Endpoints Proposal Update

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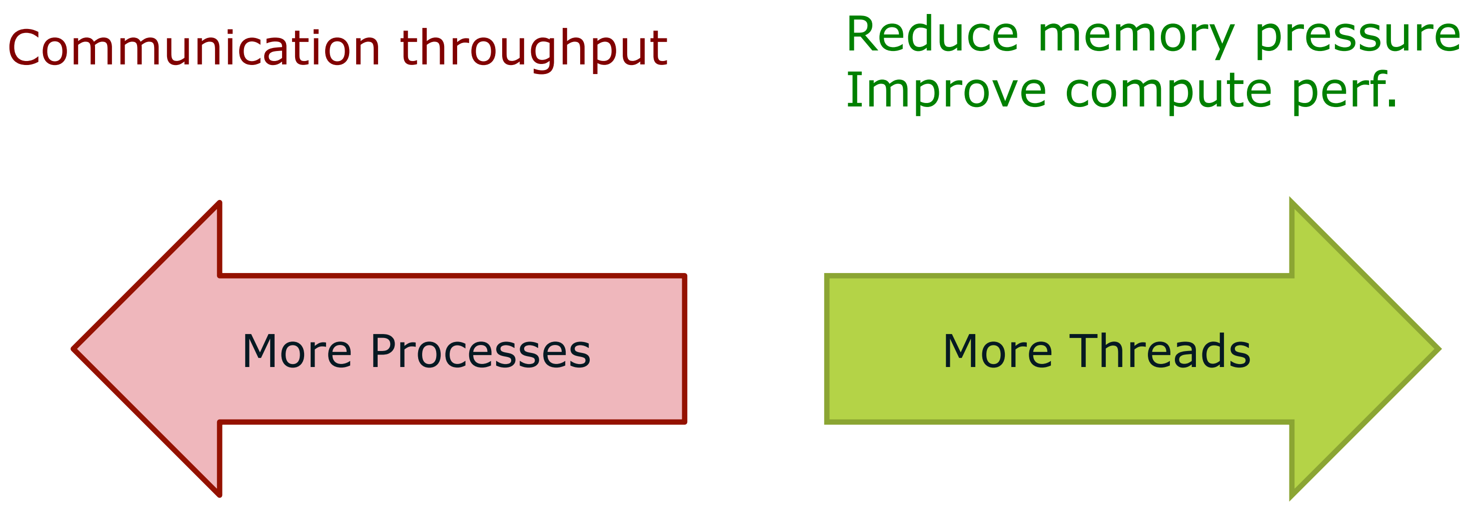
Outline

1. Big picture, performance perspective
2. New performance studies
   - Extended journal version of EuroMPI paper
     - Measure process/thread performance tradeoffs
   - Implementation work in progress
     - Results consistent with claims, will present in Japan
3. Endpoints interface review
4. Recent developments in the proposal
   - Primarily address gaps that arise when MPI processes share a virtual address space
   - Query function, communicator/group comparisons

