A Novel Framework for Efficient Offloading of Communication Operations to Bluefield SmartNICs[*]

Presentation at the 11th Annual MVAPICH User Group (MUG) Conference (MUG '23)

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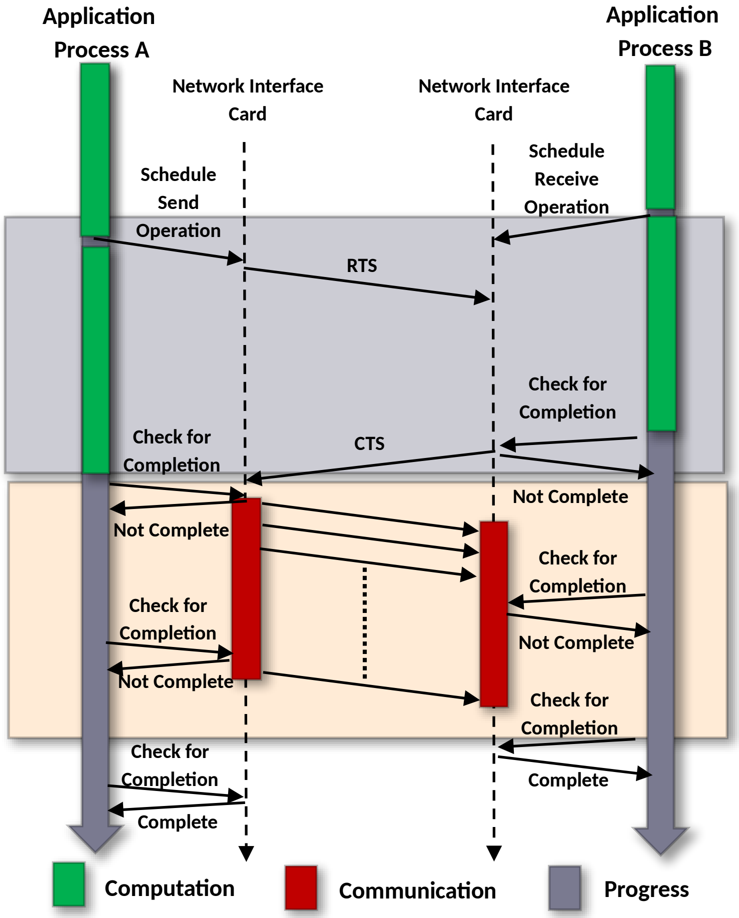
[*] A Novel Framework for Efficient Offloading of Communication Operations to Bluefield SmartNICs, K. Suresh, B. Michalowicz, B. Ramesh, N. Contini, J. Yao, S. Xu, A. Shafi, H. Subramoni, D. Panda, 37th IEEE International Parallel & Distributed Processing Symposium (IPDPS '23), May 2023

Introduction: HPC, MPI, Overlap

- MPI is the de-facto programming model in High Performance Computing (HPC)
- HPC applications have computation and communication
- HPC application performance can be improved by overlap
- MPI non-blocking primitives allows compute and communication overlap
- Progression of communication is needed to achieve overlap

