Evaluating the Performance of One-sided Communication on CPUs and GPUs

Nan Ding, Muhammad Haseeb, Taylor Groves, Samuel Williams
Lawrence Berkeley National Laboratory
nanding@lbl.gov

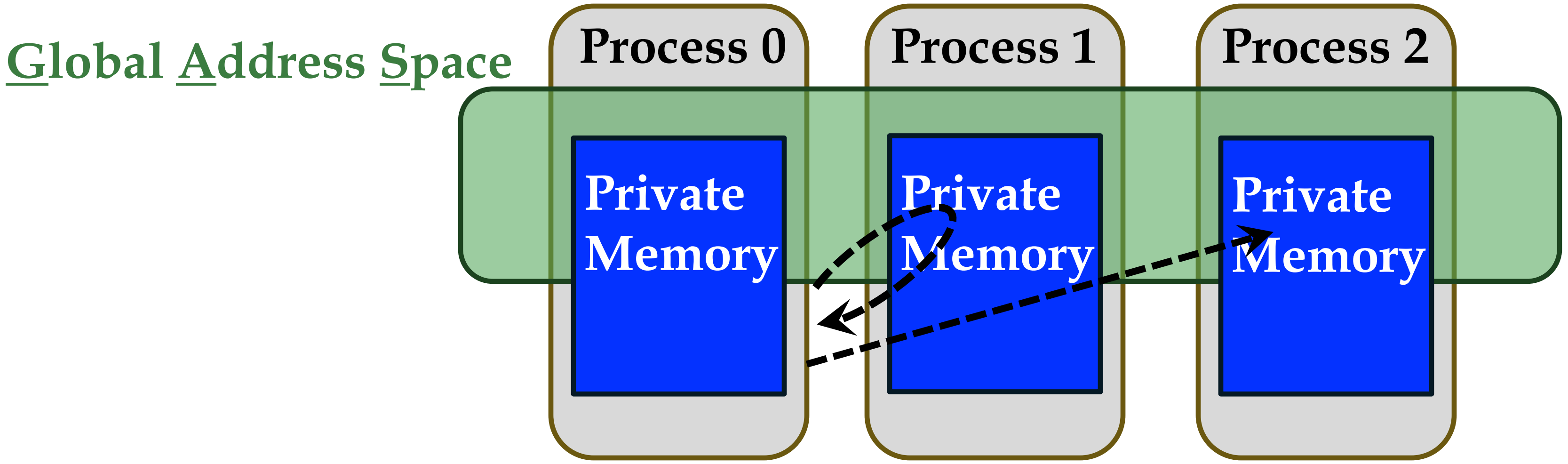
Outline

- Benefit and Challenges
- Message Roofline Model
- Results

What is One-Sided MPI?

- Two-Sided MPI: both sender and receiver are involved in data transfer
  - Example :MPI_Send/MPI_Recv

- One-Sided MPI: decouple data movement with process synchronization
  - PGAS model: one process can directly access other processes' memory
  - move data without requiring that the remote process synchronize
  - Example: MPI_Put



Benefits and Challenges

- Common way to communication on multiple GPUs

CPU (control flow) | GPU

Loop:

    <<<…>>> do computation
    ** synchronization**
    ** do communication **

- **Increased algorithm complexity and decreased program productivity**
- **Hard to scale DAG-like computation**

- GPU-initiated communication (One-Sided): NVSHMEM/ROC_SHMEM

CPU | GPU (control flow)

<<<…>>> everything

Loop:

    ** do computation **
    ** do communication **

- **Program like on traditional CPU nodes**
- **Makes scaling DAG-like computation more feasible**
- **Preserve portability by using a common SHMEM interface that could be applied to CPUs and GPUs**
- **Highlights the use of one-sided communication on CPUs**

