Charm++ Interoperability

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Motivation

- Charm++ RTS is powerful - message driven, optimized communication layer, load balancing, fault tolerance, power management, partitioning.
- But legacy codes are huge - rewriting them to use Charm++ may be significant work.
- Can one use Charm++ *without code changes* or *partially* to
    - Get concrete evidence of performance benefits for an application.
    - Improve performance of a few kernels.
    - Chunk by chunk transition to Charm++.

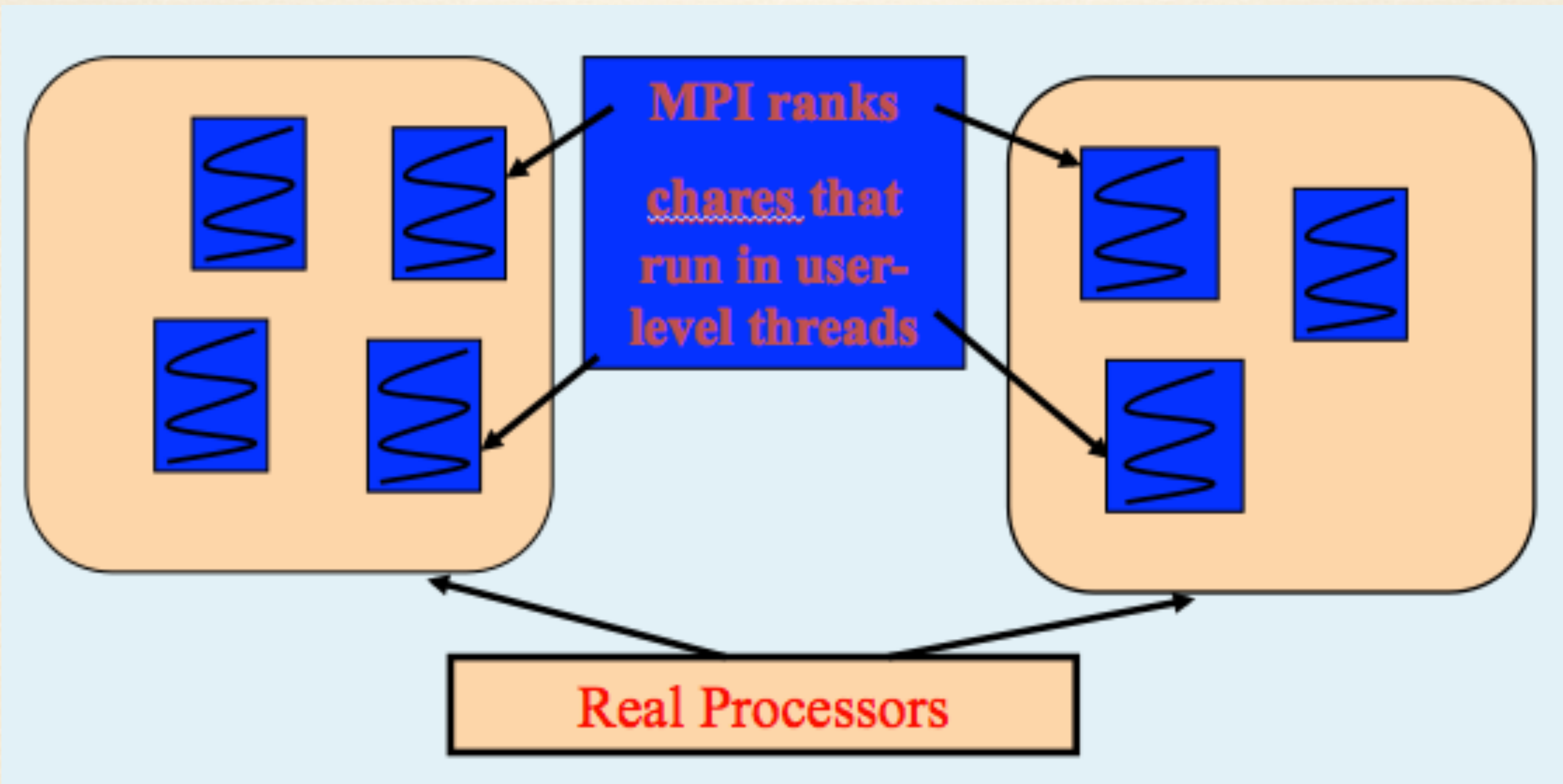
Proposed Paths

- For OpenMP
  - Charm++ is not a new language - direct use of existing code.
- For MPI applications
  - Use Adaptive MPI.
  - Interoperate Charm++ with MPI.
- Others - we implement front-end APIs as need arise.

Approach 1 - Adaptive MPI

- Charm++'s implementation of MPI
  - with useful additions.
- Over-decomposition infused by treating each MPI rank as a virtual process (VP) that executes in its own user-level thread.
- Each core hosts multiple VPs that are treated as chares of a chare array with scheduling controlled by Charm++ RTS.

