Collective Operations with Notified Communication in Shared Windows

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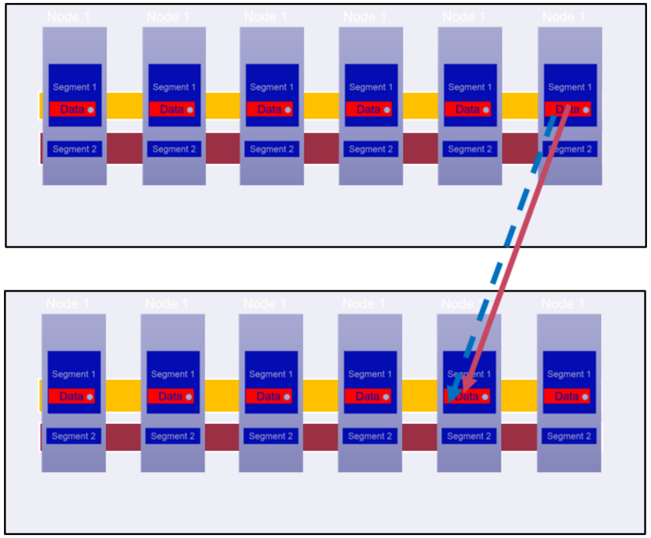
Notified communication in shared memory

Context: Extension of GASPI notified communication for shared memory.

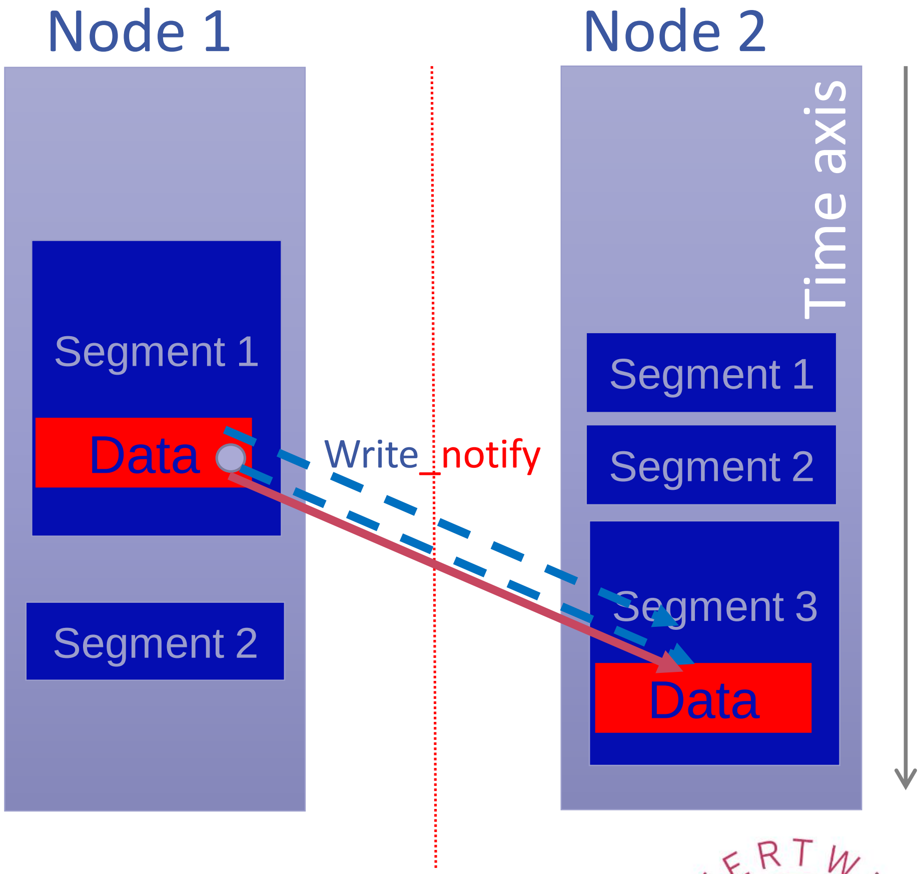
- Collectives as testbed for evaluating programmability and performance.

