NETWORK-BASED COMPUTING LABORATORY

LiMIC: Support for High-Performance MPI Intra-Node Communication on Linux Cluster

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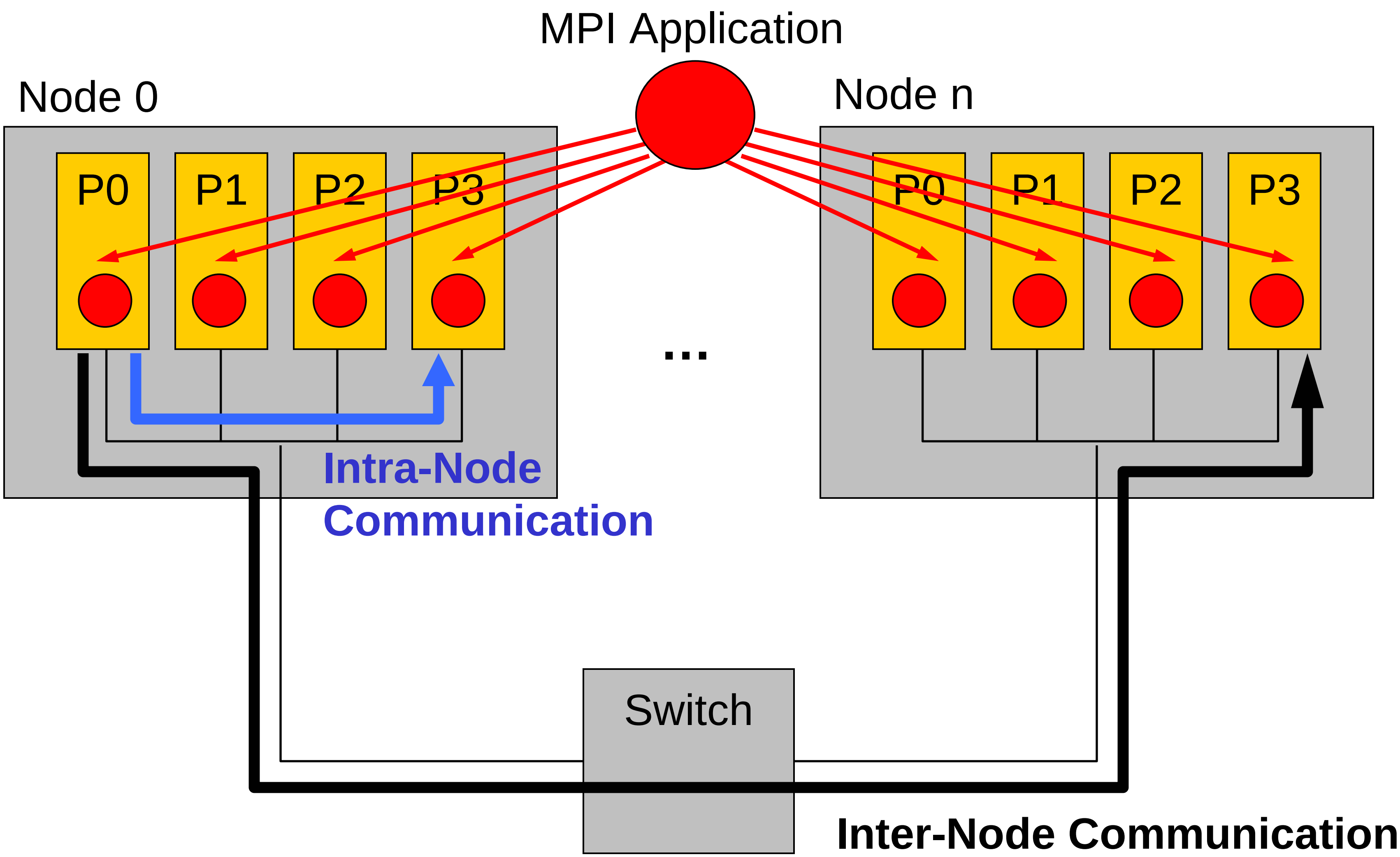
Contents

Introduction

- Cluster of Workstations
  - Symmetric multi-processor (SMP) nodes
    - commonly 2 to 8 processors
    - up to 256 processors (e. g., NASA Columbia)
  - High-speed interconnects
    - InfiniBand, Myrinet, Quadrics, etc.
- Message Passing Interface (MPI)
  - *De facto* standard for writing parallel applications