[1] https://www.top500.org/

Benefits and Challenges

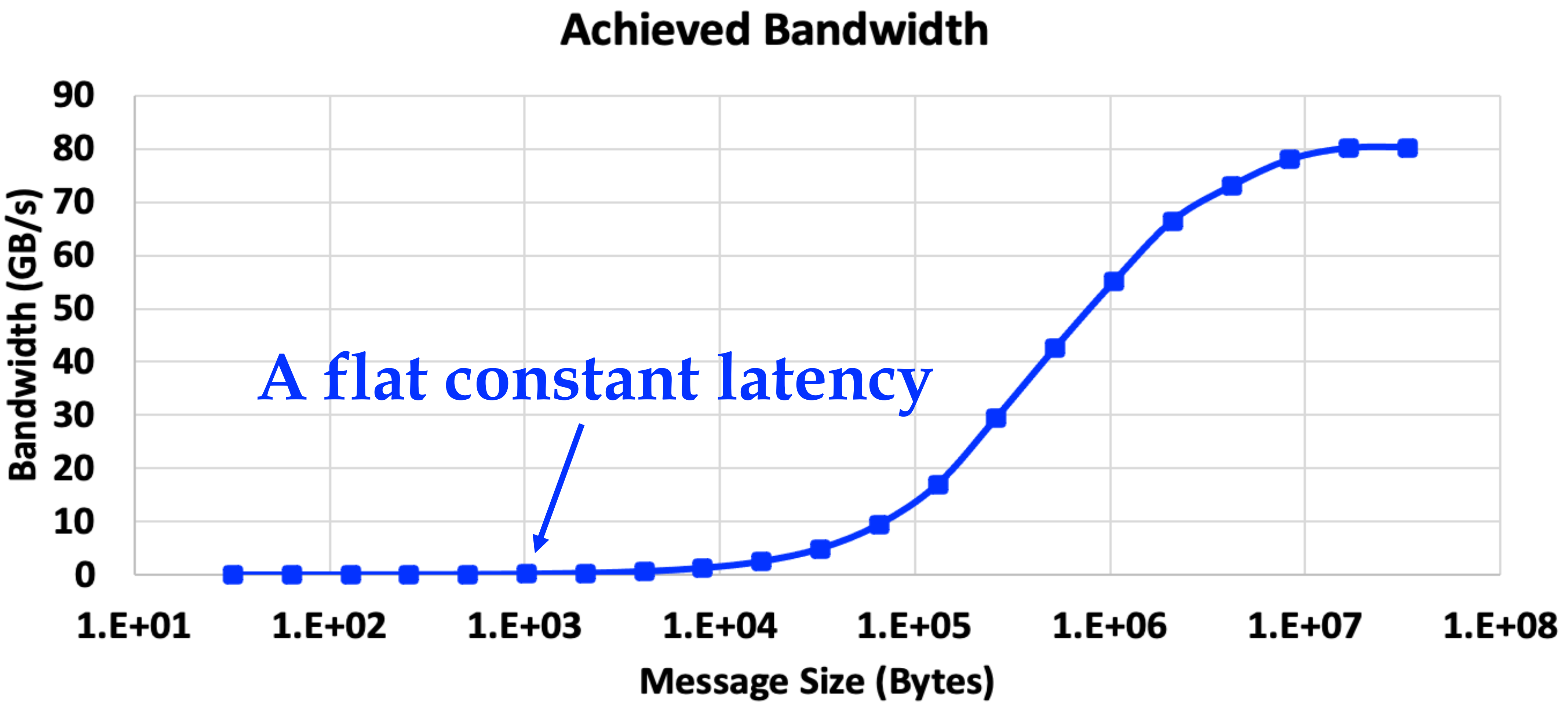
- Challenges:
  - Requires more careful management of data placement and synchronization
    - Two-Sided communication: MPI_Recv handles everything
      - Data transfer is complete at the receiver side
      - Receive buffer can be easily re-usable
    - One-Sided communication: NA
      - Need user effort to manage data placement and receiver notification

[1] https://www.top500.org/

What’s the Achieved Communication Performance?

