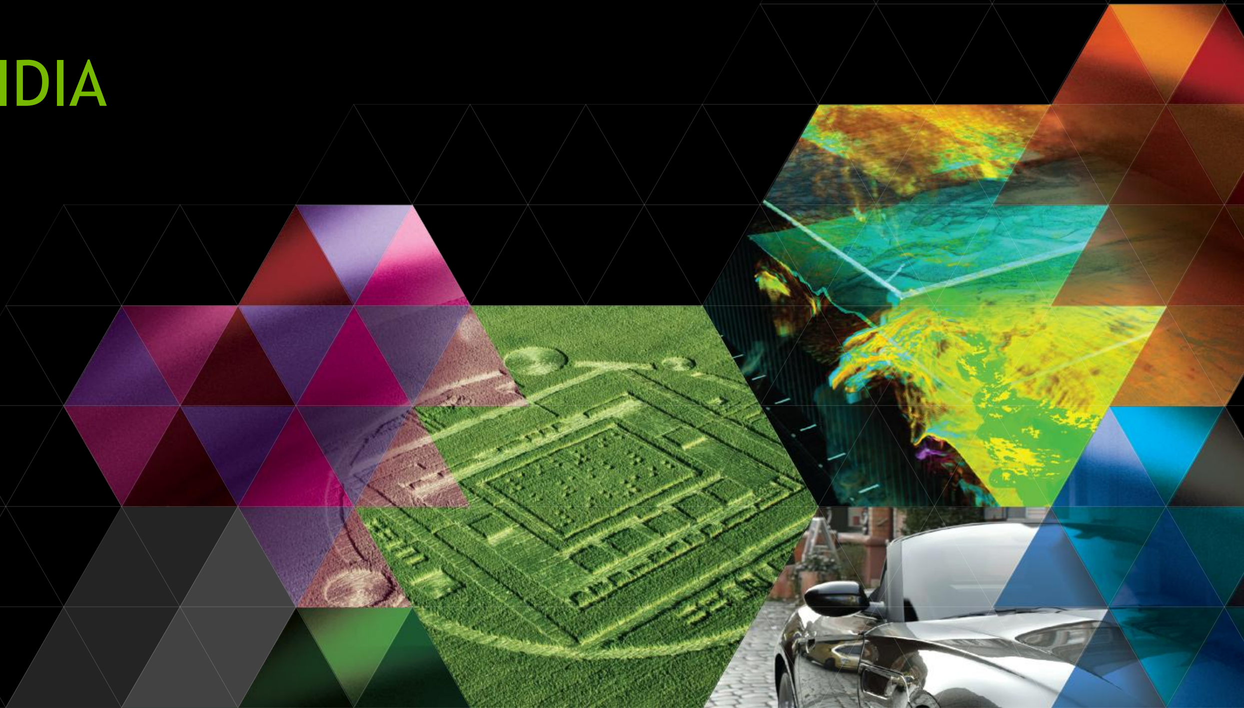
GPU TECHNOLOGY CONFERENCE

OPEN MPI WITH RDMA SUPPORT AND CUDA

Rolf vandeVaart, NVIDIA



OVERVIEW

- What is CUDA-aware
- History of CUDA-aware support in Open MPI
- GPU Direct RDMA support
- Tuning parameters
- Application example
- Future work

CUDA-AWARE DEFINITION

Regular MPI

```
//MPI rank 0
cudaMemcpy(s_buf_h,s_buf_d,size,…);
MPI_Send(s_buf_h,size,…);

//MPI rank n-1
MPI_Recv(r_buf_h,size,…);
cudaMemcpy(r_buf_d,r_buf_h,size,…);
```

CUDA-aware MPI

```
//MPI rank 0
MPI_Send(s_buf_d,size,…);

//MPI rank n-1
MPI_Recv(r_buf_d,size,…);
```

CUDA-aware MPI makes MPI+CUDA easier.

CUDA-AWARE MPI IMPLEMENTATIONS

- Open MPI 1.7.4
  http://www.open-mpi.org
- MVAPICH2 2.0
  http://mvapich.cse.ohio-state.edu/overview/mvapich2
- IBM Platform MPI 9.1.2
  http://www.ibm.com/systems/technicalcomputing/platformcomputing/products/mpi
- CRAY MPT

