System Software Laboratory

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The LiMIC Strikes Back

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Contents

- MPI Intra-node Communication
- Introduction of LiMIC
- Optimization for Huge Pages
- Conclusions and Future Work

Multi/Many-core Processors

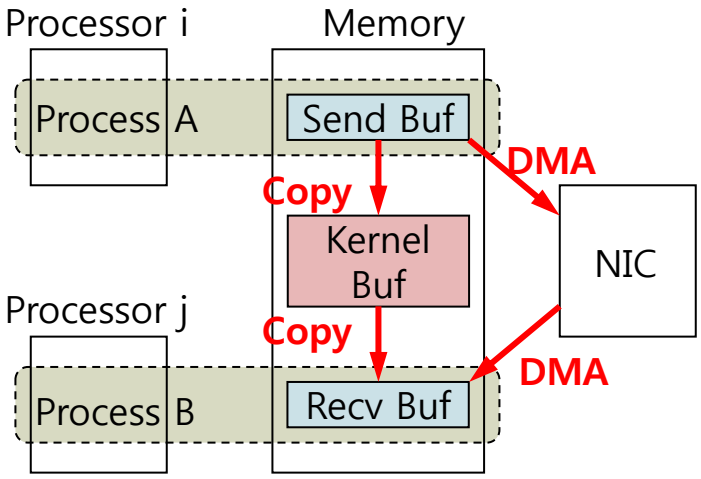
Xeon 5100 Series (Woodcrest)	Xeon 5500 Series (Gainestown)	Xeon 5600 Series (Westmere-EP)	Xeon E5-2600 Series (Sandy Bridge-EP)
2	4	6	8

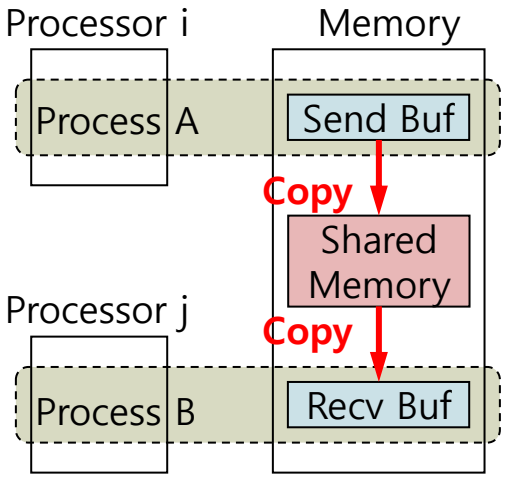
Xeon E5-2600 v2 Series (Ivy Bridge-EP)	Xeon E5-2600 v3 Series (Haswell-EP)	Xeon E7 v4 Family (Broadwell)
12	18	24

Xeon Phi X100 Series (Knights Corner)	Xeon Phi 7200 Series (Knights Landing)
61	72

MPI Intra-node Communication

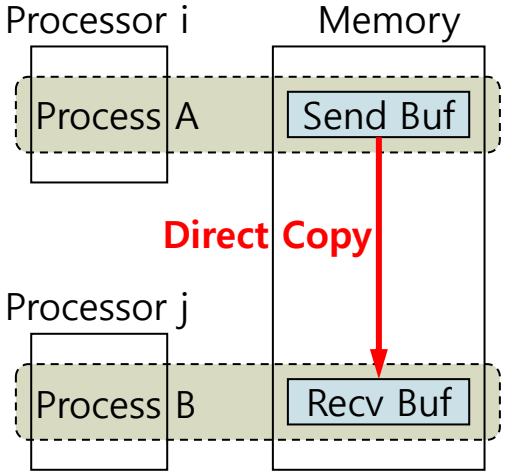
- Loopback
  - NIC and TCP/IP provide a loopback path
  - Two DMAs or two data copies + system calls
- Shared Memory
  - Communicate through a memory area shared between MPI processes
  - Two data copies