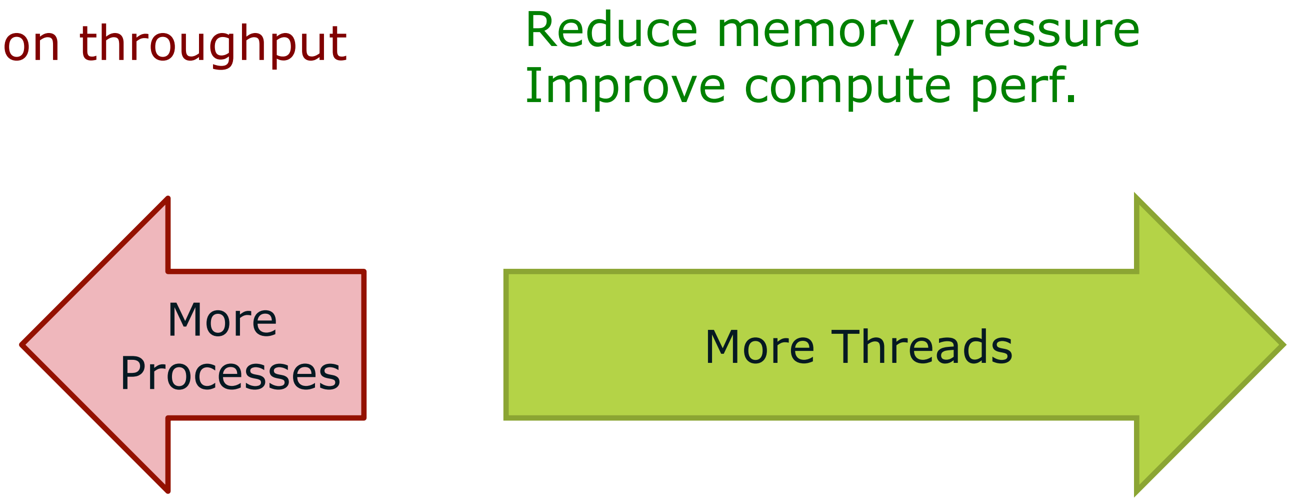
Today: Threads/Processes Tradeoff



Threads/proc. are entangled, users must make tradeoff

- Benefits of threads to node-level performance/resources
- Versus benefits of processes to communication throughput

Future: MPI Endpoints



Enable threads to achieve process-like communication perf.

- Eliminate negative interference between threads
  - Both semantics (ordering) and mechanics (implementation issues)
- Enable threads to drive independent traffic injection/extraction points

Measure Process/Thread Tradeoffs

"*Enabling Communication Concurrency through Flexible MPI Endpoints*." James Dinan, Ryan E. Grant, Pavan Balaji, David Goodell, Douglas Miller, Marc Snir, and Rajeev Thakur. Submitted to IJHPCA.

Look at communication performance trends in many-core system

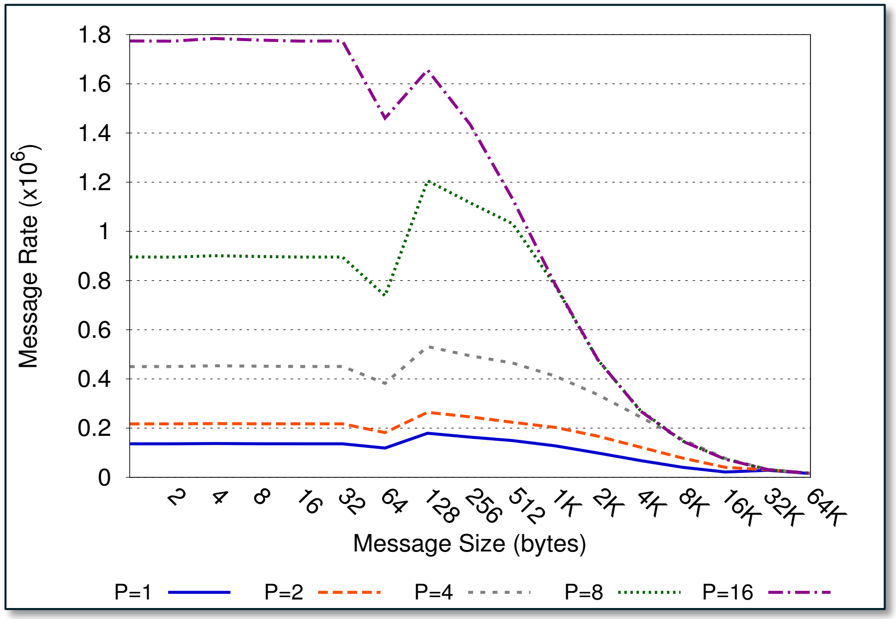
Identify/measure opportunities for endpoints to improve performance

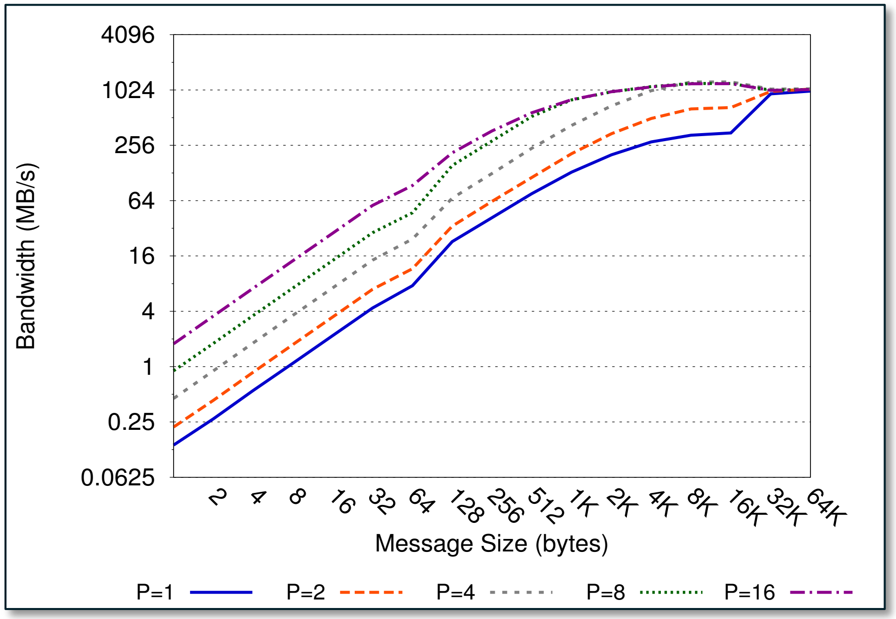
System setup:

- Intel® Xeon Phi™ 5110P "Knight's Corner" Coprocessors
  - 60 cores @ 1.053 GHz, 8GB memory, 4-way hyperthreading
- Intel MPI Library v4.1 update 1, Intel C Compiler v13.1.2
  - Run in native mode – Phi cores do MPI processing
- Mellanox 4x QDR InfiniBand, max bandwidth 32 GB/sec

Intended to represent future systems where network is designed to support traffic from many cores

Impact of Increasing Num. Processes



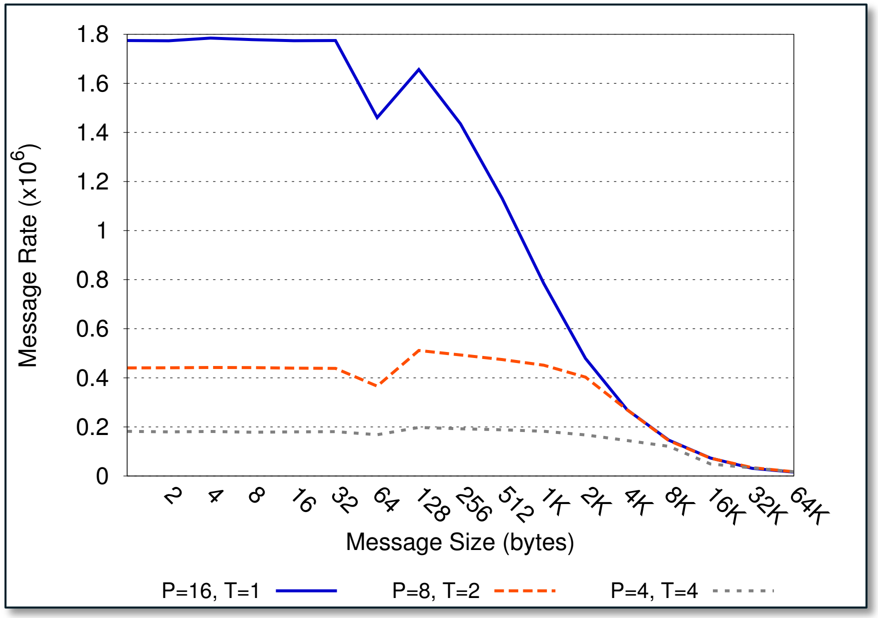


Measure communication performance between two nodes
- OSU benchmark - N senders and N receivers per node
- Performance increases with more processes (P) driving communication

