Validation of OpenMPI transferred data using Merkle Trees

Secure Coding 2024/2025

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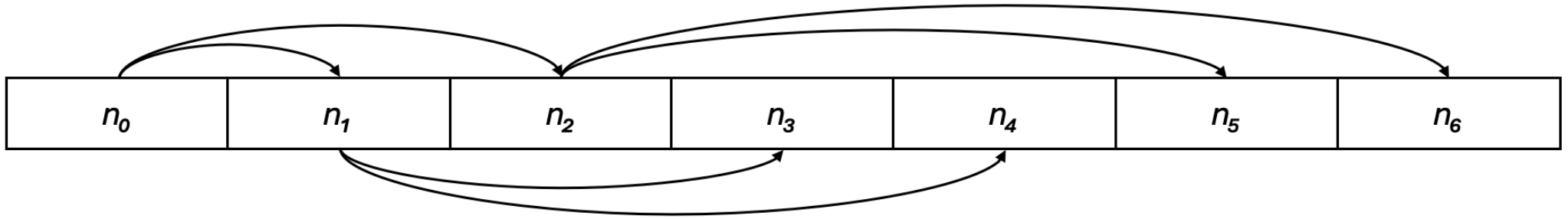
Motivation

- Ensuring data integrity in High-Performance Computing (HPC) domain
- Message Passing Interface (MPI)
- Common transmission protocols – TCP/IP, Infiniband, ROCE
- Error detection in transmission protocols
- MPI mechanisms to prevent common faults
- Hardware error detection and correction mechanisms

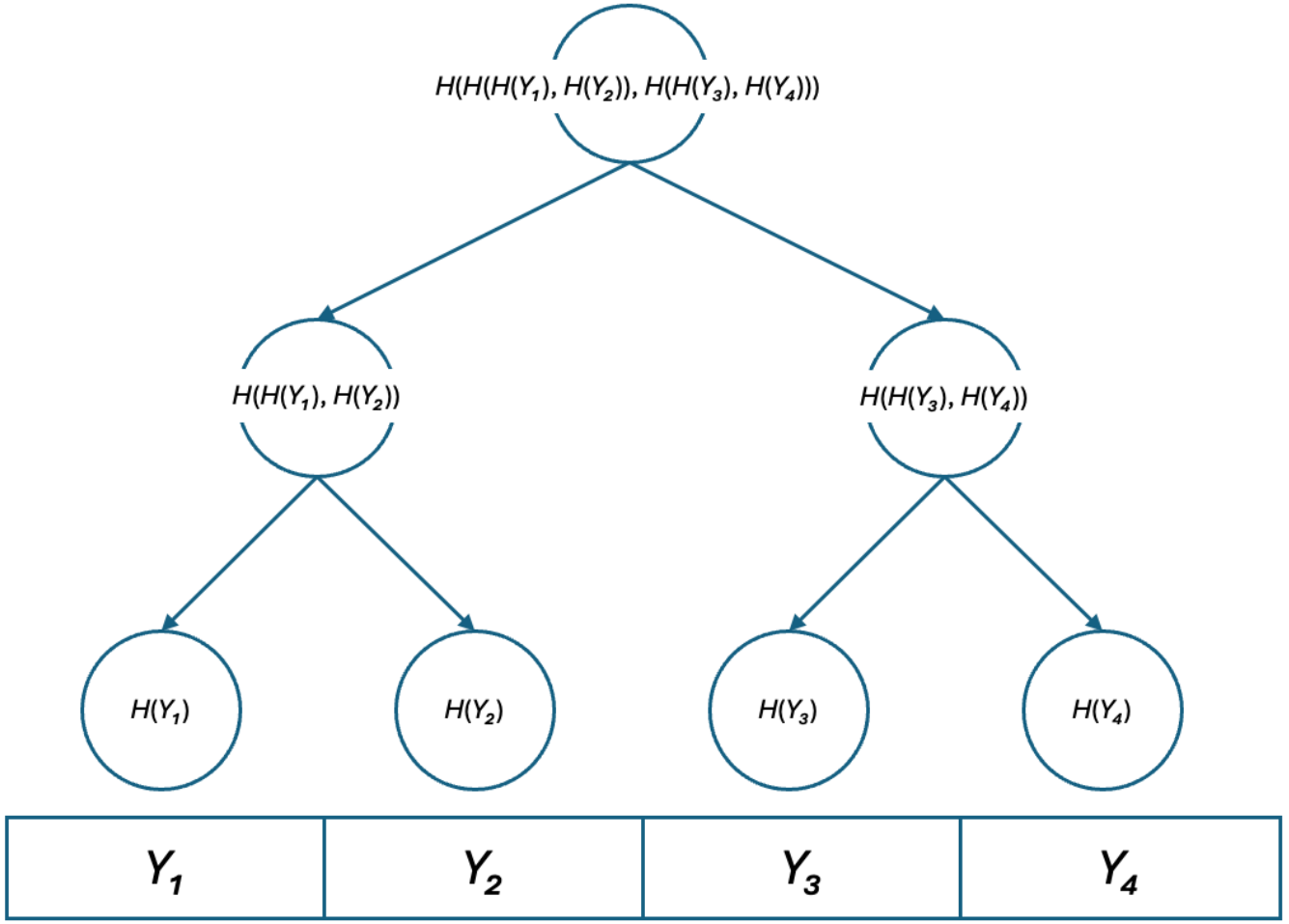
Scenarios leading to errors in transmission

