MVAPICH

MPI, PGAS and Hybrid MPI+PGAS Library

High Performance Broadcast with GPUDirect RDMA and InfiniBand Hardware Multicast for Streaming Applications

GTC 2015

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Presented By

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- Introduction
- Motivation and Problem Statement
- Design Considerations
- Proposed Approach
- Results
- Conclusion and Future Work

- Examples - surveillance, habitat monitoring, etc..
- Require efficient transport of data from/to distributed sources/sinks
- Sensitive to latency and throughput metrics
- Require HPC resources to efficiently carry out compute-intensive tasks

- Proliferation of Multi-Petaflop systems
- Heterogeneity in compute resources with GPGPUs
- High performance interconnects with RDMA capabilities to host and GPU memories
- Streaming applications leverage on such resources

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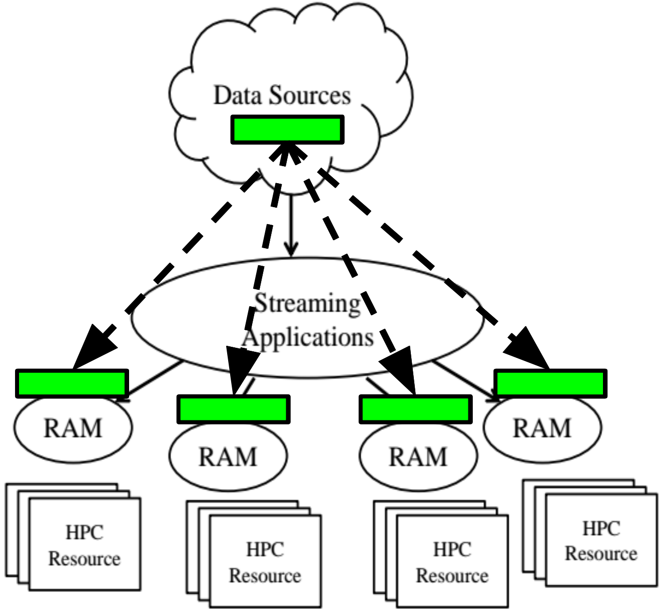
Nature of Streaming Applications

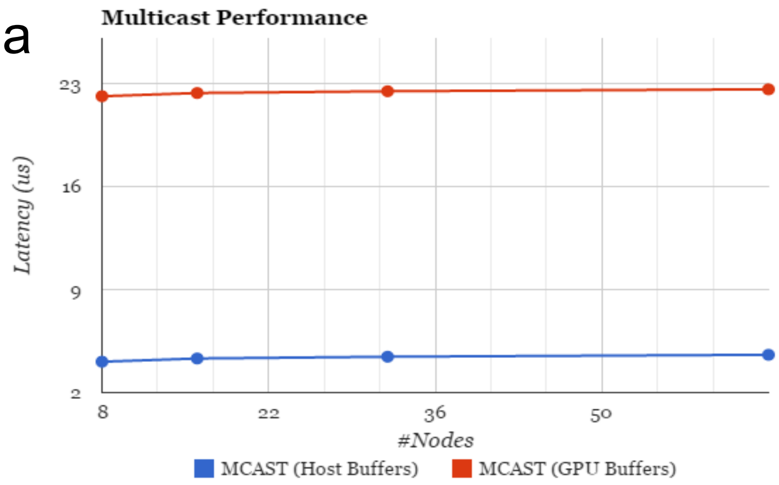
- Pipelined data parallel compute phases that form the crux of streaming applications lend themselves for GPGPUs
- Data distribution to GPGPU sites occur over PCIe within the node and over InfiniBand interconnects across nodes
- Broadcast operation is a key dictator of throughput of streaming applications
  - Reduced latency for each operation
  - Support multiple back-to-back operations
  - More critical with accelerators

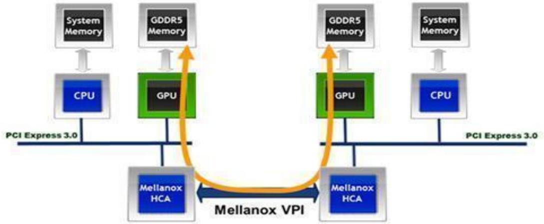


Courtesy: Agarwalla, Bikash, et al. "Streamline: A scheduling heuristic for streaming applications on the grid." *Electronic Imaging 2006*