Introduction: Overlap in Rendezvous Protocol

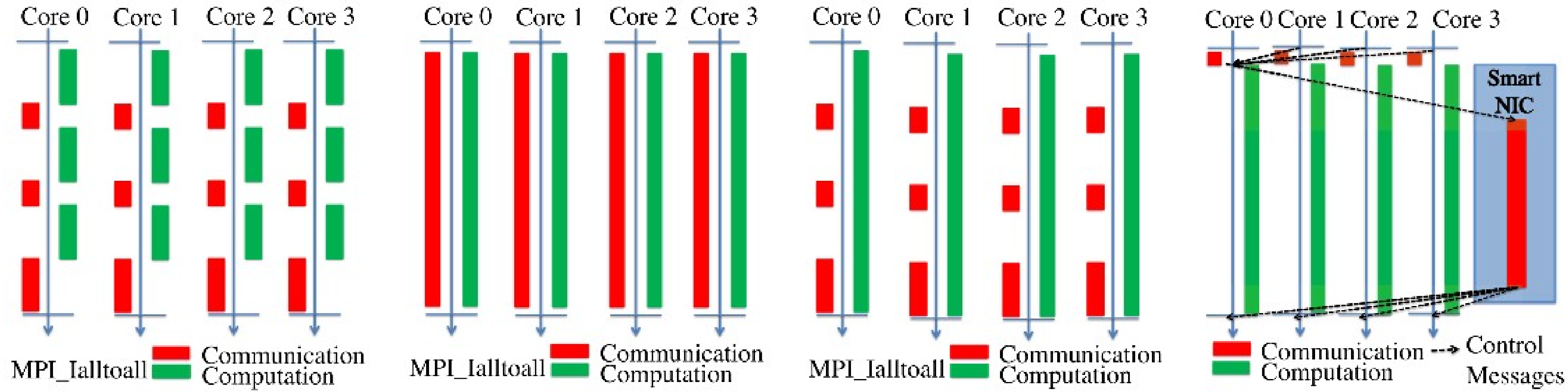


- Application processes schedule communication operation
- Application process free to perform useful compute in the foreground
- Little communication progress in the background
- All communication takes place at final synchronization

- **Reduced buffer requirement**
- **Good communication performance if used for large message sizes and operations where communication library is progressed frequently**

- **Poor overlap of computation and communication => Poor Overall Application Performance**

Introduction: Different ways of overlapping computation and communication



(a) MPI_Test

(b) MPICH Async Thread

(c) MVAPICH2 Async Thread

(d) Proposed

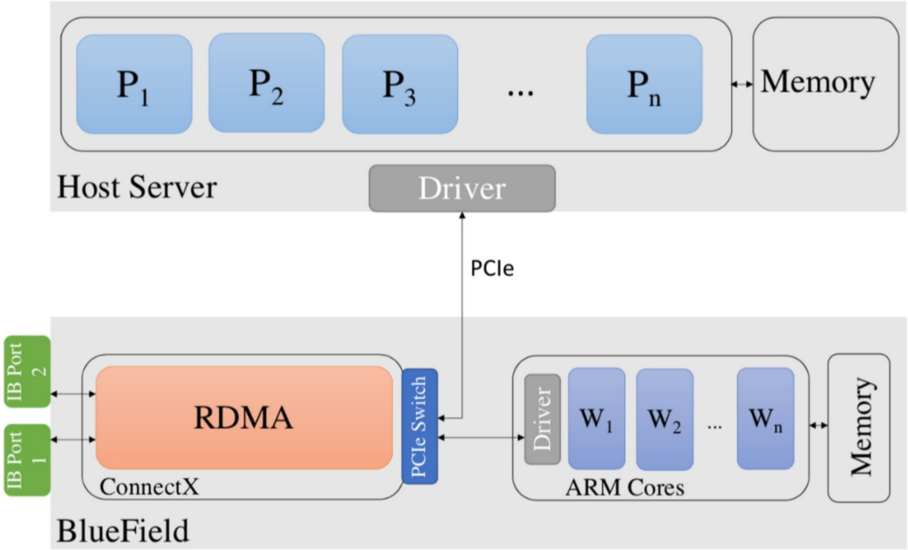
Background: BlueField DPU / Smart NIC Architecture

- BlueField includes the ConnectX6 network adapter and data processing cores

- System-on-chip containing 64-bit ARMv8 A72

- BlueField DPU has two modes of operation:

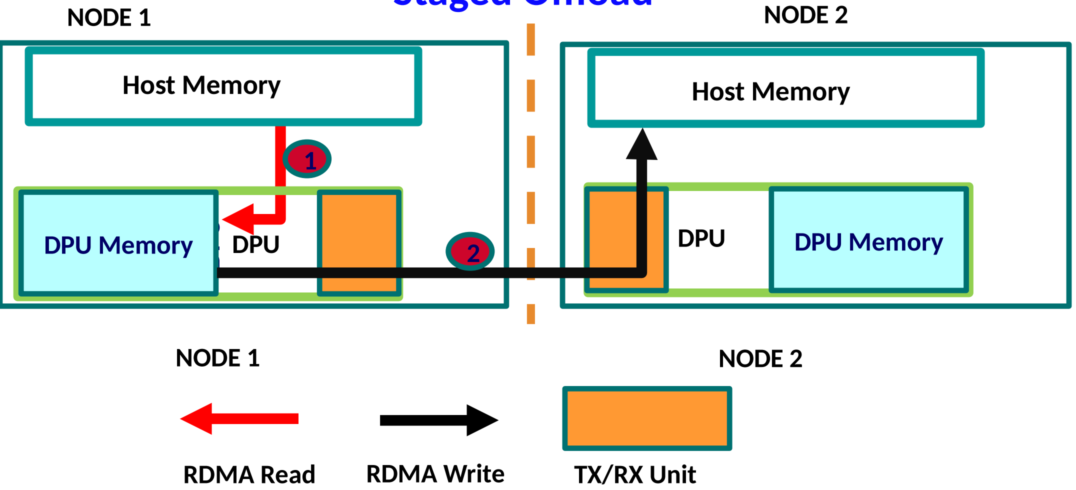
- Separated Host mode
  - The ARM cores can appear on the network as any other host and the main CPU



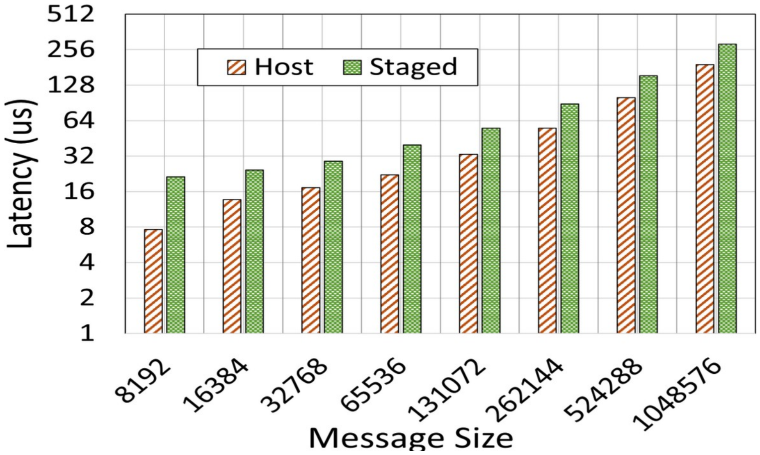
Motivation: Problem with the existing Offload framework

- BluesMPI[1] is a prior work that offloads certain MPI collectives to the DPU
  - Eg: Ring based broadcast in HPL

Staged Offload



Overhead of staging



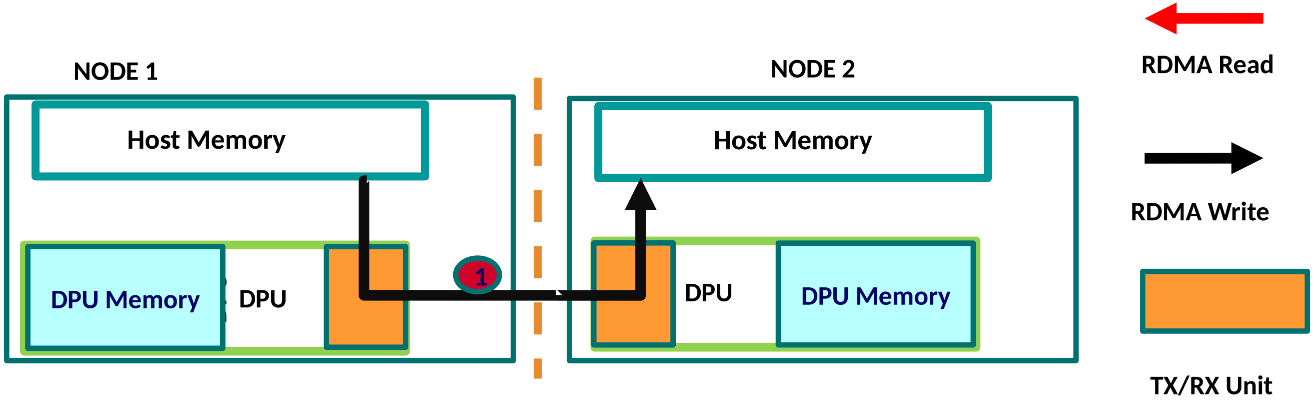
Staged offload by DPU requires 2 RDMA operations:

- Local-Host-to-DPU Read, DPU-to-Remote-Host Write

Host-to-host latency with and without staged offload

[1] Mohammadreza Bayatpour, Nick Sarkauskas, Hari Subramoni, Jahanzeb Maqbool Hashmi, and Dhabaleswar K. Panda. 2021. BluesMPI: Efficient MPI Non-blocking Alltoall Offloading Designs on Modern BlueField Smart NICs. In High Performance Computing: 36th International Conference, ISC High Performance 2021

Design: Optimized Offload Mechanism

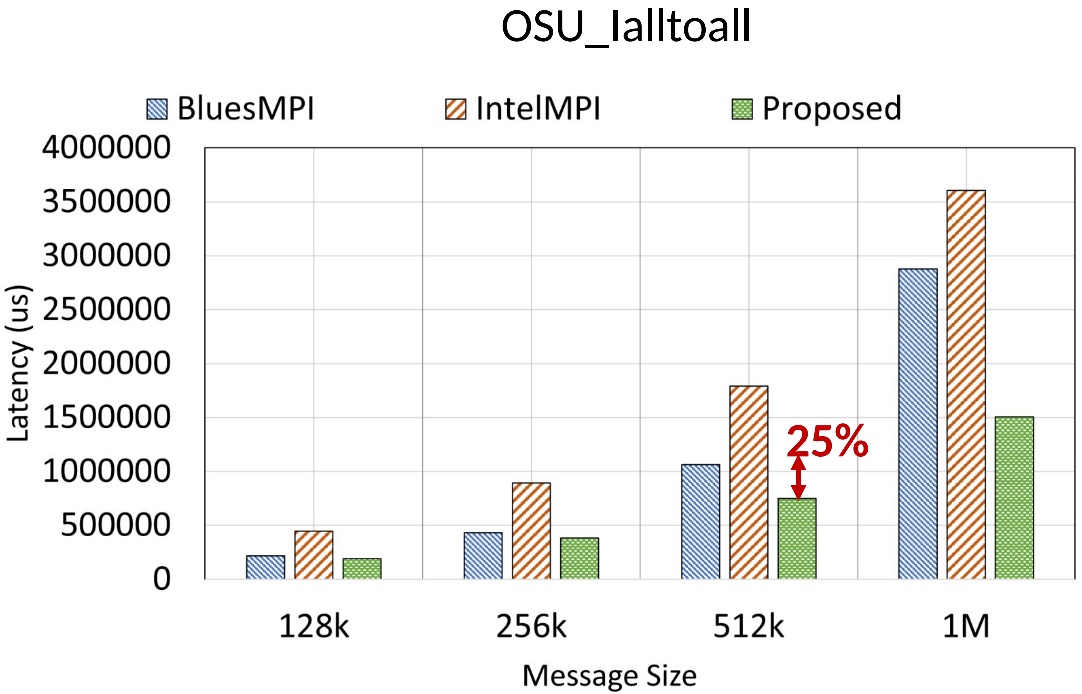


GVMI Transfer

- Guest Virtual Machine ID (GVMI) is a capability provided by the Bluefield DPUs
  - Allows DPU process to move data from one local to any remote host process without staging.
- Introduces addition overheads:
  - Host-level, DPU-level memory registrations and key-exchanges
- We provide efficient designs by amortizing the GVMI overheads

