Hybrid MPI: Efficient Message Passing for Multi-core Systems

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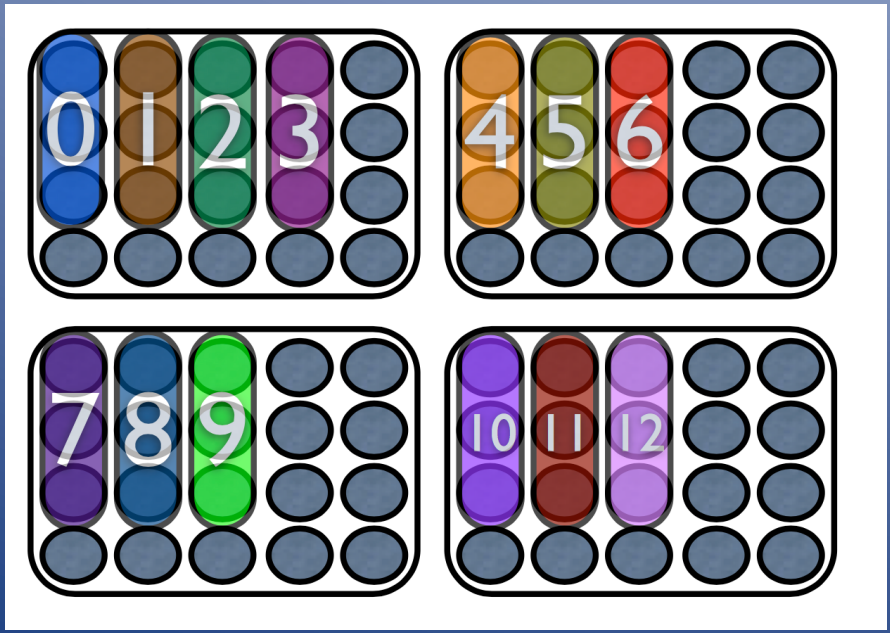
Background

- Modern multi-core system
- MPI communication overhead
- OPENMP thread-safety issue




```
#SBATCH -n 13
#SBATCH −c 3
#SBATCH −N 4
```

Outline

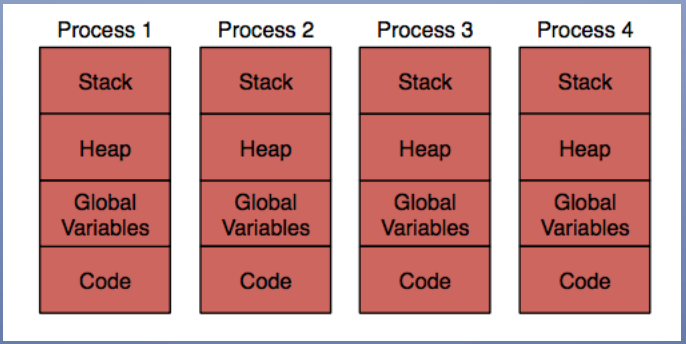
1. Objective of HMPI
2. Current MPI implementation
3. HMPI architecture
4. Communication protocols
5. Result analysis
6. Conclusion
7. Q&A

Objective

- Intra-node communication performance
  - Share memory between ranks
- Portability
  - No extra knowledge needed for MPI user
- Without root access to modify system