Shortcomings of Existing GPU Broadcast

- Traditional short message broadcast operation between GPU buffers involves a Host-Staged Multicast (HSM)
  - Data copied from GPU buffers to host memory
  - Using InfiniBand Unreliable Datagram (UD)-based hardware multicast
- Sub-optimal use of near-scale invariant UD-multicast performance
- PCIe resources wasted and benefits of multicast nullified
- GPU-Direct RDMA capabilities unused





Problem Statement

- Can we design a GPU broadcast mechanism that can completely avoid host-staging for streaming applications?
- Can we harness the capabilities of GPU-Direct RDMA (GDR)?
- Can we overcome limitations of UD transport and realize the true potential of multicast for GPU buffers?
- Succinctly, how do we multicast GPU data using GDR efficiently?

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Factors to Consider for an Efficient GPU Multicast

- Goal is to be able to multicast GPU data in lesser time than the host-staged multicast (~20us)
- Cost of cudamemcpy is ~8us for short messages for host->gpu, gpu->host and gpu->gpu transfers
- Cudamemcpy costs and memory registration costs determine the viability of a multicast protocol for GPU buffers

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  - Eager Protocol
  - Rendezvous Protocol
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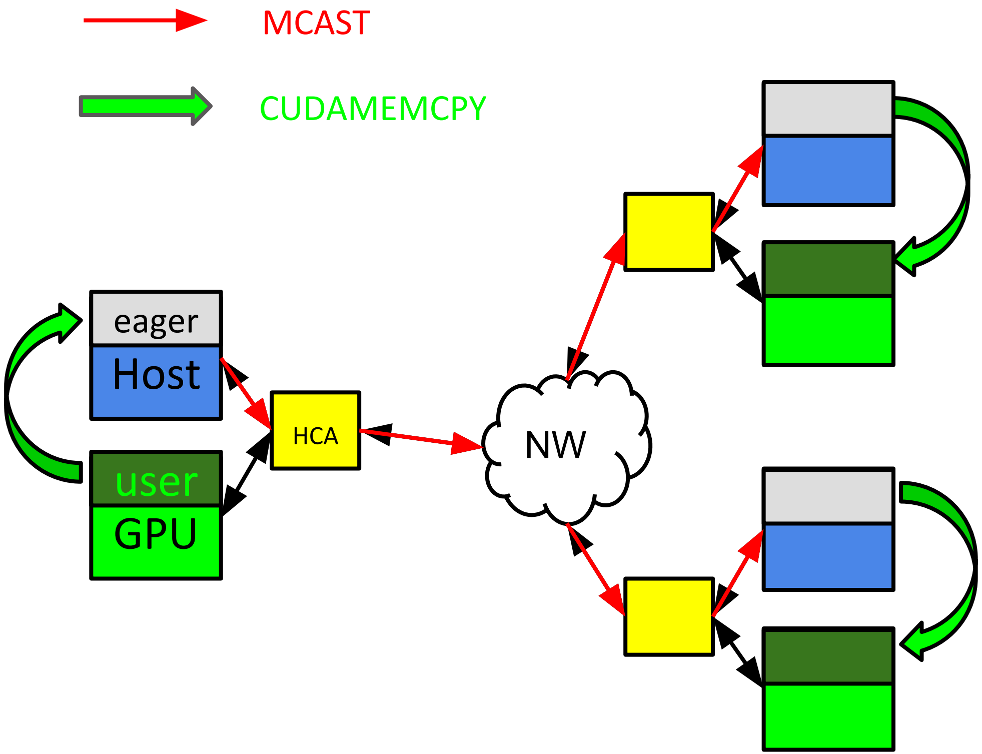
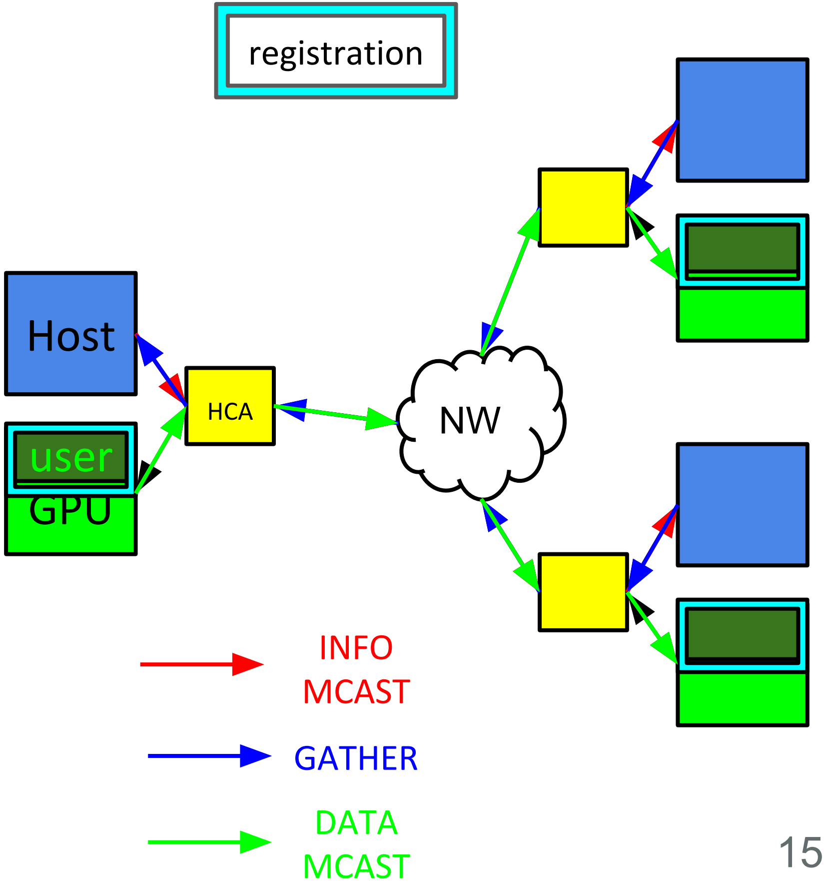
- Copy user GPU data to host eager buffers
- Perform Multicast and copy back
- Cudamemcpy dictates performance
- Similar variation with eager buffers on GPU