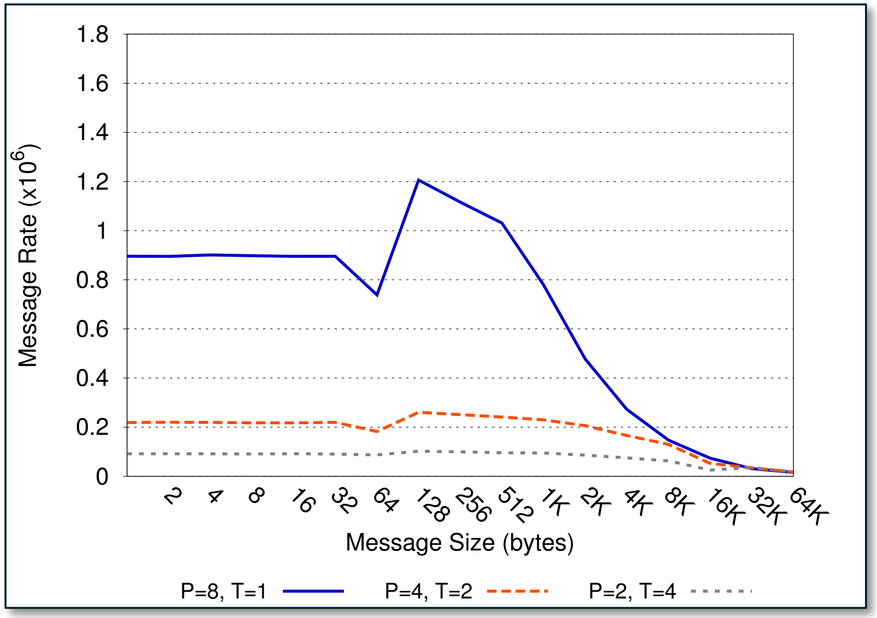
Processes represent "ideal" endpoints
- Private communication state and communication resources
- Represent performance upper bound

Threads/Proc. Tradeoff (Msg. Rate)

16 Cores



8 Cores



"I have N cores, how do I use them?"

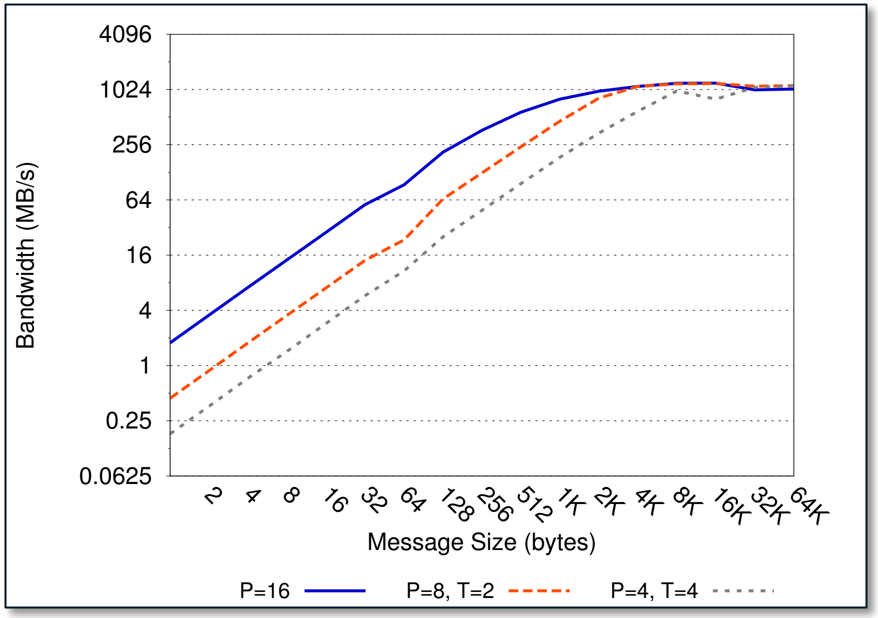
- Threads address node level concerns (e.g. memory pressure)
- Processes provide better communication performance

Endpoints will enable threads to behave like processes

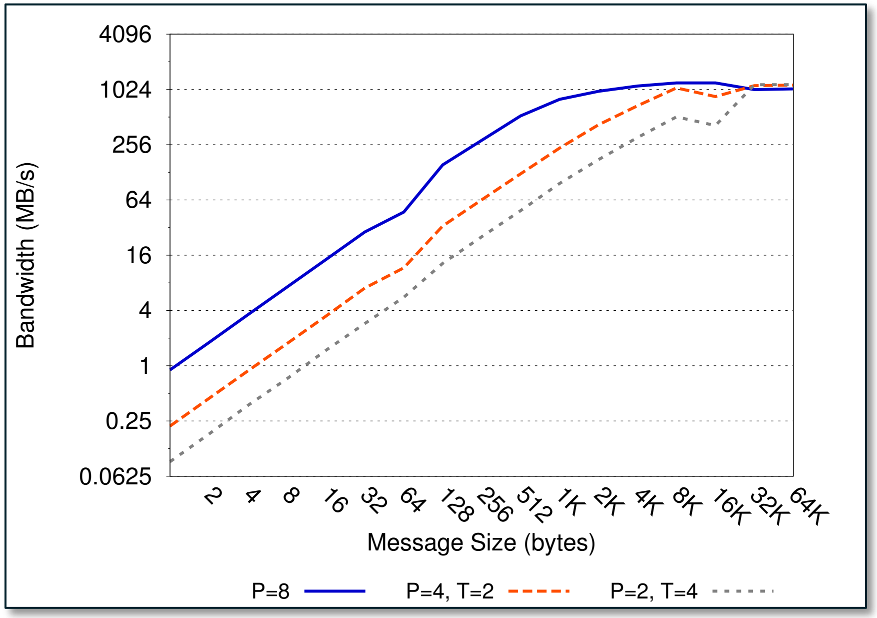
- Decouple threads in mechanics – private communication state
- Decouple threads in semantics – isolate in message ordering