AMPI: User and System View



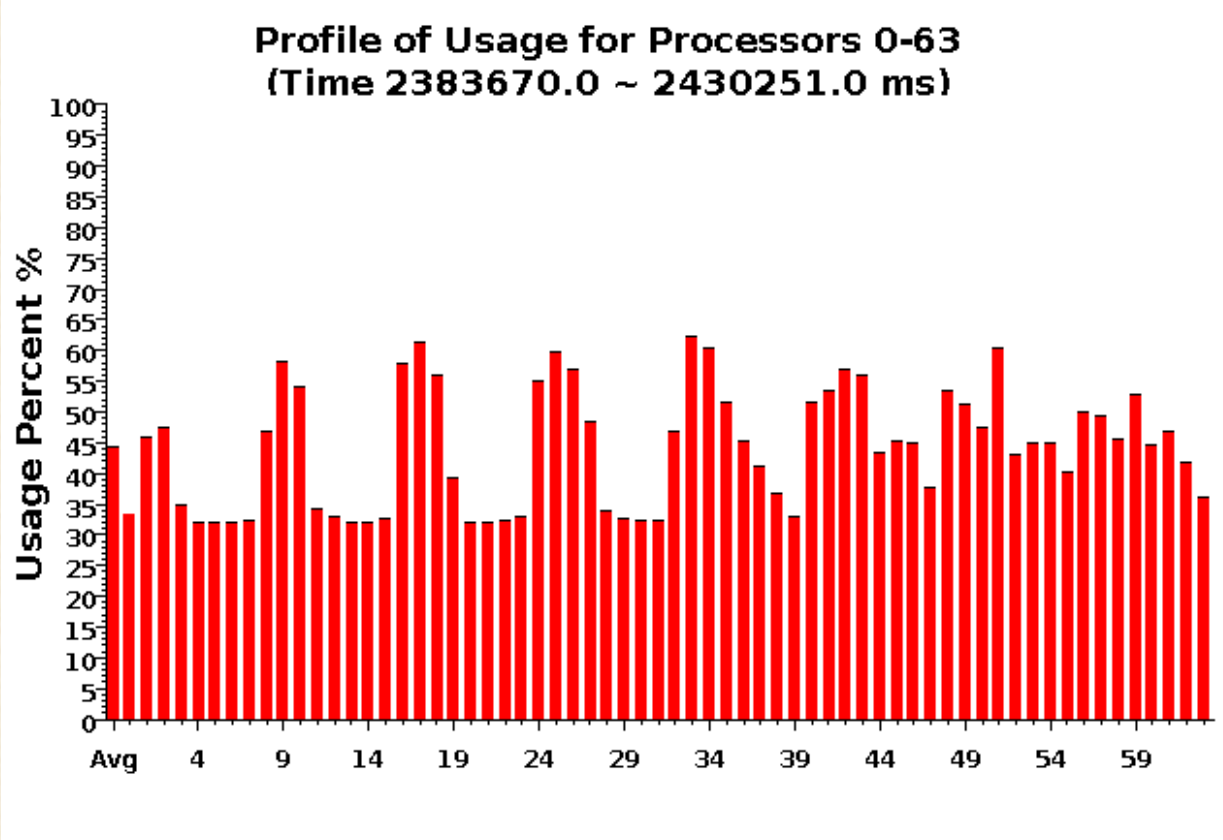
AMPI: Augmentations

- Additional functions-
  - MPI_Migrate - perform load balancing.
  - MPI_Checkpoint - checkpoint to disk.
  - MPI_MemCheckpoint - checkpoint to memory.
  - Non-blocking collectives - also in MPI-3 standard.
- Isomalloc - automated tracking of user data for migration/checkpointing.
- Swapglobals - automated handling if global data exists.

AMPI: Applications

- Our aim is to enable execution of any MPI code as AMPI
- Some Examples:
  - BRAMS - Brazilian Weather code based on RAMS
  - ISAM - Integrated Science Assessment Model for assessment of climate change
  - NAS Parallel Benchmarks
  - Mantevo Benchmarks
  - Lulesh

AMPI: BRAMS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(Time 2383670.0 ~ 2430251.0 ms)
Usage Percent %
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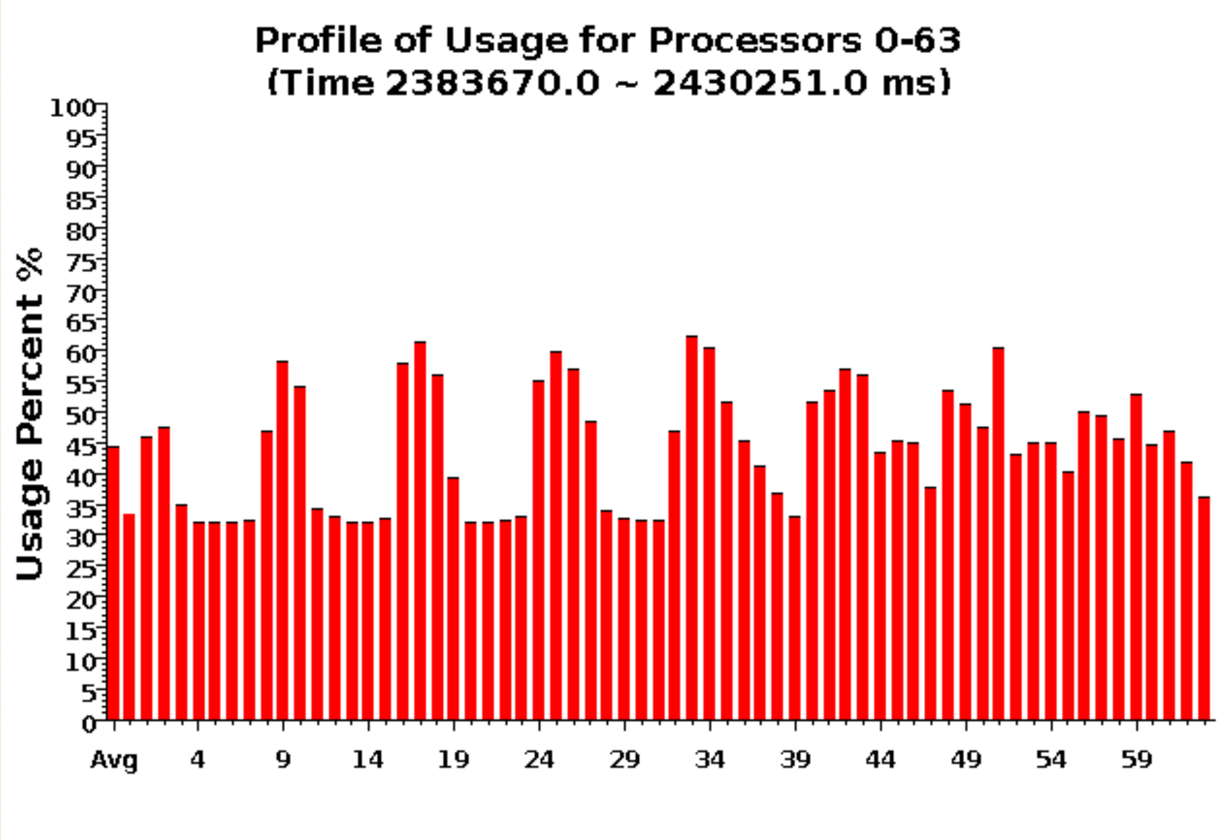
AMPI: BRAMS