Current MPI implementation

1. Process-based MPI



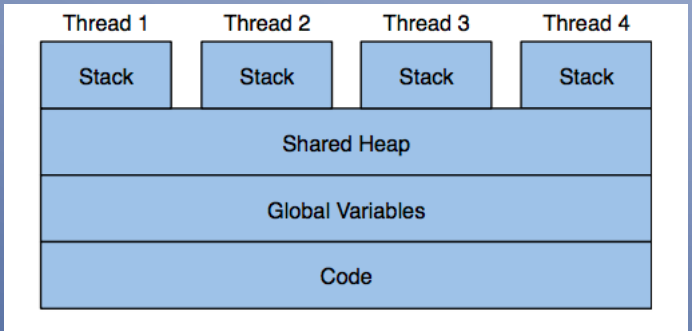
Advantage: No synchronization

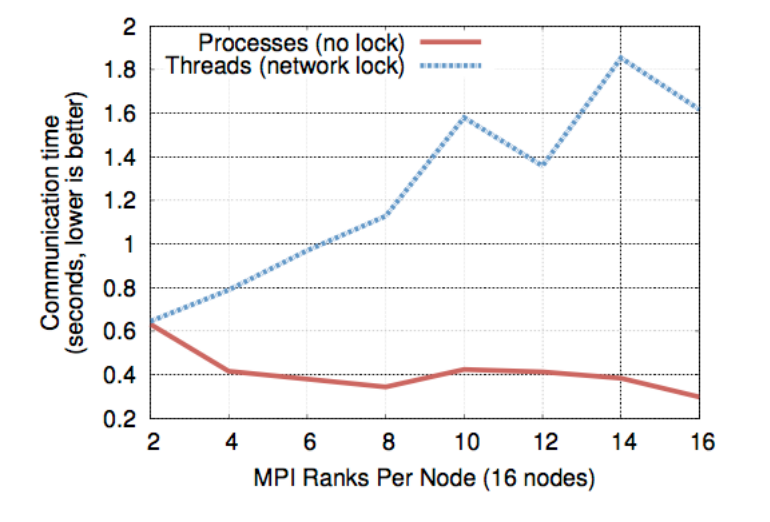
Disadvantage: 1. Two-copy per message (pipeline)

2. Pair-wise memory allocation (memory consuming)

Current MPI implementation

2. Thread-based MPI





Advantage: Shared memory

Disadvantage: Race condition (global variable)

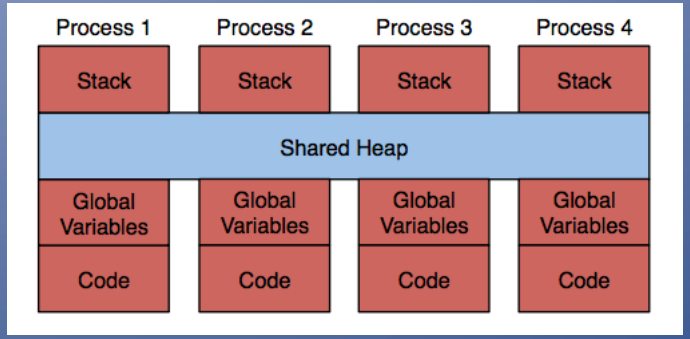
i. Complier transformation tool

ii. Thread-safe API only

HMPI architecture

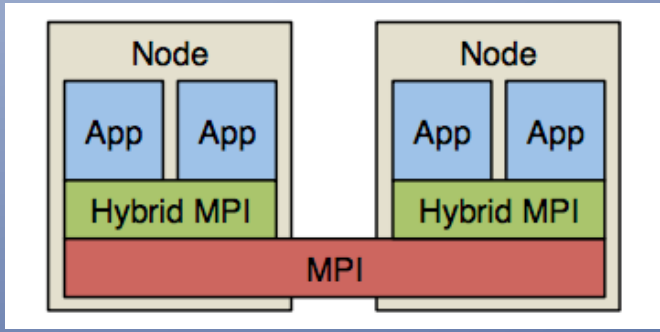
1. Shared memory allocation
   a) Some systems allow memory mapping from other process (require root access)

   b) In HMPI, *mmap* and *sbrk* are used to modify *dlmalloc*
      - virtual memory
      - process owned share memory
      - one 16G physical memory, up to 16G virtual memory could be allocated for each process