Intra-Node Communication



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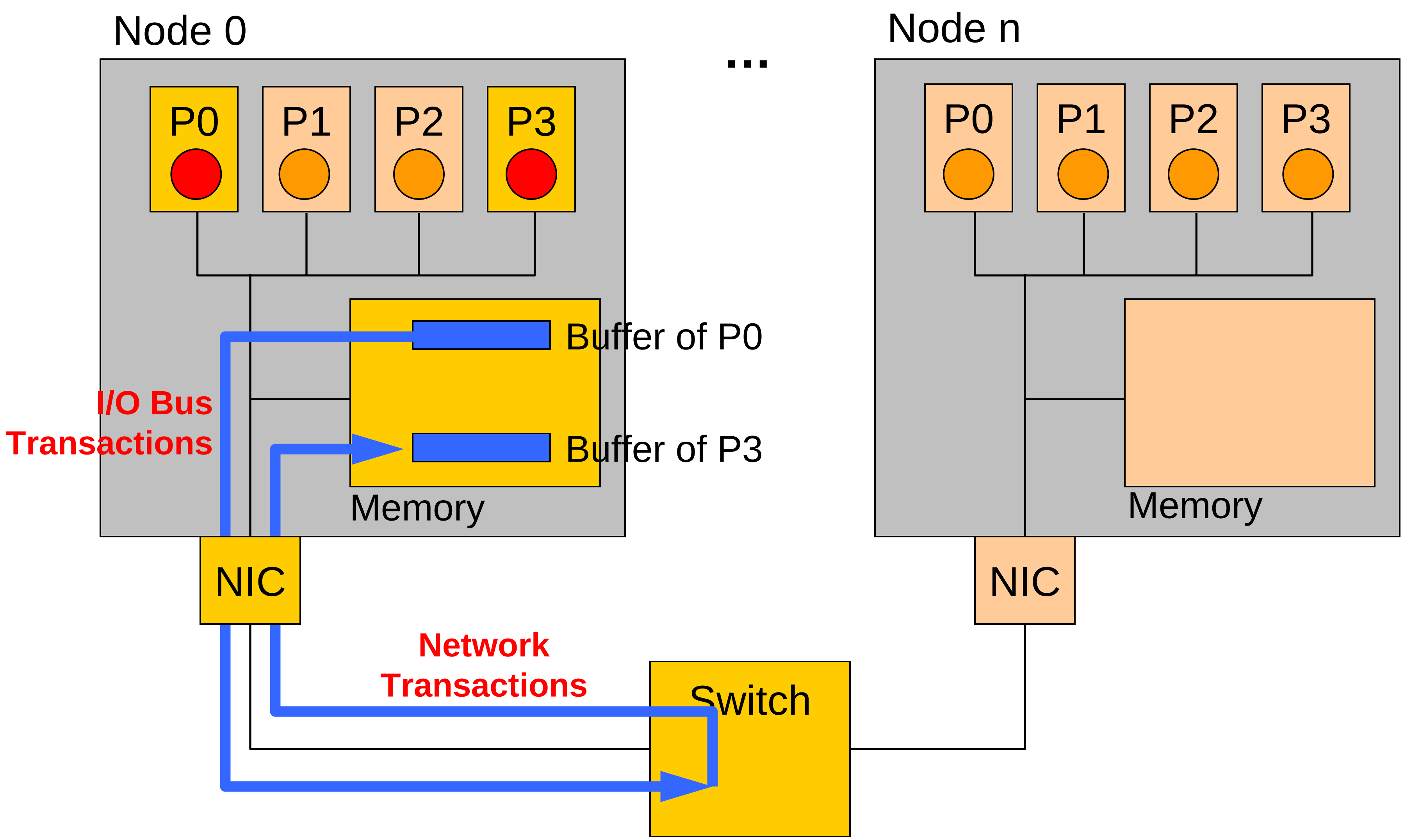
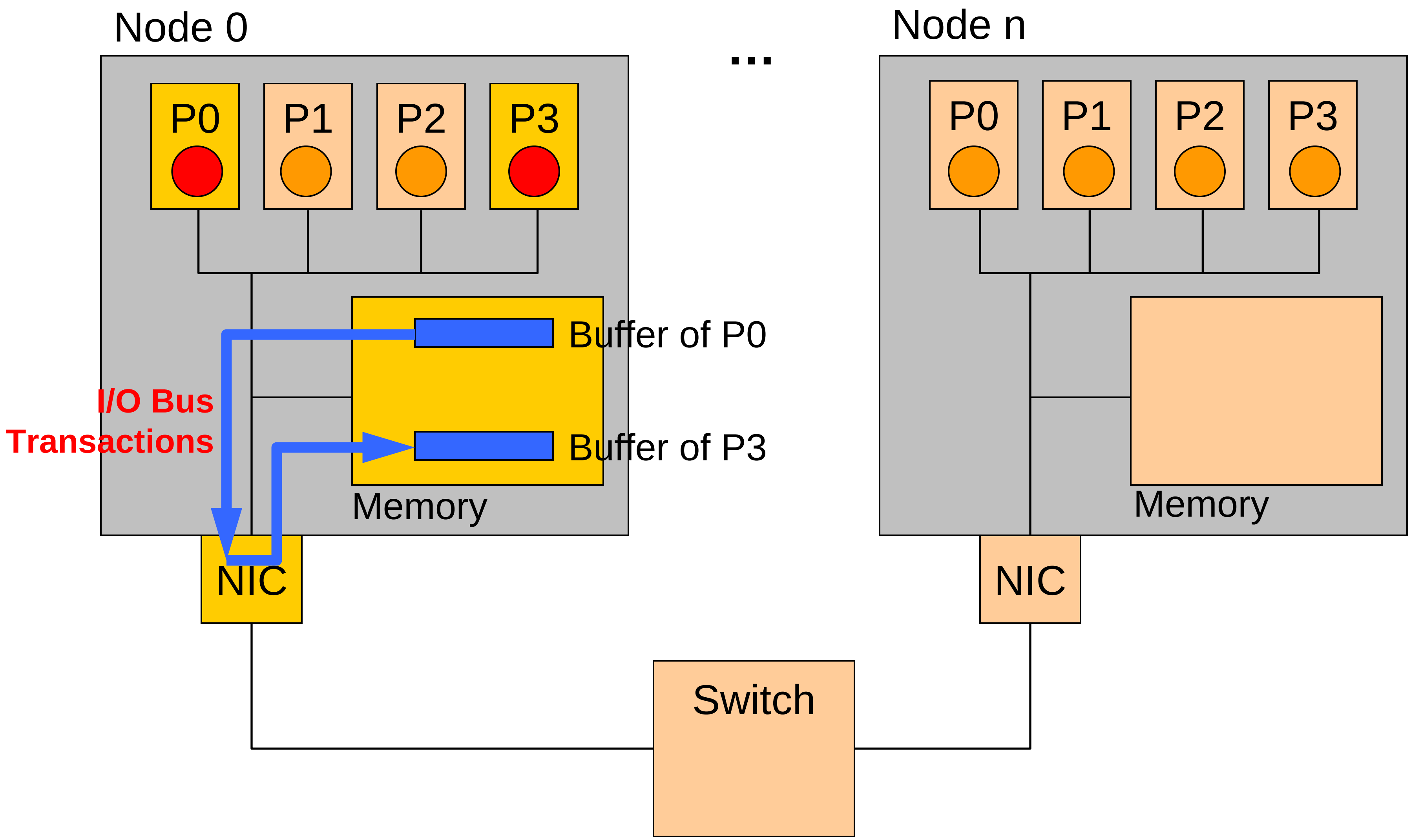
- Existing Intra-Node Communication Mechanisms
- Our Approach: LiMIC
- Design and Implementation Issues
- Performance Evaluation
- Conclusions and Future Work

