Analysis of Energy and Performance of Code Transformations for PGAS–based Data Access Patterns

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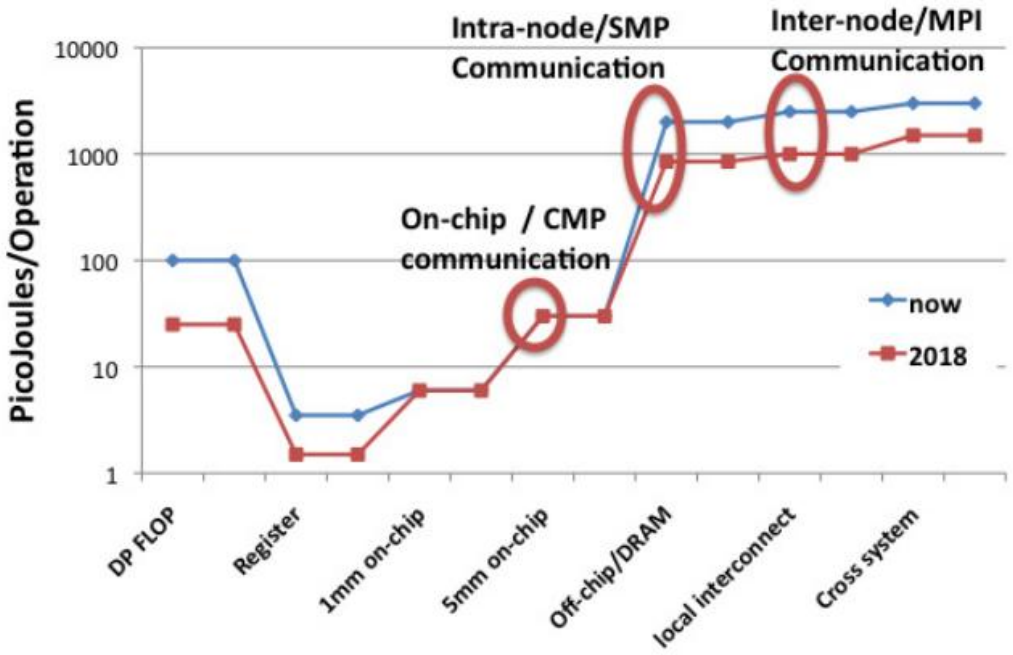
Barbara Chapman (UH)

PGAS, 2014
Oct 10, 2014

Why Talk About Energy?



Engineering FLOPs is not a design constraint – data movement presents the most daunting engineering and computer architecture challenge

Source: "*Exascale Computing Technology Challenges*", John Shalf, Sudip Dosanjh, and John Morrison

Outline

- Motivation
- Energy Cost Factors Across the H/W - S/W Stack
- Design of Data Access Patterns
- Access Pattern Transformations
- Analysis of Empirical Results
- Conclusions and Future Work

Motivation

- Energy savings is clearly a concern

  • DVFS techniques to achieve energy savings
  - Vishnu et al. (2013)

  • Energy study of point-to-point and collective operations
  - Venkatesh et al., Jana et al. (2013~14)

- What kernel characteristics should we be looking into?

- What layer within the software stack should we target?

Factors impacting energy consumption

Impact across the hardware-software stack

Intra-node Constraints	**Inter-node Constraints**
e.g. Cache sizes, set-associativity, cache-coherency protocol memory bandwidth, Hyperthreading, page-replacement	e.g. router-switch, organization, network topology, reliability, latency, peak-bandwidth

Factors impacting energy consumption

Impact across the hardware-software stack

Implementation Details e.g. Polling, registration of memory, reliability, reusability of memory, caching, memory management, fault-tolerance	**Flow / Congestion control** e.g. routing protocols, deadlock handling, load-balancing, quality-of-service
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Factors impacting energy consumption

Impact across the hardware-software stack

Choice of Transport Layer e.g. TCP, OpenFabrics, shared memory	**Communication Protocols** e.g. Message passing (Eager, Rendezvous) or Direct access
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Factors impacting energy consumption

Impact across the hardware-software stack

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Factors impacting energy consumption

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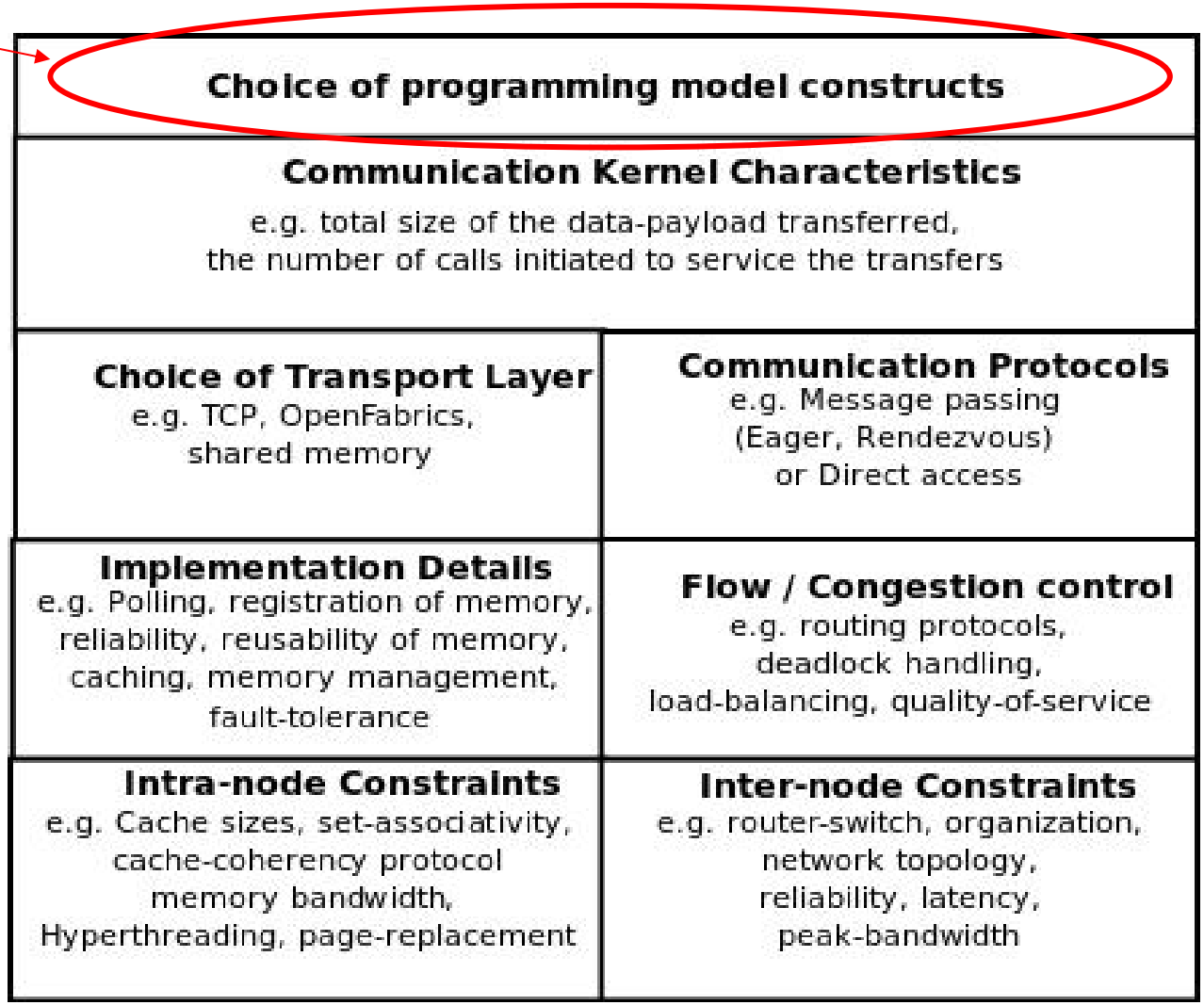
Factors impacting energy consumption