HISTORY OF CUDA-AWARE OPEN MPI

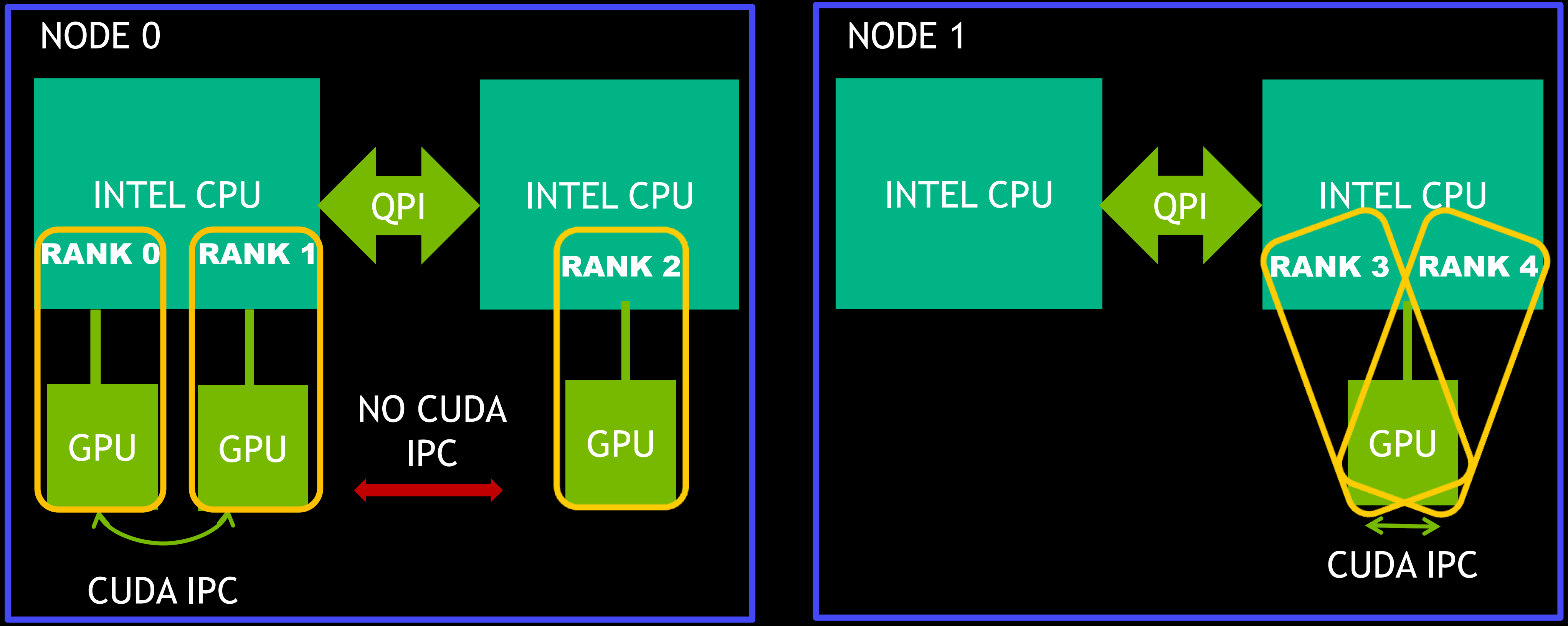
- Open MPI 1.7.0 released in April, 2013
- Pipelining with host memory staging for large messages (utilizing asynchronous copies) over verbs layer
- Dynamic CUDA IPC support added
- GPU Direct RDMA support
- Use Open MPI 1.7.4 to get all the latest features

MPI API SUPPORT

- Yes
  - All send and receive types
  - All non-arithmetic collectives
- No
  - Reduction type operations – MPI_Reduce, MPI_Allreduce, MPI_Scan
  - Non-blocking collectives
  - MPI-2 and MPI-3 (one sided) RMA

- FAQ will be updated as support changes

CUDA IPC SUPPORT IN OPEN MPI



CUDA IPC SUPPORT IN OPEN MPI

- Open MPI dynamically detects if CUDA IPC is supported between GPUs within the same node.
- Enabled by default

    --mca btl_smcuda_use_cuda_ipc 0

- To see if it is being used between two processes

    --mca btl_smcuda_cuda_ipc_verbose 100

- CUDA 6.0 has performance fixes

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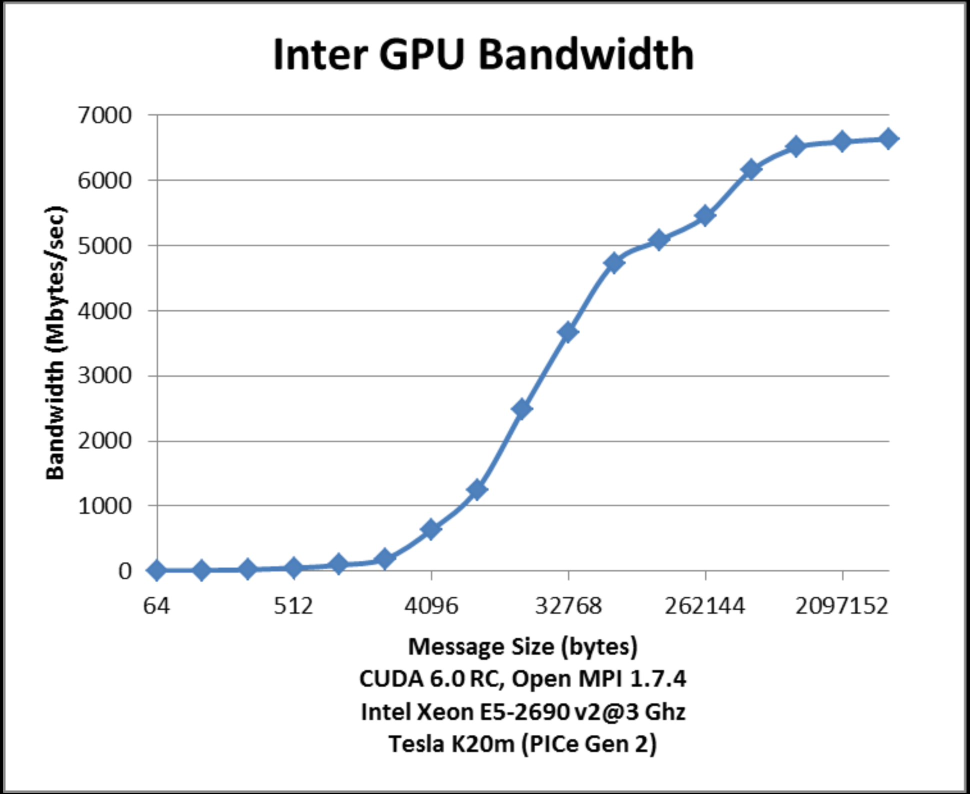
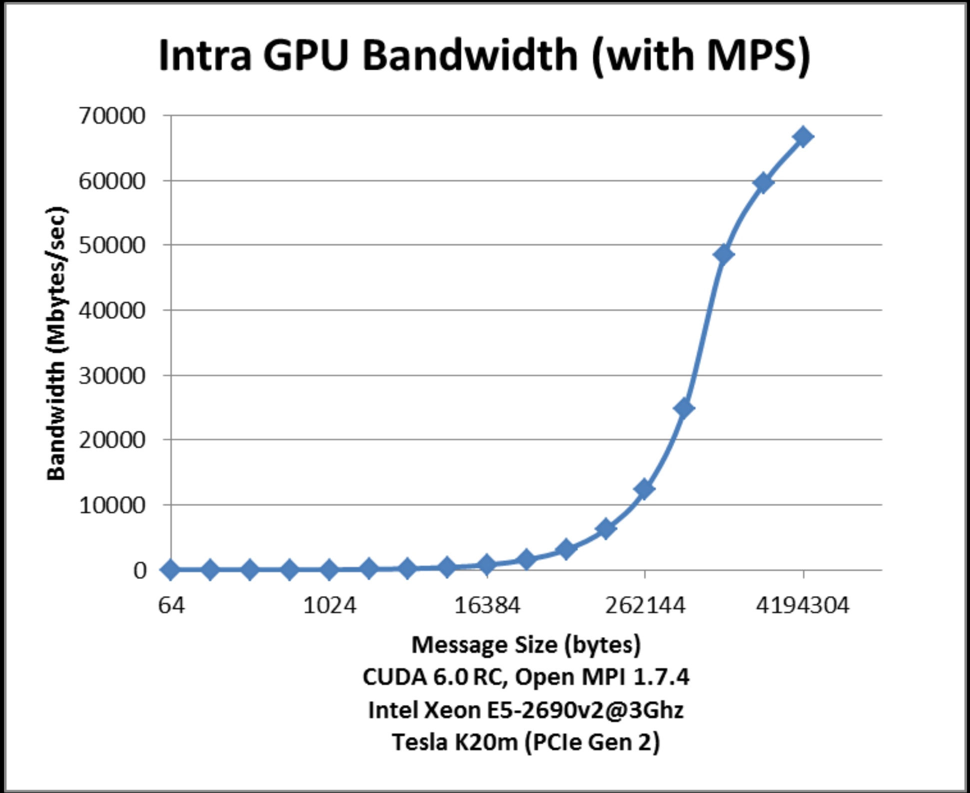
CUDA IPC SUPPORT IN OPEN MPI