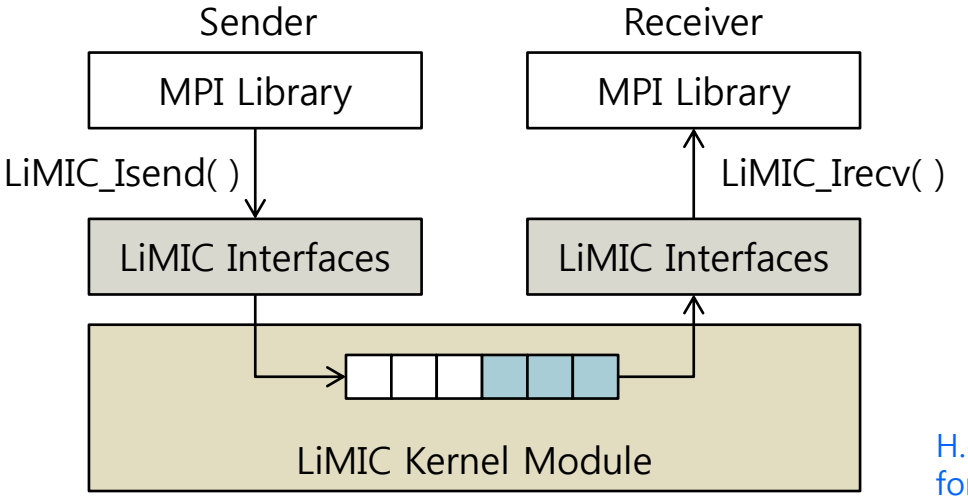
MPI Intra-node Communication

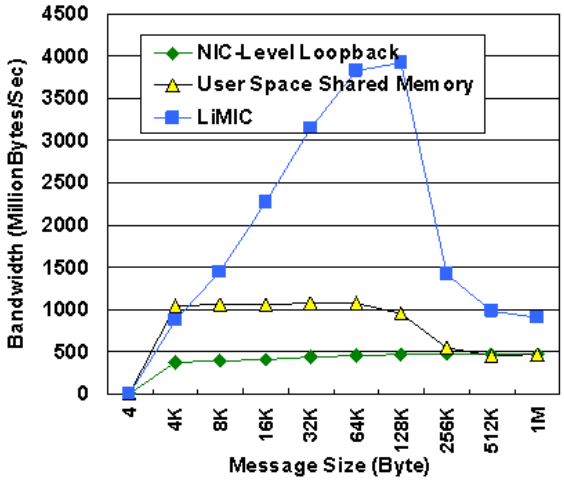
- Memory Mapping
  - Single data copy by means of memory mapping
    - Beneficial for large messages
  - LiMIC (**Li**nux kernel module for **MPI** **I**ntra-node **C**ommunication) is the first implementation of the memory mapping mechanism



History of LiMIC

- 1st Generation LiMIC
  - A stand-alone kernel module for intra-node comm.
  - Could improve the latency and bandwidth up to 71% and 313%, respectively
  - Internal queues had several scalability and stability issues

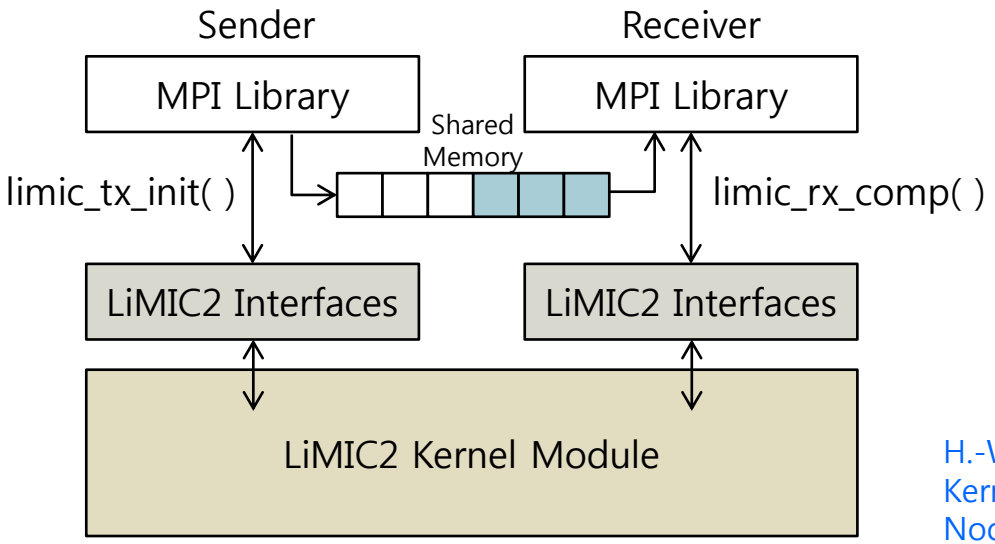


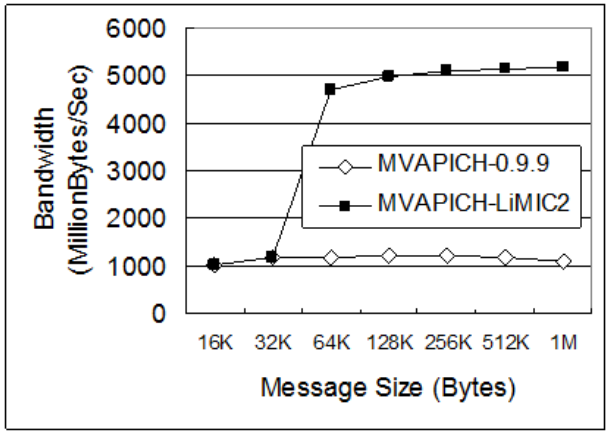


H.-W. Jin, S. Sur, L. Chai, and D. K. Panda, "LiMIC: Support for High-Performance MPI Intra-Node Communication on Linux Cluster," In Proc. of ICPP-05, Jun. 2005.

History of LiMIC

- 2nd Generation LiMIC (LiMIC2)
  - Provided primitives to handle memory mapping
  - Removed in-kernel message queues
  - Could improve the latency and bandwidth up to 81% and 358%, respectively





H.-W. Jin, S. Sur, L. Chai, and D. K. Panda, "Lightweight Kernel-Level Primitives for High-Performance MPI Intra-Node Communication over Multi-Core Systems," In Proc. of Cluster 2007, Sep. 2007.