- Memory corruption
- Race conditions
- Buffer overflows
- Implementation bugs
- Hardware malfunctions

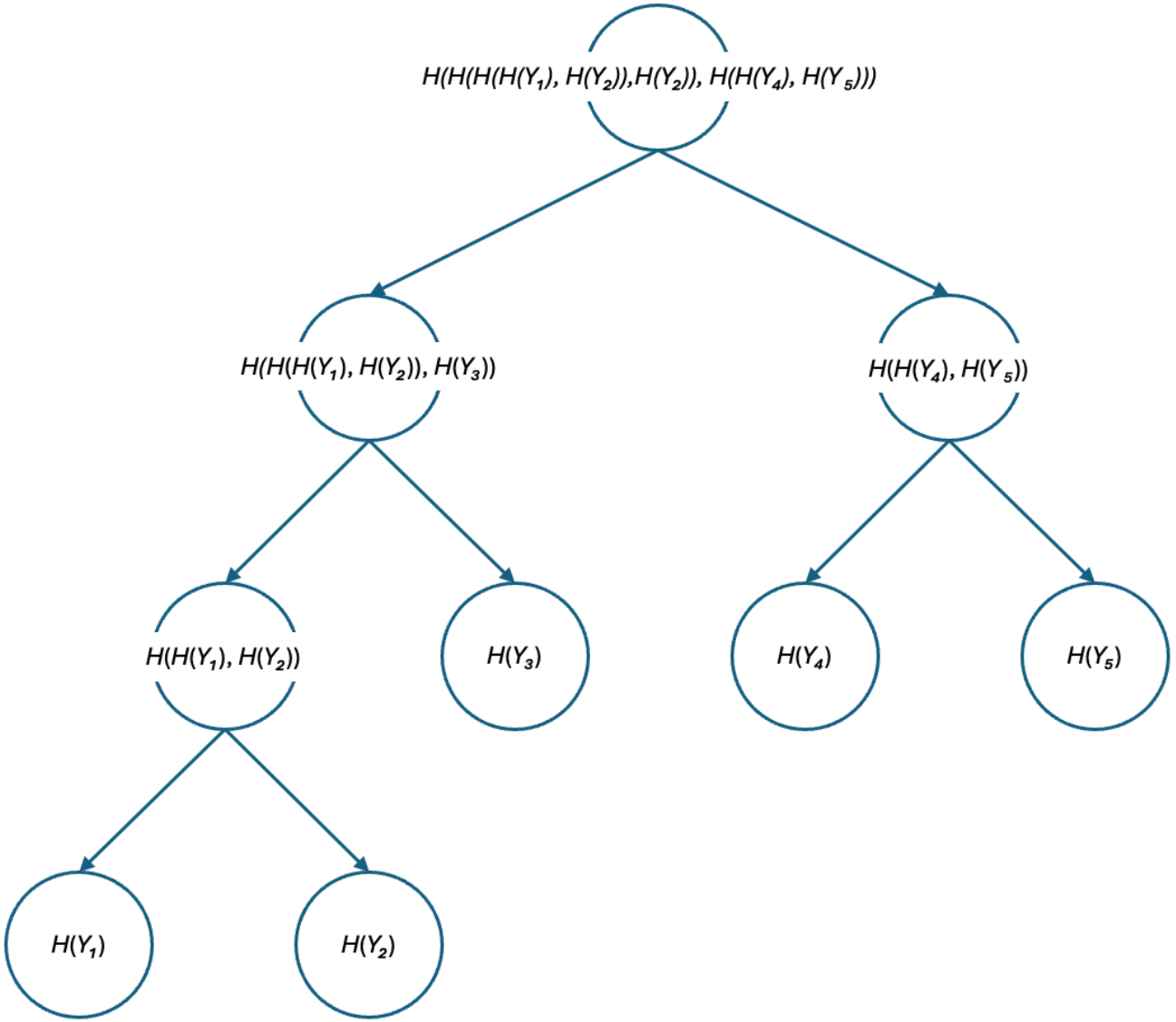
Merkle Tree Construction



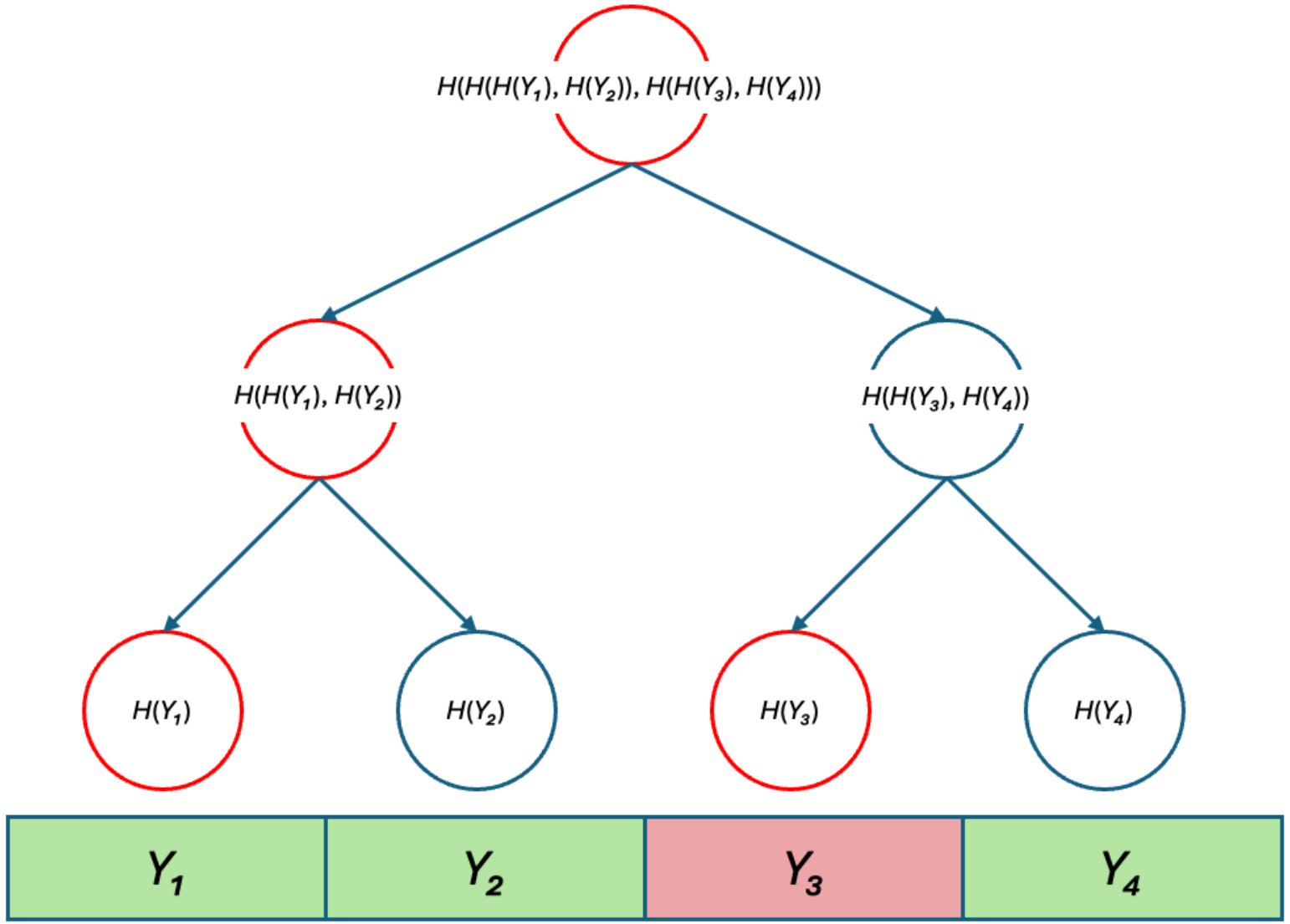
Merkle tree construction