HMPI architecture

2. HMPI inheritance



- Hybrid MPI library

  Advantages:

  a) portability: Just link it to application

  b) transparency: No code transformations, or library modifications are needed

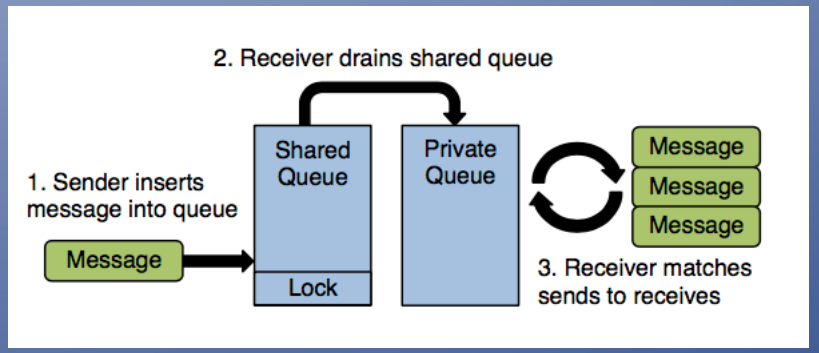
HMPI architecture

3. Message matching

   a) two message queues per receiver, one private, one global.

   b) MCS lock (FIFO)

   c) Drain from global to private in constant time

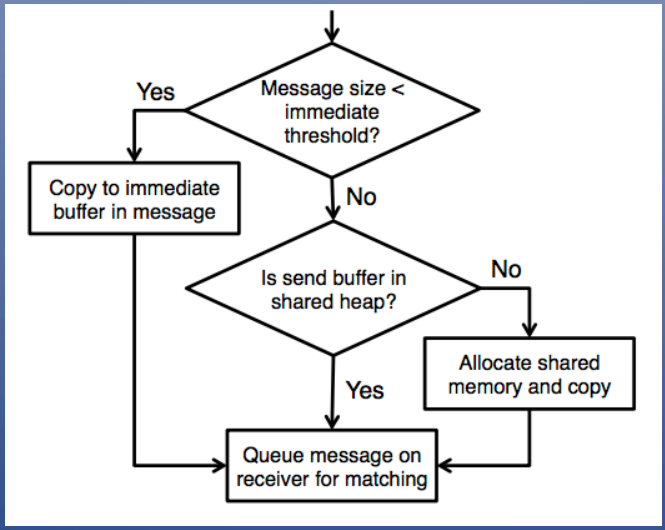


Communication protocols

1. Immediate Transfer Protocol

   memcpy is not always first choice

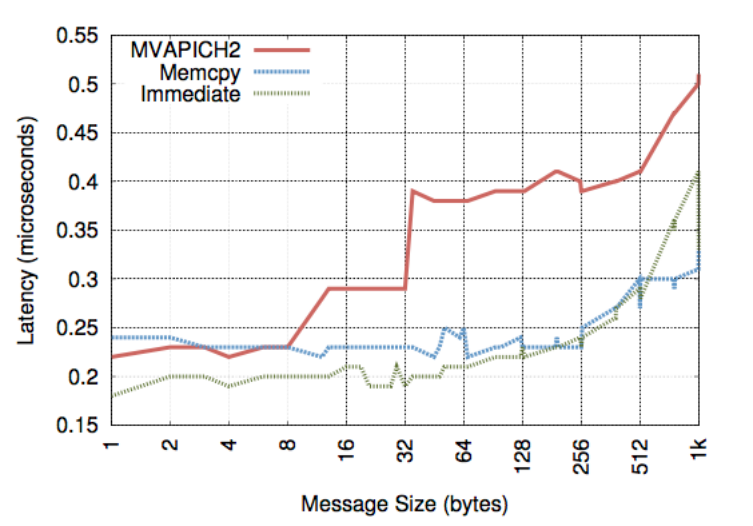
   For small message, use two-copy method