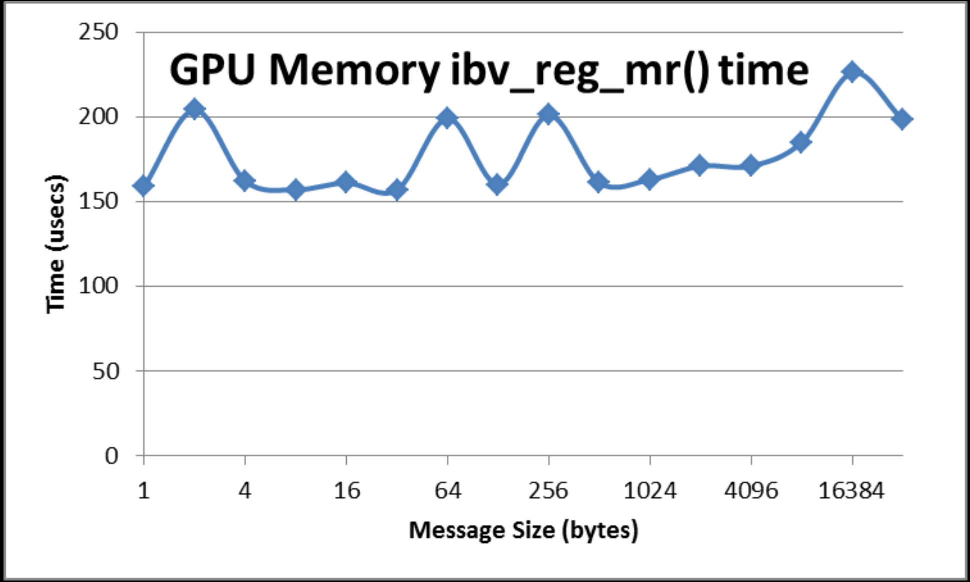


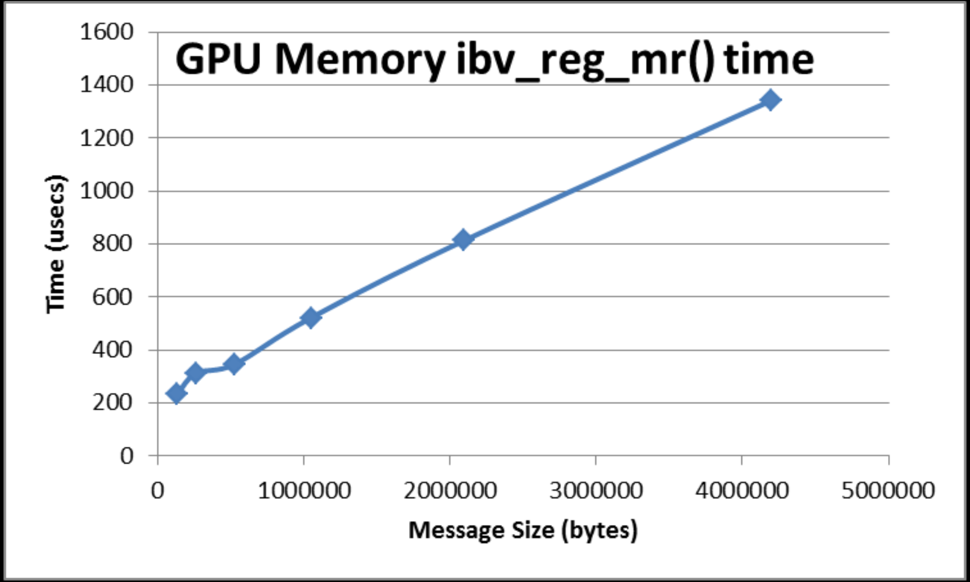
GPU DIRECT RDMA SUPPORT

- Kepler class GPUs (K10, K20, K40)
- Mellanox ConnectX-3, ConnectX-3 Pro, Connect-IB
- CUDA 6.0 (EA, RC, Final), Open MPI 1.7.4 and Mellanox OFED 2.1 drivers.
- GPU Direct RDMA enabling software
  http://www.mellanox.com/downloads/ofed/nvidia_peer_memory-1.0-0.tar.gz

