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Communication Systems

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Persistent and Partitioned MPI for Stencil Communication

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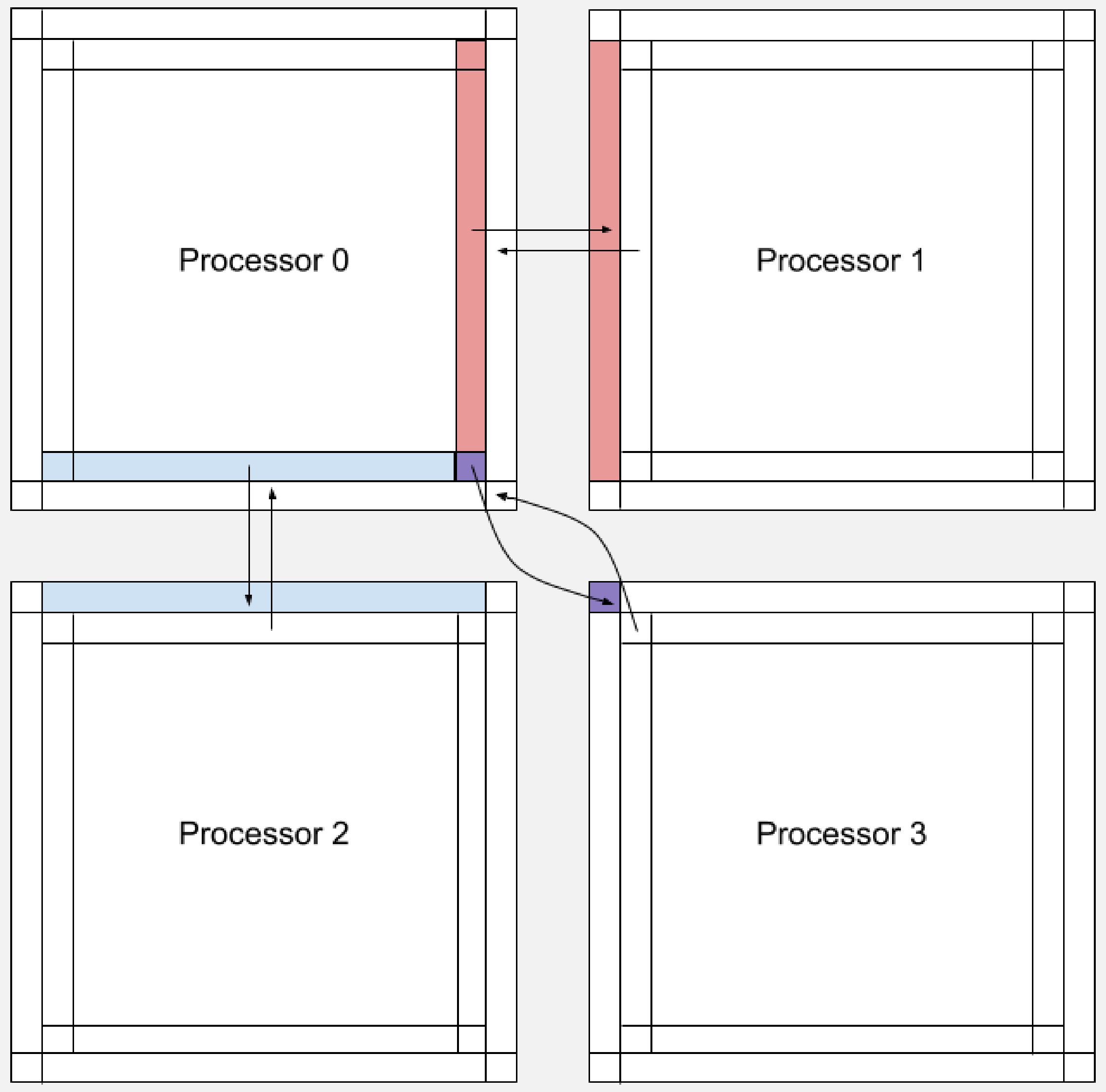
Background