History of LiMIC

- MVAPICH2 with LiMIC2
  - (Jun. 2009) LiMIC2-0.5 was publically released with MVAPICH2-1.4RC1
  - (Current) LiMIC2-0.5.6 is being released with the latest MVAPICH2 version
    - mvapich2-src]$ ./configure --with-limic2 [omit other configure options]
    - mvapich2-src]$ mpirun_rsh -np 4 -hostfile ~/hosts MV2_SMP_USE_LIMIC2=1 [path to application]

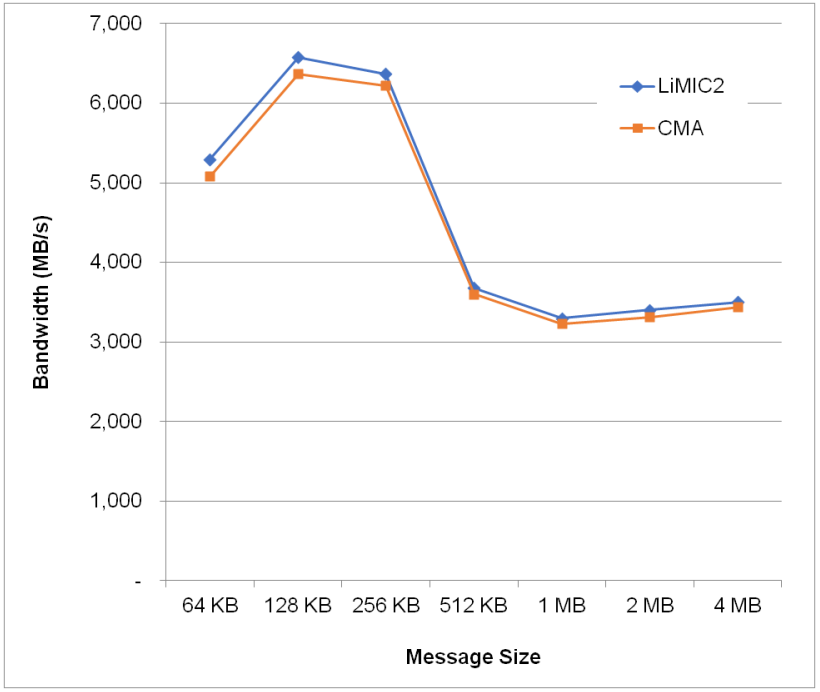
MVAPICH

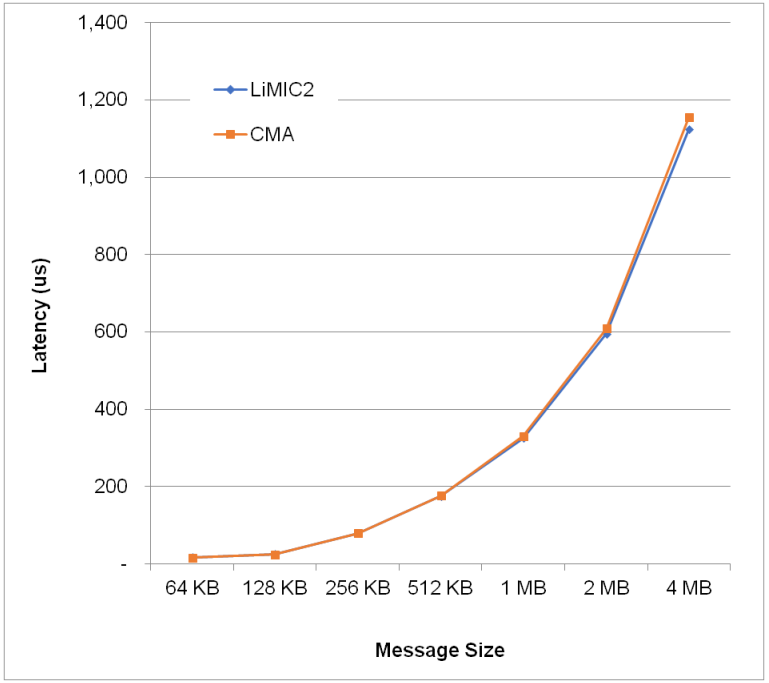
History of LiMIC

- LiMIC2 Has Inspired Several Studies
  - KNEM
    - Addressed a security issue
      - B. Goglin and M. Stephanie, "KNEM: a generic and scalable kernel-assisted intra-node MPI communication framework," JPDC, Feb. 2013.
    - OpenMPI includes KNEM support
  - CMA
    - In-kernel implementation + New system calls
      - J. Vienne, "Benefits of Cross Memory Attach for MPI Libraries on HPC Clusters," In Proc. of XSEDE 14, Jul. 2014.
    - Default intra-node communication channel for large messages in MVAPICH2