256 bytes threshold

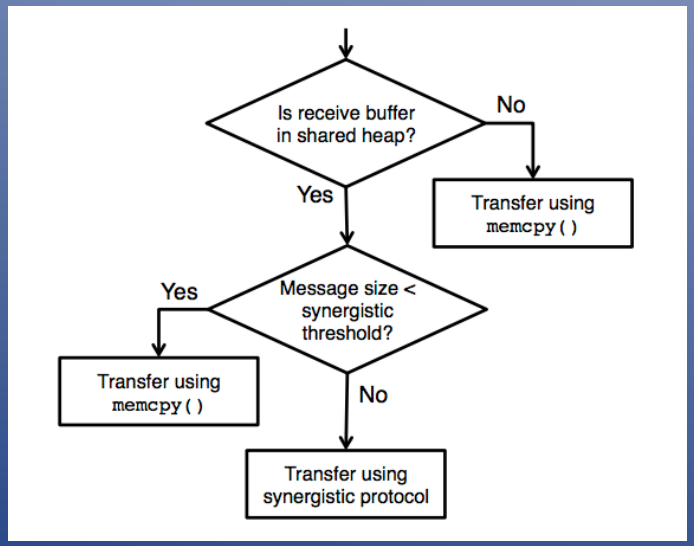
Communication protocols

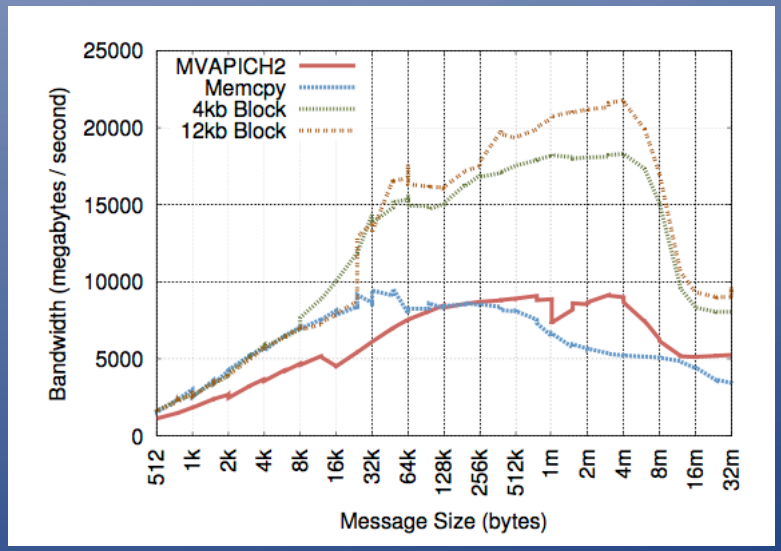
- Sender bring the message into cache
- The time saved by avoiding the cache miss more than makes up for the cost of doing two copies