Stencil Communication

- Halo Exchange: the communication of boundary values between neighboring processes
- Packing: copying data into a contiguous message buffer

Persistent MPI

- Amortizes setup costs by e.g. caching arguments

Partitioned MPI

- Partition messages to mark portions as ready to send or check if received
- MPI + threads
- Early work, early communication

Algorithms

Point-to-Point Baseline

```
Algorithm 1: Exchange
Input: msgs_info, requests
    {message information (process pairs, data sources), requests storage array}

parallel region                                              {OpenMP Region}
    // Copy data from mesh to contiguous message buffer
    pack(msgs_info)

// Begin communication
for $i \leftarrow 0$ to $n_{send}$ do
    MPI_Isend(msgs_info[$i$], requests[i])
for $i \leftarrow 0$ to $n_{recv}$ do
    MPI_Irecv(msgs_info[$i + n_{send}$],
     requests[$i + n_{send}$])

// Wait on messages
MPI_Waitall(requests)

parallel region
    // Copy values from message buffer into mesh
    unpack(msgs_info, msgs_info)
```

Persistent MPI Interfaces

1) Initialization:
   - Provide message info
   - Once before exchanges
   - Returns persistent request
2) Communication exchanges:
   - Start persistent request and wait for completion
   - Repeat for each exchange
3) Cleanup:
   - Free persistent requests

Persistent MPI

```
Algorithm 2: Persistent Init
Input: msgs_info, requests
    {message information (process pairs, data sources), requests storage array}

// Initialize messages
for $i \leftarrow 0$ to $n_{send}$ do
    MPI_Send_init(msgs_info[$i$],
     requests[$i$])
for $i \leftarrow 0$ to $n_{recv}$ do
    MPI_Recv_init(msgs_info[$i + n_{send}$],
     requests[$i + n_{send}$])
```

```
Algorithm 3: Persistent Exchange
Input: msgs_info, requests
    {message information (process pairs, data sources), requests storage array}

parallel region                                              {OpenMP Region}
    // Copy data from mesh to contiguous message buffer
    pack(msgs_info)

// Begin communication
MPI_Startall(requests)

// Wait on messages
MPI_Waitall(requests)

parallel region
    // Copy values from message buffer into mesh
    unpack(msgs_info)
```

```
Algorithm 4: Persistent Destroy
Input: requests                                     {requests storage array}
for $i \leftarrow 0$ to $n_{recv} + n_{send}$ do
    MPI_Request_free(requests[$i$])
```