  -Header encoding expensive



Rendezvous Protocol for GPU multicast

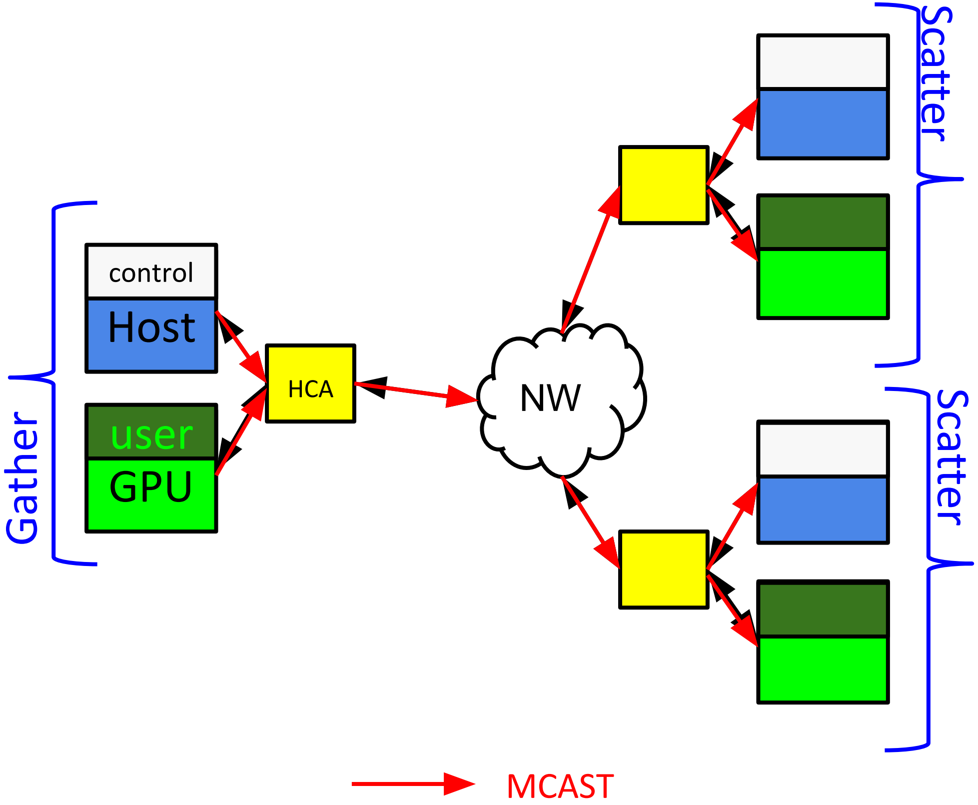
- Register user GPU data and start *RTS multicast* with control info
- Confirm ready receivers ≡ 0-byte gather
- Perform Data Multicast
- Registration cost and gather limitations
- Handshake for each operation – not required for streaming applications which are error tolerant