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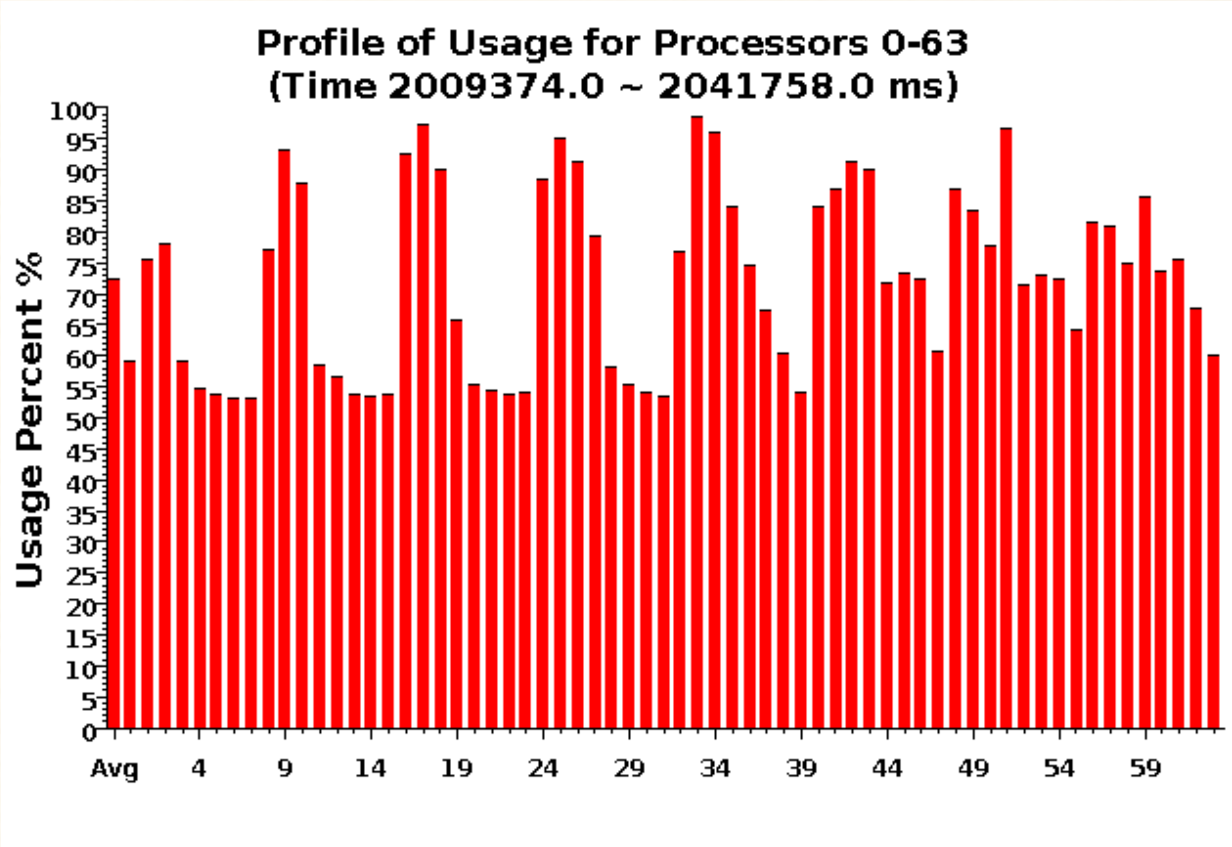