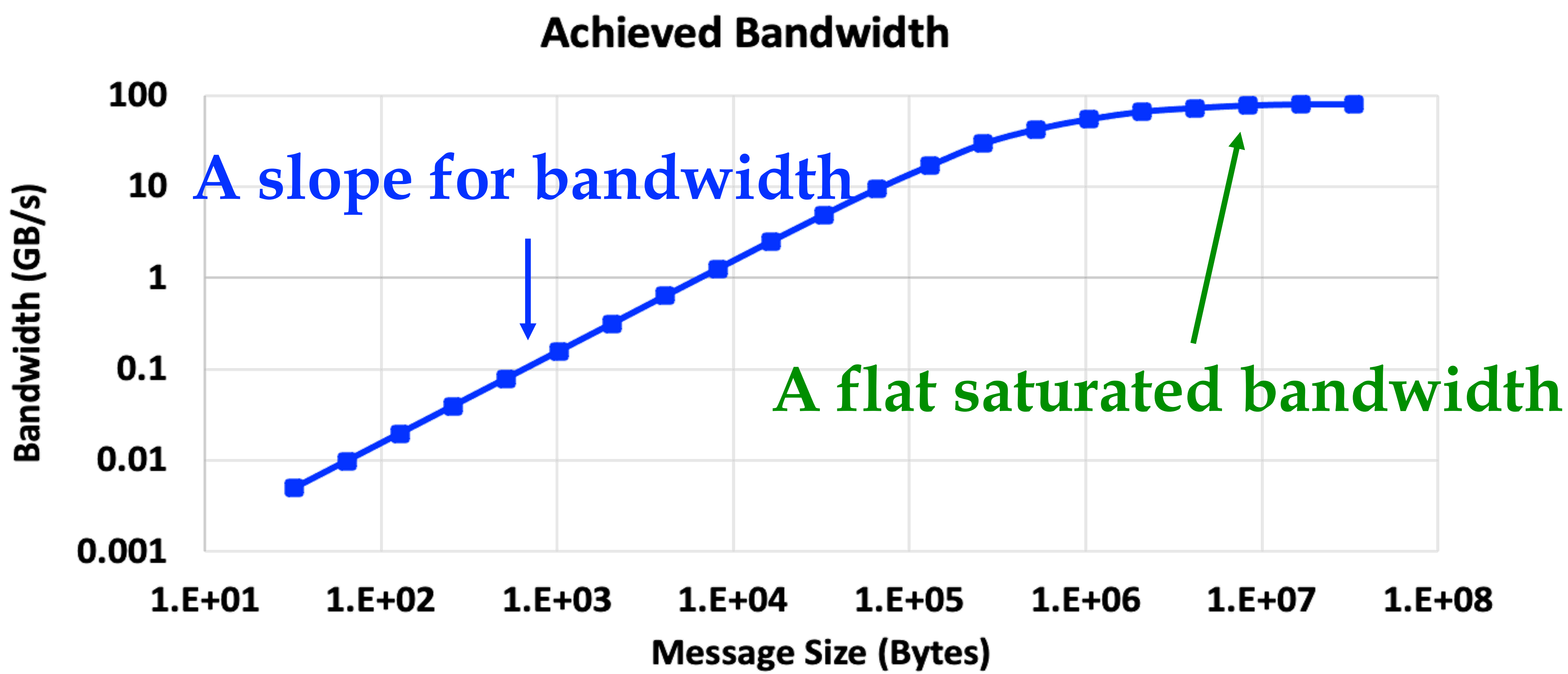
- Message Roofline Model provides a realistic bound on the communication performance based on the number of messages per synchronization