- Allreduce
  - Pipelined ring
  - Dissemination
- AllgatherV



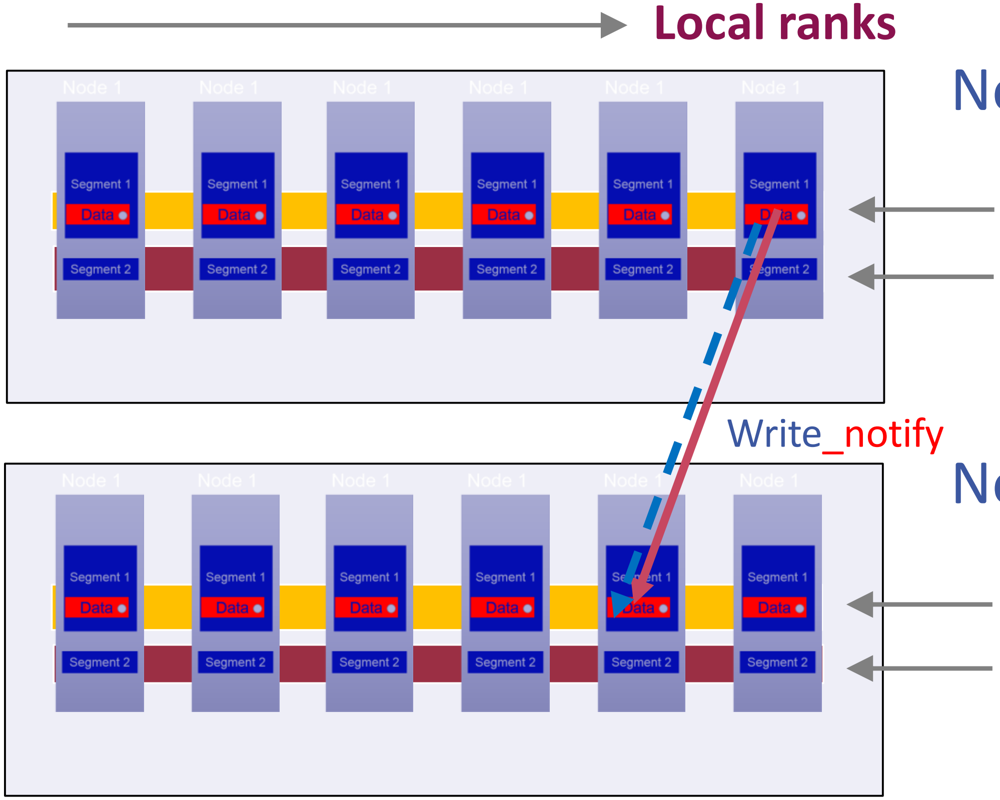
Synchronisation with Notifications

- **Designated communication areas in GASPI are called memory segments.**
- **Segments are freely configurable.**
- **GASPI uses notified write and read (weak synchronization).**
- **GASPI also supports bundled write and notify as a single call: write_notify (and read_notify)**
- **GASPI is interoperable with MPI and allows incremental porting**



Synchronisation with Notifications

- Q: How can we extend notified communication for shared segments ?
  A: Use local notifications in shared data segments and share remote notifications across local ranks.