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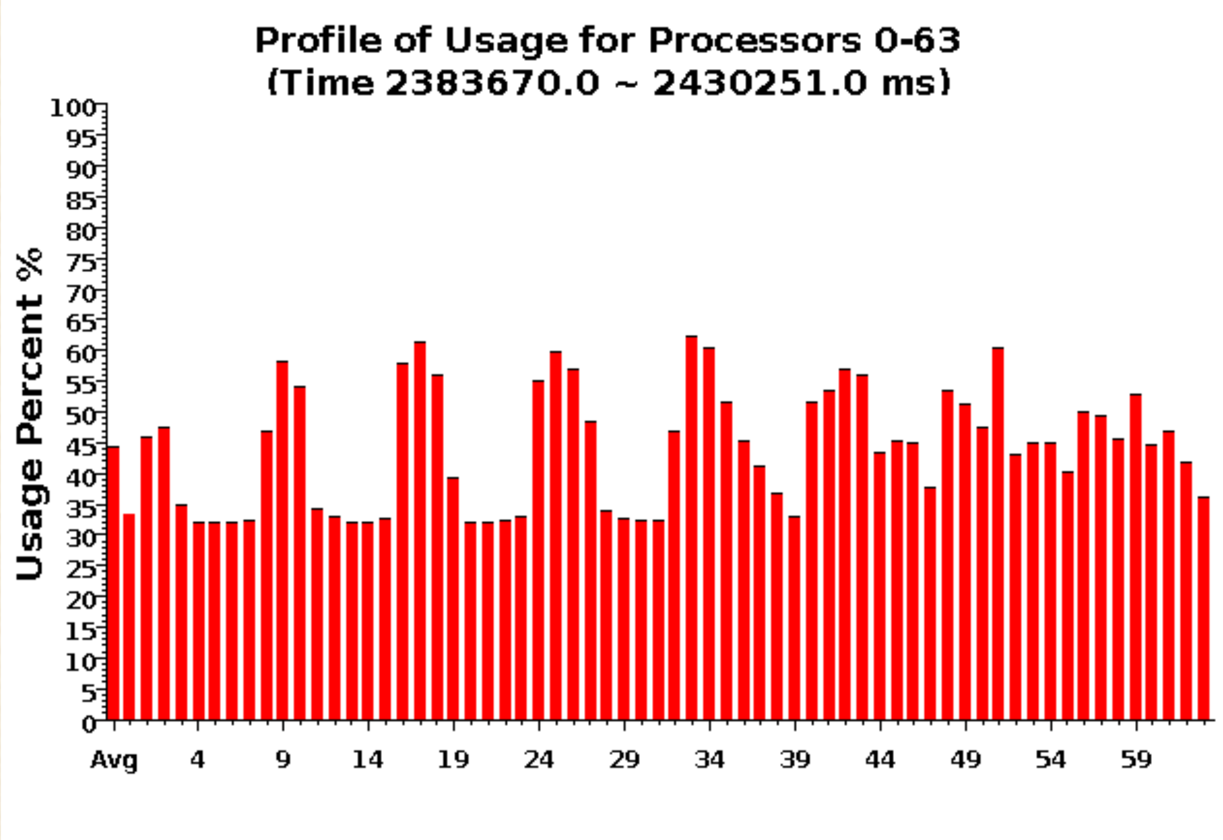
AMPI: BRAMS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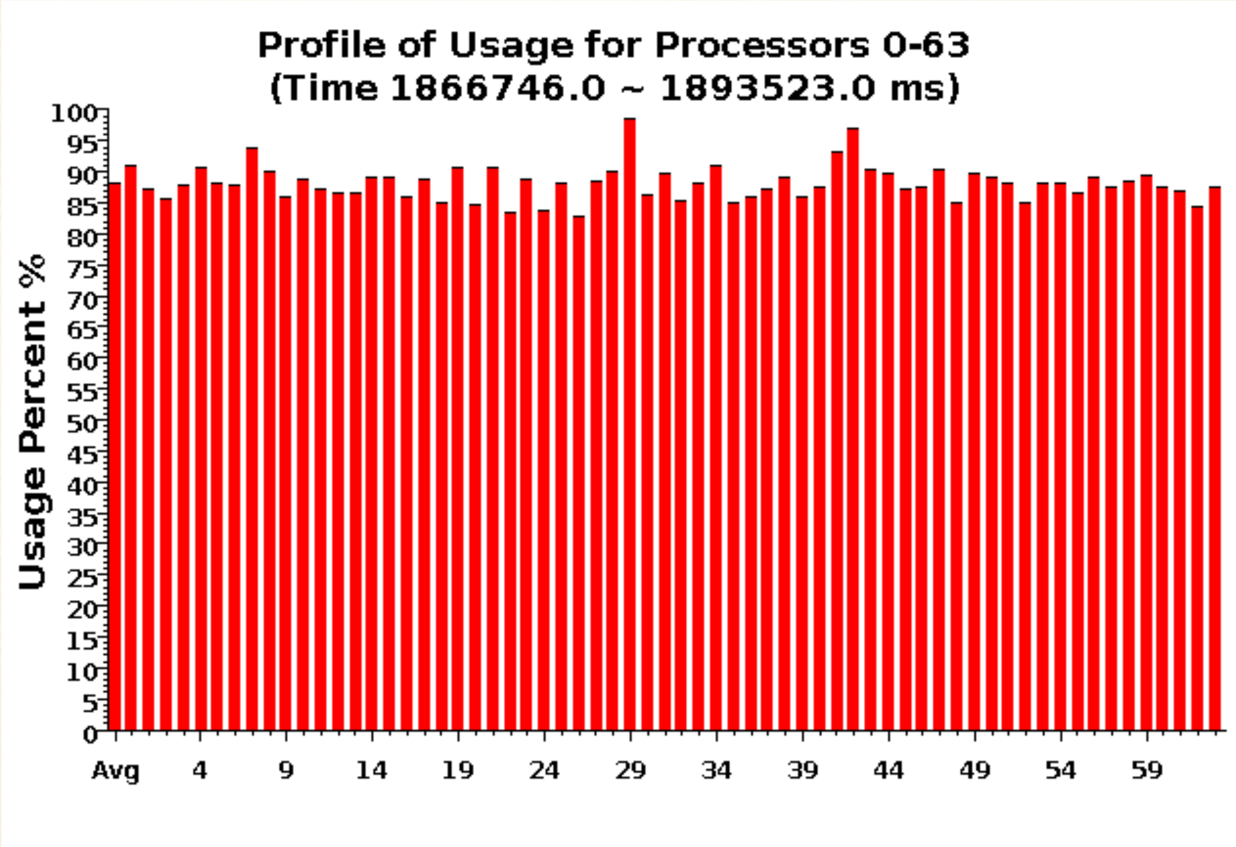
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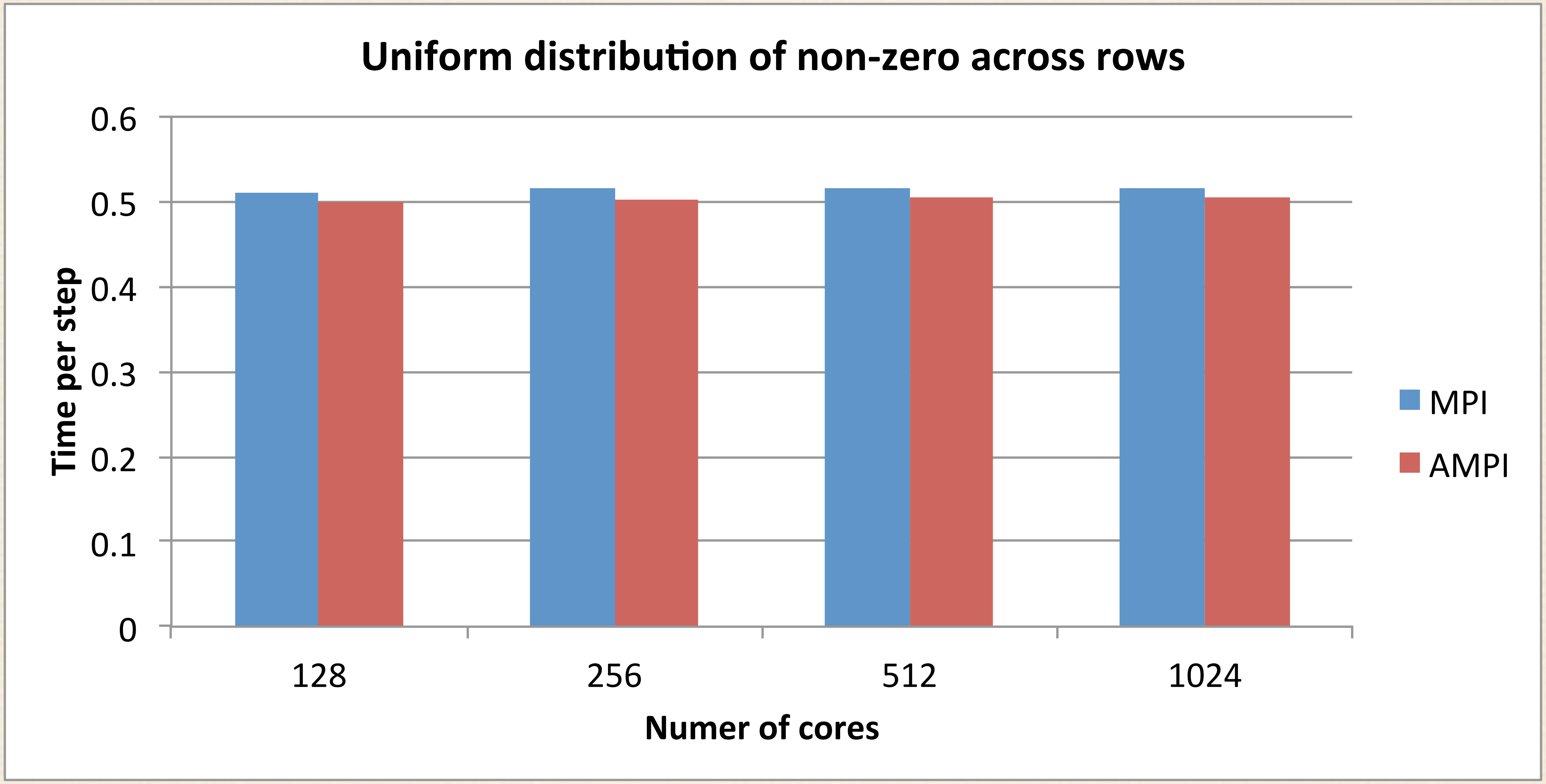
AMPI: HPCCG