GPU DIRECT RDMA SUPPORT

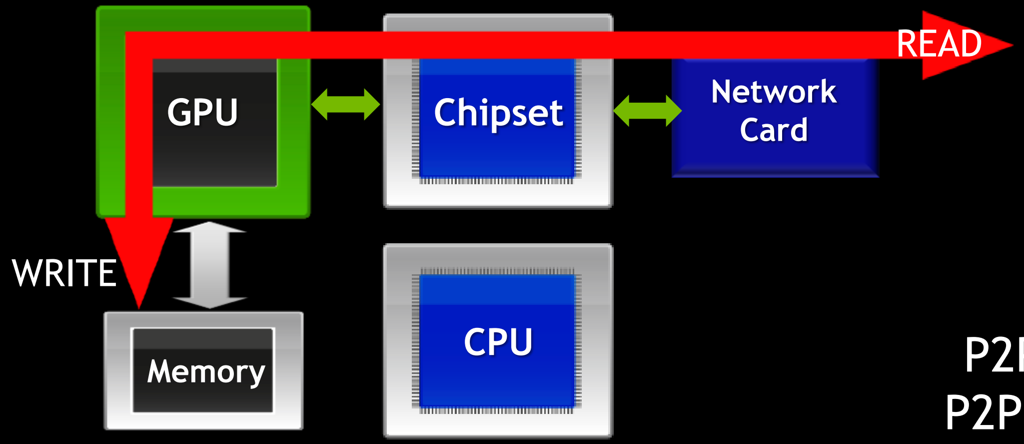
- Implement with RDMA type protocol
- Register send and receive buffers and have NIC transfer data
- Memory registration is not cheap – need to have registration cache





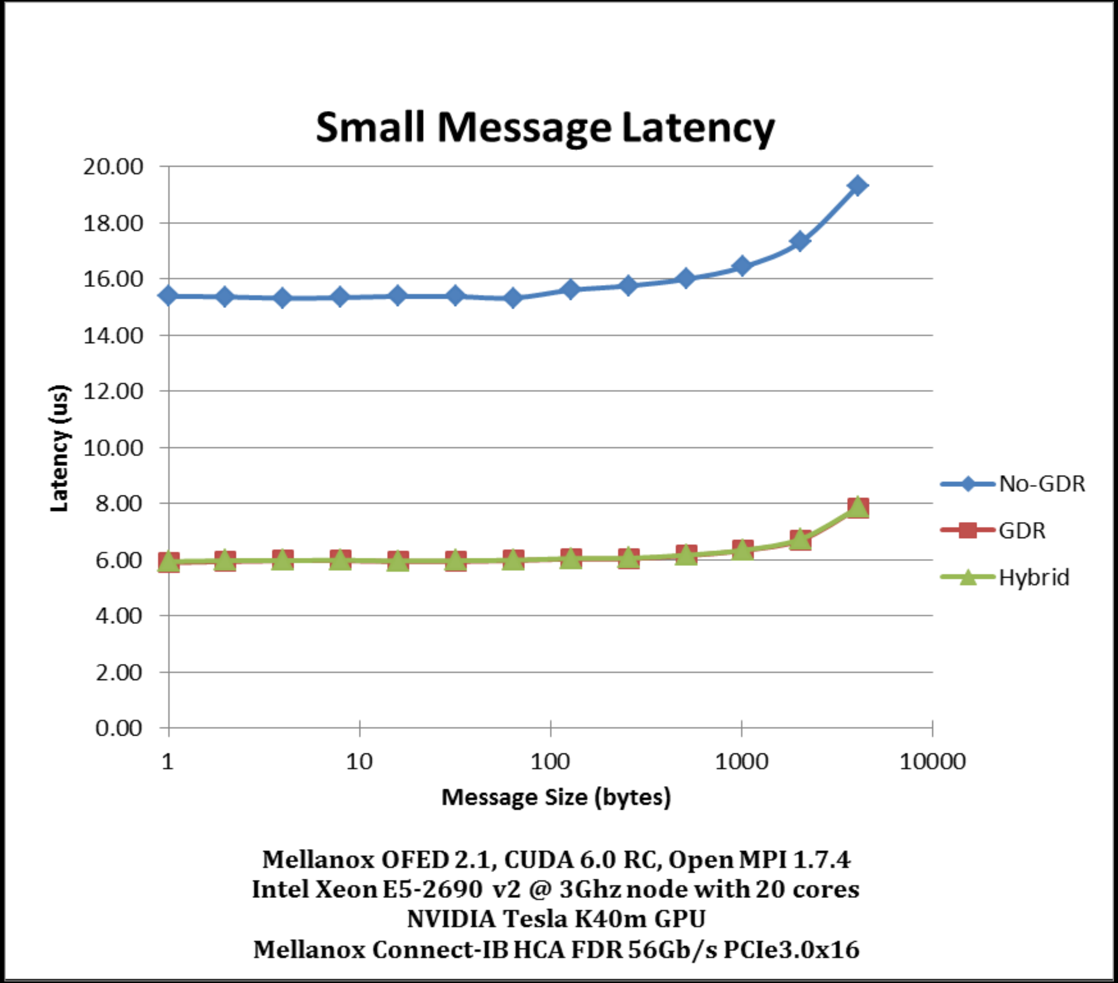
GPU DIRECT RDMA SUPPORT

- Chipset implementations limit bandwidth at larger message sizes
- Still use pipelining with host memory staging for large messages (utilizing asynchronous copies)
- Final implementation is hybrid of both protocols