Log-linear Plot: CAN NOT Interpret Small Message Performance

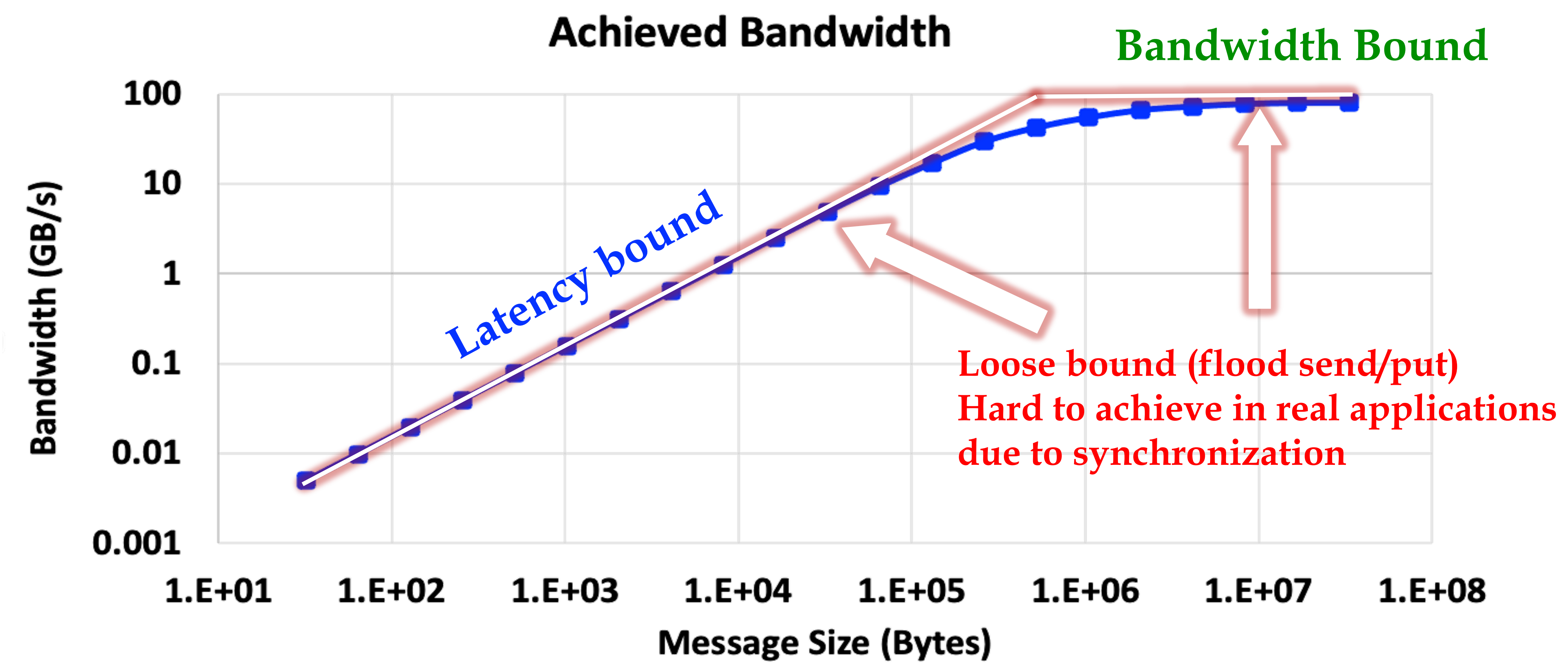


Log-Log Plot: CAN Interpret Small Message Performance

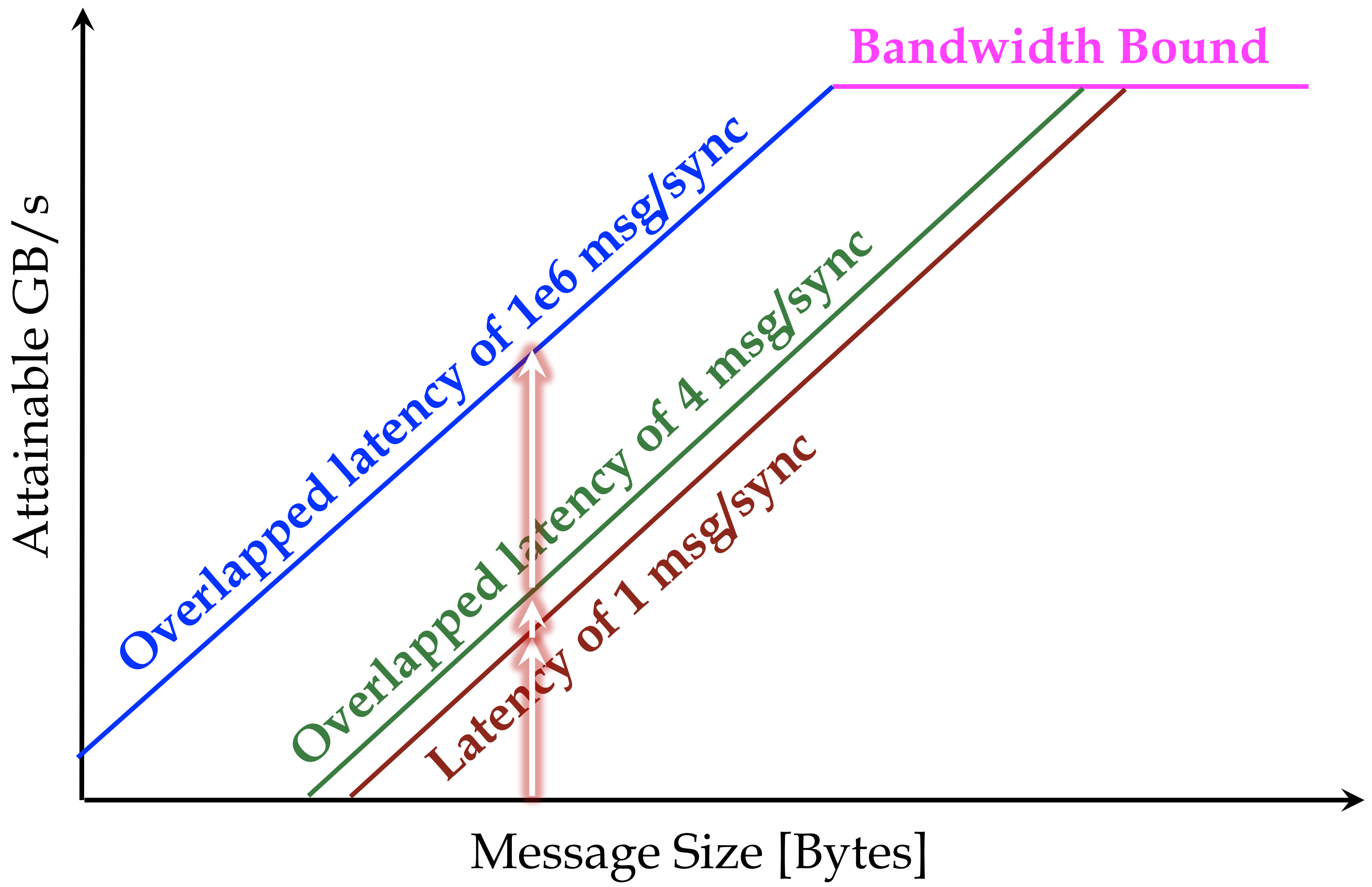
Achieved Bandwidth = F(message size)