Communication protocols

2. Synergistic transfer protocol
   a) Bandwidth bottleneck
   b) Receiver can copy entire message without sender





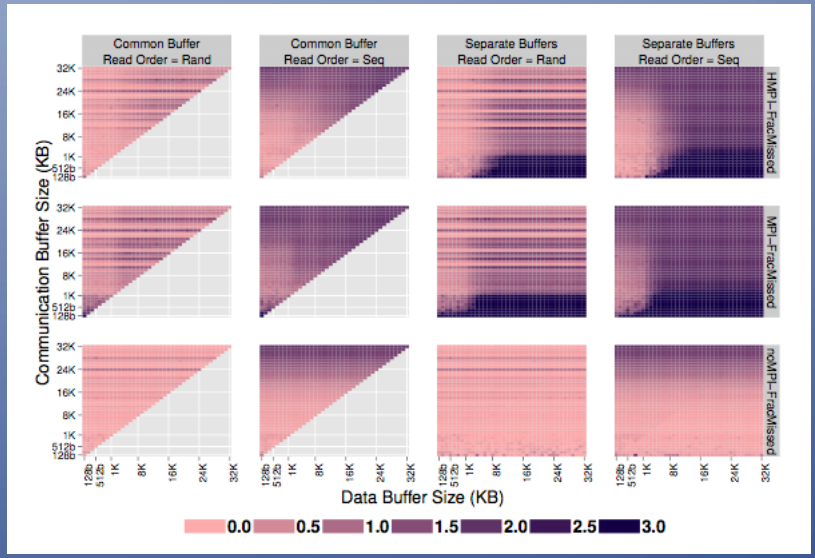
Result analysis

I. Communication analysis

a) Lowest cache miss if no communication

b) HMPI has lower cache miss than MPI

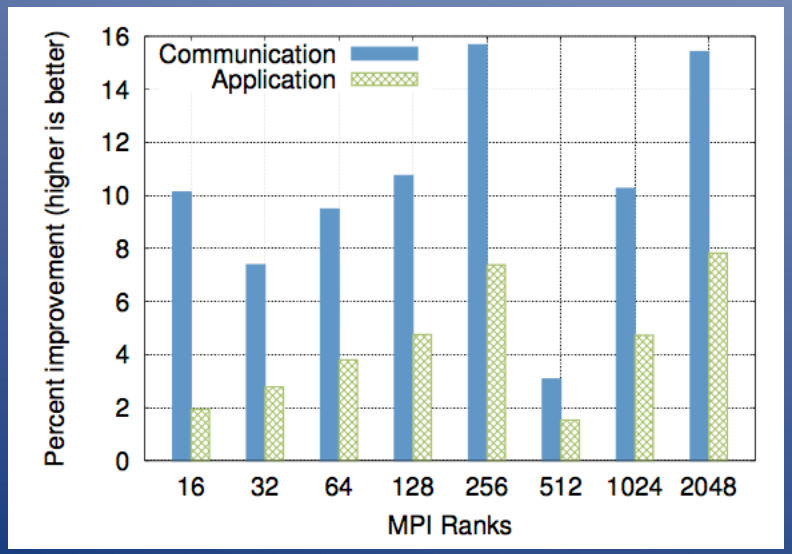
c) Random reading has a better cache hit means cache replacement algorithm not good enough.



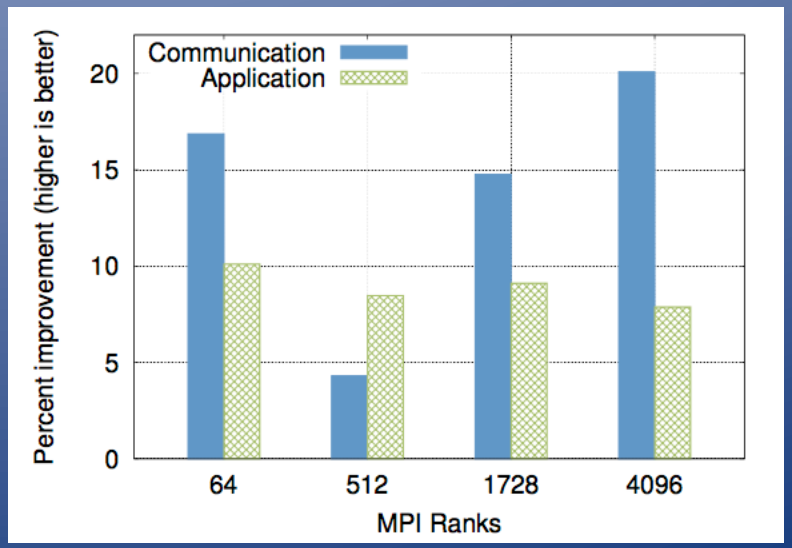
Result analysis

II. Application analysis

1. For MiniMD, communicationg speedups of 3.1-15.7%, resulting in total application time improvements of 1.5-7.9%
2. For LULESH, communication time speedups of 11-46.1% and application time speedups of 14.1% - 19.5%



MiniMD performance



LULESH performance

Conclusion

Approach

- Exploit shared memory hardware in MPI programs that are written for distributed memory systems.
- Utilize a layered model for implementing our optimizations.
- Use above two mechanisms to develop HMPI, a fast layered MPI library that optimizes hybrid shared memory communication

Result

- less on-node communication overheads
- Integrates transparently into legacy applications

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Questions?