Impact across the hardware-software stack

Scope of this work

Past work



Factors impacting energy consumption

Impact across the hardware-software stack

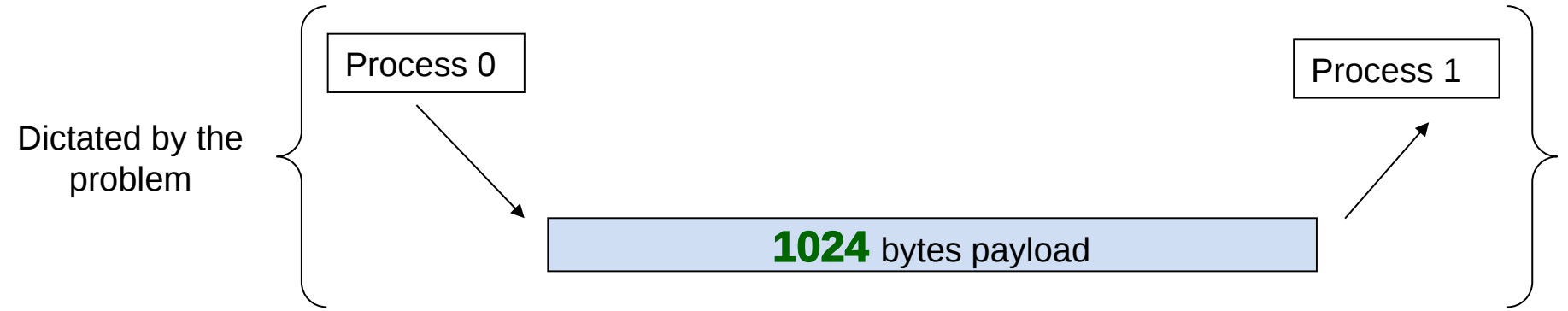
Choice of programming model constructs

Characteristics of a communication kernel

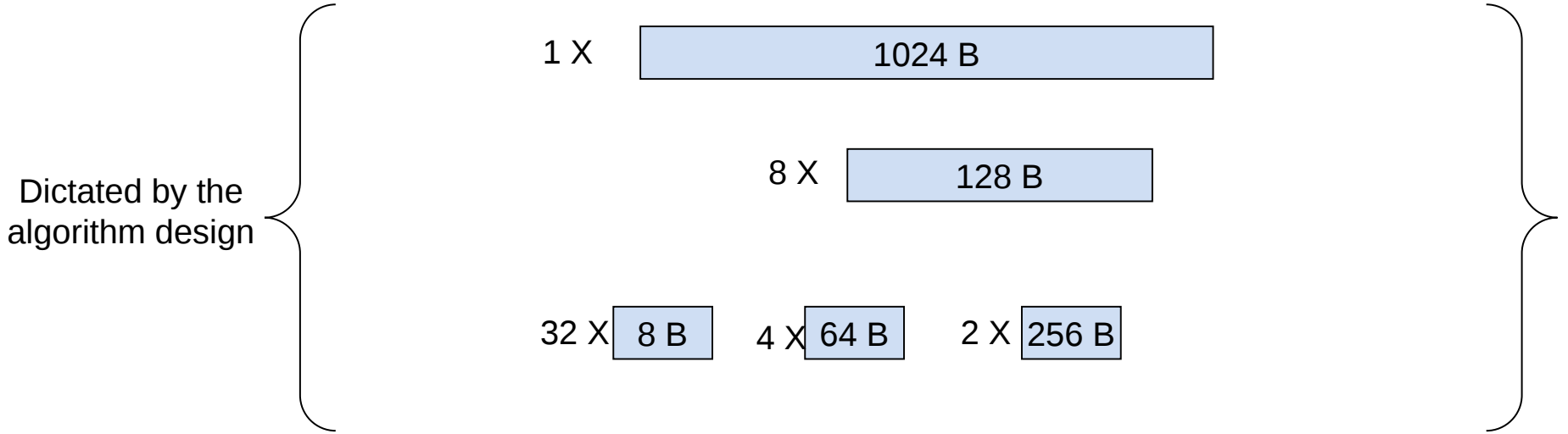
Characteritics of individual RDMA PUTs

Characteristics of a Communication Kernel

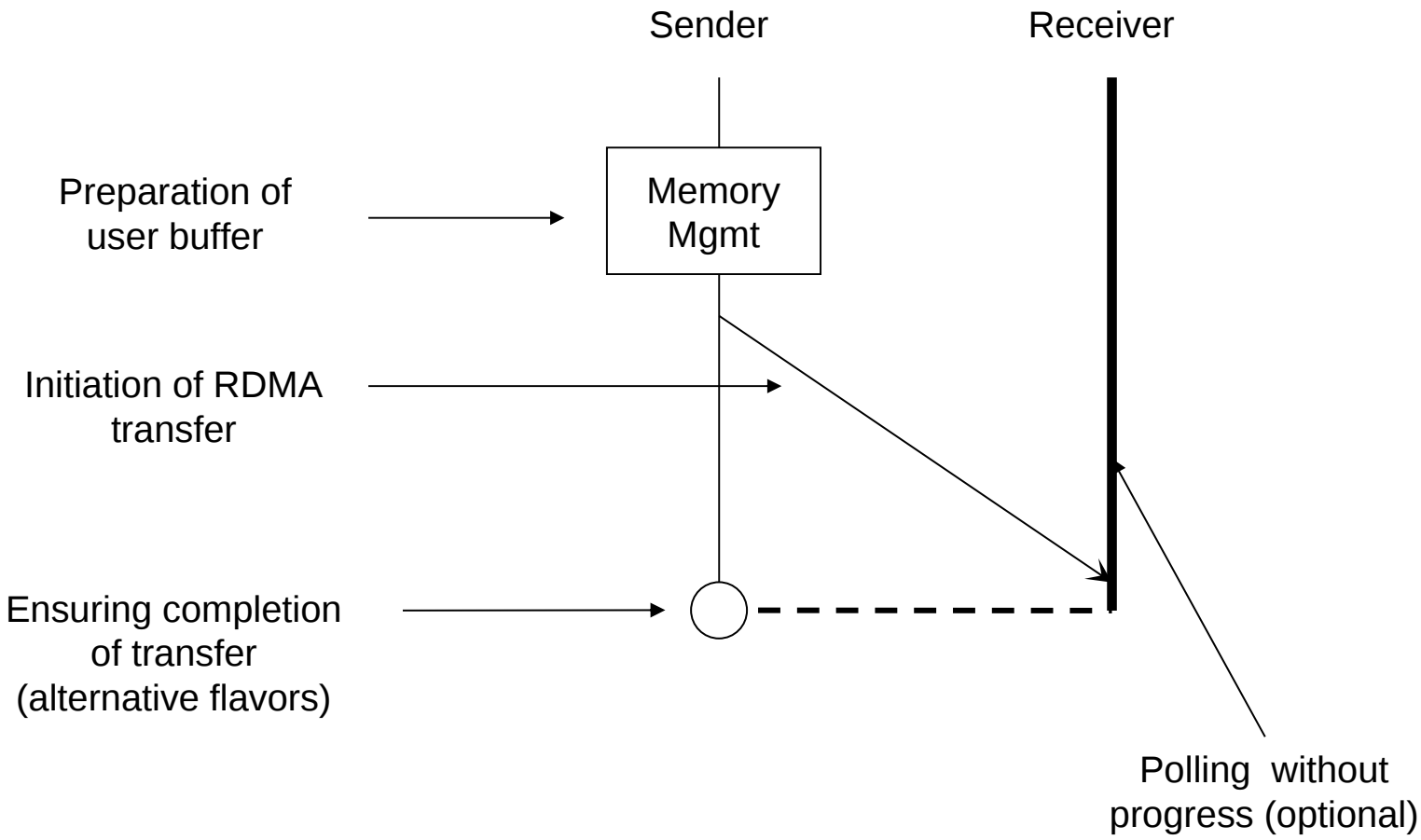
Consider the following case:



This can be transferred as:

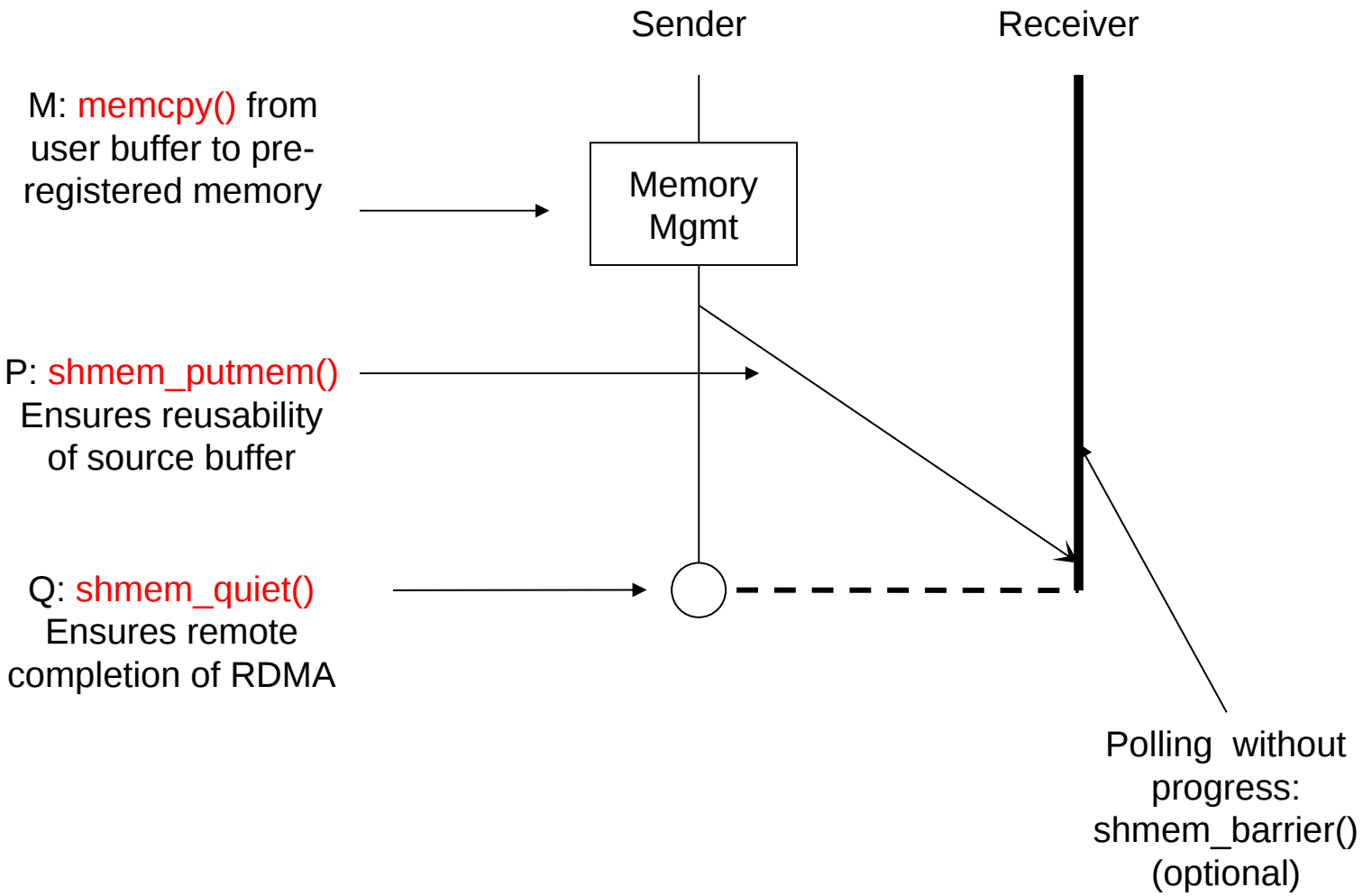


Costs Associated With RDMA Write Operations

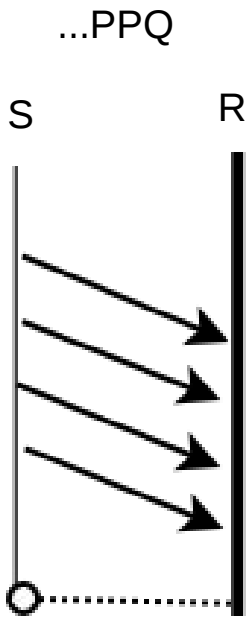


Costs Associated With RDMA Write Operations

In terms of OpenSHMEM



Analyzing Data Access Patterns



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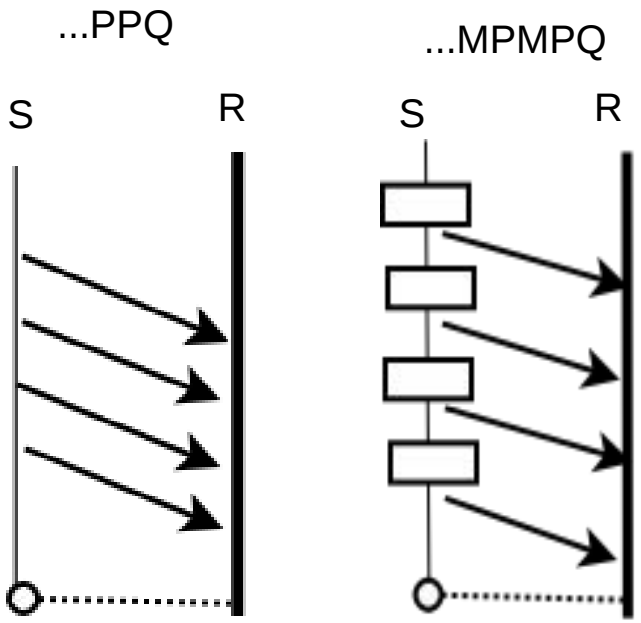

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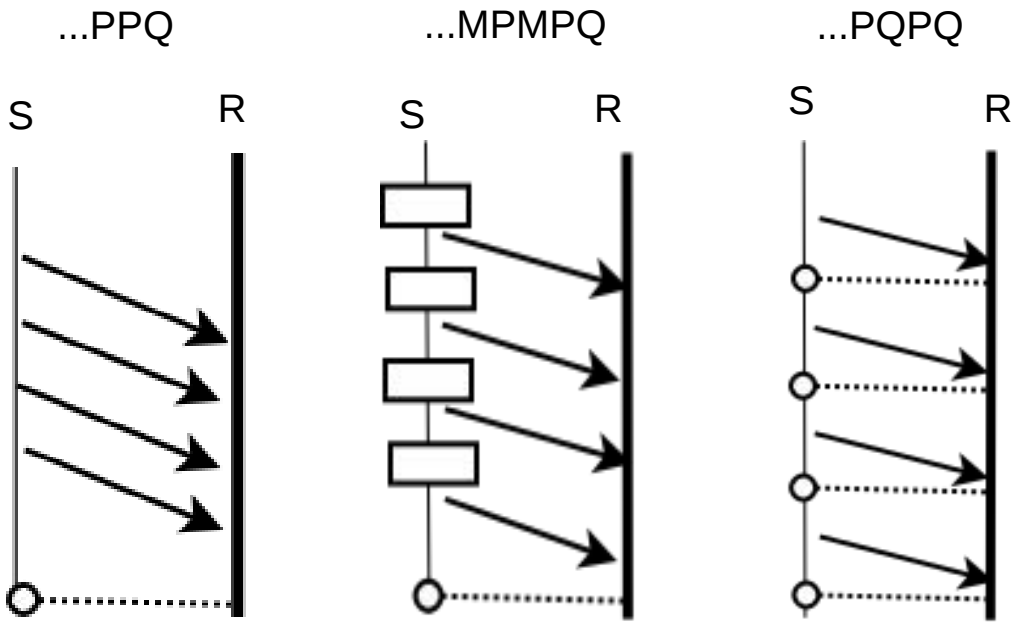