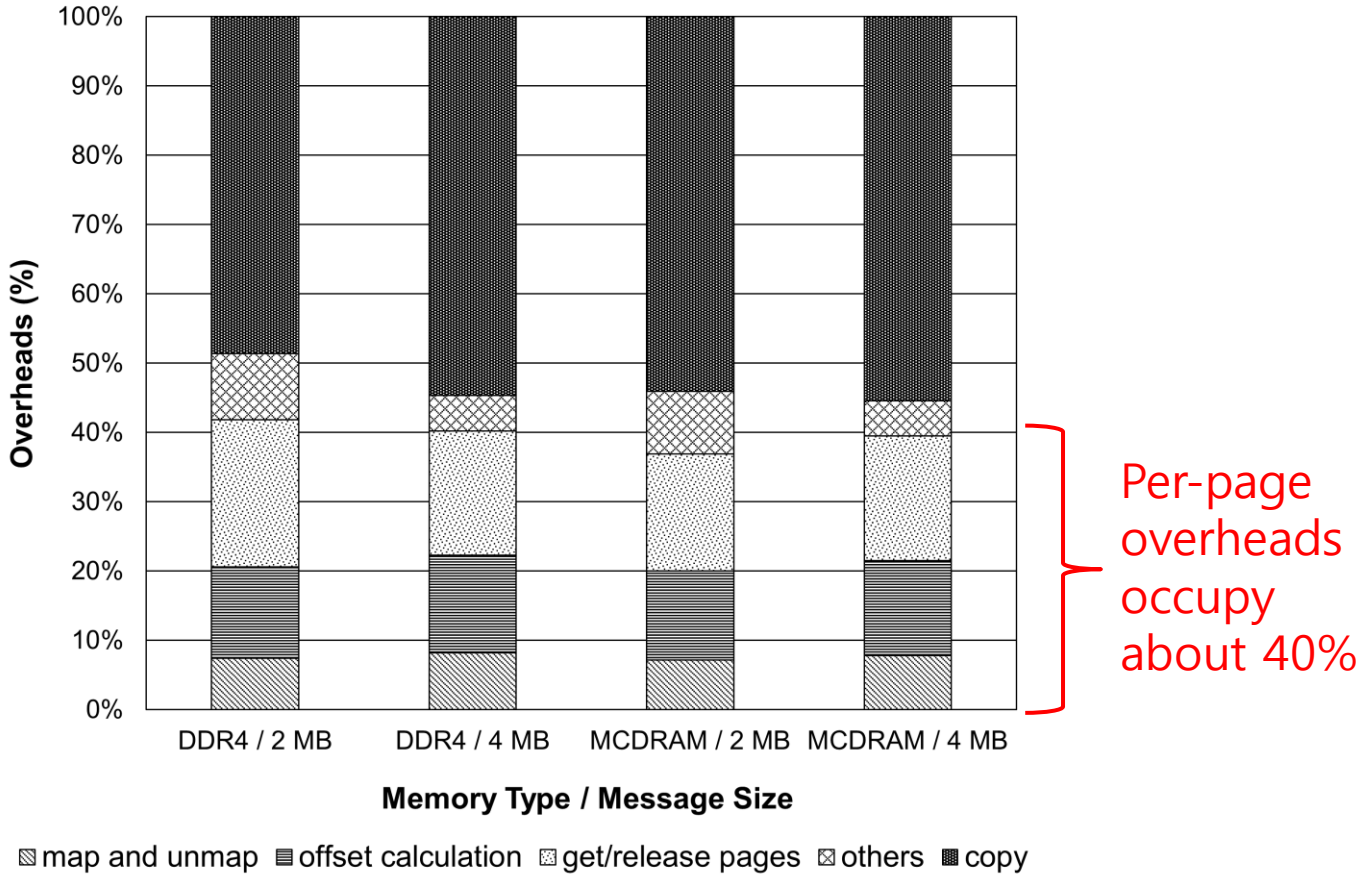
No More Significant Performance Optimizations?

- MPI Point-to-Point Communication
  - LiMIC2 and CMA show almost the same performance