Can you achieve the peak?

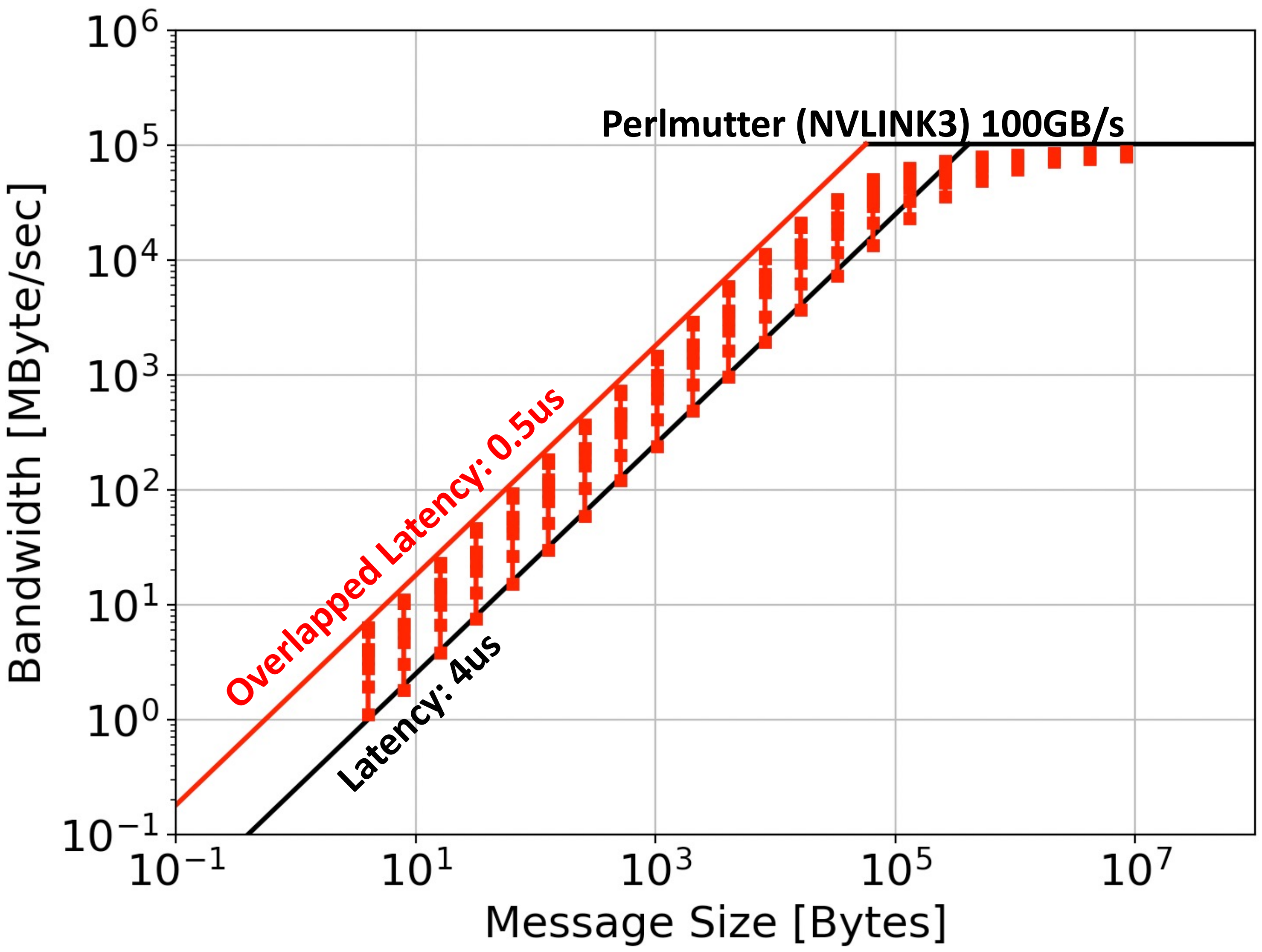


Msg/sync Tells A Tight Communication