Merkle tree construction



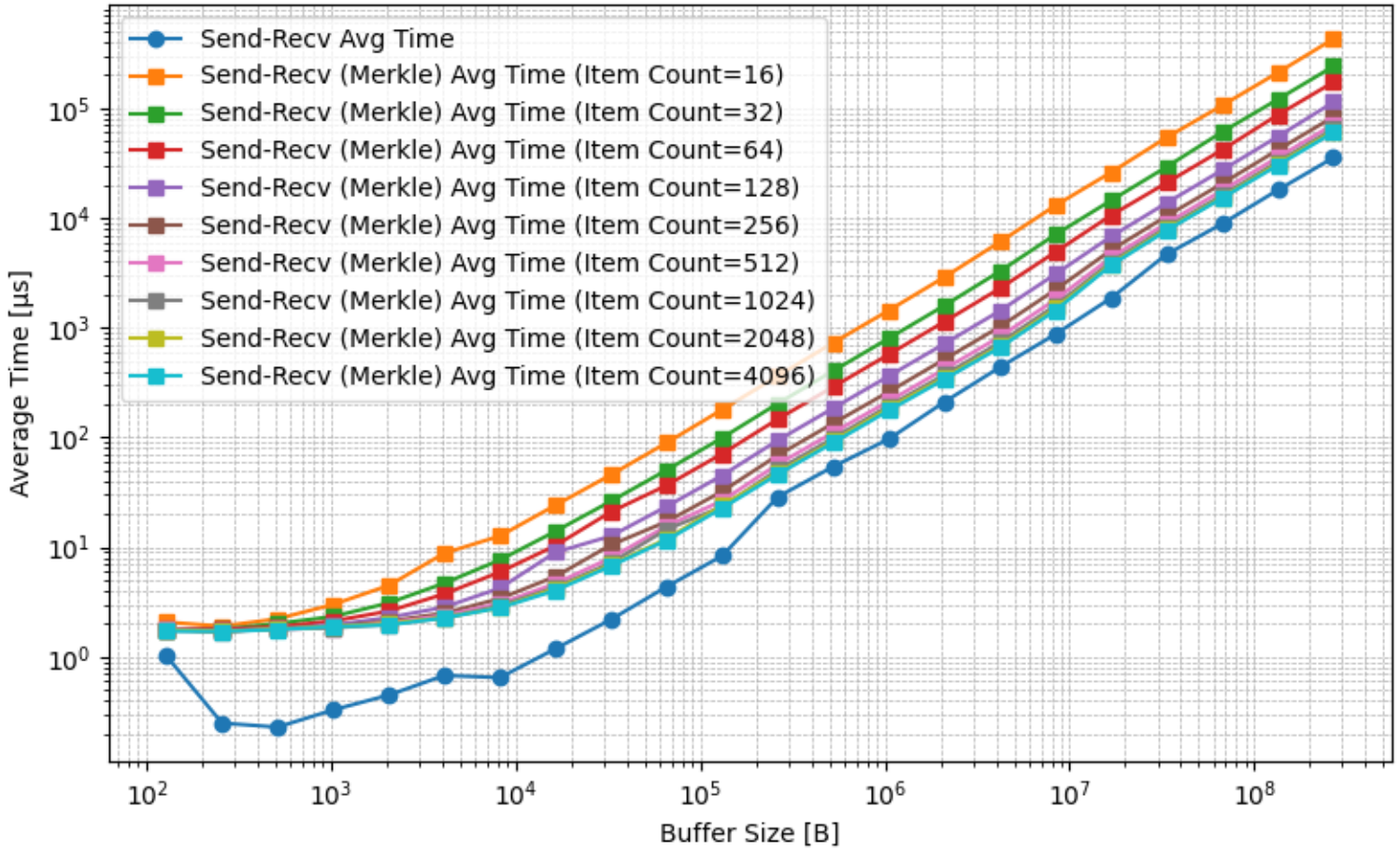
Data validation validation post transmission