Local ranks

Node 1

Shared data segment

Shared notification segment

Node 2

Shared data segment

Shared notification segment

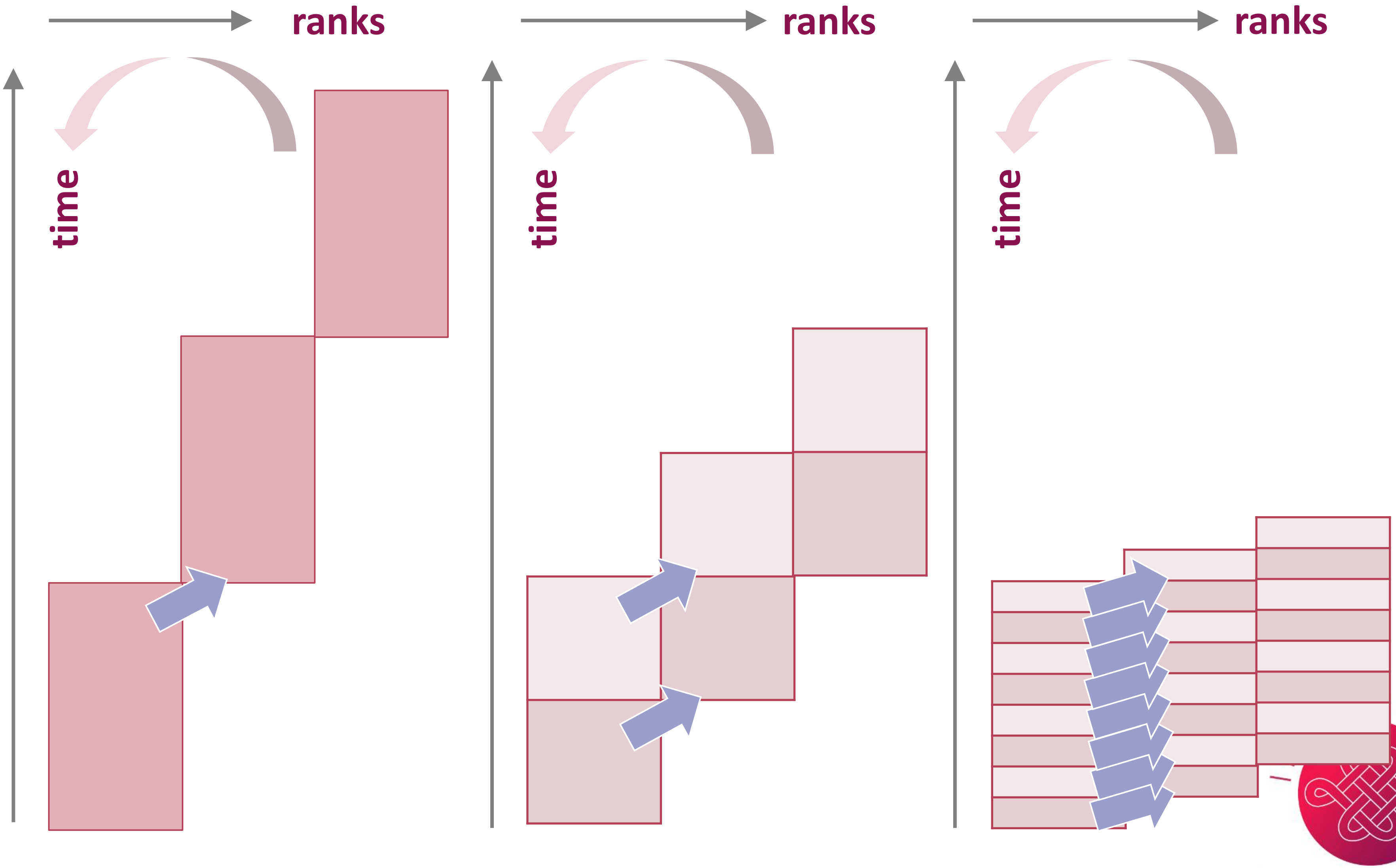
Testbed – Collectives in Shared Windows

Testbed for notified communication - Collectives.

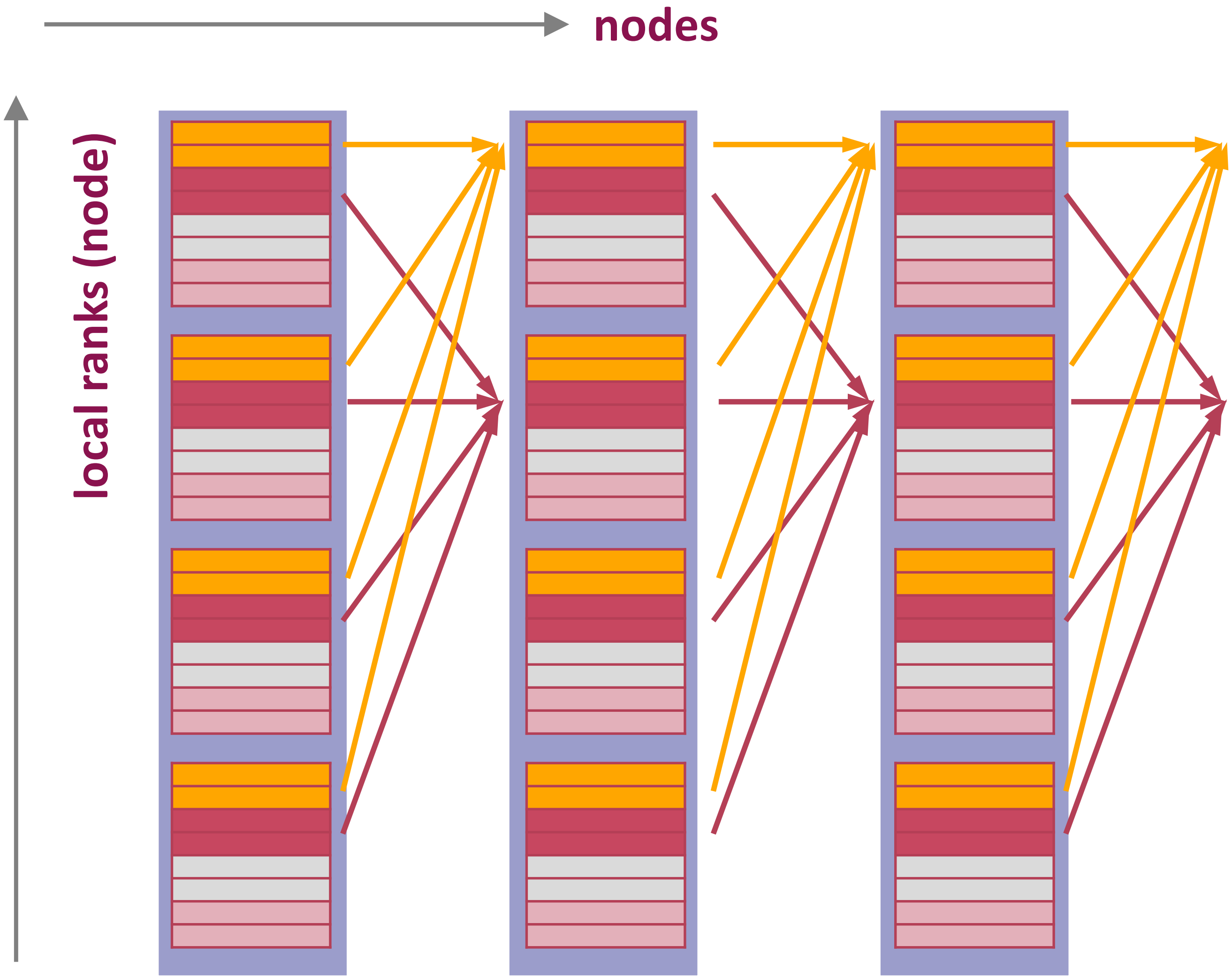
Allreduce with GASPI shared segments

- **Pipelined Ring for large message sizes**
  - **2-stage pipelined process, reduce + broadcast**
  - **Highly parallel pipeline for fast ramp-up (latency ~2(n-1))**
  - **Shared memory for node internal communication**
  - **Leverage available bandwidth / compute for reduce**