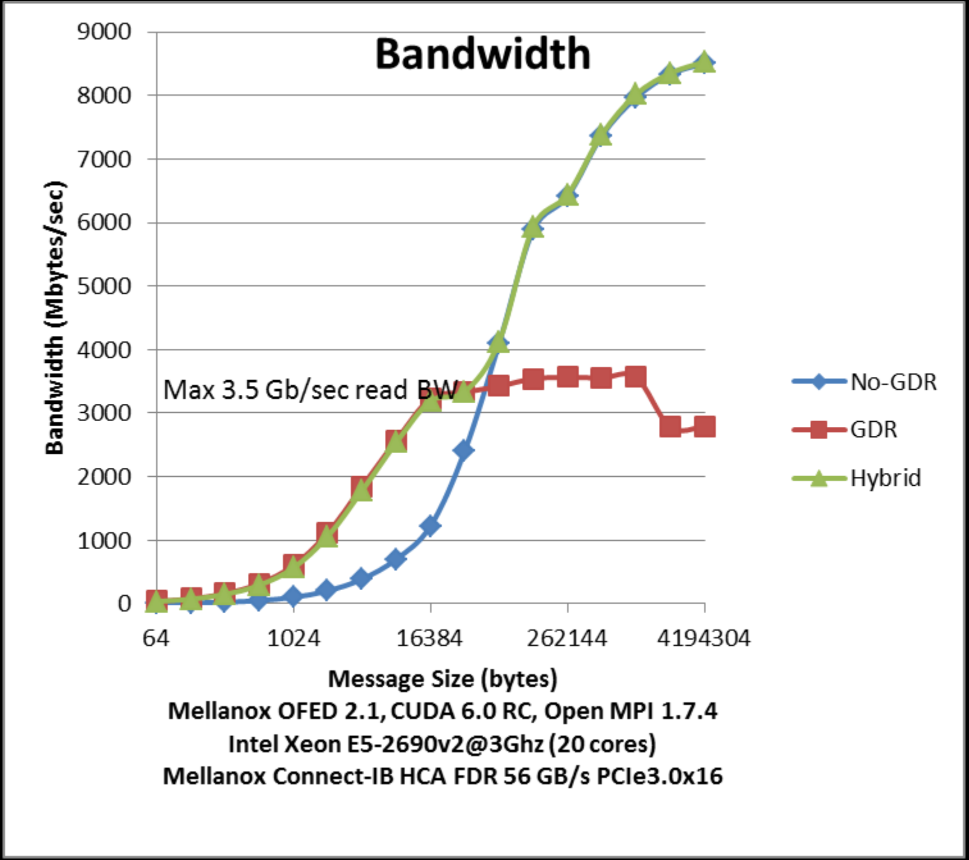


IVY BRIDGE
P2P READ: 3.5 Gbyte/sec
P2P WRITE: 6.4 Gbyte/sec

GPU DIRECT RDMA SUPPORT - PERFORMANCE



GPU DIRECT RDMA SUPPORT - PERFORMANCE



GPU DIRECT RDMA SUPPORT – CONFIGURE

- Nothing different needs to be done at configure time
- > configure --with-cuda

The support is configured in if CUDA 6.0 cuda.h header file is detected.

- To check:
  - > ompi_info --all | grep btl_openib_have_cuda_gdr
    MCA btl: informational "btl_openib_have_cuda_gdr" (current value: "true", data source: default, level: 4 tuner/basic, type: bool)
  - > ompi_info -all | grep btl_openib_have_driver_gdr
    MCA btl: informational "btl_openib_have_driver_gdr" (current value: "true", data source: default, level: 4 tuner/basic, type: bool)

GPU DIRECT RDMA SUPPORT - TUNING PARAMETERS

- Runtime parameters
  - Enable GPU Direct RDMA usage (off by default)