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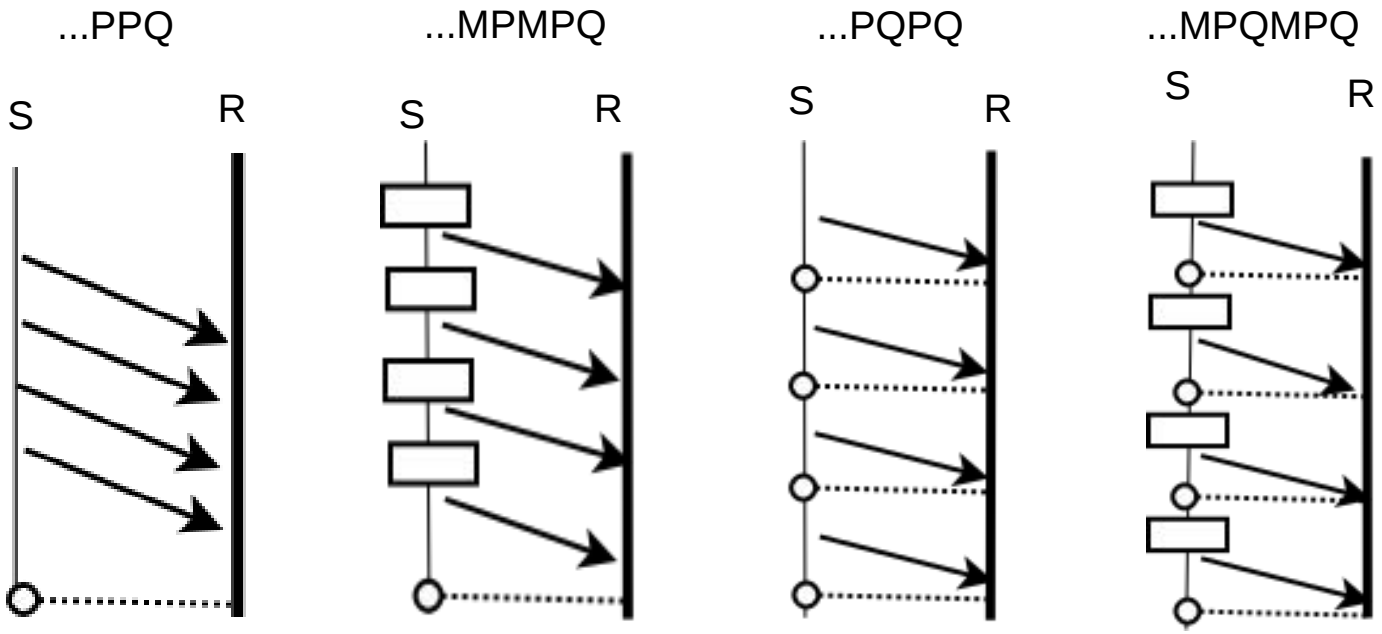

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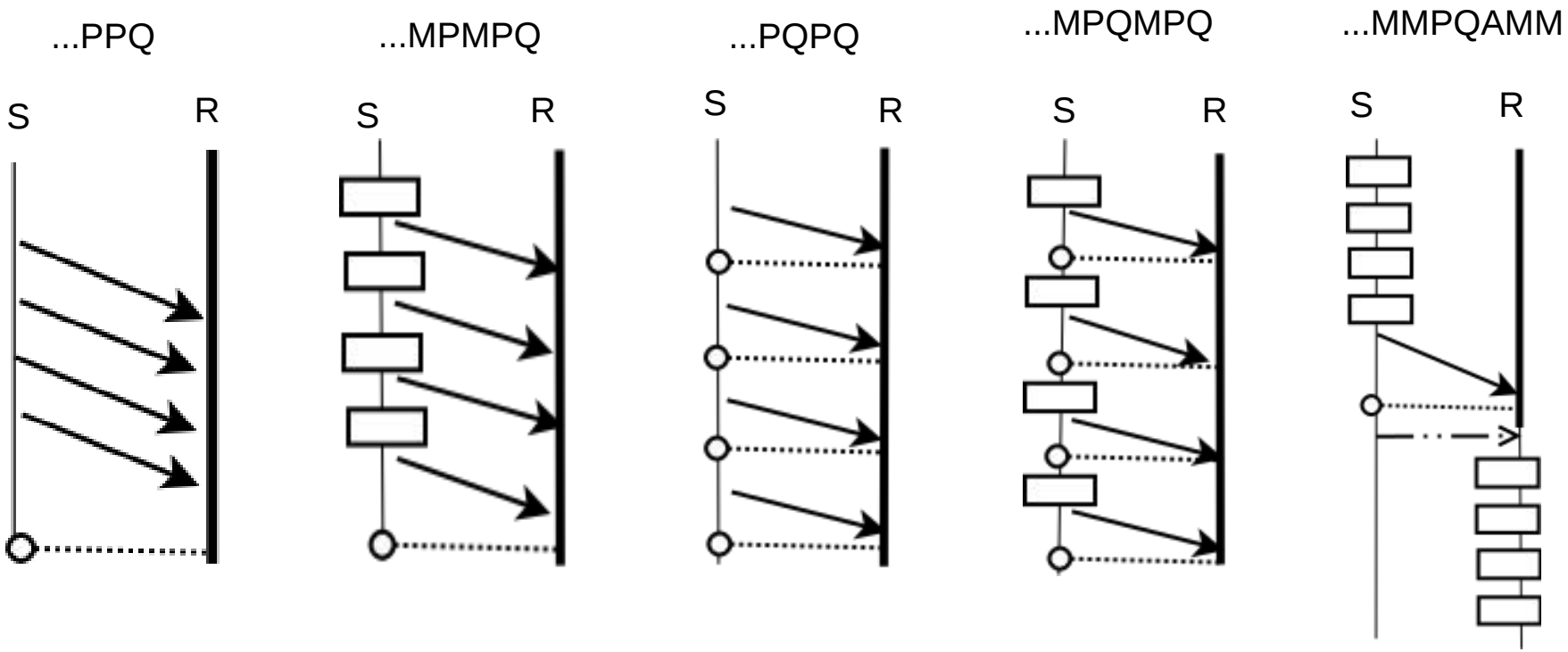
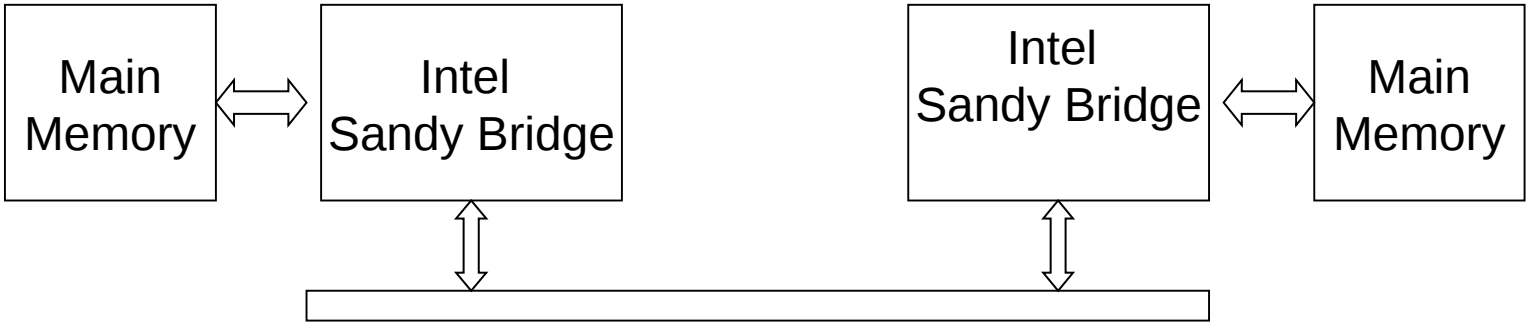


Experimental Setup

- CPU: Intel Sandy Bridge E5-2690
- NIC: Mellanox MT27500 : Connect-X
- One process (OpenSHMEM PE) per node
- Mellanox Scalable SHMEM



