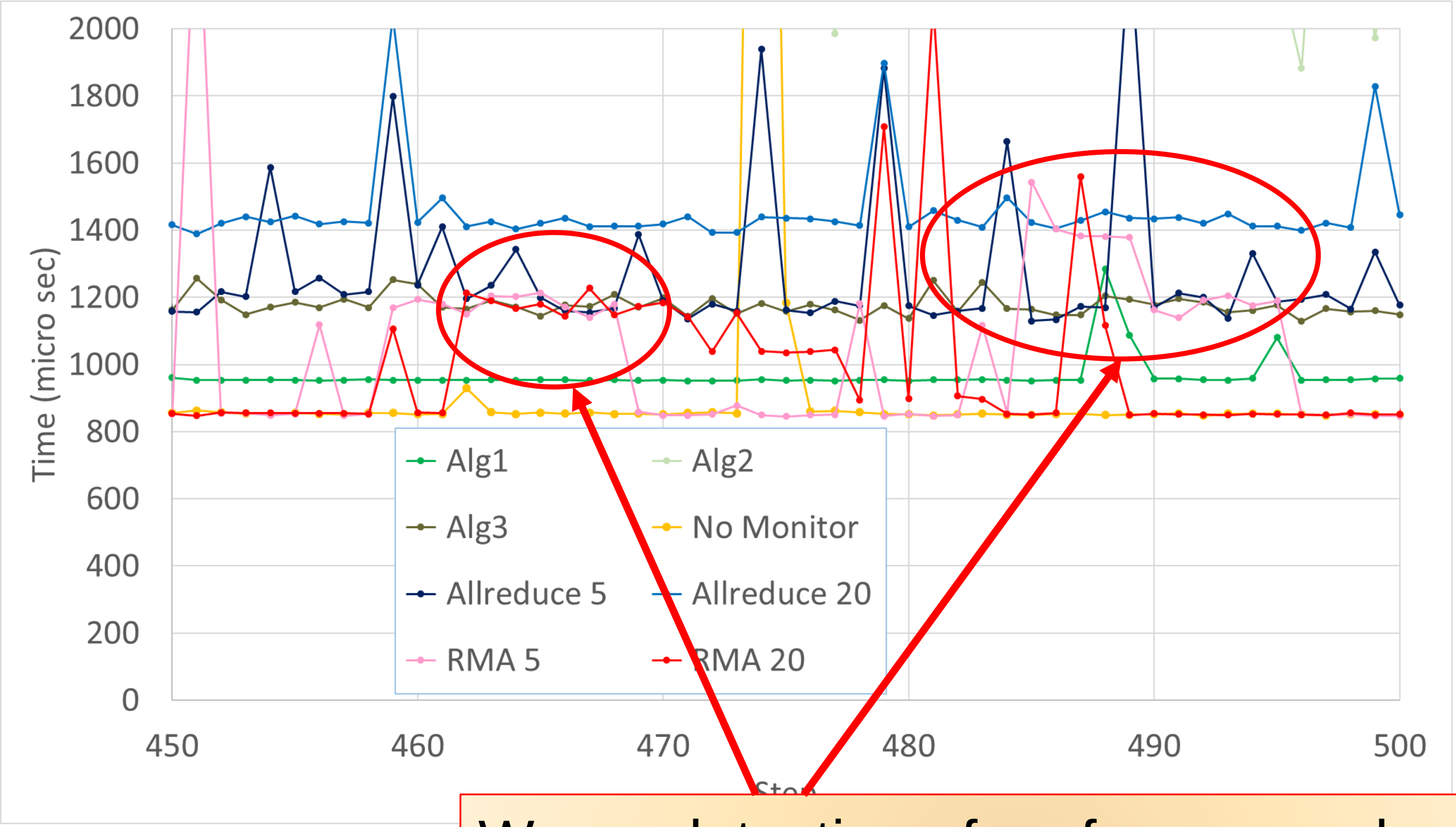
Results:
Sometimes, it worked well



At 700th step, best algorithm changed from Alg3 to Alg1.

After re-entering "Learning Phase", RMA5 and 20 could re-select the best one.

Sometimes, not.



Wrong detection of performance change caused worse performance than "No Monitor".

Conclusion

- Examined RMA-based monitoring in the framework of runtime algorithm selection of collectives.
- Confirmed reduction of overhead.
- Future works:
  - Refinement of runtime algorithm selection
    - Modify policies to avoid miss detection
  - Other collectives
  - Other runtime optimizations
  - Common framework for runtime optimization