Upper Bound



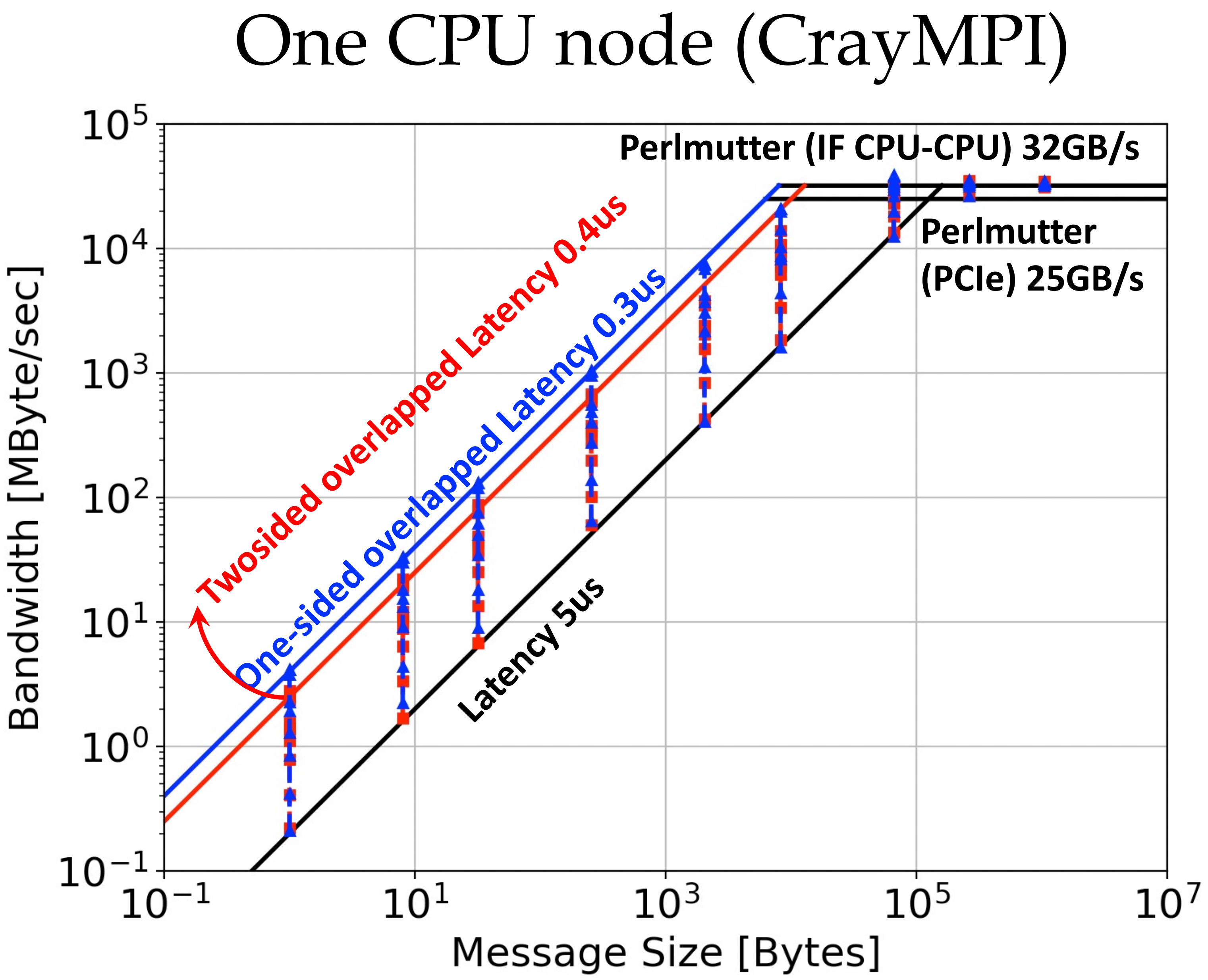
Communication performance on Perlmutter GPUs