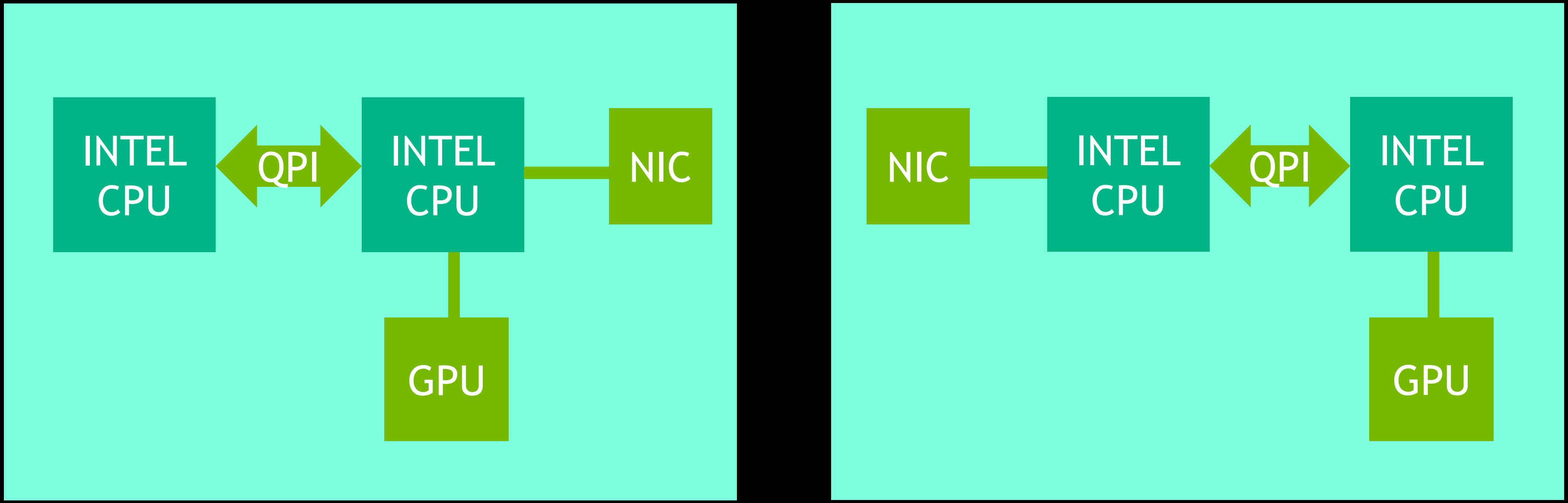
    --mca btl_openib_want_cuda_gdr 1

  - Adjust when we switch to pipeline transfers through host memory. Current default is 30,000 bytes

    --mca btl_openib_cuda_rdma_limit 60000

GPU DIRECT RDMA SUPPORT – NUMA ISSUES

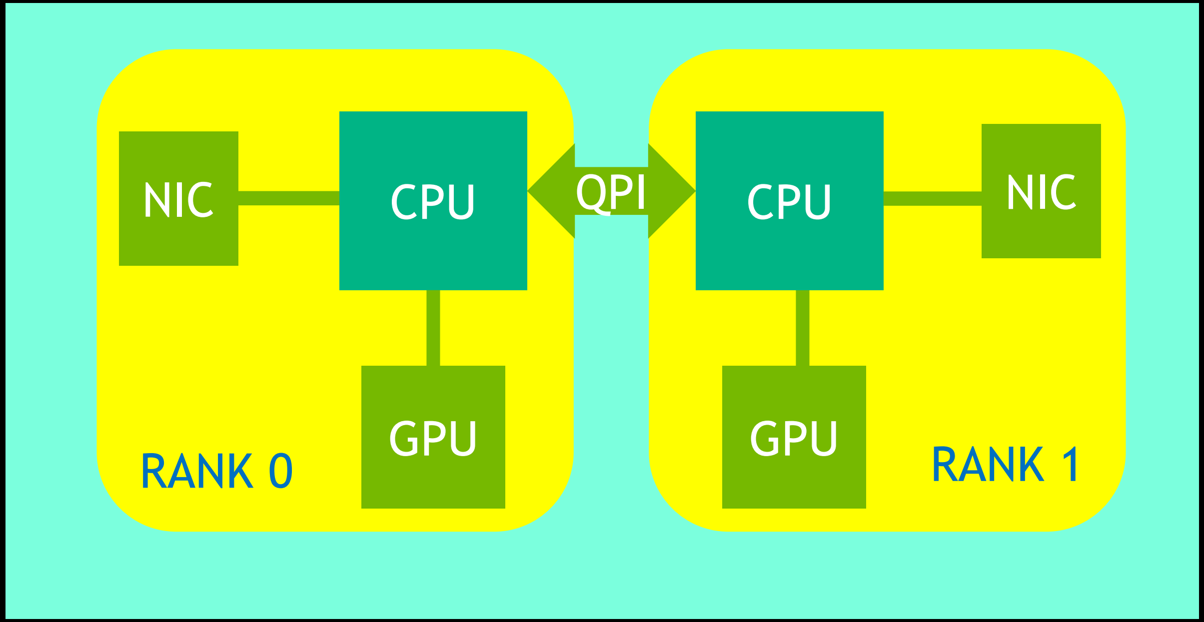
- Configure system so GPU and NIC are close