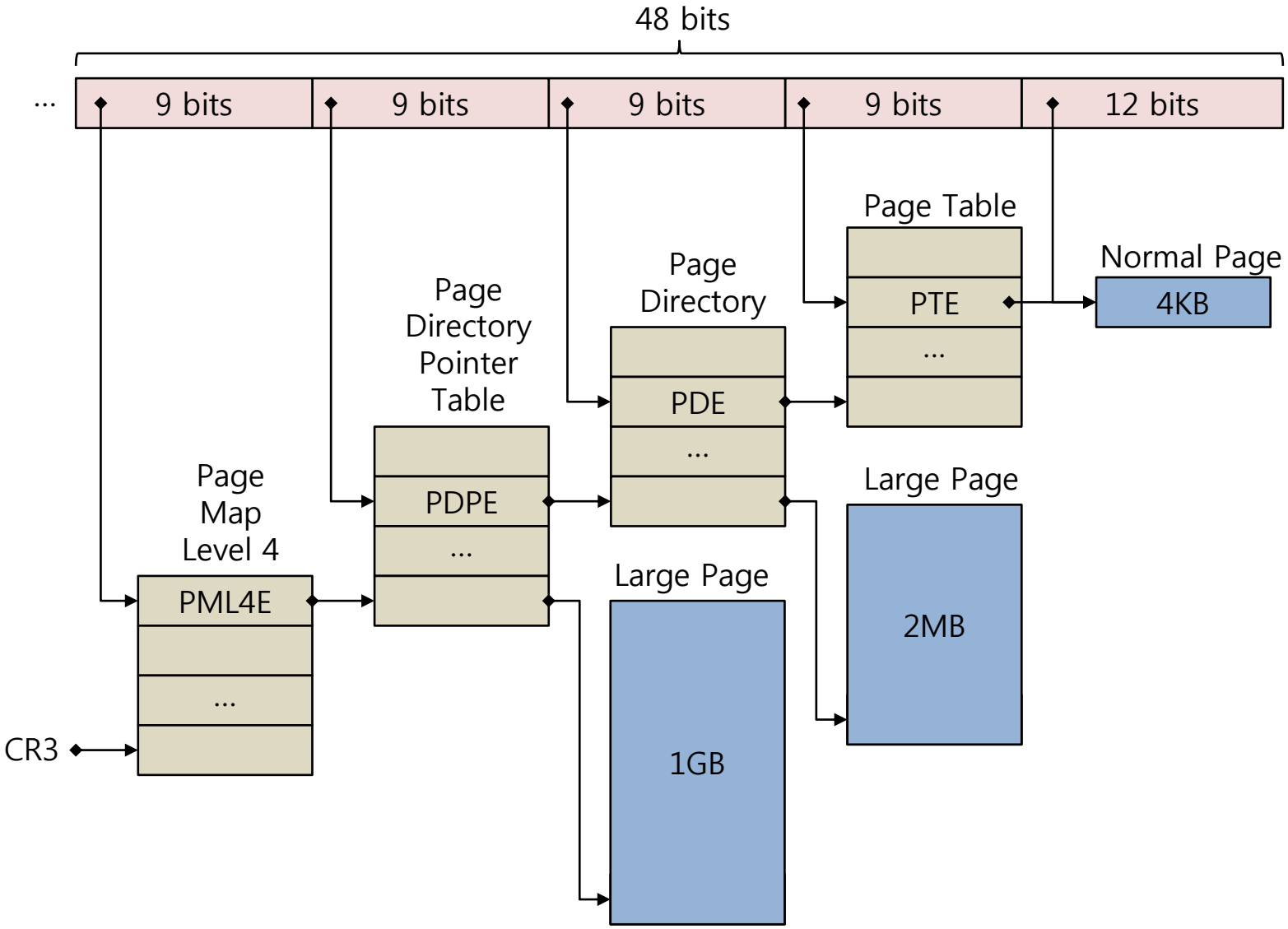




Overhead Breakdown



Large Pages in x86-64

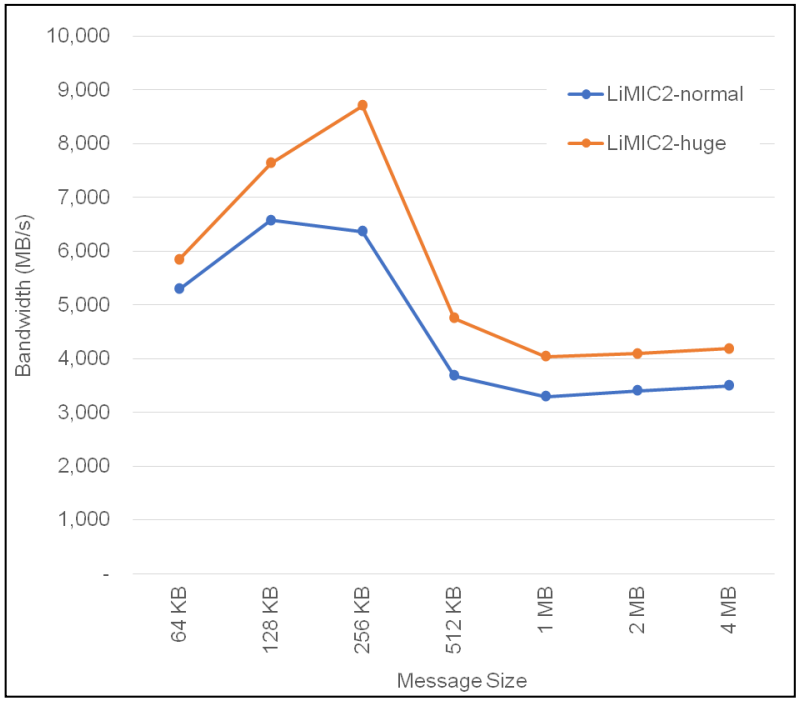


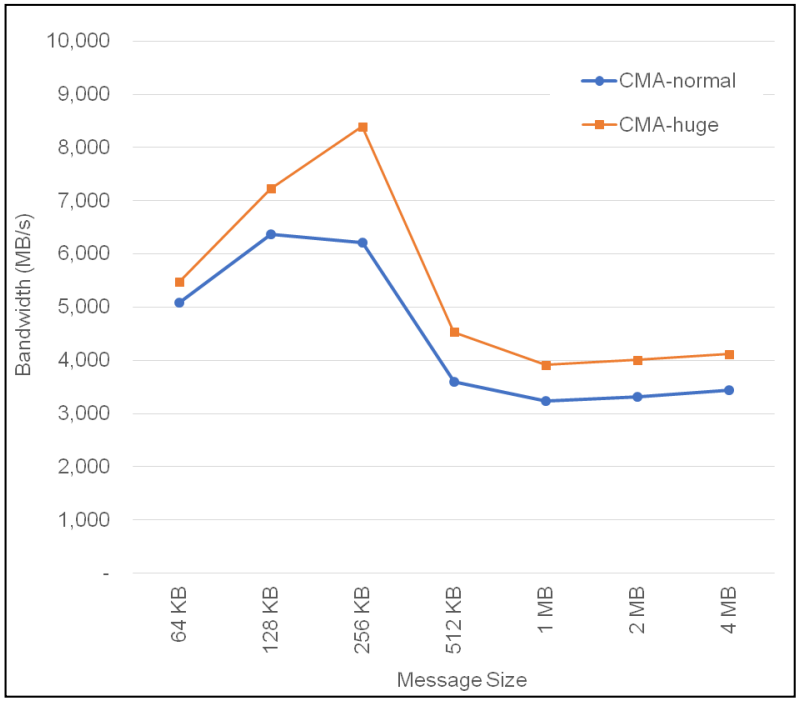
Large Pages in Linux

- Persistent Huge Pages
  - Provide a persistent pool for huge pages that are not split into normal pages
  - hugetlbfs
    - ~]$ echo [# of huge page] > /proc/sys/vm/nr_hugepages
    - `get_huge_pages()` and `free_huge_pages()` in libhugetlbfs
- Transparent Huge Pages
  - Transparent to user applications in allocation and use