Uniform distribution of non-zero across rows
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Time per step
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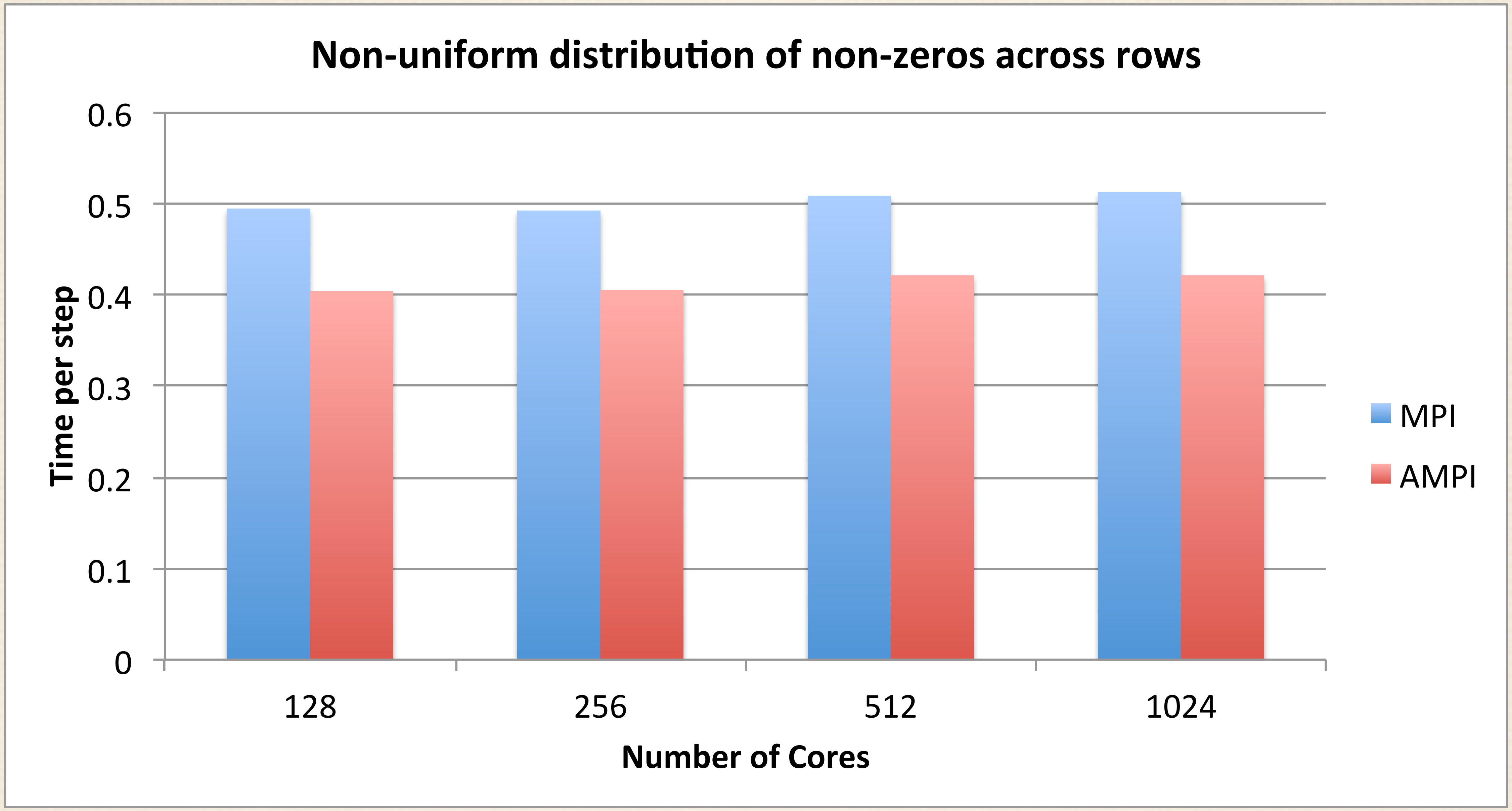
256
512
1024
Numer of cores
MPI
AMPI