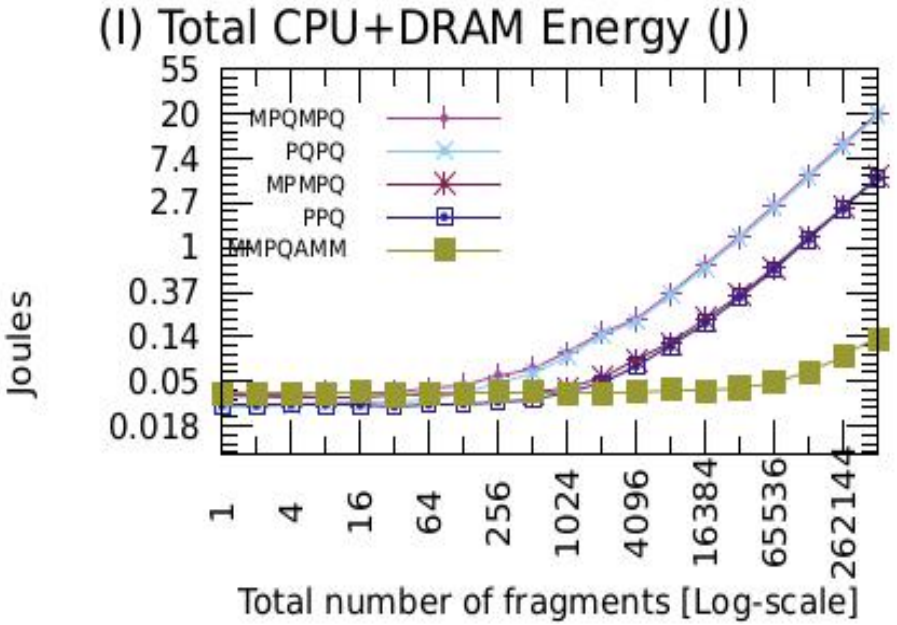
Infiniband (Mellanox)

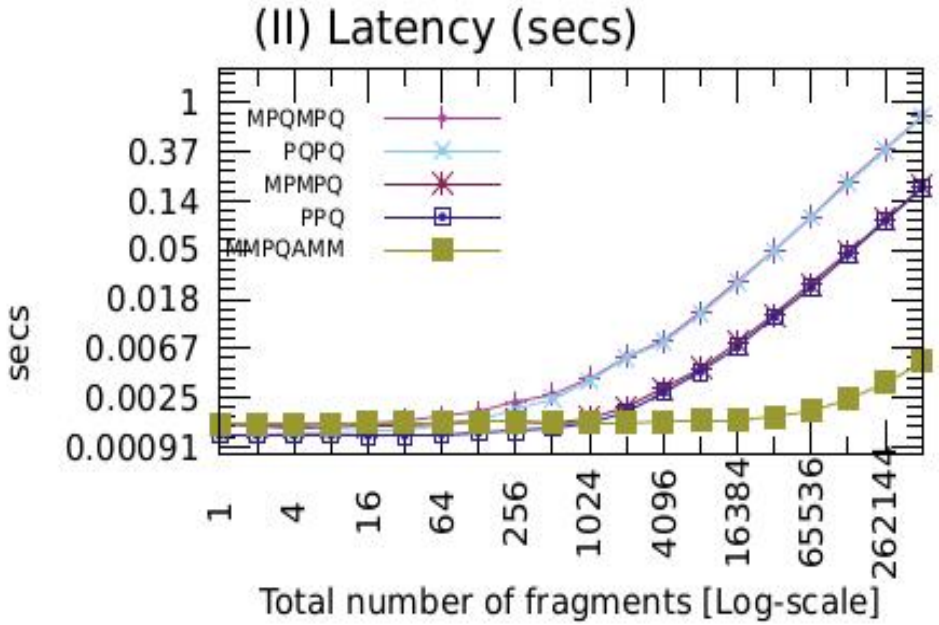
- Use of Voltage Regulators + FPGA
- Power measured at various levels of granularity
  - CPU, DRAM, Blade
  - 1KHz granularity

Peformance Characteristics of Data Access Patterns

Lower is better

For medium ~ bulk transfers:
MPQMPQ ~ PQPQ > MPMPQ ~ PPQ > MMPQAMM
Blocking versions > Non-blocking semantics > Aggregation





Total size of data payload = 0.5MB
Number of fragments (N) = Number of discrete user buffers
Size of a data buffer = 0.5MB/ N
Measurements in log-scale

Peformance Characteristics of Data Access Patterns

Higher is better

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MPQMPQ ~ PQPQ < MPMPQ ~ PPQ < MMPQAMM
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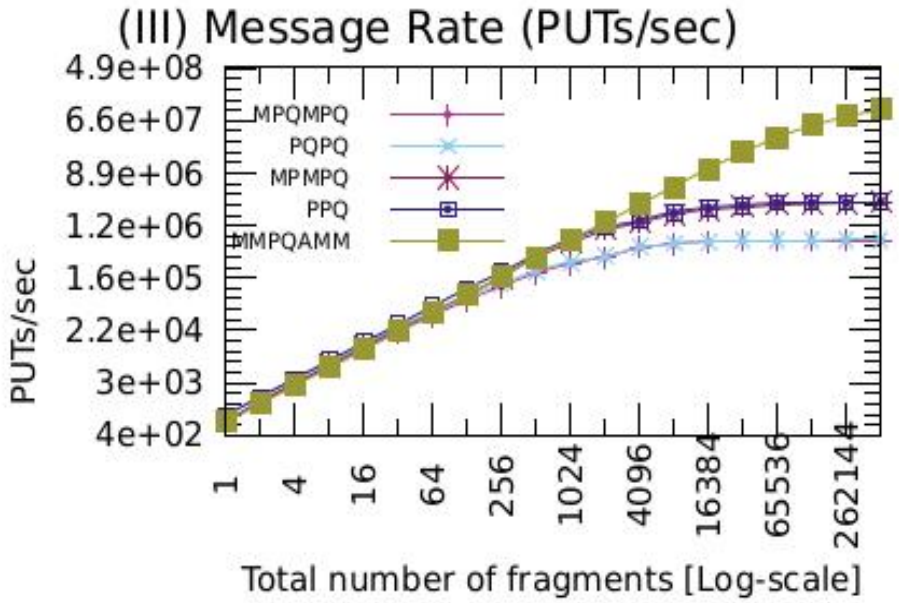