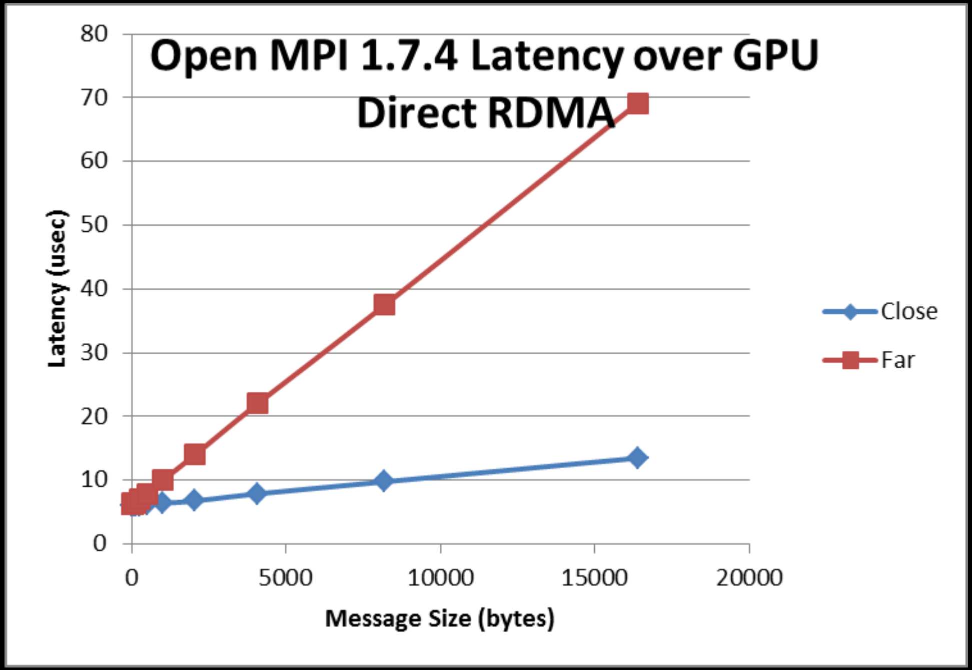
BETTER

GPU DIRECT RDMA SUPPORT – NUMA ISSUES

- Multi NIC - multi GPU: use hwloc to select GPU near NIC



LATENCY COMPARISON – CLOSE VS FAR GPU AND NIC



CUDA-AWARE OPEN MPI AND UNIFIED MEMORY

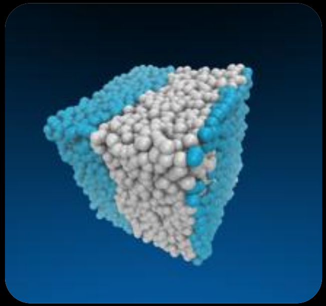
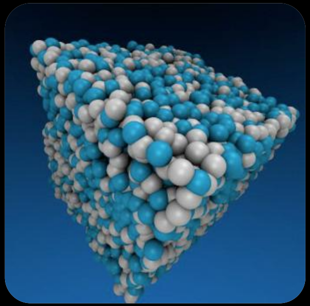
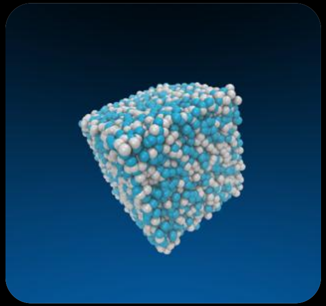
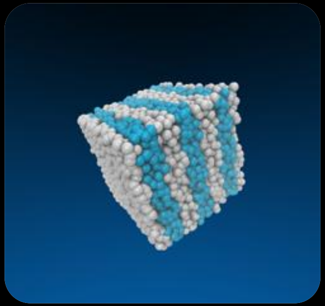
- CUDA 6 Unified Memory

```
cudaMallocManaged(buf, BUFSIZE, cudaMemAttachGlobal)
```

- Unified Memory may not work correctly with CUDA-aware Open MPI
- Will fix in future release of Open MPI

HOOMD BLUE PERFORMANCE

- Highly Optimized Object-oriented Many-particle Dynamics - **Blue** Edition
  - Performs general purpose particle dynamics simulations
  - Takes advantage of NVIDIA GPU
  - Simulations are configured and run using simple python scripts
  - The development effort is led by Glotzer group at University of Michigan

Source: http://www.hpcadvisorycouncil.com/pdf/HOOMDblue_Analysis_and_Profiling.pdf

HOOMD – CLUSTER 1

- Dell™ PowerEdge™ R720xd/R720 cluster
  - Dual-Socket Octa-core Intel E5-2680 V2 @ 2.80 GHz CPUs (Static max Perf in BIOS), Memory: 64GB DDR3 1600 MHz Dual Rank Memory Module, OS: RHEL 6.2, MLNX_OFED 2.1-1.0.0 InfiniBand SW stack
- Mellanox Connect-IB FDR InfiniBand, Mellanox SwitchX SX6036 InfiniBand VPI switch, NVIDIA® Tesla K40 GPUs (1 GPU per node), NVIDIA® CUDA® 5.5 Development Tools and Display Driver 331.20, Open MPI 1.7.4 rc1, GPUDirect RDMA (nvidia_peer_memory-1.0-0.tar.gz)
- Application: HOOMD-blue (git master 28Jan14), Benchmark datasets: Lennard-Jones Liquid Benchmarks (16K, 64K Particles)

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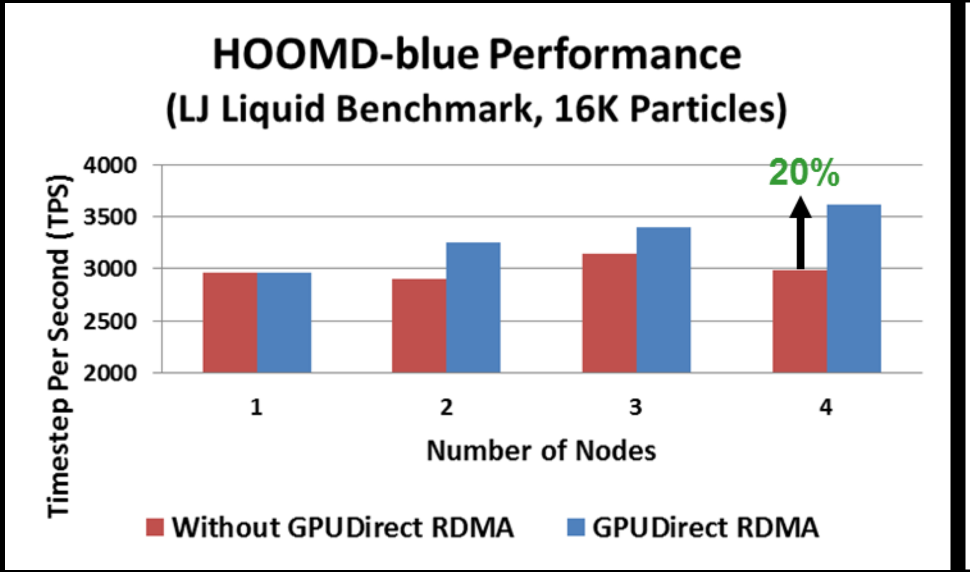
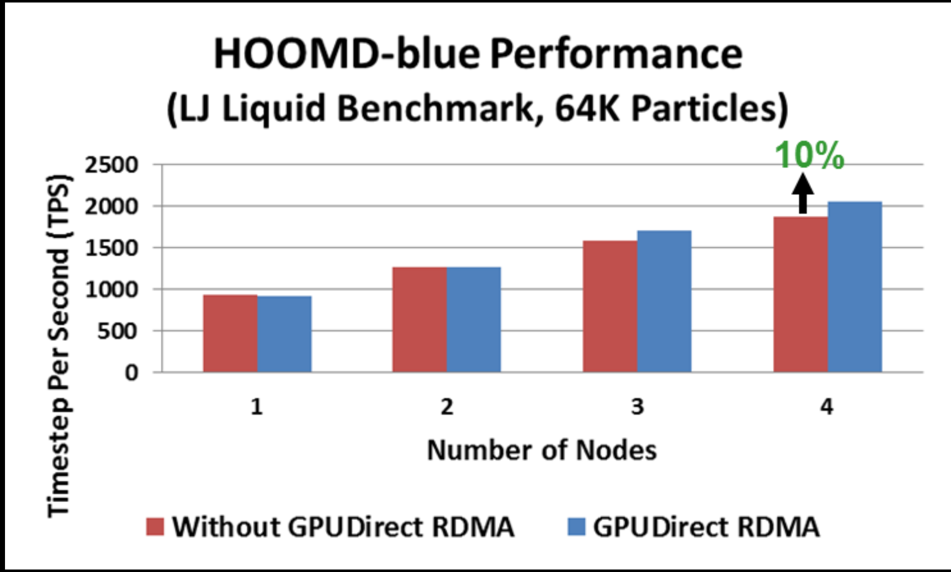
GPU DIRECT RDMA SUPPORT – APPLICATION PERFORMANCE