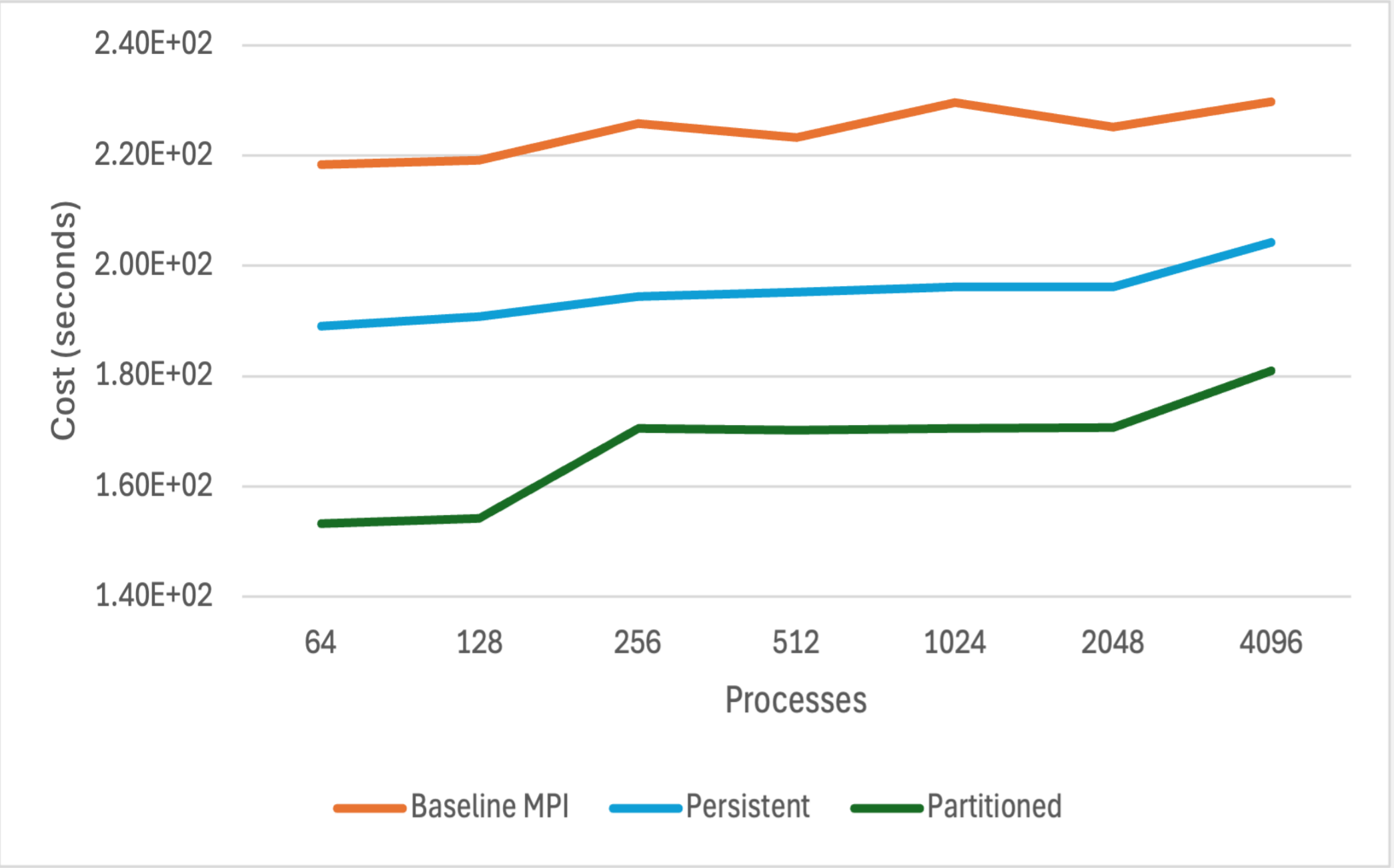
Partitioned MPI

```
Algorithm 5: Partitioned Init
Input: n_parts, msgs_info, requests
    {number of partitions, message information (process pairs, data sources),
  requests storage array}

// Initialize messages
for $i \leftarrow 0$ to $n_{send}$ do
    MPI_Psend_init(n_parts,
     msgs_info[$i$], requests[$i$])
for $i \leftarrow 0$ to $n_{recv}$ do
    MPI_Precv_init(n_parts,
     msgs_info[$i + n_{send}$],
     requests[$i + n_{send}$])
```

```
Algorithm 6: Partitioned Exchange
Input: msgs_info, requests
    {message information (process pairs, data sources), requests storage array}

// Begin communication
MPI_Startall(requests)

parallel region                                              {OpenMP Region}
    // Copy data from mesh to contiguous message buffer
    pack(msgs_info)
    // Mark partition of current thread as ready
    MPI_Pready(partition)

// Wait on messages
MPI_Waitall(requests)

parallel region
    // Copy values from message buffer into mesh
    unpack(msgs_info)
```