Threads/Proc. Tradeoff (BW)

16 Cores



8 Cores



Thread/processes tradeoff impacts bandwidth

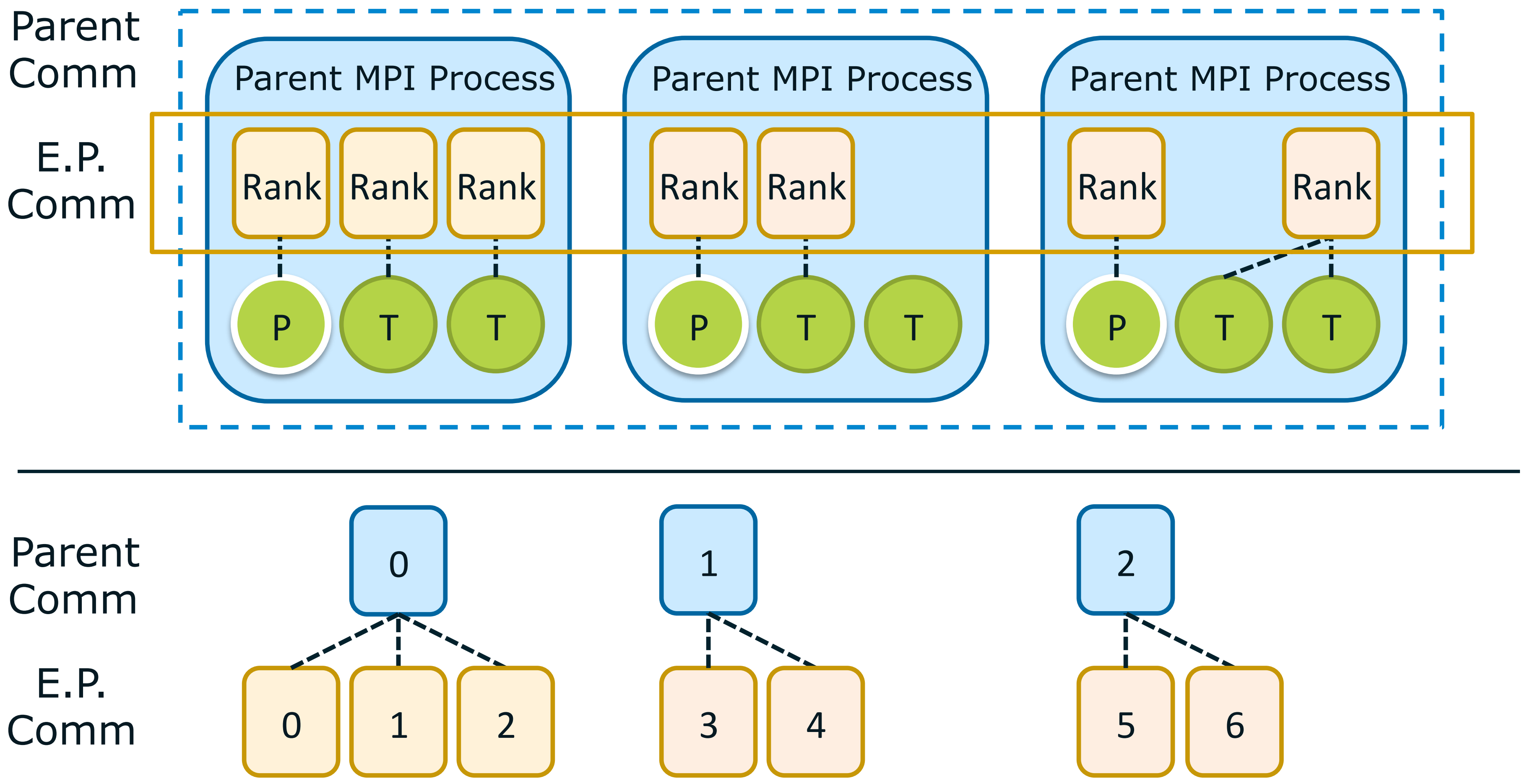
Saturate for 32KiB+ messages

More processes = better throughput for smaller messages

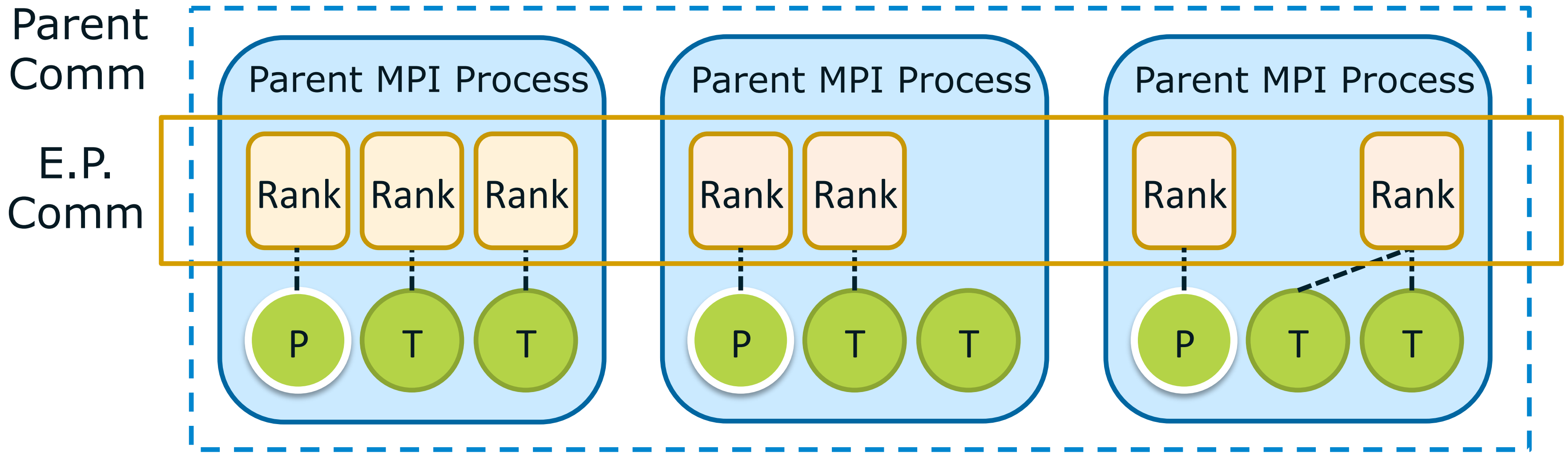
Highlights the problem, hope to show the solution next time

MPI Endpoints

Relax the 1-to-1 mapping of ranks to threads/processes