Higher is better

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HOOMD – CLUSTER 2

- Dell™ PowerEdge™ T620 128-node (1536-core) Wilkes cluster at Univ of Cambridge
  - Dual-Socket Hexa-Core Intel E5-2630 v2 @ 2.60 GHz CPUs, Memory: 64GB memory, DDR3 1600 MHz, OS: Scientific Linux release 6.4 (Carbon), MLNX_OFED 2.1-1.0.0 InfiniBand SW stack
- Mellanox Connect-IB FDR InfiniBand adapters, Mellanox SwitchX SX6036 InfiniBand VPI switch, NVIDIA® Tesla K20 GPUs (2 GPUs per node), NVIDIA® CUDA® 5.5 Development Tools and Display Driver 331.20, Open MPI 1.7.4rc1, GPUDirect RDMA (nvidia_peer_memory-1.0-0.tar.gz)
- Application: HOOMD-blue (git master 28Jan14)
- Benchmark datasets: Lennard-Jones Liquid Benchmarks (512K Particles)

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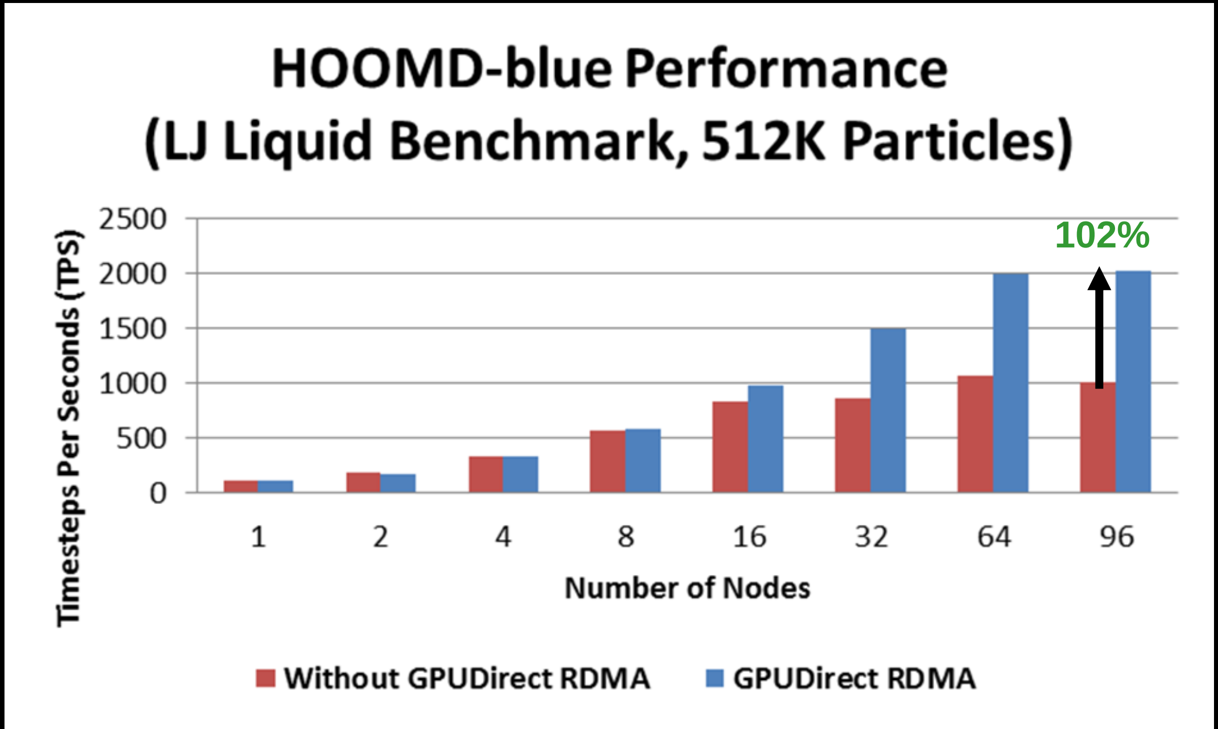
GPU DIRECT RDMA SUPPORT – APPLICATION PERFORMANCE



Higher is better

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OPEN MPI CUDA-AWARE

- Work continues to improve performance
  - Better interactions with streams
  - Better small message performance – eager protocol
  - CUDA-aware support for new RMA
  - Support for reduction operations
  - Support for non-blocking collectives

- Try it!
- Lots of information in FAQ at the Open MPI web site
- Questions?