  - Can be fallen back to normal pages if necessary

Current Implementations

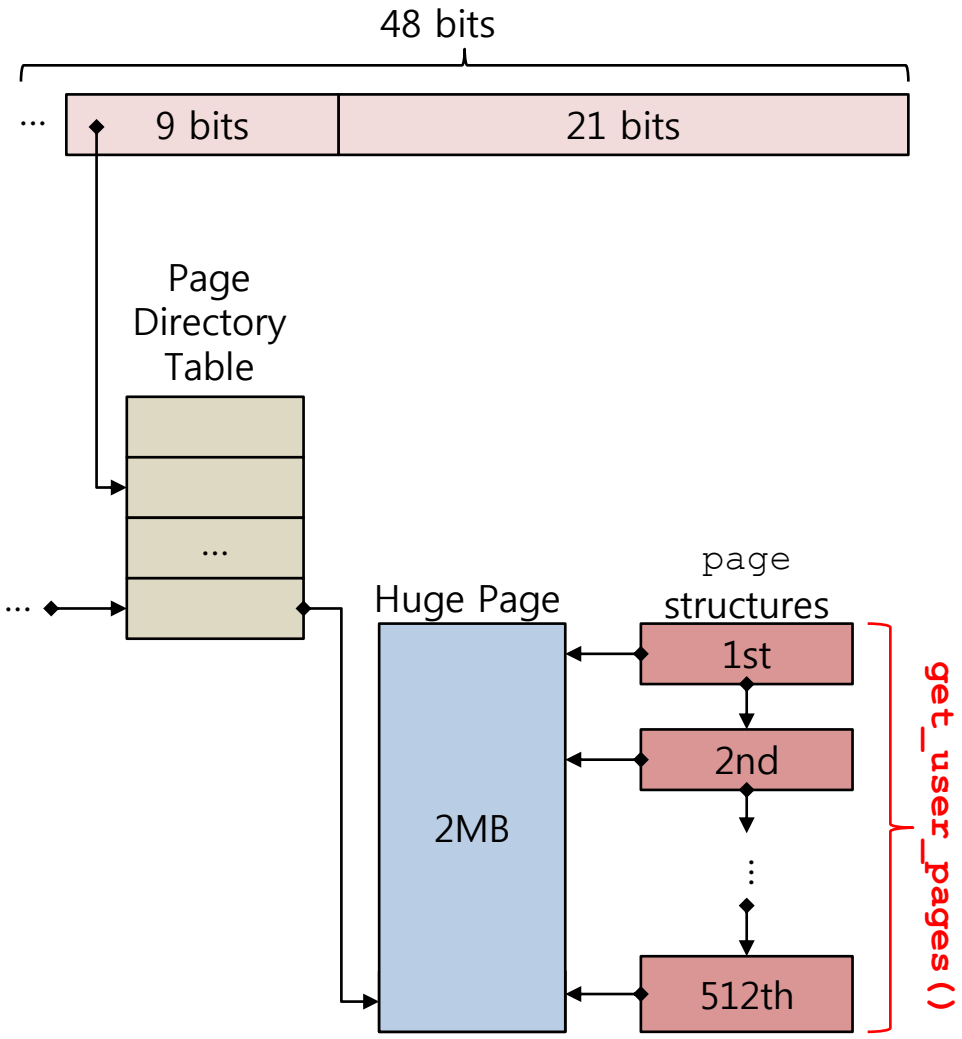
- Performance with Huge Pages
  - Using huge pages improves the bandwidth up to 37% with LiMIC2 and 35% with CMA, respectively
  - Most of benefits come from less number of TLB misses





Current Implementations

- Assume Normal Page
  - Offset calculation
    - Uses PAGE_SIZE
  - `get_user_pages()`
    - Returns the corresponding `page` structures for a given virtual address