MPI Endpoints Semantics



MPI Process: Set of resources supporting execution of MPI comm's

- MPI rank and execution resources to drive it when needed
- Endpoints have MPI process semantics (e.g. progress, matching, …)
  - Collectives are called concurrently on all endpoints (MPI processes)

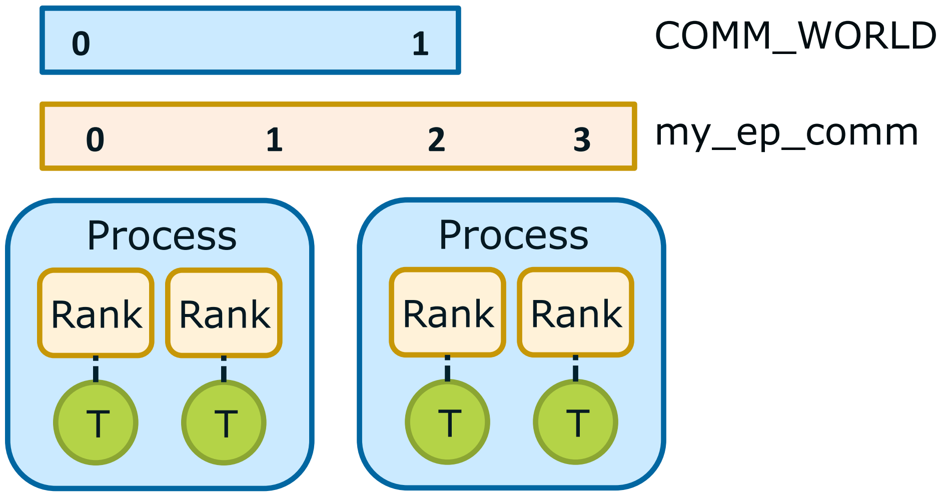
Improve programmability of MPI + Threads