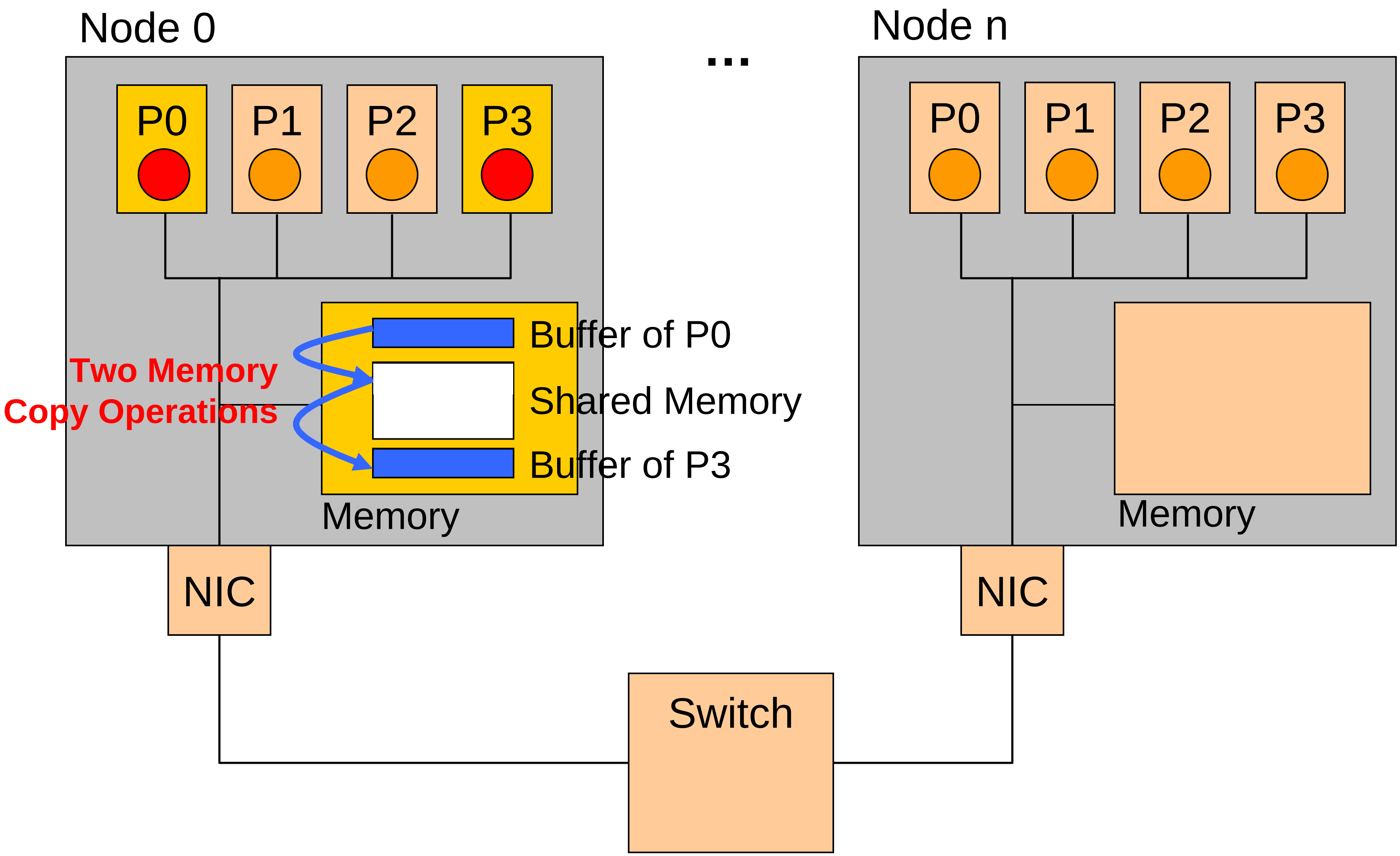
Switch-Level Loopback



NIC-Level Loopback



User-Space Shared Memory



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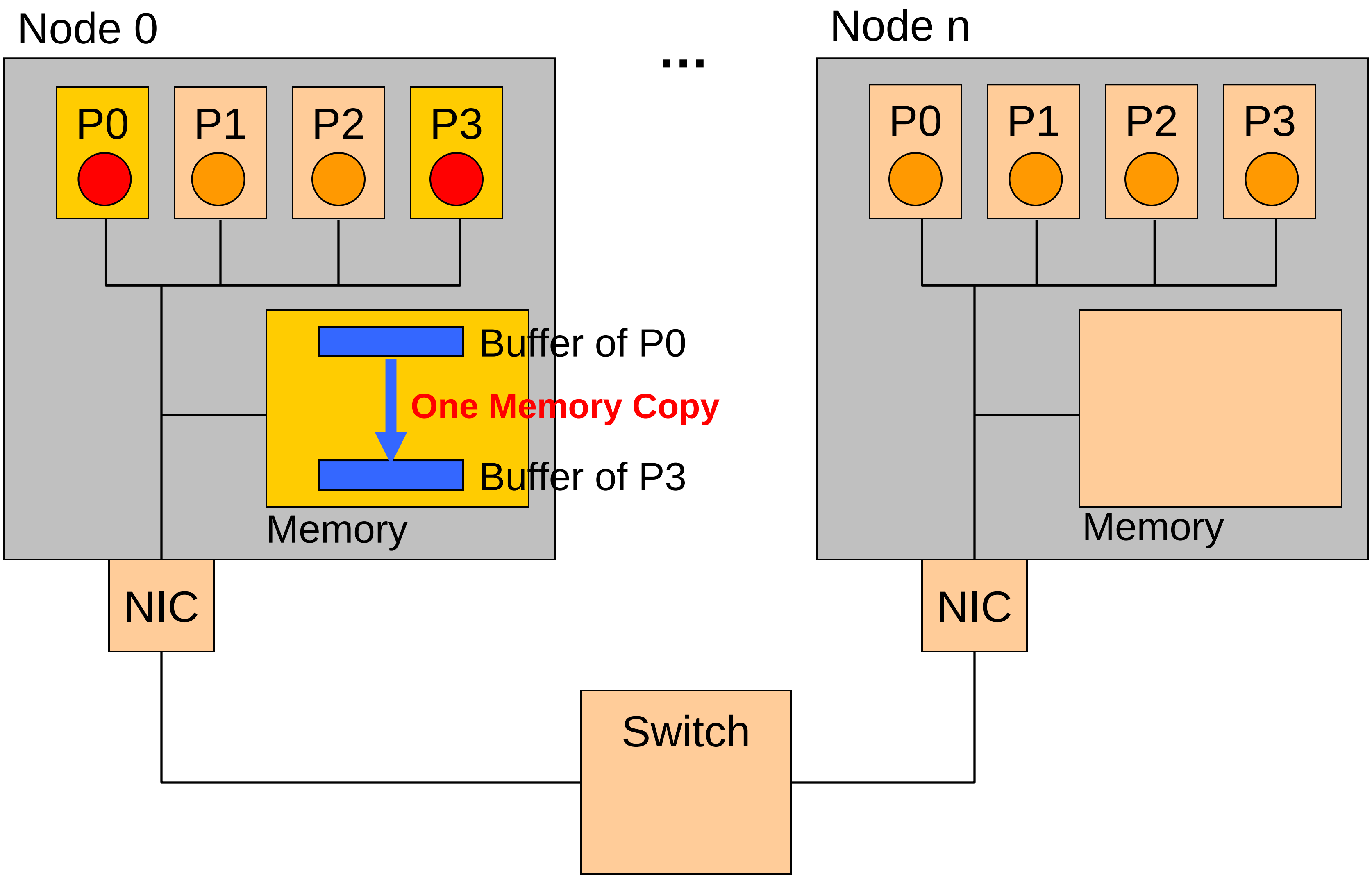
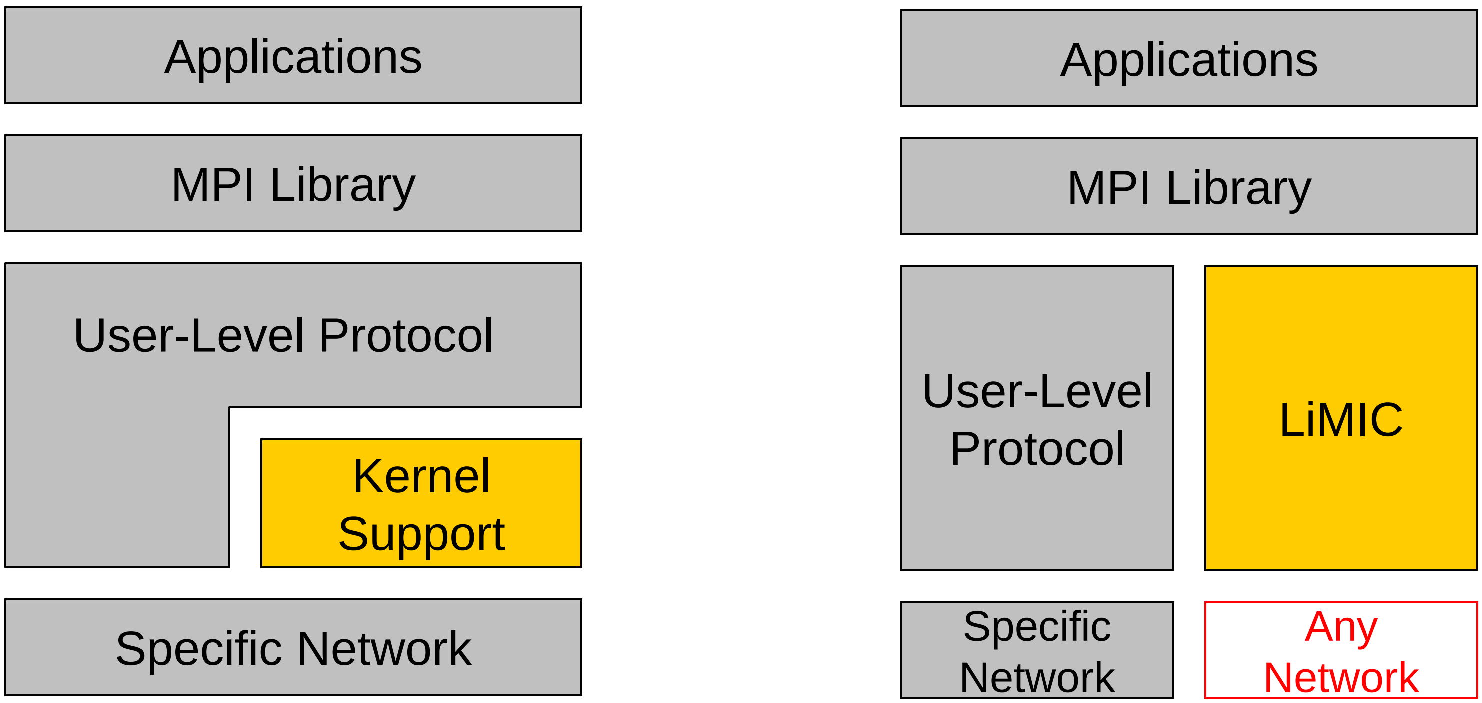
Kernel-Based Memory Mapping



Our Approach: LiMIC

(Linux Kernel Module for MPI Intra-Node Communication)

Earlier Design Approach | LiMIC Design Approach



No portability to other user-level protocol

No optimization-space for the MPI library developer

No other current generation MPI implementations provide such a kernel support !!!