Allreduce / Allgather(V) - Pipelined Ring

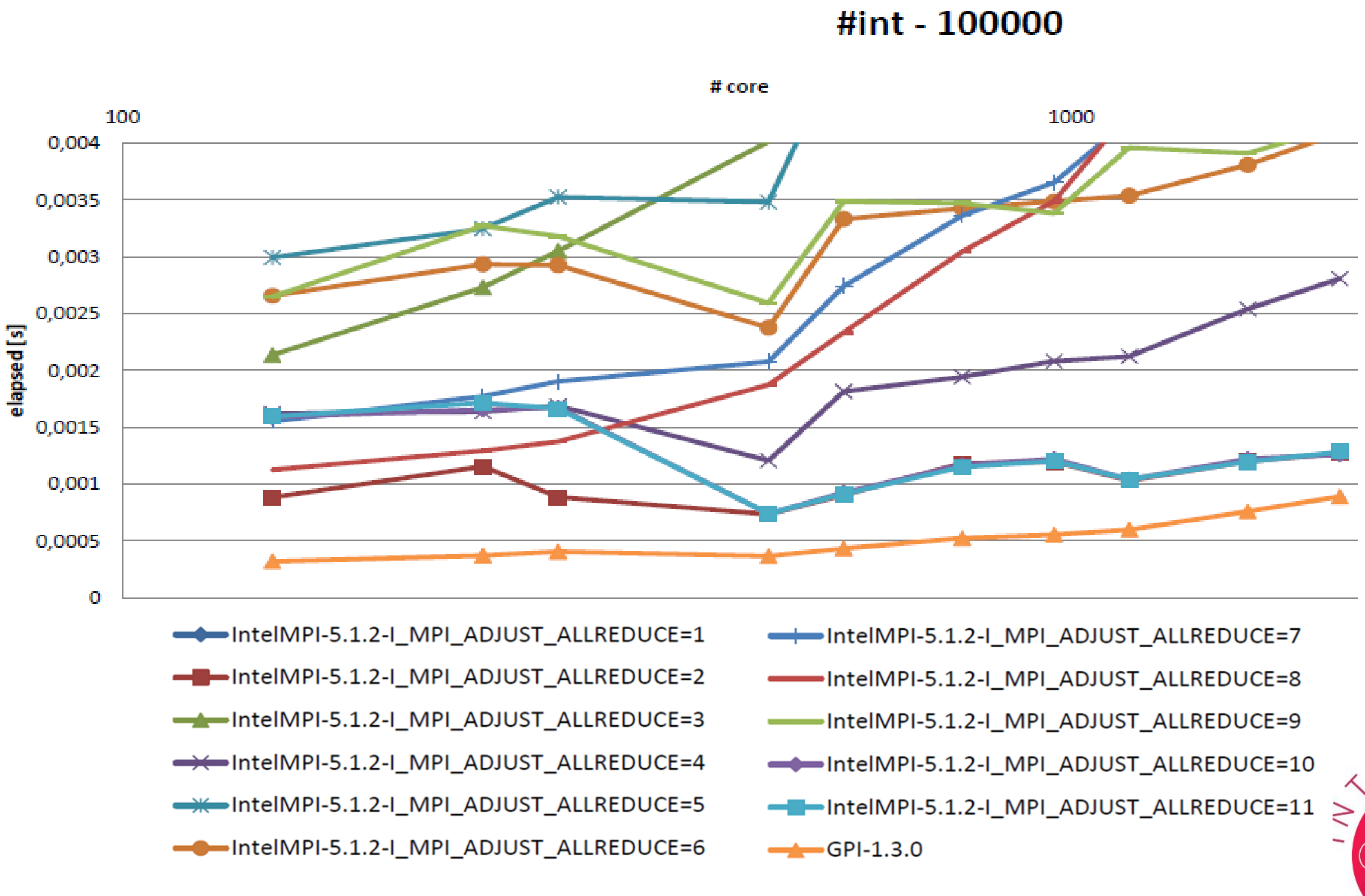


Allreduce / Allgather(V) - Load Distribution across Local Ranks

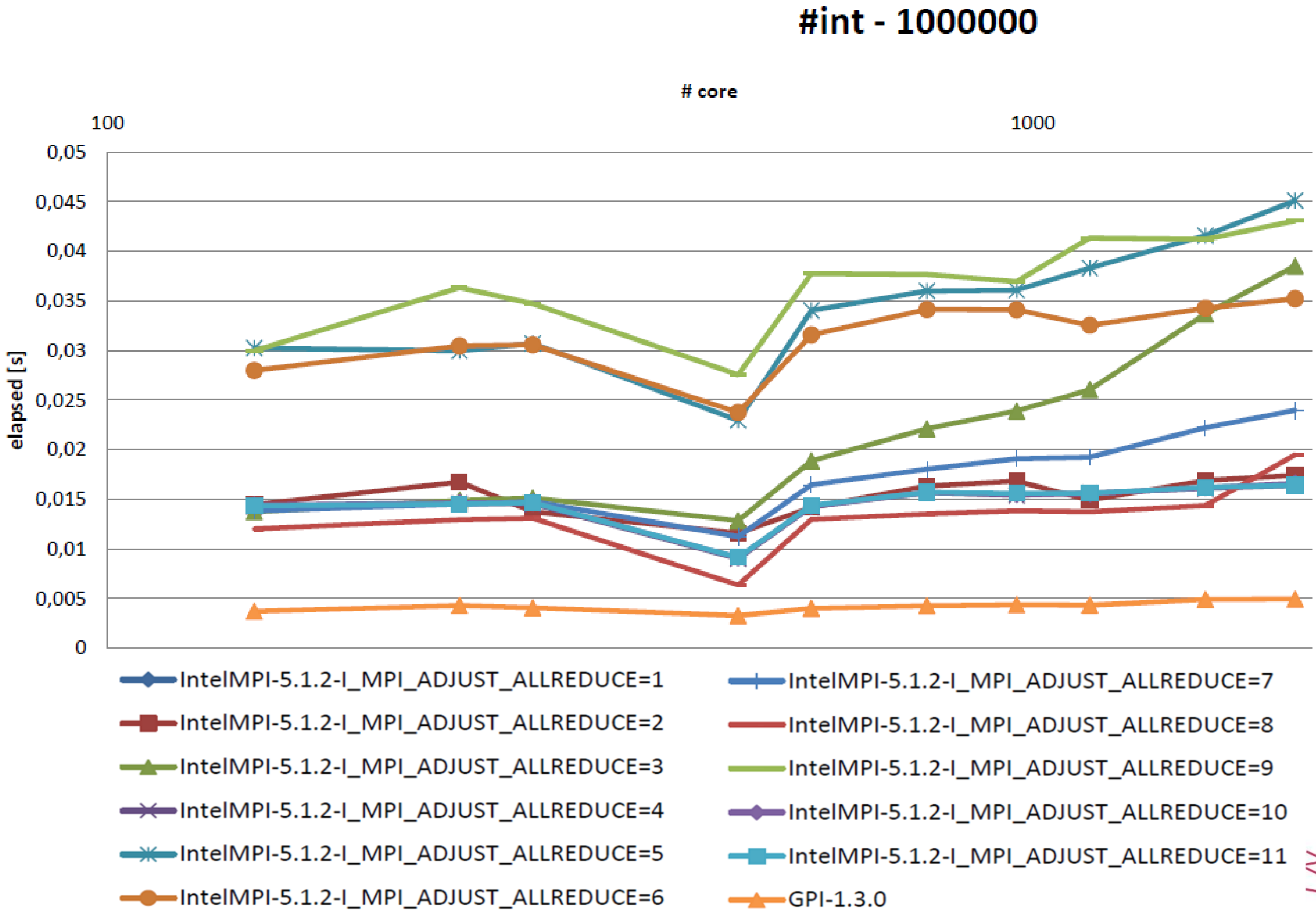


All ranks participate in reducing and forwarding data at any point in time

Allreduce – Pipelined Ring



Allreduce – Pipelined Ring



Testbed – Collectives in Shared Windows

Testbed for notified communication - Collectives.

Allreduce with GASPI shared segments

- Dissemination algorithm
  - Log2(m) dissemination steps, where m <= 2^n.
  - Hide communication of additionally required dissemination steps for m != 2^n
  - Decompose number of ranks as

$$n = \sum_{k=l}^{0} c_k 2^k, \text{ with } c_k \in \{0, 1\}$$

  - In step j, rank i writes additional out of band msg to target t where

$$t = (i + \sum_{k=l}^{j+1} c_k 2^k)$$

Allreduce – Async Dissemination Algorithm

Step 0

ranks

state

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Allreduce - Async Dissemination Algorithm

Step 0

ranks

state

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
14	0	1	2	3	4	5	6	7	8	9	10	11	12	13
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
1	2	3	4	5	6	7	8	9	10	11	12	13	14	0

Allreduce - Async Dissemination Algorithm

Step 1

ranks

state

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
14	0	1	2	3	4	5	6	7	8	9	10	11	12	13
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
1	2	3	4	5	6	7	8	9	10	11	12	13	14	0

Allreduce - Async Dissemination Algorithm

Step 1

ranks

state

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
14	0	1	2	3	4	5	6	7	8	9	10	11	12	13
13	14	0	1	2	3	4	5	6	7	8	9	10	11	12
12	13	14	0	1	2	3	4	5	6	7	8	9	10	11
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
3	4	5	6	7	8	9	10	11	12	13	14	0	1	2
2	3	4	5	6	7	8	9	10	11	12	13	14	0	1
1	2	3	4	5	6	7	8	9	10	11	12	13	14	0