AMPI: HPCCG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AMPI

AMPI: Work in Progress

- Improved efficiency - newer algorithms.
- Optimized support on IBM Blue Gene/Q
  - No support for mmap - no isomalloc.
  - Swapping globals.

Approach 2 - Interoperability

- Chunk by chunk transition to Charm++.
- Identify kernels that are better suited to Charm++.
- Implement them in Charm++.
- Make *calls to Charm++ code from MPI* based code.

Interoperability

- Charm++ resides in the same memory space as the MPI based code.
  - Performs necessary low level initializations and resource procurement.
  - Pass memory locations - no messaging required.
- Control transfer between Charm++ and the MPI based code analogous to the control transfer between the MPI based code and any other external library such as ParMETIS, FFTW etc.

Interoperability: Modes

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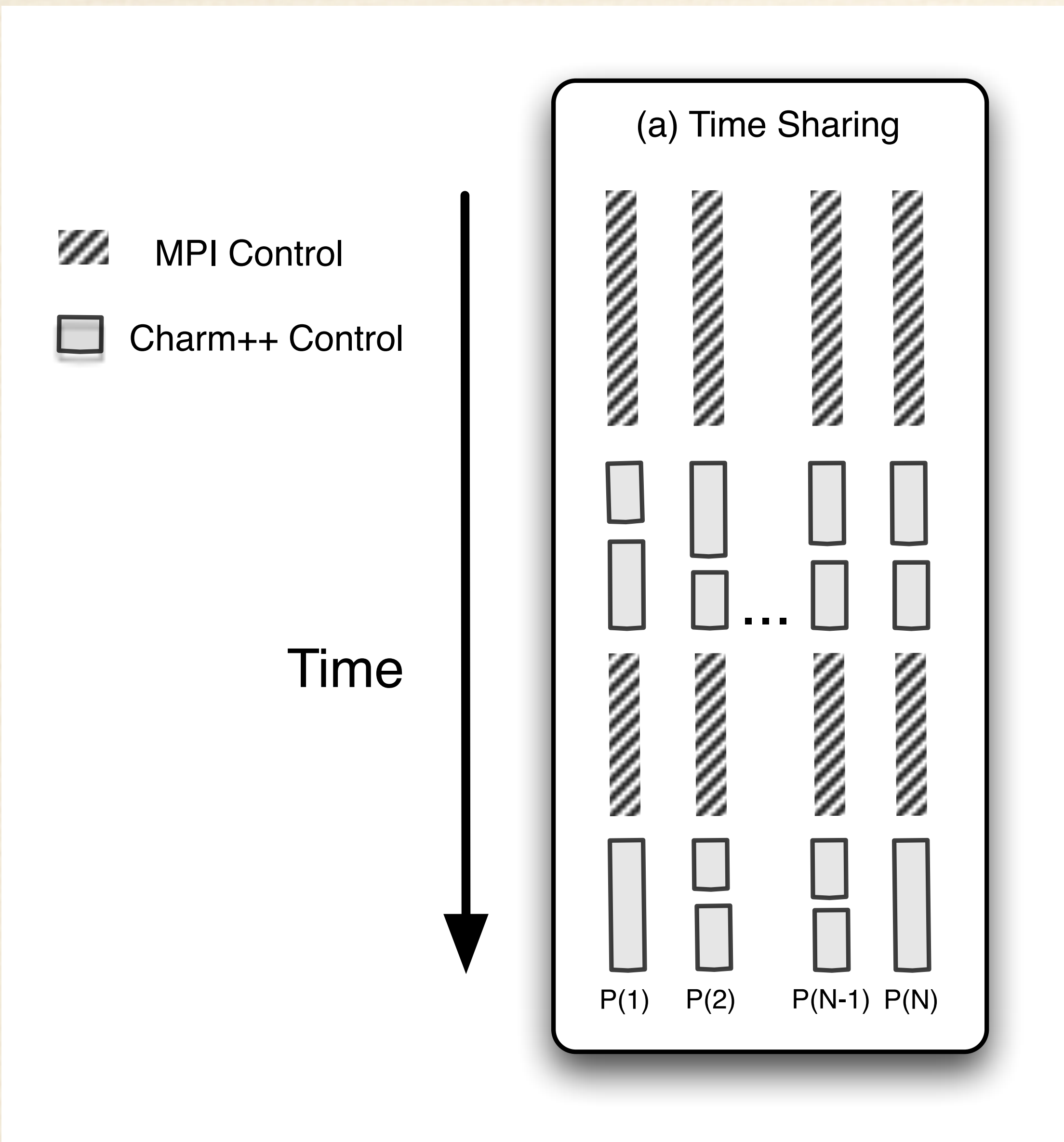