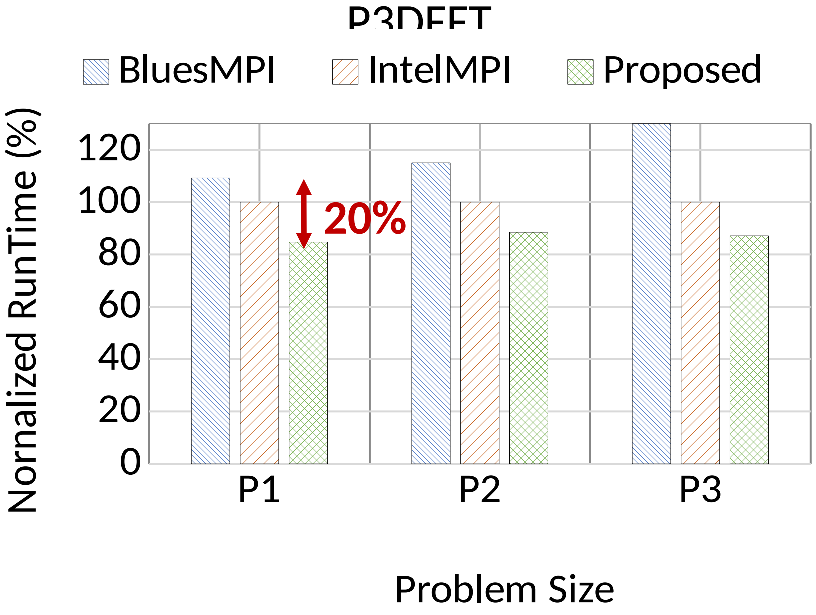
Benchmark Results: MPI_Ialltoall

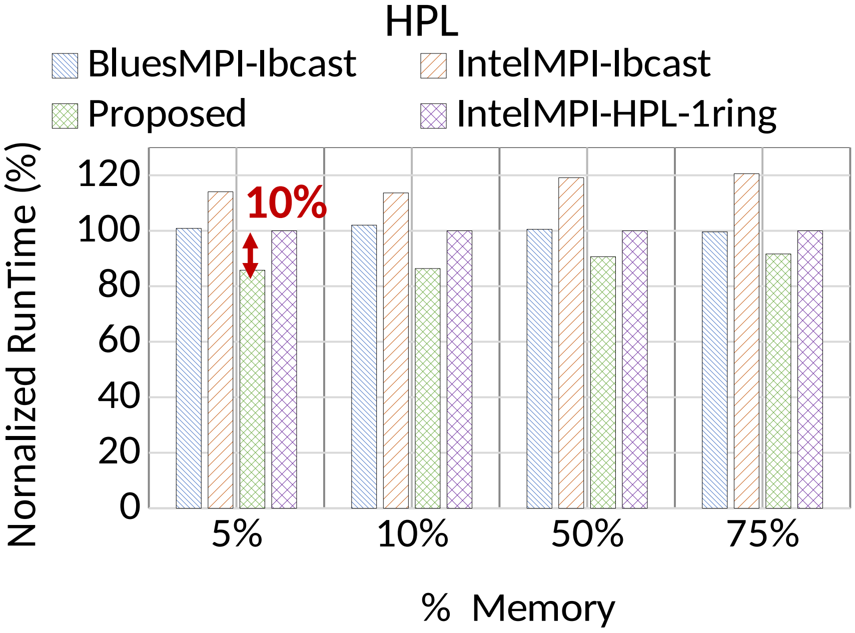
- OSU Microbenchmarks (OMB)
- 16 Nodes 32 PPN
- Proposed* Scheme at-least 25% better than BluesMPI
- Reason for improvements:
  - ~100% overlap
  - Absence of staging overhead



* Our Designs are available in the MVAPICH2-DPU library

Application Results: P3DFFT, HPL





- 16 Nodes 32 PPN
- Proposed* Scheme at-least 20% better than BluesMPI

- 16 Nodes 32 PPN
- Proposed* Scheme at-least 8% better than HPL-1ring

* Our Designs are available in the MVAPICH2-DPU library and HPL-DPU

Conclusion & Future Work

- Conclusion
  - DPU based communication progression better than host-based progression
  - Offloading MPI non-blocking primitives using GVMI
  - Showed Application-level improvements
    - HPL, P3DFFT
- Future Work
  - Accelerate additional applications such as Octopus
  - Offload OpenSHMEM based applications

THANK YOU!

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

MVAPICH

MPI, PGAS and Hybrid MPI+PGAS Library

The High-Performance MPI/PGAS Project

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