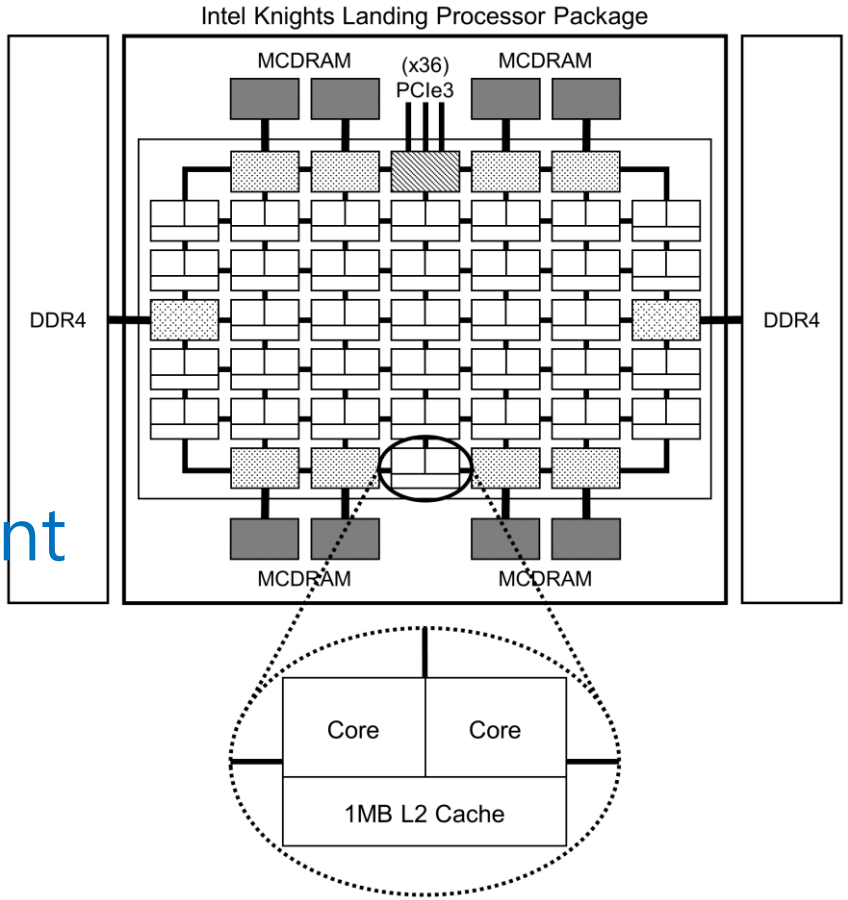


Support for Huge Pages

- Checking If a Page is Huge
  - Persistent huge pages
  - Transparent huge pages
- Offset Calculation for Less Iteration
  - Uses HPAGE_SIZE for buffers backed by huge pages
- Efficient Usage of `get_user_pages()`
  - The first `page` structure is sufficient to map all pages that belong to the huge page

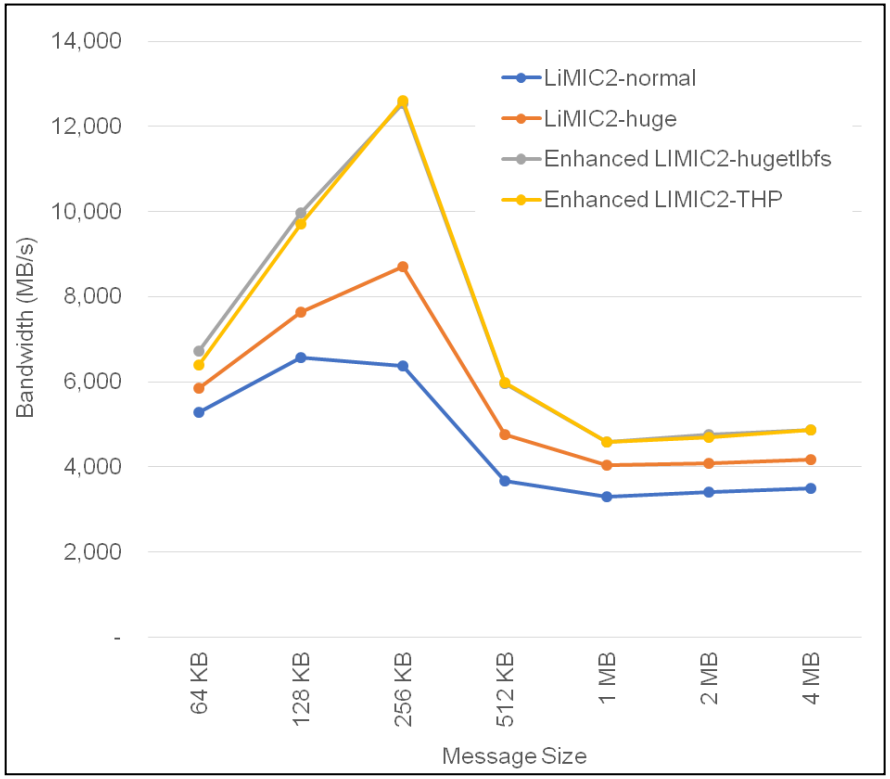
Performance Evaluation

- Experimental System
  - Intel KNL 7210
    - 64 cores
    - 16GB MCDRAM
      - Flat mode
    - Quadrant mode
  - 96GB DDR4
- Performance Measurement
  - OSU-microbenchmarks
    - osu_bw
    - osu_latency
    - osu_alltoall