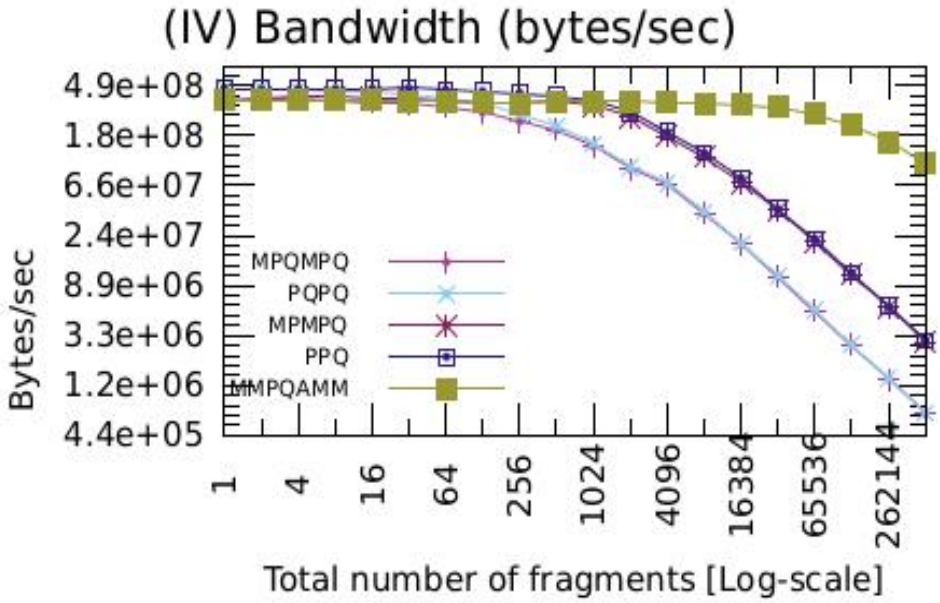

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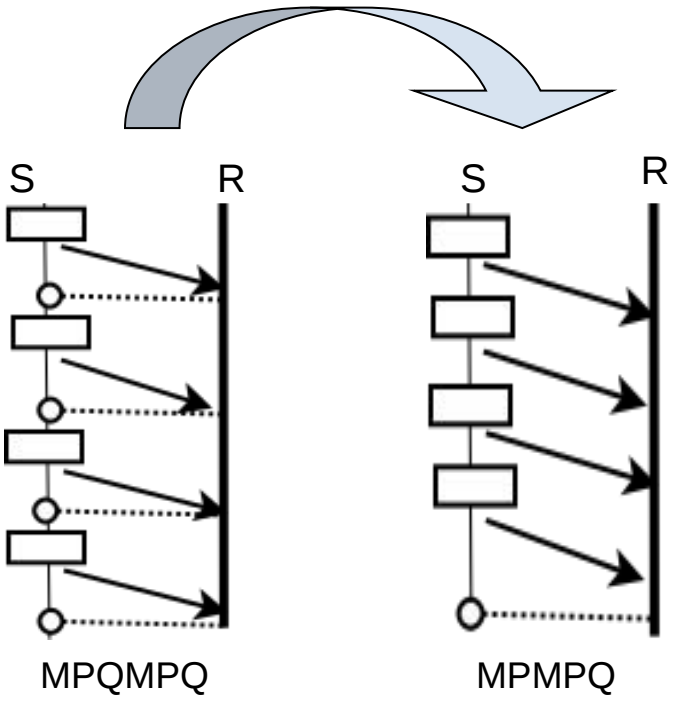
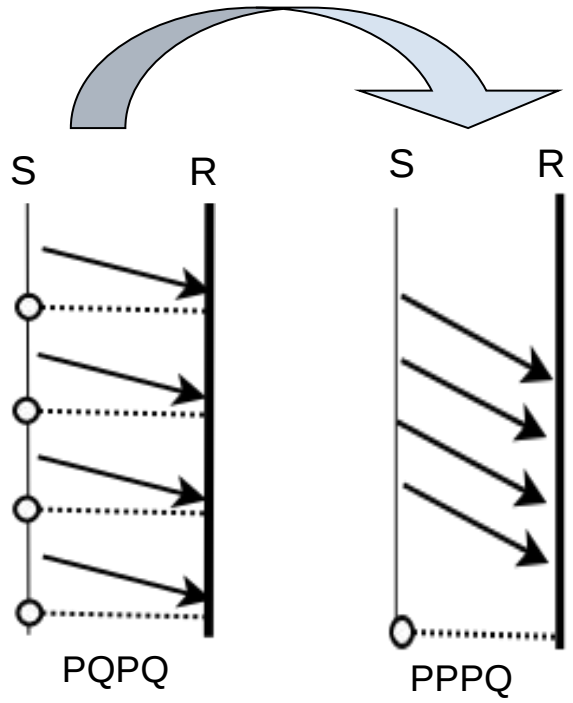
Cost Savings Using Non-blocking operations