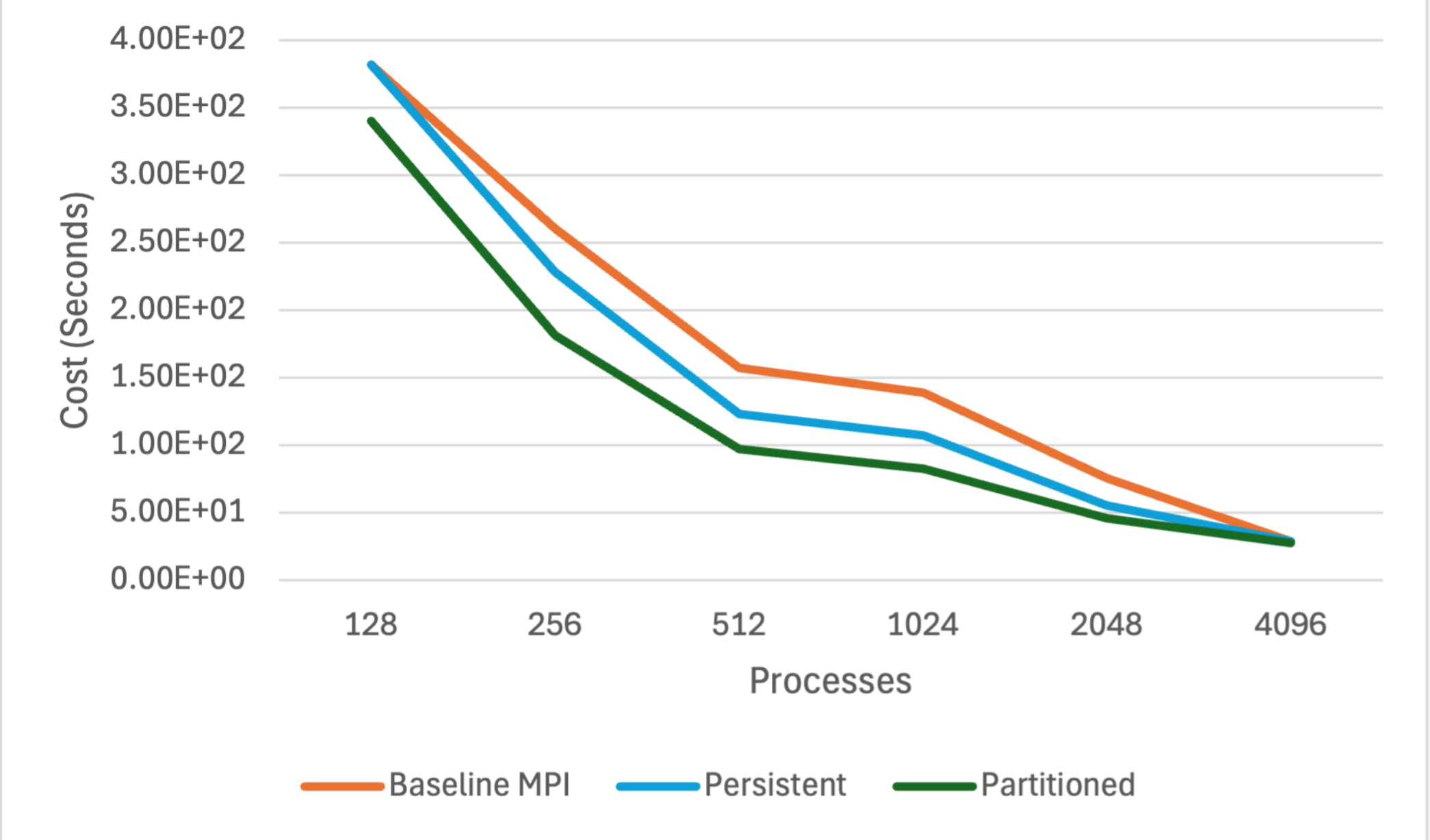
```
Algorithm 7: Partitioned Destroy
Input: requests                                     {requests storage array}
for $i \leftarrow 0$ to $n_{recv} + n_{send}$ do
    MPI_Prequest_free(requests[$i$])
```