Portability and Optimizations

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Design and Implementation Issues

- Kernel Module Based Design
- Portable and MPI Friendly Interface
- Memory Mapping Mechanism
- Copy Mechanism
- MPI Message Matching

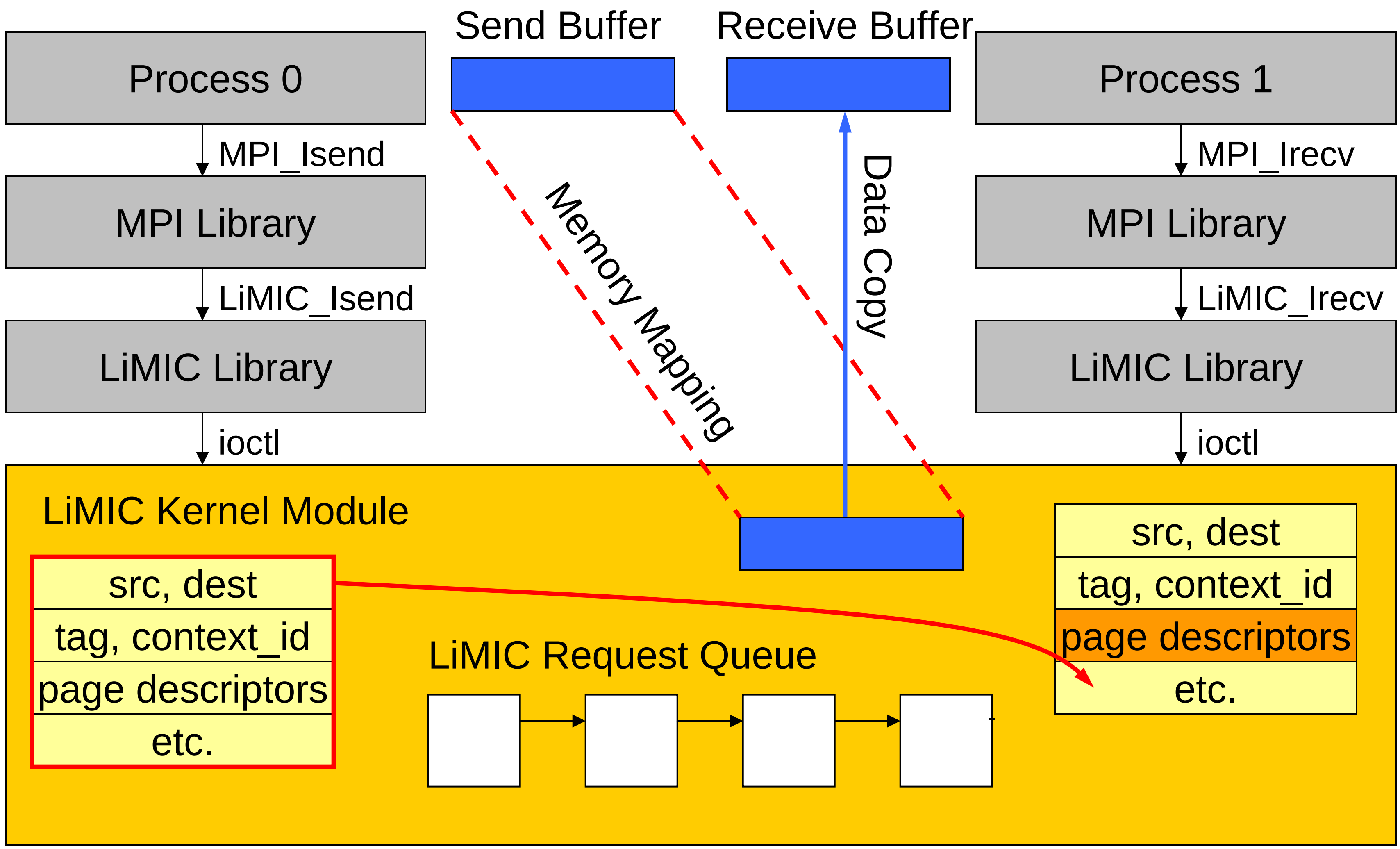
Kernel Module Based Design

- Linux Run-Time Loadable Kernel Module
  - No kernel modification
  - Portable across major versions
- LiMIC Kernel Module Can Be Either:
  - An independent module with device driver
  - Or extensions of device driver

Portable and MPI Friendly Interface

- Independent Interface on:
  - Communication library
  - MPI implementation
- Interfaces
  - **`LiMIC_Isend (dest, tag, context_id, buf, len, req)`**
  - **`LiMIC_Irecv (src, tag, context_id, buf, len, req)`**
  - **`LiMIC_Wait (src/dest, req)`**
  - Etc.
- Interfaces trap into the kernel internally by calling **`ioctl()`** system call

Memory Mapping Mechanism



Copy Mechanism

- Design Alternatives:
  – Copy on function calls of receiver
    - receiver dependent progress
  – Copy on wait function call
    - memory pin-down on both sender and receiver
  – Copy on send and receive calls
    - better progress
    - less resource usage
    - not prone to skew between processes