Allreduce - Async Dissemination Algorithm

Step 2

ranks

state

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
14	0	1	2	3	4	5	6	7	8	9	10	11	12	13
13	14	0	1	2	3	4	5	6	7	8	9	10	11	12
12	13	14	0	1	2	3	4	5	6	7	8	9	10	11
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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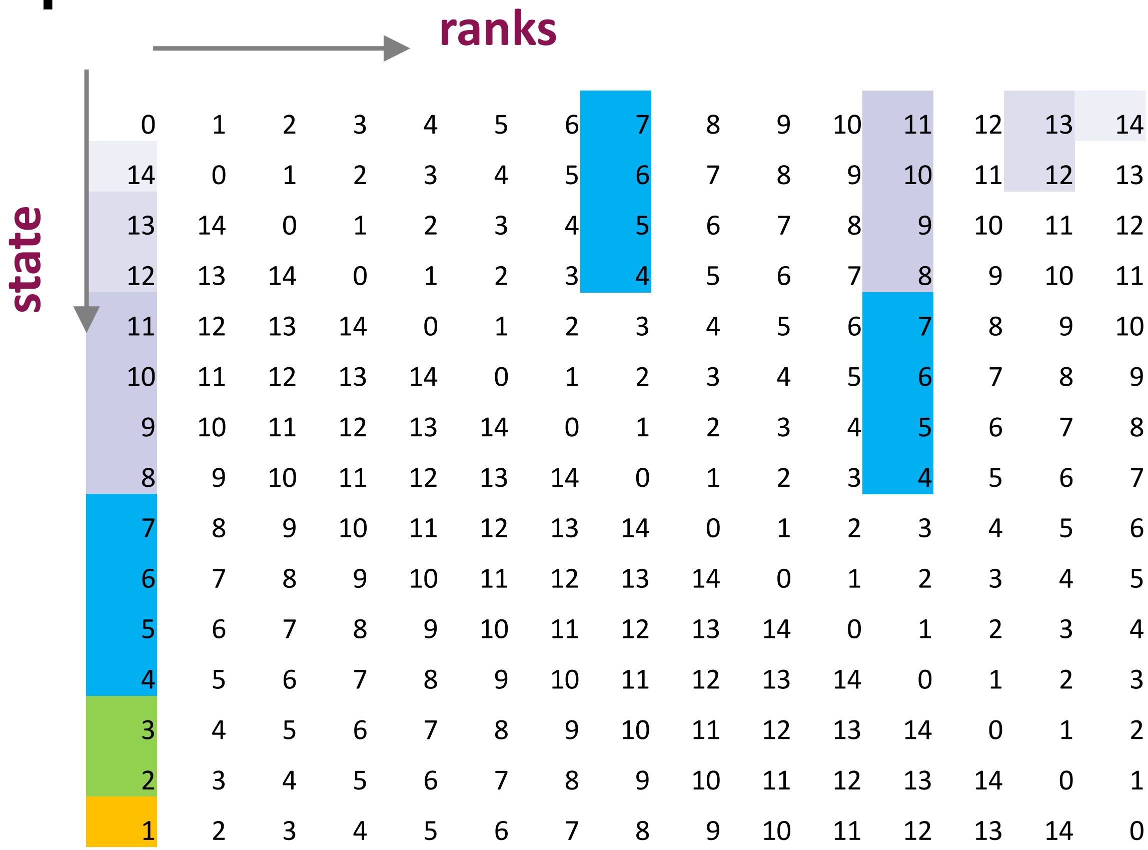
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
3	4	5	6	7	8	9	10	11	12	13	14	0	1	2
2	3	4	5	6	7	8	9	10	11	12	13	14	0	1
1	2	3	4	5	6	7	8	9	10	11	12	13	14	0