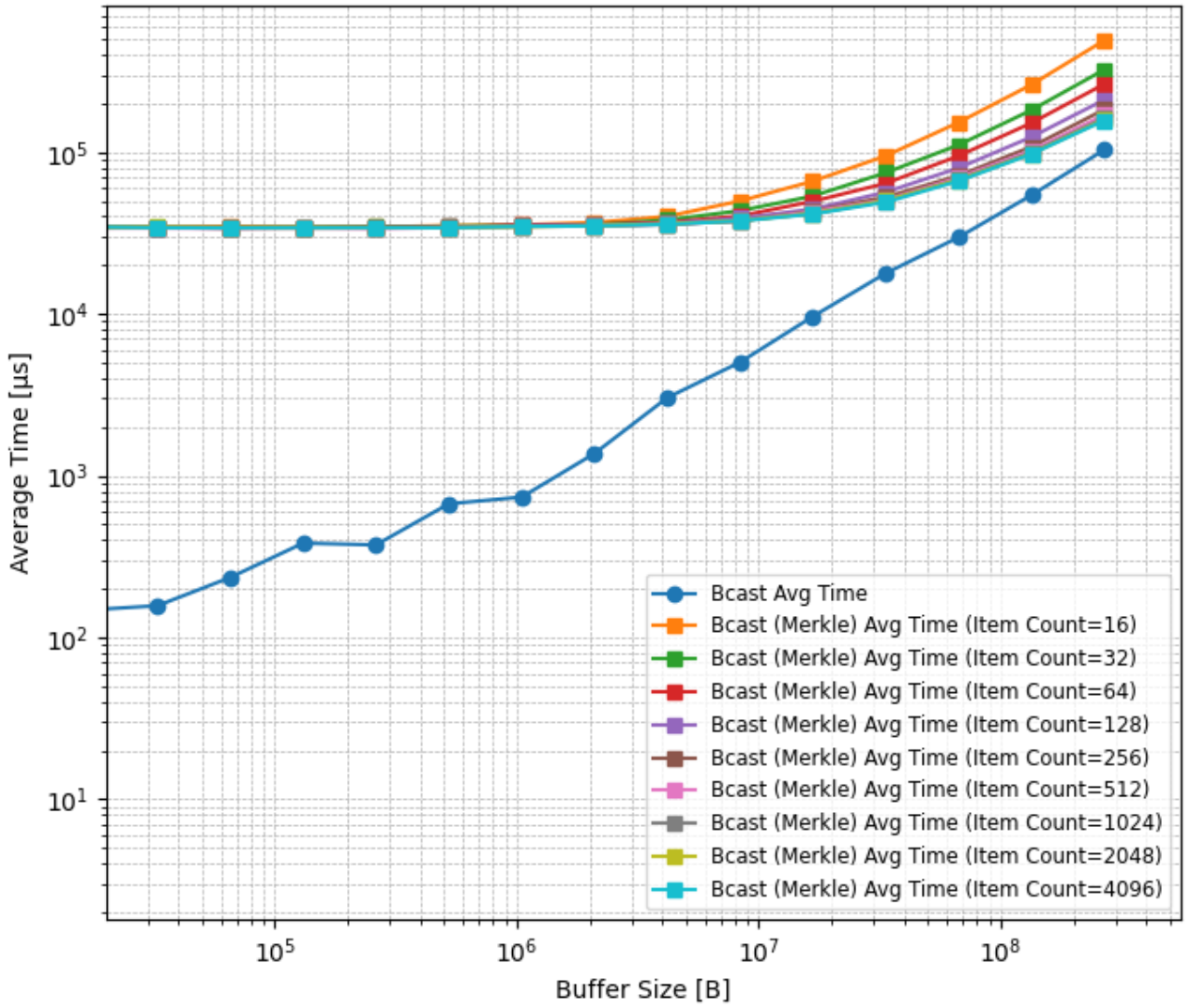
Data validation validation post transmission

- Faulty segment detection O(1)
- Faulty segment localization O(logn)
- `XXH3()` hashing function
- Data validation and correction communication protocol
- Usage of OpenMP for parallelization
- Implementation of several MPI Point-to-Point and Collective functions

Benchmarking MPI_Send,MPI_Recv



Benchmarking `MPI_Bcast`, 16 ranks



Benchmarking `MPI_Allgather`, 16 ranks