One GPU node (NVSHMEM)



- Sender: put-with-signal and nvshmem_quiet to ensure the data transfer is completed at the receiver side.

Communication performance on Perlmutter CPUs



Two-Sided:

- MPI_Isend
- MPI_Recv

One-Sided:

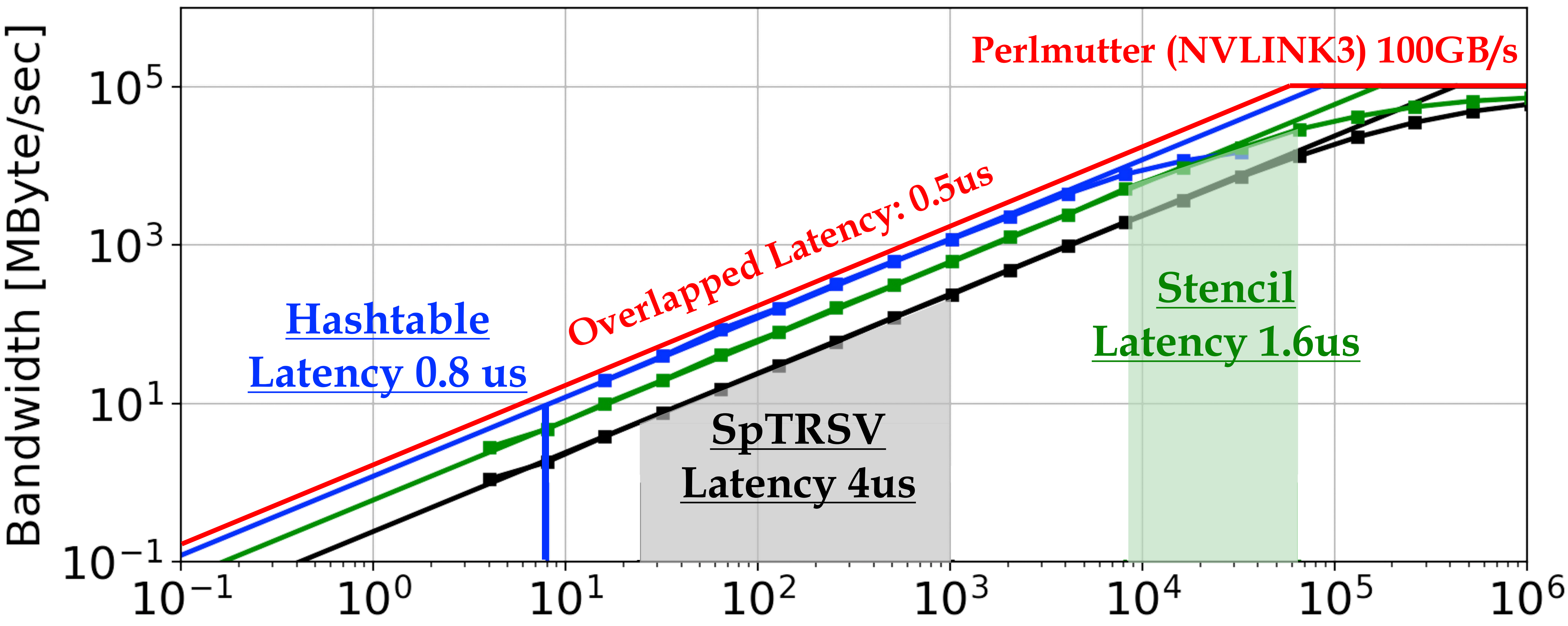
- MPI_Put (data)
- MPI_Win_flush /* memory order */
- MPI_Put (signal)
- MPI_Win_flush /* avoid a delayed signal */

CPU one-sided MPI has potential to outperform the two-sided by supporting put-with-signal and receiver notification operations.