MPI Message Matching

- MPI_Init
  - Exchange node information for every processes
- Message Matching Based on Source
  - Source in the same node
  - Source in a different node
  - Source in the same node and MPI_ANY_TAG
  - MPI_ANY_SOURCE and MPI_ANY_TAG
    - receive request is posted in the MPI queue
    - progress engine calls LiMIC_Iprobe
    - If message matches with request, calls LiMIC_Irecv

MVAPICH: MPI over InfiniBand

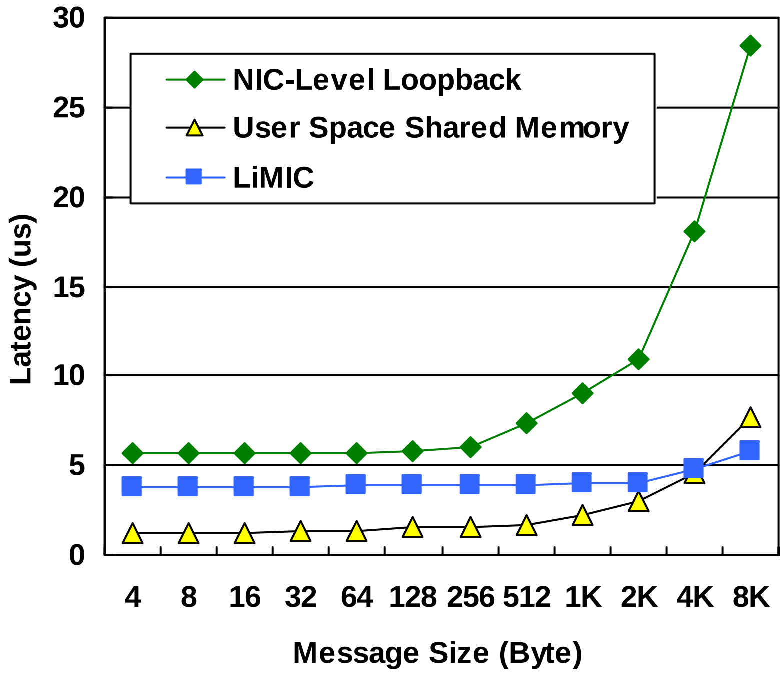
- http://nowlab.cis.ohio-state.edu/projects/mpi-iba/
- Powering Supercomputers in the TOP 500 List
  - 7th, 1100-node dual Apple Xserve 2.3 GHz cluster at Virginia Tech
  - 98th, 288-node dual Opteron 2.2 GHz cluster at United Institute of Informatics Problems (Belarus)
- Being Used by More than 220 Organizations World-Wide
- Latest Release
  - MVAPICH (MPI-1): 0.9.5
  - MVAPICH2 (MPI-2): 0.6.0

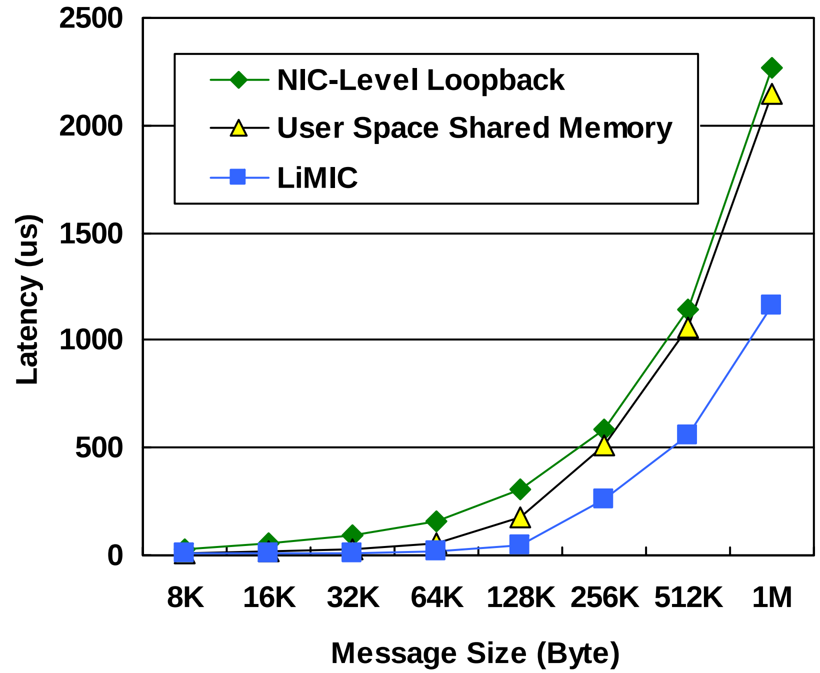
Contents

Performance Evaluation

- Experimental System
  - Cluster A
    - 8 nodes with dual Intel Xeon 3.0GHz processor and 512KB L2 cache
  - Cluster B
    - 8 nodes with dual Intel Xeon 2.4GHz processor and 512KB L2 cache
- Experimental Results
  - Microbenchmarks: Latency and Bandwidth
  - Cost Breakdown
  - HPCC Effective Bandwidth
  - NAS Integer Sort