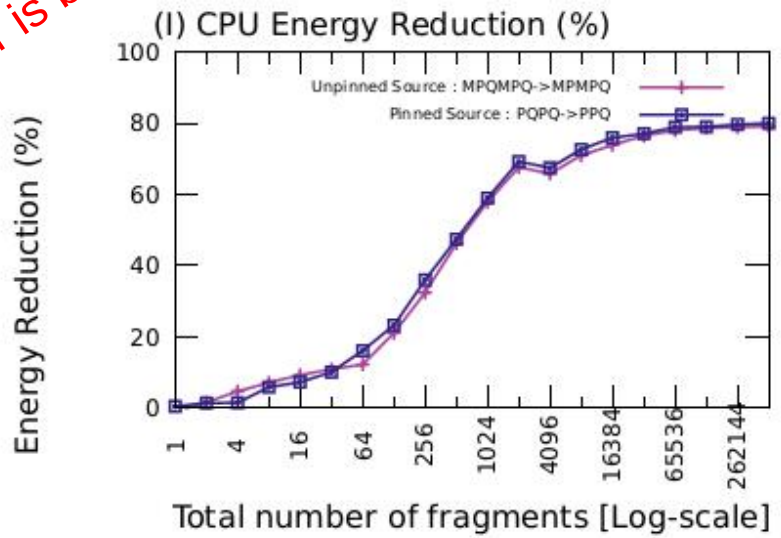
Case1: With unregistered buffers

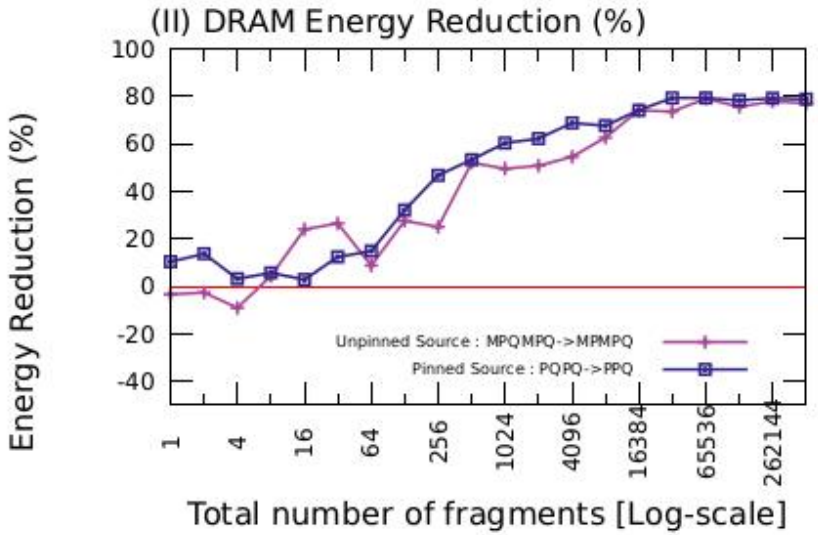


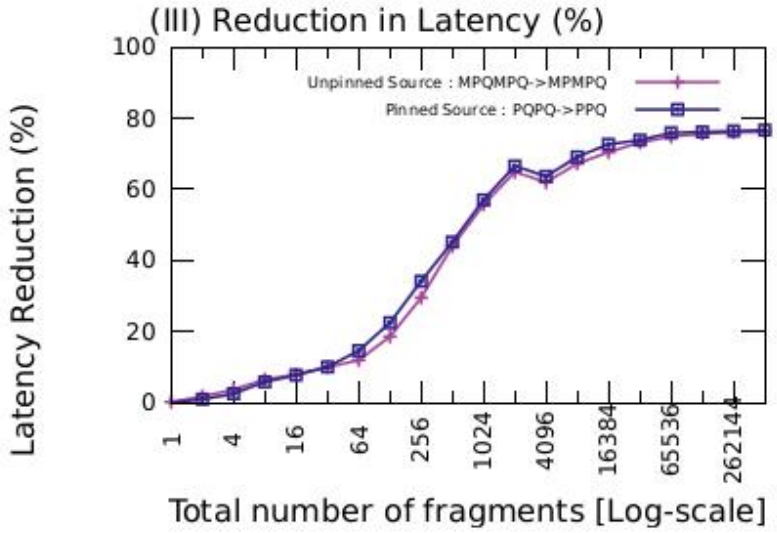
Case2: With registered buffers

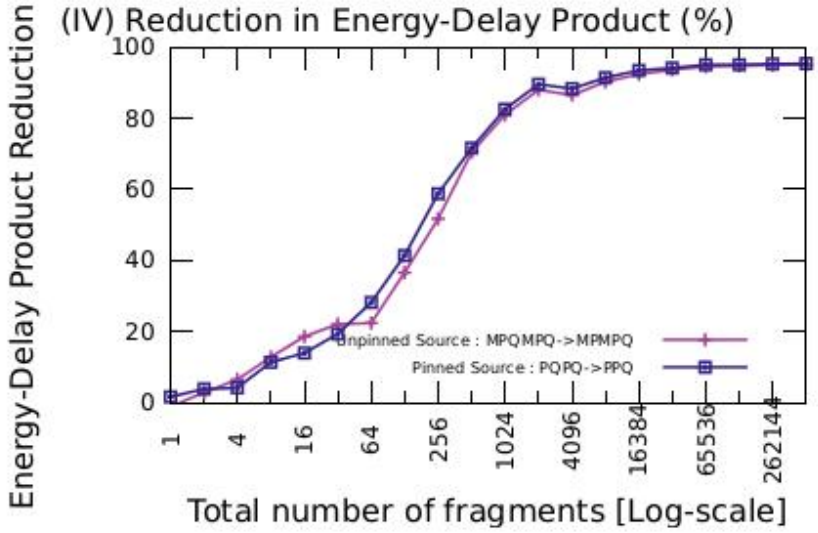
Impact of Using Non-blocking operations

Higher is better

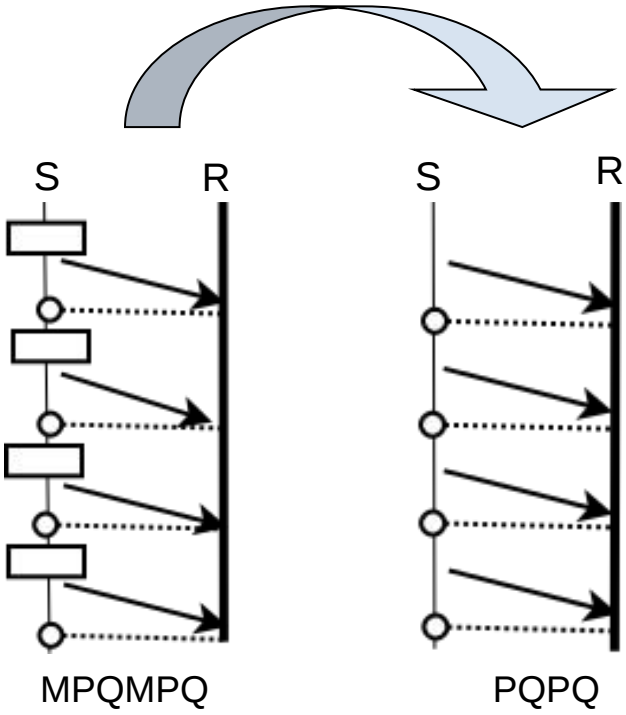




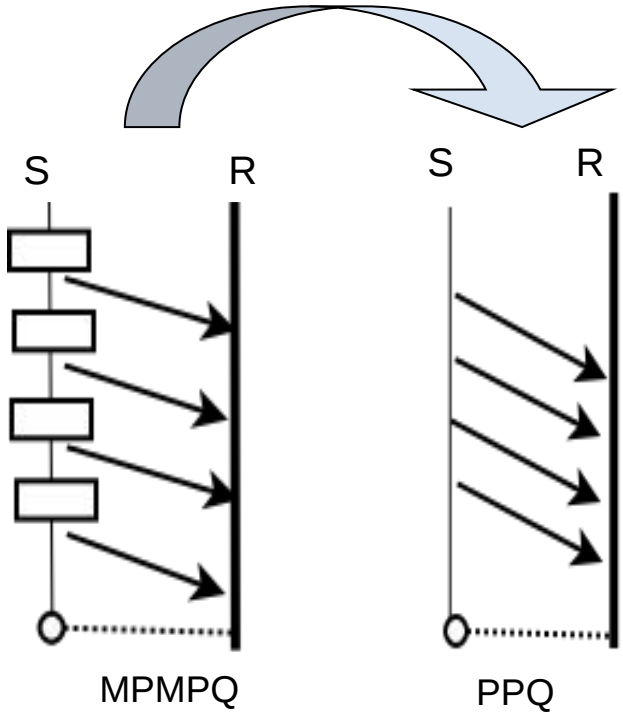




Costs Savings Using NIC-Registered Buffers



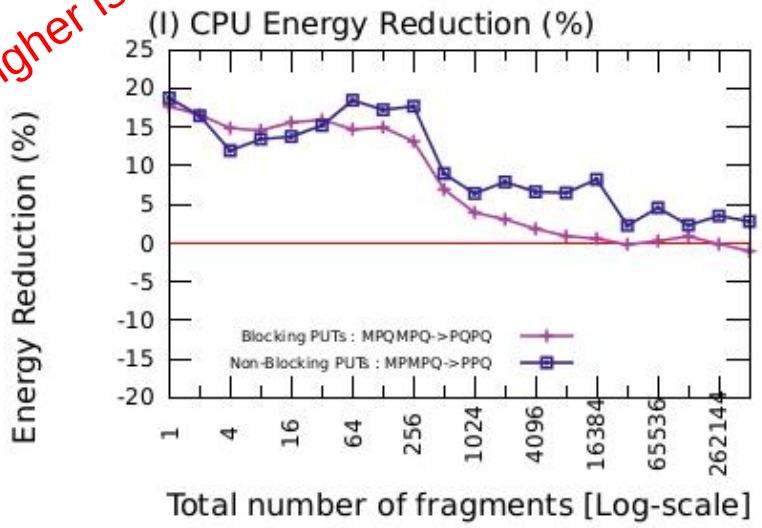
Case1: With blocking PUTs

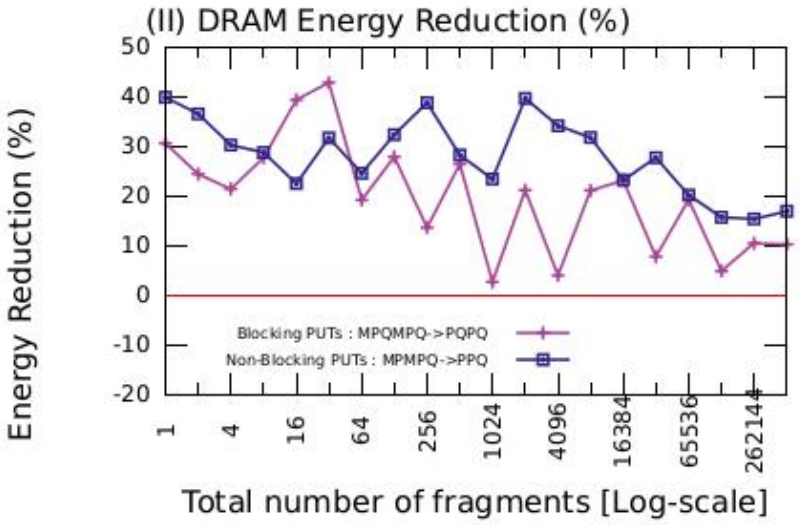


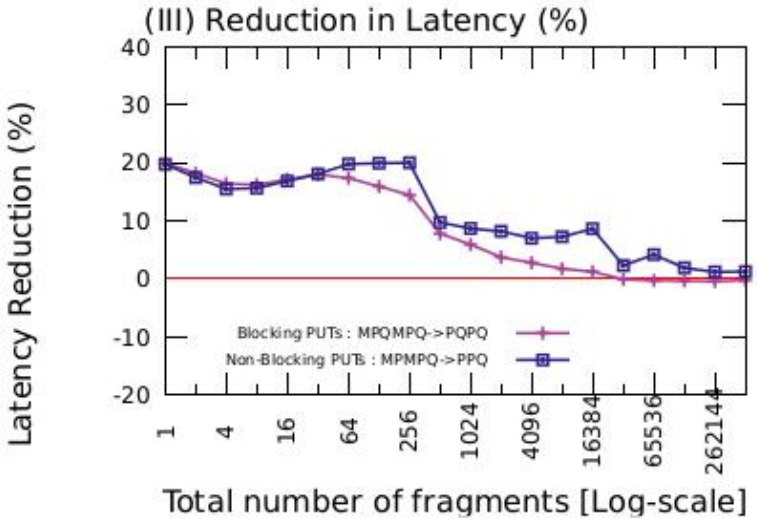
Case2: With non-blocking PUTs

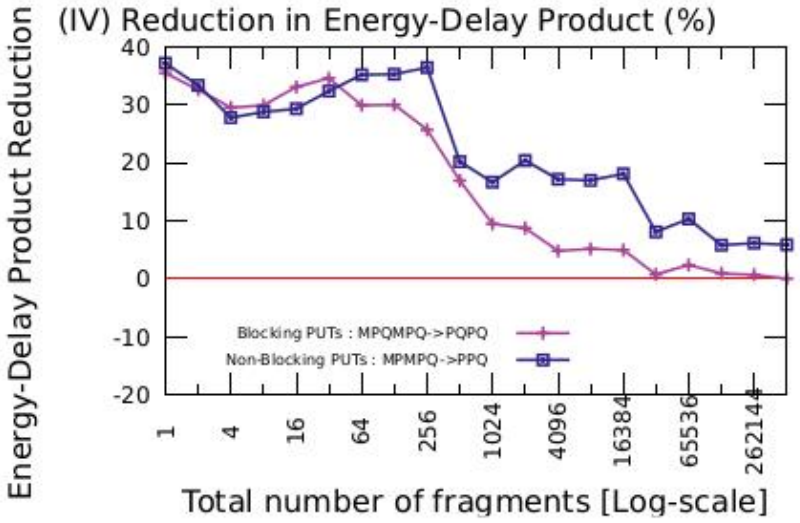
The Impact of Using NIC-Registered Buffers