Results



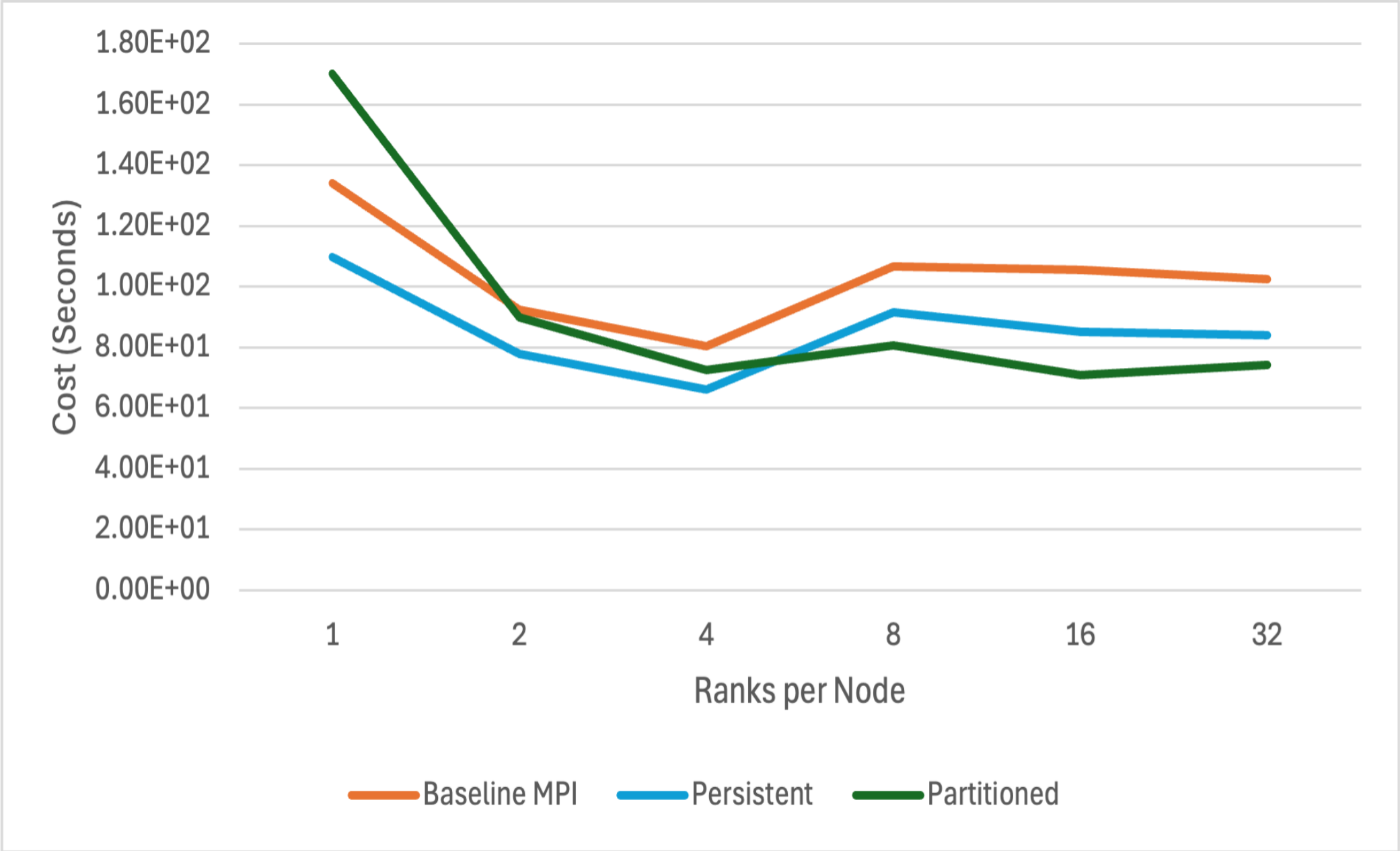
Weak Scaling

- MPIPCL, System: Quartz (Intel Xeon system at LLNL)
- Timed 1000 exchanges, 3 runs
- One core, two threads per MPI Process
- 512^3 cells per process, 3 mesh variables
- messages sizes of 524,288 doubles
- Persistent MPI: 16% speedup
- Partitioned MPI: 42% speedup