Outline

Orchestration of GDR-SGL-MCAST (GSM)

- One time registration of window of persistent buffers in streaming apps
- Combine control and user data at the source and scatter them at the destinations using *Scatter-Gather-List* abstraction
- Scheme lends itself for pipelined phases abundant in Streaming Applications and avoids stressing PCIe



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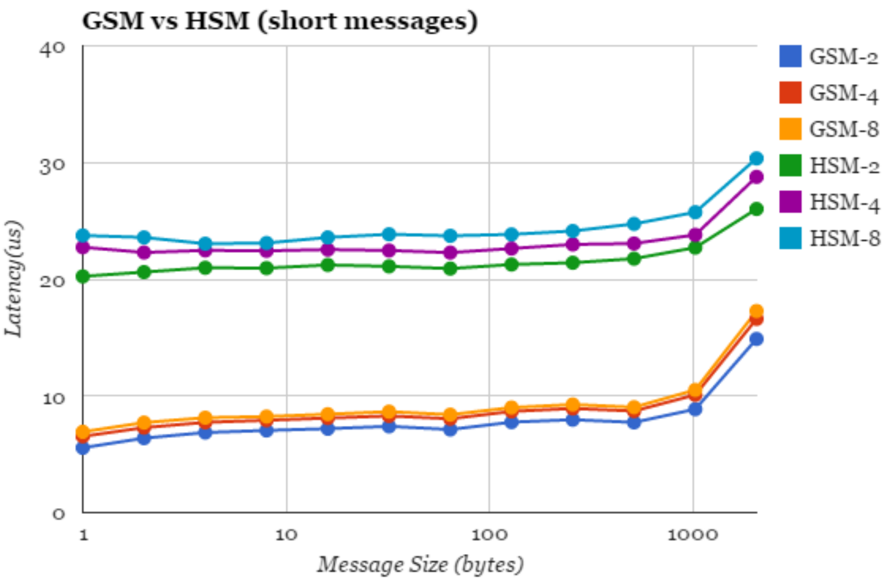
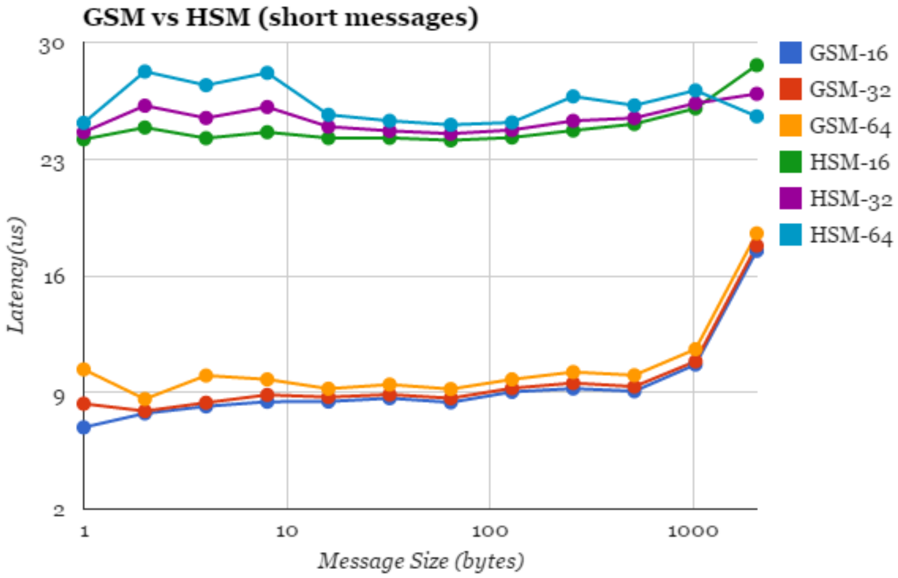
Experiment Setup