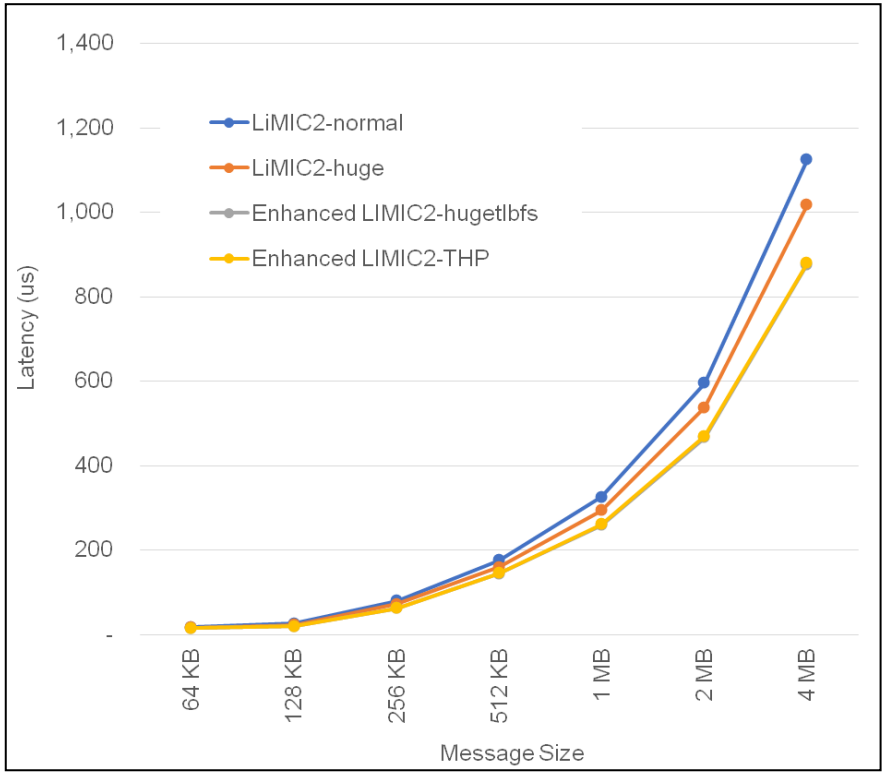
Performance Evaluation

- Point-to-Point Bandwidth
  - Enhanced LiMIC2 could improve the bandwidth up to 44% with huge pages



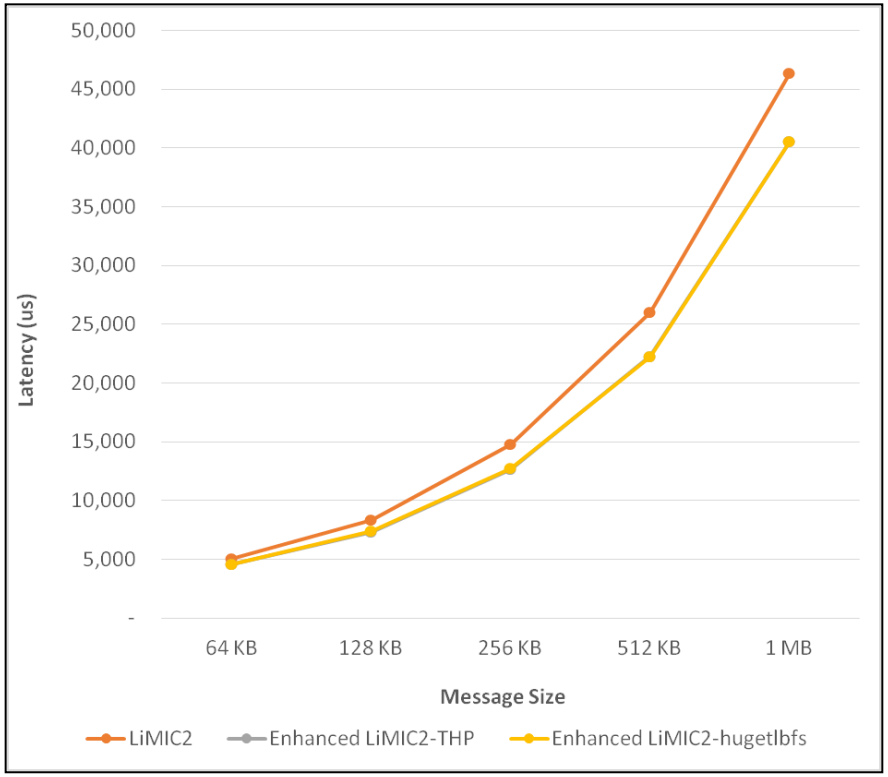
Performance Evaluation

- Point-to-Point Latency
  - Enhanced LiMIC2 could reduce the latency up to 14% with huge pages



Performance Evaluation

- All-to-All Collective
  - Enhanced LiMIC2 could reduce the collective latency up to 14% with huge pages



EuroMPI/USA 2017

- J.-Y. Cho, H.-W. Jin and D. Nam, "Enhanced Memory Management for Scalable MPI Intra-node Communication on Many-core Processor," In Proc. of EuroMPI/USA 2017, Sep. 2017
  - Efficient buffer allocation for on-package memory (i.e., MCDRAM)
  - Enhancement for huge pages
  - Evaluation results for concurrent point-to-point communications

Concluding Remark

- Support for Huge Pages
  - Existing implementations for intra-node communication could not fully benefit from huge pages
  - Suggested an enhanced memory mapping scheme for huge pages
    - Improved the bandwidth and latency up to 44% and 14%, respectively
- Future Work
  - Application-level evaluation
  - Patches for LiMIC2

Thank You!

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