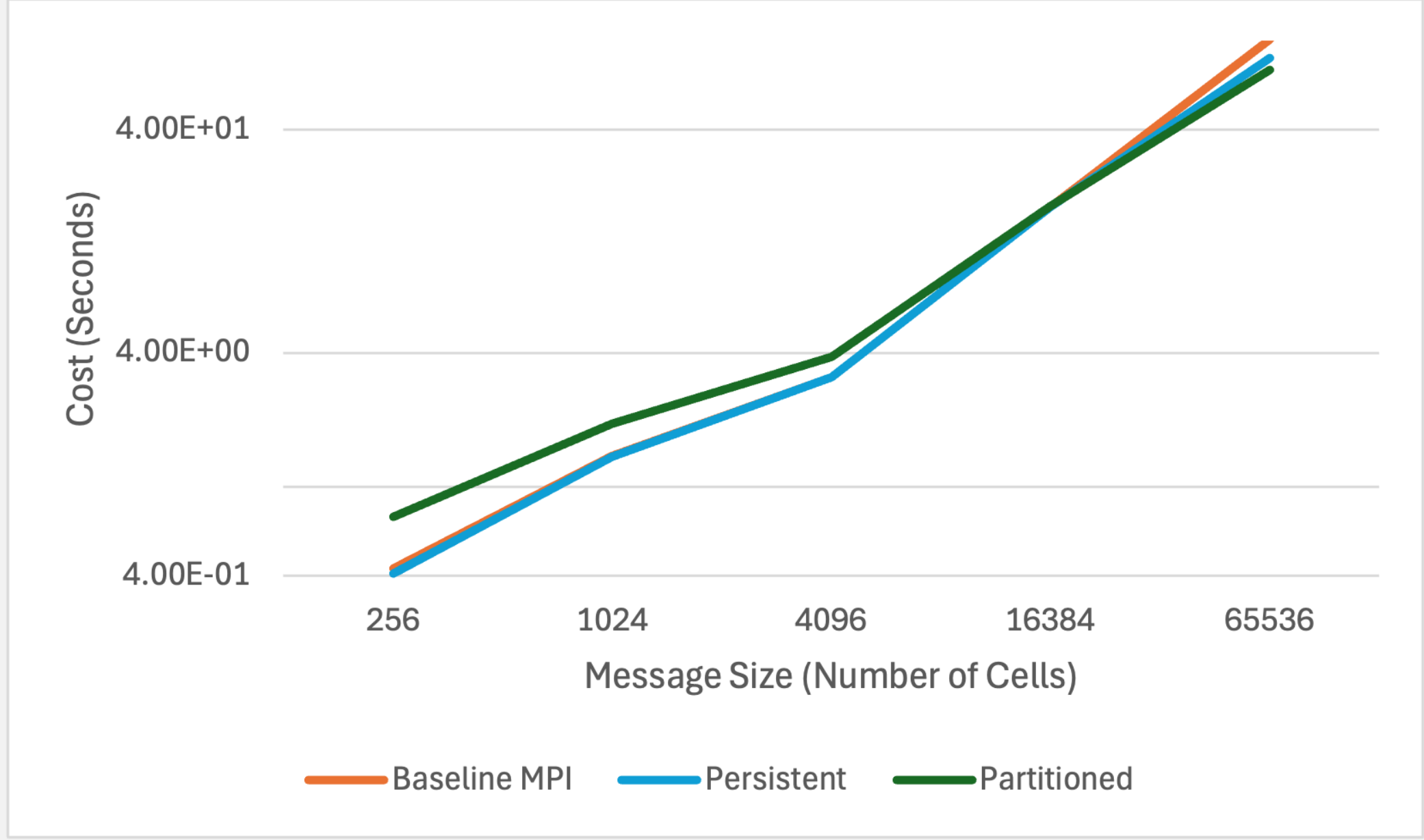
Strong Scaling

- 2048^3 cell problem with message sizes of 260k doubles, decreasing with scale
- Persistent MPI: 37% speedup
- Partitioned MPI: up to 68% total speedup



Scaling Ranks/Node

- 64 nodes, 32 active cores per node, 64 OpenMP threads per node
- 2048 x 4096 x 4096 cells
- Higher ranks/node → lower threads/rank
- Persistent MPI: ~20% speedup
- Partitioned MPI: slowdown before overtaking both other methods



Message Size Scaling

- 4096 processes on 128 nodes
- Persistent MPI: matches baseline for smaller messages, 21% faster for largest tested message
- Partitioned MPI: baseline is 73% faster for smaller messages, partitioned MPI is 37% faster for larger messages