- Experiments were run on Wilkes @ University of Cambridge
- 12-core Ivy Bridge Intel(R) Xeon(R) E5-2630 @ 2.60 GHz with 64 GB RAM
- FDR ConnectX2 HCAs
- NVIDIA K20c GPUs
- Mellanox OFED version MLNX OFED LINUX-2.1-1.0.6 which supports GPUDirect-RDMA (GDR) required
- Baseline Host-based MCAST uses MVAPICH2-GDR (http://mvapich.cse.ohio-state.edu/downloads)
- GDR-SGL-MCAST is based on MVAPICH2-GDR



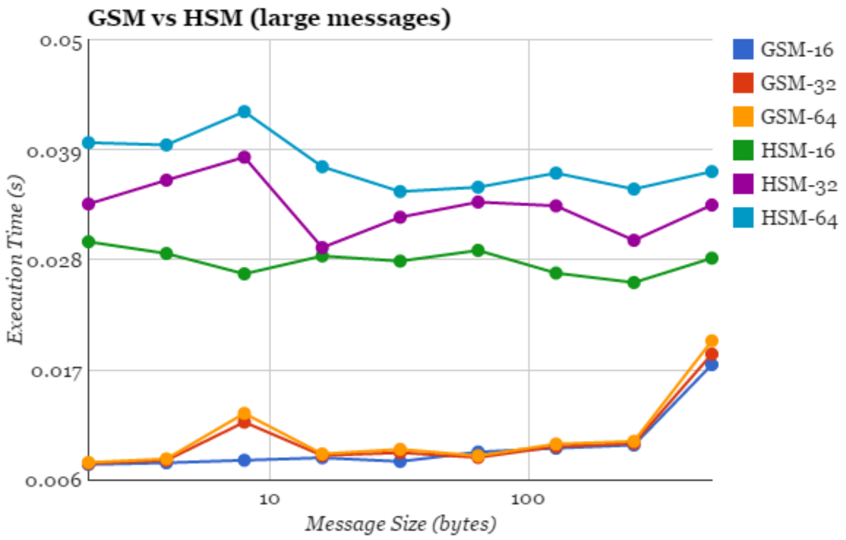
- GDR-SGL-MCAST (GSM)
- Host-Staged-MCAST (HSM)
- GSM Latency ≤ ~10us vs HSM Latency ≤ ~23us
- Small latency increase with scale

A. Venkatesh, H. Subramoni, K. Hamidouche and D. K. Panda, A High Performance Broadcast Design with Hardware Multicast and GPUDirect RDMA for Streaming Applications on InfiniBand Clusters, IEEE International Conference on High Performance Computing (HiPC '14), Dec 2014.



- Both GSM and HSM continue to show near scale invariant latency with 60% improvement (8 bytes)

- Based on a synthetic benchmark that mimics broadcast patterns in Streaming Applications
- Long window of persistent m-byte buffers with 1,000 back-to-back multicast operations issued
- Execution time reduces by 3x-4x



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Conclusion and Future work

- Designed an efficient GPU data broadcast for streaming applications which uses near-constant-latency hardware multicast feature and GPUDirect RDMA
- Proposed a new methodology which overcomes the performance challenges posed by UD transport
- Benefits shown with latency and streaming-application-communication mimicking throughput benchmark
- Exploration of NVIDIA's Fastcopy module for MPI_Bcast

Learn about recent advances and upcoming features in CUDA-aware MVAPICH2-GPU library

- S5461 - Latest Advances in MVAPICH2 MPI Library for NVIDIA GPU Clusters with InfiniBand
- Thursday, 03/19 (Today)
- Time: 17:00–17:50
- Room 212 B

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MVAPICH

Network Based Computing Laboratory

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Backup

- UD makes no ordering and reliability guarantees
- UD requires memory registration and has an MTU of 2KB
- Notification through *polling* preferred for performance
- Multicast scheme is window-based and NACK-based
- GDR allows buffers on GPU memory to be registered
- Once registered, the IB network interface can directly access GPU memory

- IB specifies use of SG elements for non-contiguous transfer
- Control and data specified in an array of SG elements
- Avoids expensive cudaMemcpy calls
- Persistent buffers amortize registration costs and facilitate pipelining in SA