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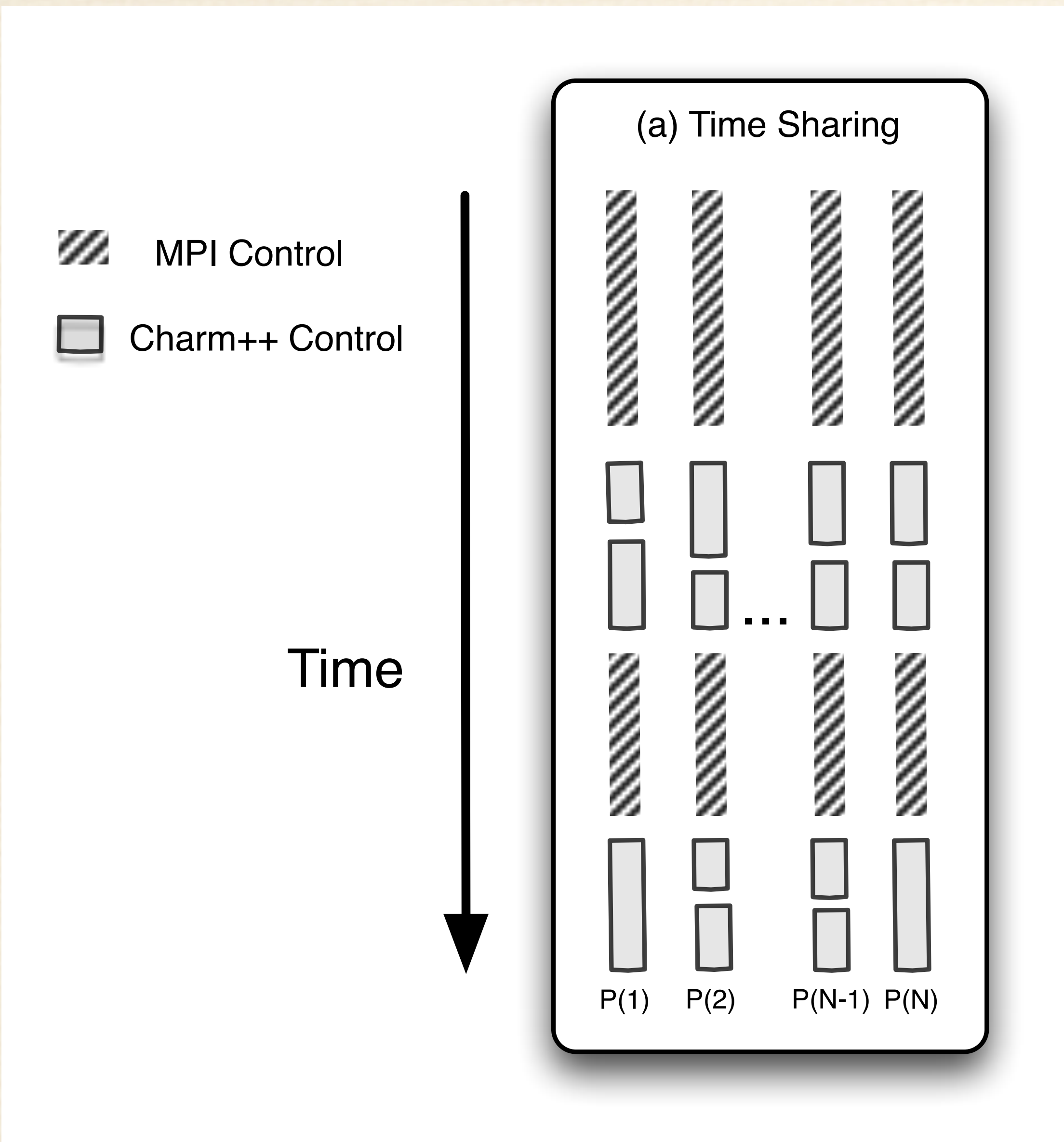