Characterize Applications using msg/sync

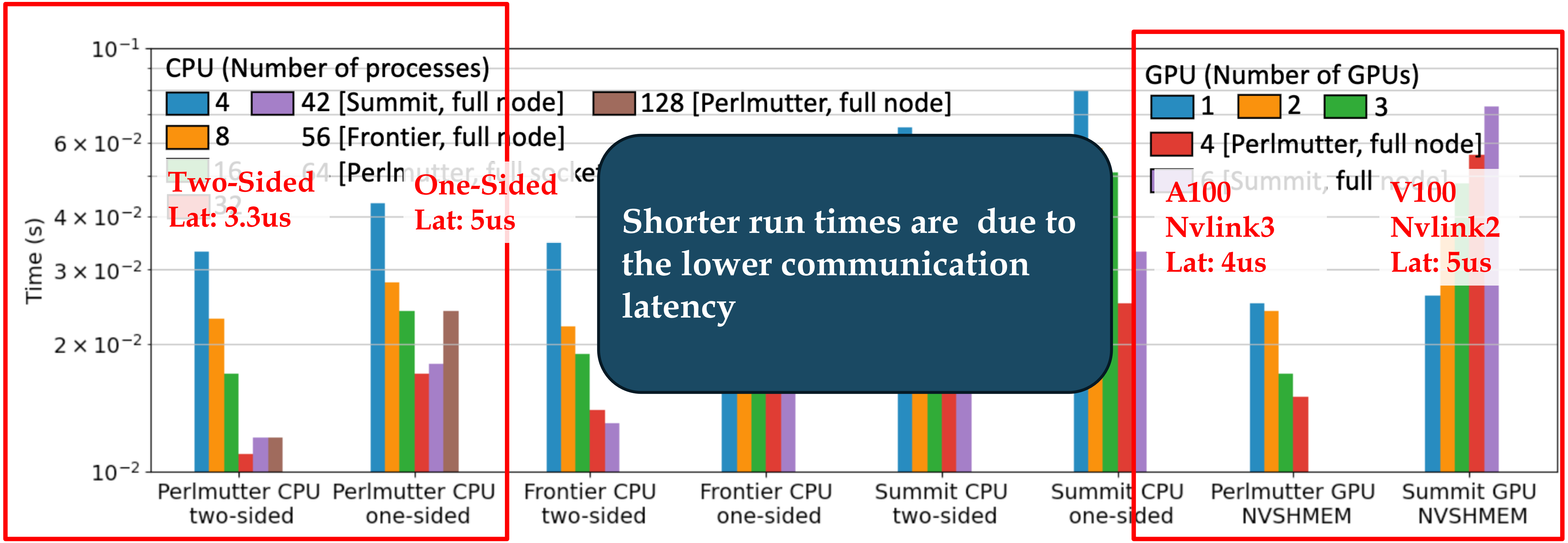
Workloads	Patterns	Need receiver Notify?	P2P pair	Msg/sync	Words/Msg
2D Stencil	BSP sync	Yes	Deterministic & fixed	4	Problem size/P
SpTRSV	DAG async	Yes	Deterministic & variable	1	Avg. 100
HashTable	Random async	No	indeterministic	Two-Sided: P	3
				One-Sided: 1e6	1

Varies Achieved Bandwidth due to different msg/sync



Case Study: SpTRSV

- Matrix (from M3D-C1): 126K x 126K, with 1E+8 non-zeros
- 1 msg/sync
- Message size: 24 bytes – 1040 bytes



Conclusion

- Propose a new metric -- the number of messages per synchronization -- to provide a tight upper bound of communication performance, and help reason performance

- Message Roofline Model can help with 3P: ***(1)Performance***: provide a tight upper bound of communication performance, ***(2) Productivity***: guide a proper communication model for applications, and ***(3) Portability (Performance):*** reason different performance trends across architectures.

- We demonstrate the potential of One-Sided MPI if put-with-signal and loose wait can be supported on CPUs.

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