- Allow threads to be MPI processes, addressable through MPI
- Make number of VA spaces free parameter for apps

Enable threads to act like processes / have process-like performance

- Per-thread communication state/resources, process-like performance

MPI Endpoints API



```
MPI_Comm_create_endpoints(MPI_Comm parent_comm, int my_num_ep,
      MPI_Info info, MPI_Comm out_comm_handles[])
```

Creates new MPI ranks from existing ranks in parent comm.

- Each process in parent comm. requests a number of endpoints

Outputs handles correspond to different ranks in the same comm.

- Takes TLS out of the implementation and off the critical path

Can return MPI_ERR_ENDPOINTS if endpoints could not be created

Hybrid MPI+OpenMP Example

With Endpoints

```
int main(int argc, char **argv) {
  int world_rank, tl;
  int max_threads = omp_get_max_threads();
  MPI_Comm ep_comm[max_threads];

  MPI_Init_thread(&argc, &argv, MPI_THREAD_MULTIPLE, &tl);
  MPI_Comm_rank(MPI_COMM_WORLD, &world_rank);

#pragma omp parallel
  {
    int nt = omp_get_num_threads();
    int tn = omp_get_thread_num();
    int ep_rank;
#pragma omp master
    {
      MPI_Comm_create_endpoints(MPI_COMM_WORLD, nt, MPI_INFO_NULL, ep_comm);
    }
#pragma omp barrier
    MPI_Comm_rank(ep_comm[tn], &ep_rank);
    ... // Do work based on 'ep_rank'
    MPI_Allreduce(..., ep_comm[tn]);

    MPI_Comm_free(&ep_comm[tn]);
  }
  MPI_Finalize();
}
```

Recent Developments

1. MPI_Comm_free() semantics
2. Query function
3. Communicator comparison
4. Group comparison

Optimization Notice

MPI_Comm_free() with Endpoints

Past: Called in series on endpoints in a hosting MPI_COMM_WORLD process

- Enable endpoints communicators to be freed when using thread level < MPI_THREAD_MULTIPLE
- Changes MPI_Comm_free semantics, would have to always do a hierarchical free algorithm on endpoints even when using MPI_THREAD_MULTIPLE
- Breaks collective semantic that is expected by attribute callbacks

New approach: Leave this undefined for now, can define MPI_Comm_free_endpoints in future

- Would need to forbid collective attribute callbacks

Query Function: What to query?

Find out if processes share an address space

- Libraries need to determine whether memory and other resources are private to an MPI rank
- Existing issue when MPI processes impl. as threads
- Also an issue with MPI endpoints
- Pursuing as a separate ticket (#425)

Query number of endpoints:

- Split with MPI_COMM_TYPE_ENDPOINTS
- MPI_Comm_num_endpoints(MPI_Comm comm, int *num_ep, int *ep_id)

Query if any processes in comm. are in same VA space:

- MPI_[Comm,Group,Win,File,]_has_sharing(…, int *flag)

Communicator Comparison

When MPI processes share a VA space, it becomes possible for a process to see multiple handles to different ranks in the same communicator

Currently comm. comparison can result in: MPI_IDENT, MPI_CONGRUENT, MPI_UNEQUAL

Past: Return MPI_IDENT, then check ranks to see if they differ.

New proposal: Return MPI_ALIASED to indicate same object, different ranks

Group Comparison

`out_comm_handles[0]` corresponds to calling process' rank in parent communicator

All other output ranks are new ranks that don't appear in any other group

Needed for group operations to make sense

- Consider my_num_ep == 1 at all processes
- Comparison with parent group should be CONGRUENT
- MPI_Group_translate_ranks between output and parent communicators should yield same ranks

More Info

Endpoints:

- https://svn.mpi-forum.org/trac/mpi-forum-web/ticket/380

Hybrid Working Group:

- https://svn.mpi-forum.org/trac/mpi-forum-web/wiki/MPI3Hybrid

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