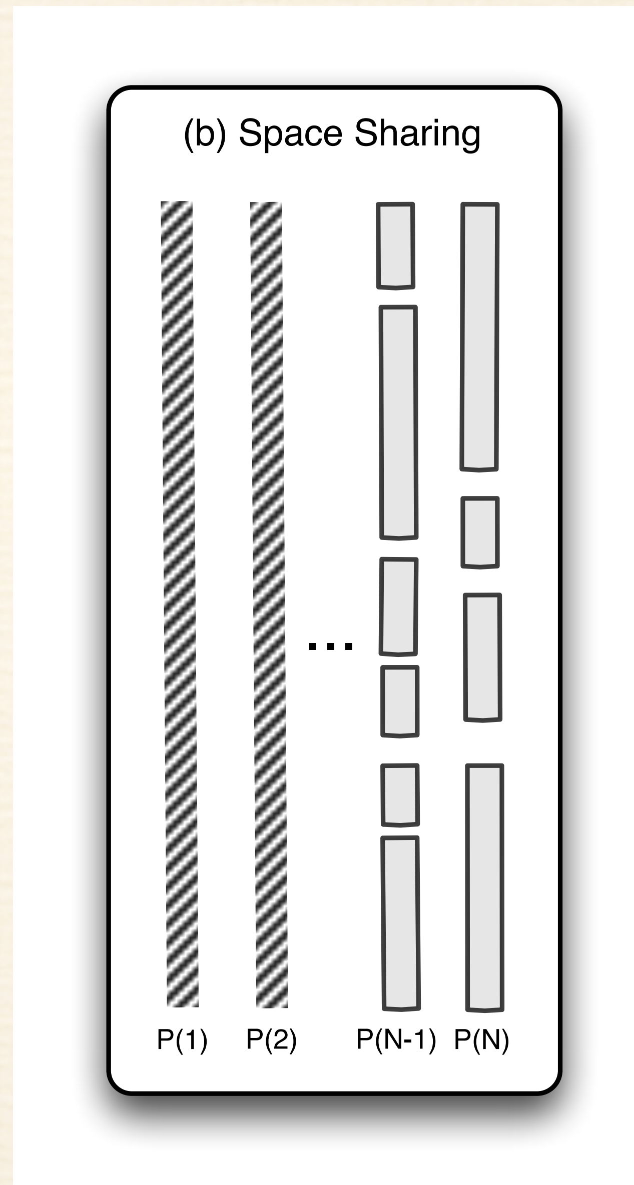

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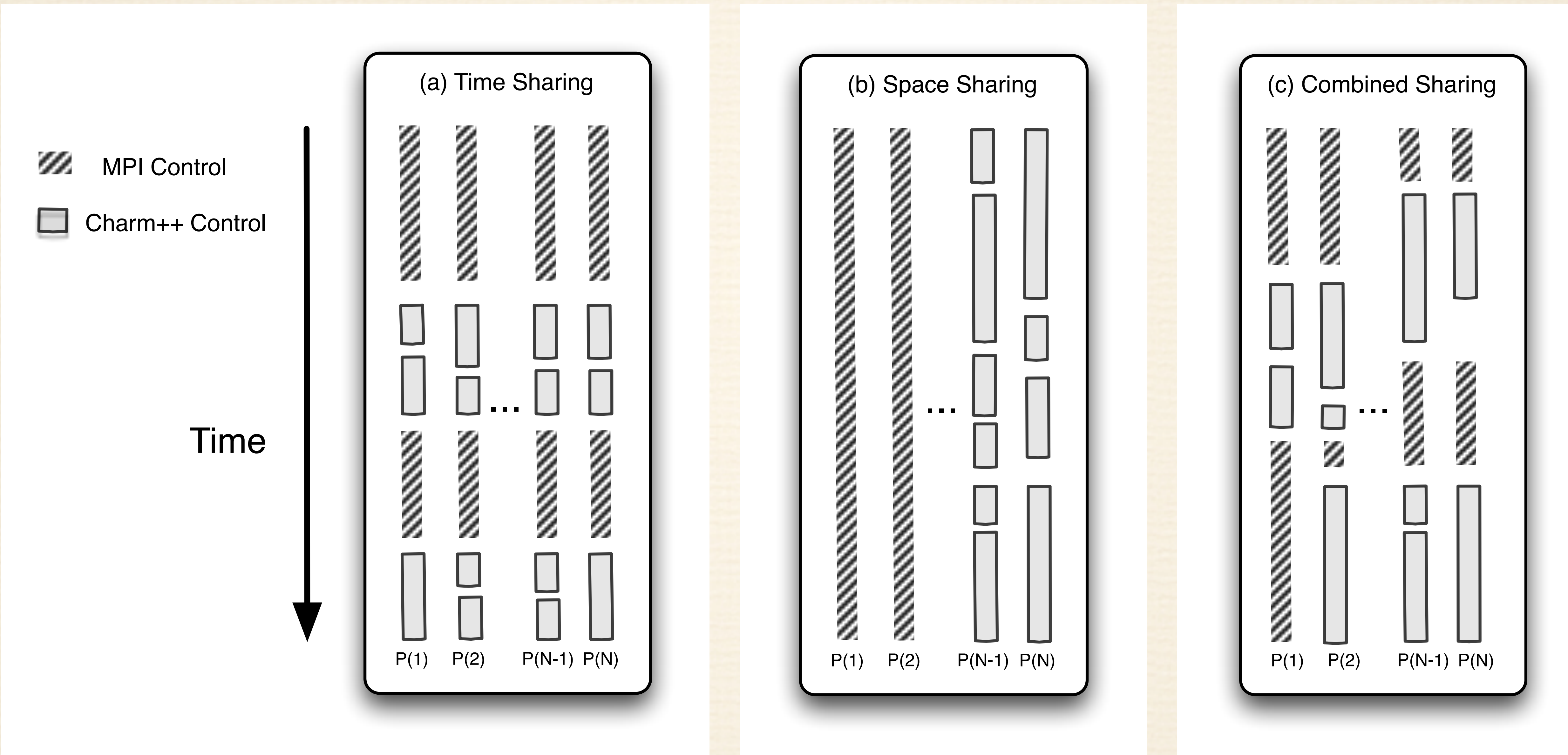

Interoperability: Charm++ Code

- Include mpi-interoperate.h.
- Add an interface function callable from the main program.

```
void HelloStart(int elems)
  if(CkMyPe() == 0) {
    CProxy_MainHello mainhello =
    CProxy_MainHello::ckNew(elems);
  }
  StartCharmScheduler();
}
```

Interoperability: Code Flow

- Begin execution at user main.
- Perform MPI initialization and application initialization.
- Create a sub-communicator for Charm++.
- Initialize Charm++ with this sub-communicator.
- for (as many times needed)
  - perform MPI based communication and application work.
  - invoke Charm++ code.
- Exit Charm++.

Interoperability: Example

```
MPI_Init(argc,argv); //initialize MPI
//Do MPI related work here
```

```
//create comm to be used by Charm++
MPI_Comm_split(MPI_COMM_WORLD, myRank % 2, myRank, newComm);
CharmLibInit(newComm,.) //initialize Charm++ over my communicator
```

```
if(myRank % 2)
  StartHello(); //invoke Charm++ library on one set
else
  //do MPI work on other set
```

```
kNeighbor(); //invoke Charm++ library on both sets
CharmLibExit(); //destroy Charm++
```

Interoperability: Use cases

- Demonstrated in HPC Challenge submission with FFT benchmark.
- High performance sorting library based on
  - Highly Scalable Parallel Sorting by Edgar Solomonik and Laxmikant Kale (IPDPS, 2009).
- Efficient collision detection library based on
  - A Voxel based Parallel Collision Detection Algorithm by Orion Lawlor and Laxmikant Kale (ICS, 2002).

Interoperability: Work in Progress

- Enable space and combined sharing on non-MPI layers such as PAMI, uGNI.
- Development of interoperable libraries in Charm++
  - Graph algorithms - BFS, Spanning tree, Shortest path etc.
  - Efficient solvers.
- Integrate performance analysis of interoperable code using Projections.

Questions