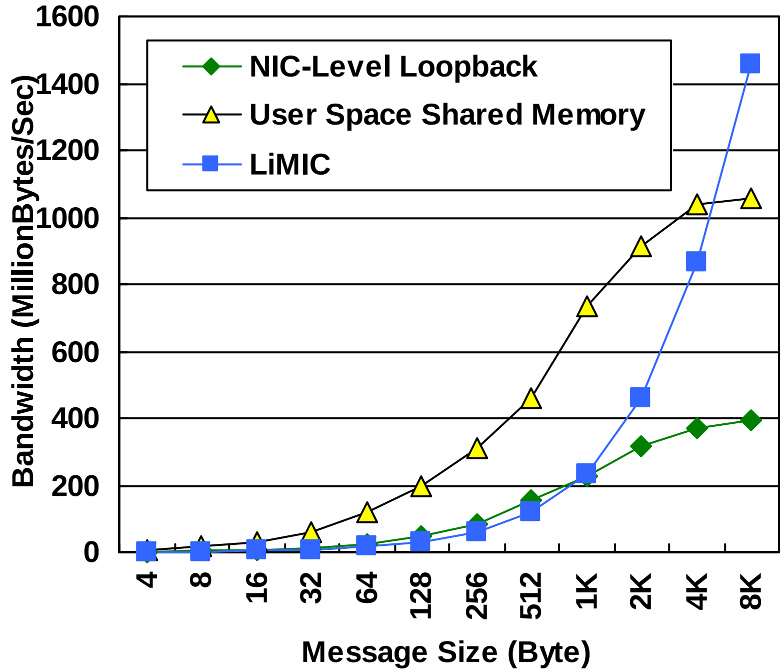
Latency

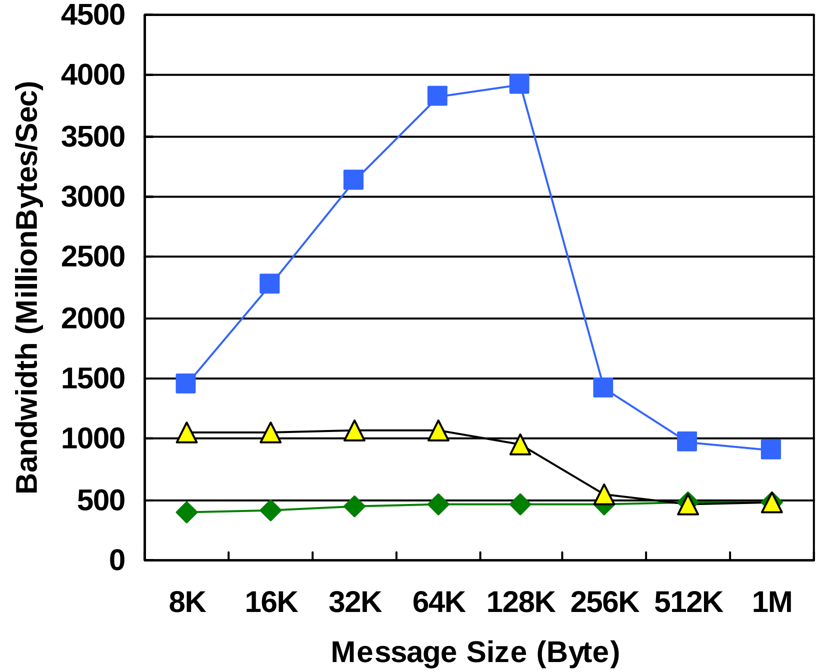




- For Small Messages, User Space Shared Memory is Better than Others
- For Medium and Large Messages, LiMIC is Better than Others
  - For 128KB, the latency of LiMIC is 71% less than that of User Space Shared Memory

Bandwidth





- For Small Messages, User Space Shared Memory is Better than Others
- For Medium and Large Messages, LiMIC is Better than Others
  - For 128KB, the bandwidth of LiMIC is 313% higher than that of User Space Shared Memory
  - The peak bandwidth is 3929 MillionBytes/Sec

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Threshold

- MVAPICH-0.9.4
  - User-space shared memory
    - Message Size <= 256KB
  - NIC-level loopback
    - Message Size > 256KB
- MVAPICH-LiMIC
  - User-space shared memory
    - Message Size <= 4KB
  - LiMIC
    - Message Size > 4KB

L. Chai, S. Sur, H. -W. Jin, and D. K. Panda, “Analysis of Design Considerations for Optimizing Multi-Channel MPI over InfiniBand,” Workshop on Communication Architecture on Clusters (CAC 05) in conjunction with IPDPS 2005, 2005.

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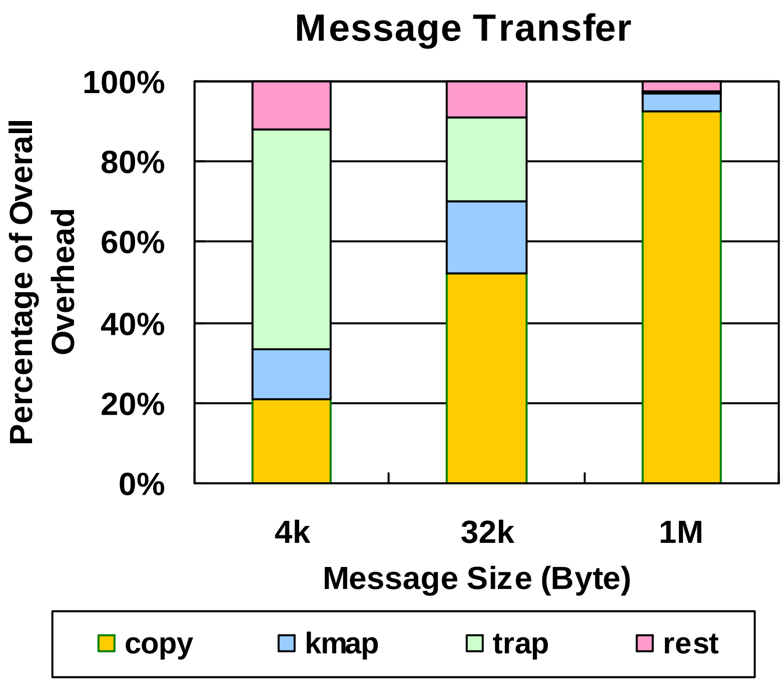
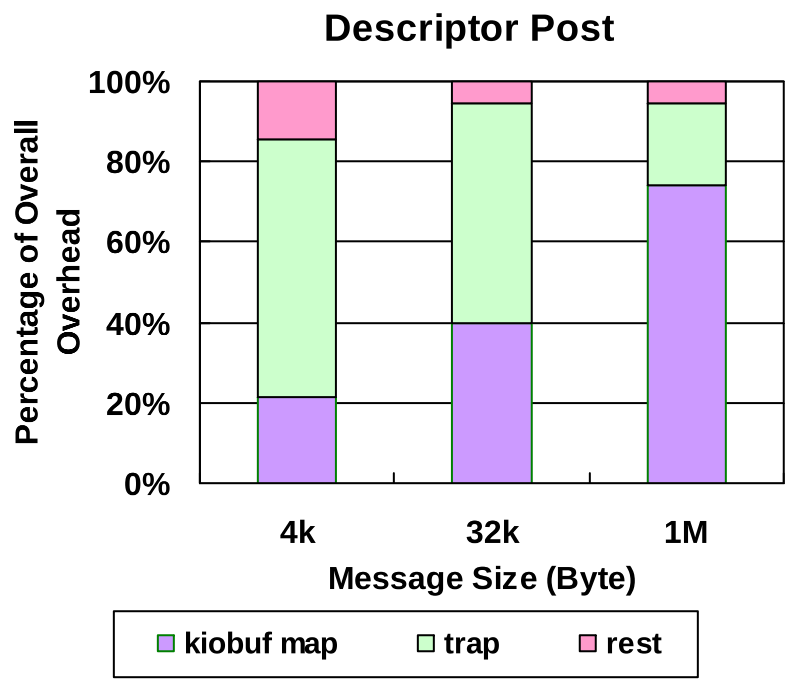
LiMIC Cost Breakdown