Higher is better

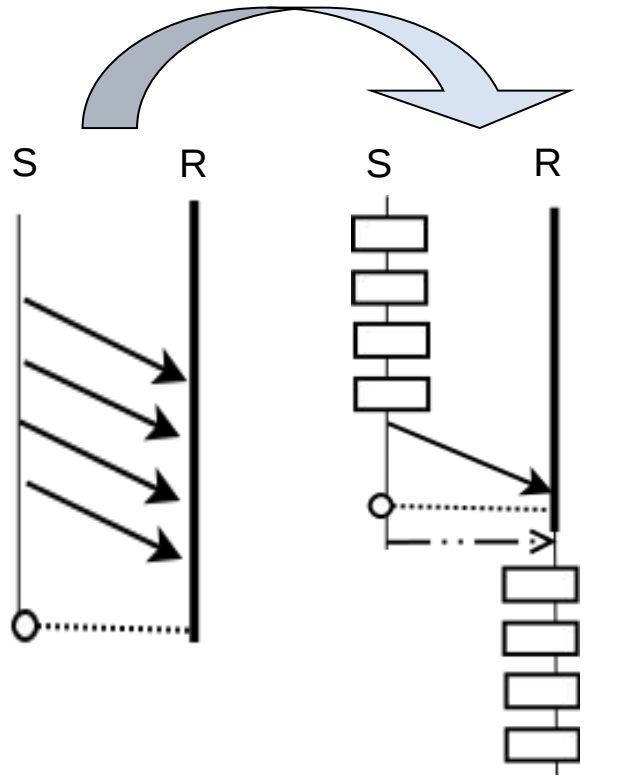








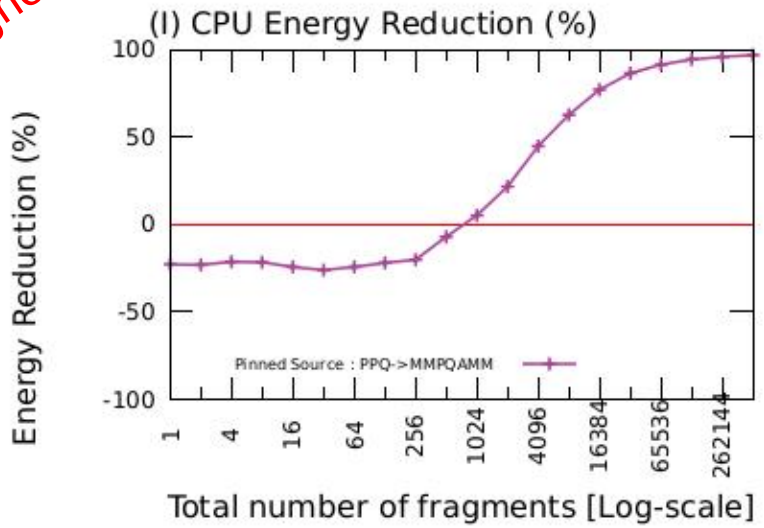
Costs Savings Using Aggregated Source Buffers

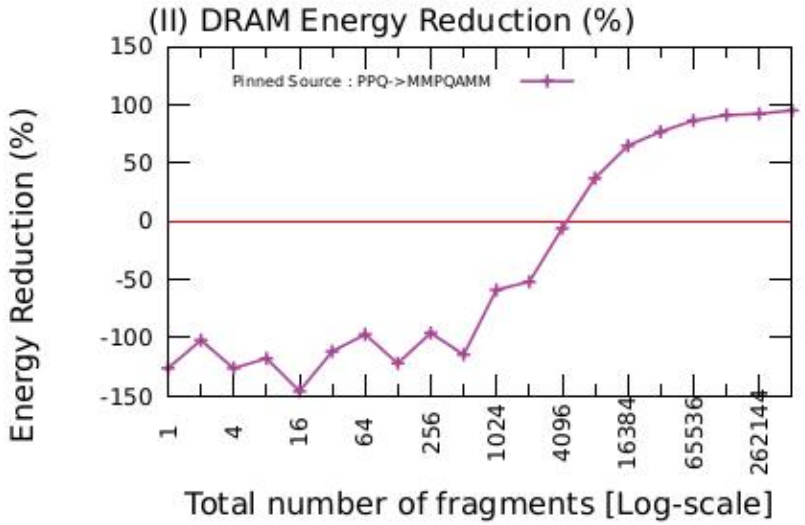


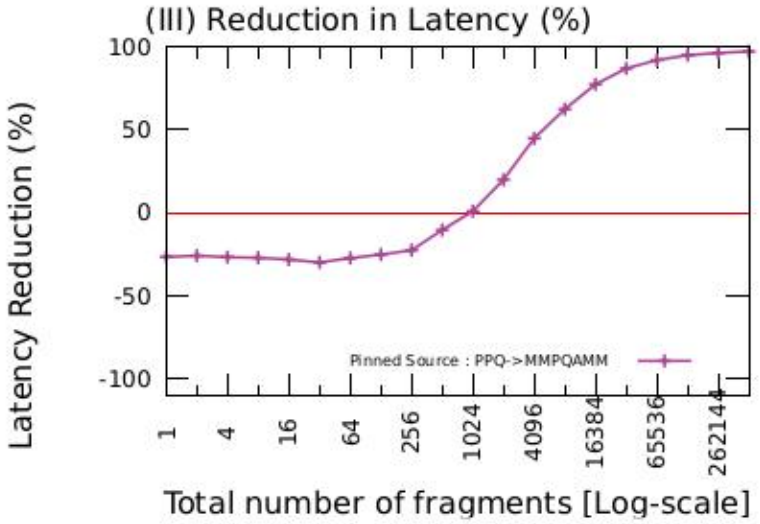
PPQ MMPQAMM

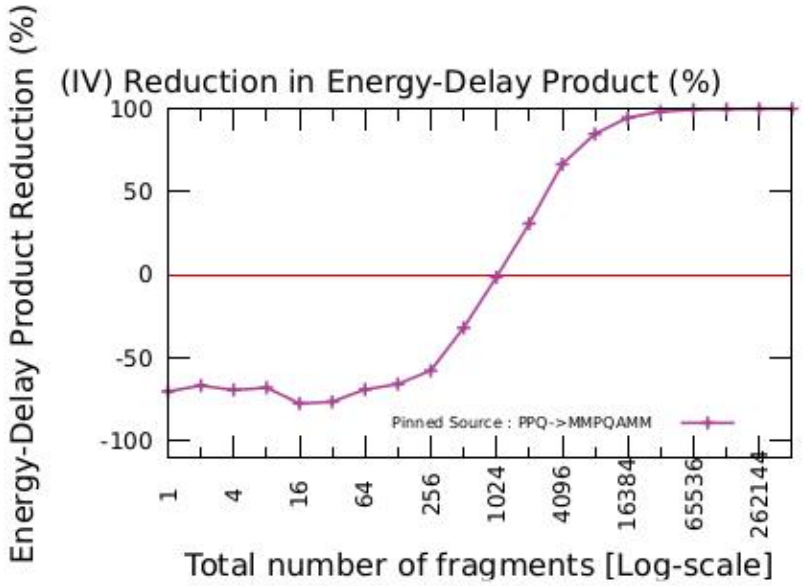
Higher is better

The Impact of Using Aggregated Source Buffers









Conclusions and Future Work

- Energy-based metrics similar to latency based results

- Analysis of different data access patterns
    - Aggregation
    - Blocking
    - Buffer registration

- Potential cost savings in converting in transformation of these patterns

Analysis of Energy and Performance of Code Transformations for PGAS-based Data Access Patterns

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