Allreduce - Async Dissemination Algorithm

Step 2

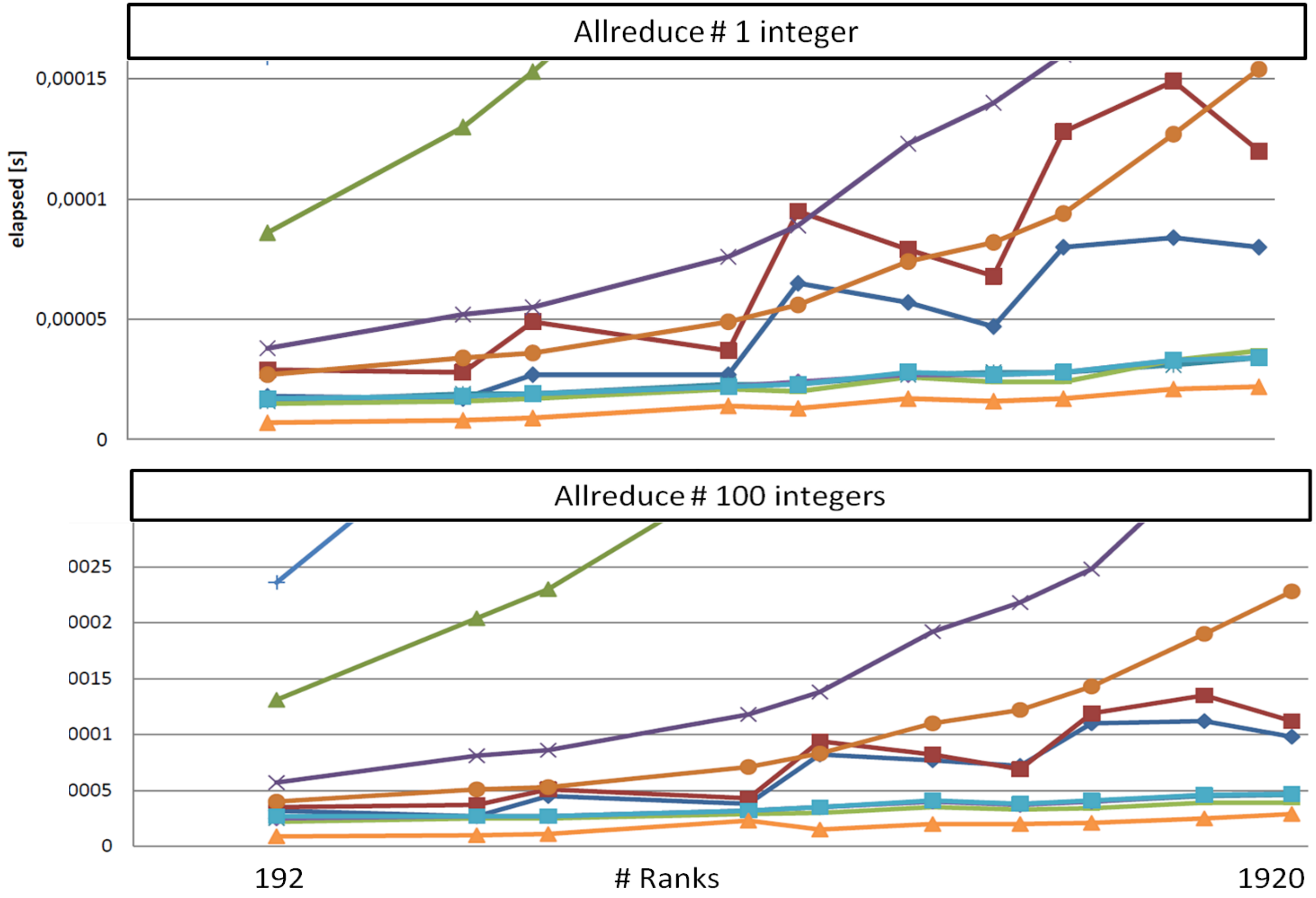


ranks

state

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
14	0	1	2	3	4	5	6	7	8	9	10	11	12	13
13	14	0	1	2	3	4	5	6	7	8	9	10	11	12
12	13	14	0	1	2	3	4	5	6	7	8	9	10	11
11	12	13	14	0	1	2	3	4	5	6	7	8	9	10
10	11	12	13	14	0	1	2	3	4	5	6	7	8	9
9	10	11	12	13	14	0	1	2	3	4	5	6	7	8
8	9	10	11	12	13	14	0	1	2	3	4	5	6	7
7	8	9	10	11	12	13	14	0	1	2	3	4	5	6
6	7	8	9	10	11	12	13	14	0	1	2	3	4	5
5	6	7	8	9	10	11	12	13	14	0	1	2	3	4
4	5	6	7	8	9	10	11	12	13	14	0	1	2	3
3	4	5	6	7	8	9	10	11	12	13	14	0	1	2
2	3	4	5	6	7	8	9	10	11	12	13	14	0	1
1	2	3	4	5	6	7	8	9	10	11	12	13	14	0