- For small messages, the kernel trap overhead is dominant
- For large messages, the copy overhead is dominant

- For small messages, the kernel trap overhead is dominant
- For large messages, the page descriptor mapping overhead is dominant

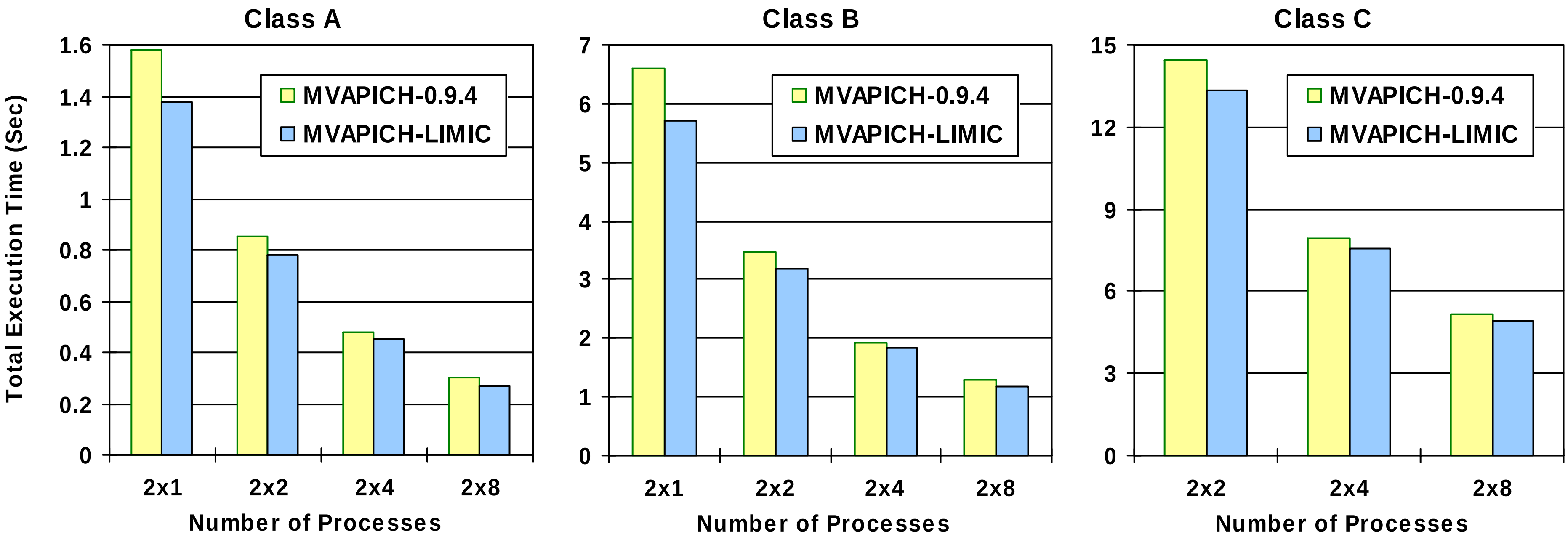
HPCC Effective Bandwidth

(MB/s)

Cluster	Config.	MVAPICH-0.9.4	MVAPICH-LiMIC	Improv.
A	2x1	152	244	61%
	2x2	317	378	19%
	2x4	619	694	12%
	2x8	1222	1373	12%
B	2x1	139	183	31%
	2x2	282	308	9%
	2x4	545	572	5%
	2x8	1052	1108	5%
A&B	2x16	2114	2223	5%

- The improvement percentage remains constant as the number of processes is increased

NAS Integer Sort



- MVAPICH-LiMIC achieves 10%, 8%, and 5% improvement of execution time running Classes A, B, and C on 2x8, respectively

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Conclusions

- LiMIC
  - High performance MPI intra-node communication
  - MPI friendly interface
  - Independent on proprietary communication libraries
- Performance Results
  - Improvement of latency and bandwidth up to 71% and 313%
  - Improvement of effective bandwidth up to 12% on an 8-node cluster
  - 10% Improvement of NAS IS Class A on an 8-node cluster

Future Work

- Zero-Copy Intra-Node Communication
  - Copy-on-write
- Blocking Support
  - Message driven process scheduling
- Linux Kernel Version 2.6
  - NUMA architecture

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Thank You

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http://nowlab.cis.ohio-state.edu/