Allreduce - Dissemination

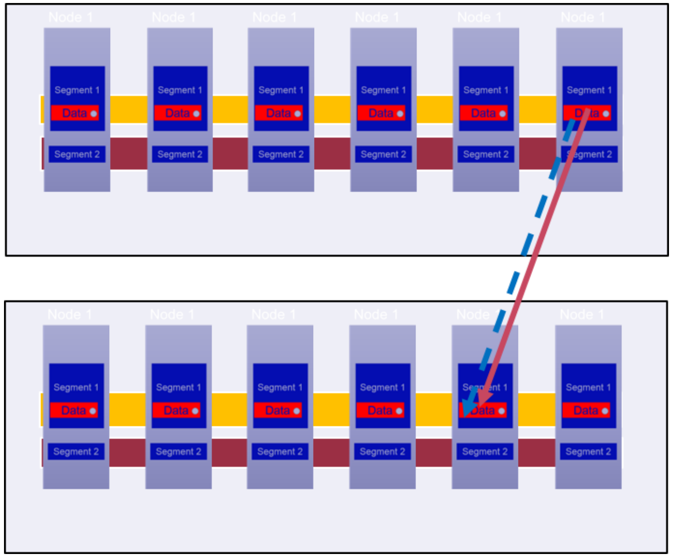


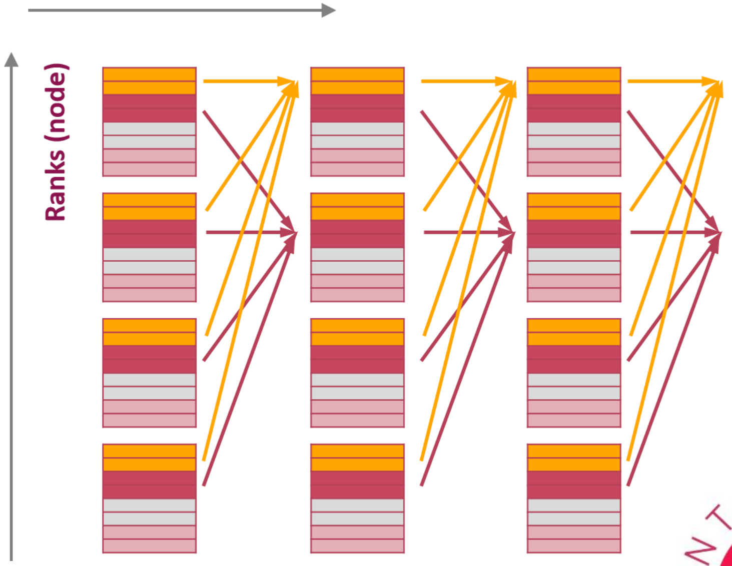
Allgather(V)

Testbed for notified communication - Collectives.

Allgather(V) with GASPI shared segments

- **Irregular data distribution**
- **Pipelined ring with dynamic load distribution**

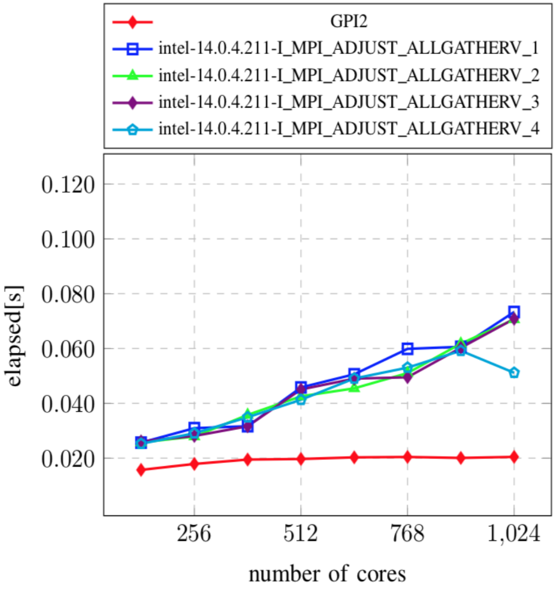




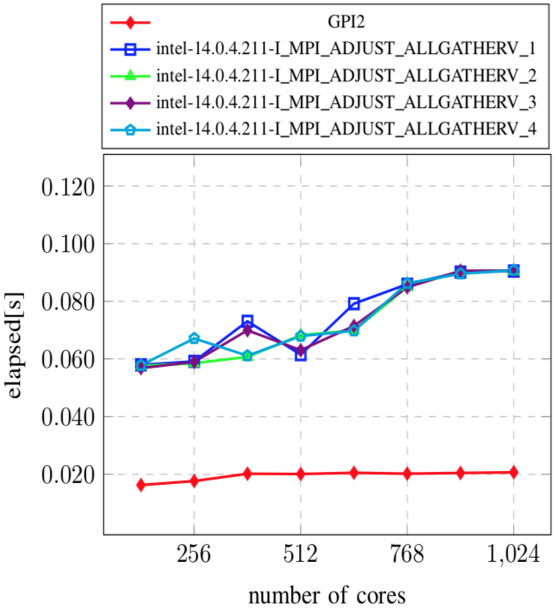
Allgather(V) : Performance results

Data distribution

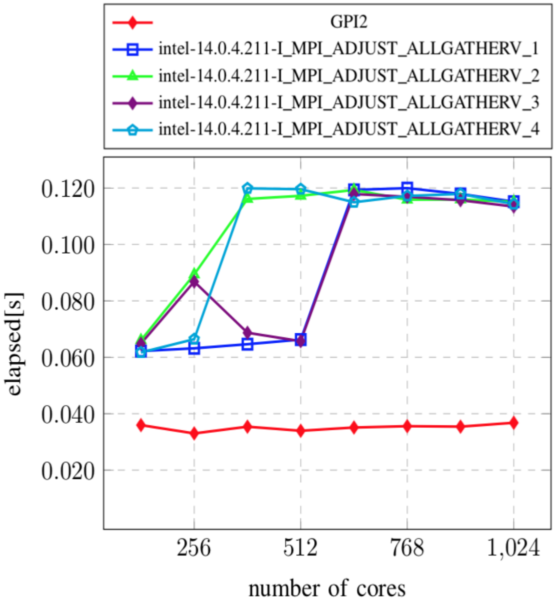
- **Regular, linear decreasing, broadcast**



(f): Regular data distribution



(g): Linearly decreasing data distribution



(h): Broadcast

Questions?

Thank you for your attention

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