Contention-aware Performance Prediction of Parallel Programs

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Guide: Preeti Malakar

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- Approaches to parallel computation:
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- Challenges - Latency, Overhead, Scalability, Predictability, Portability

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- Builds on point-to-point messages

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- Collective operations:
  - Broadcast - send to all
  - Scatter - distribute to all
  - Gather - collect messages at root
  - Reduce - find min/sum/logical AND of each member's output
  - ...

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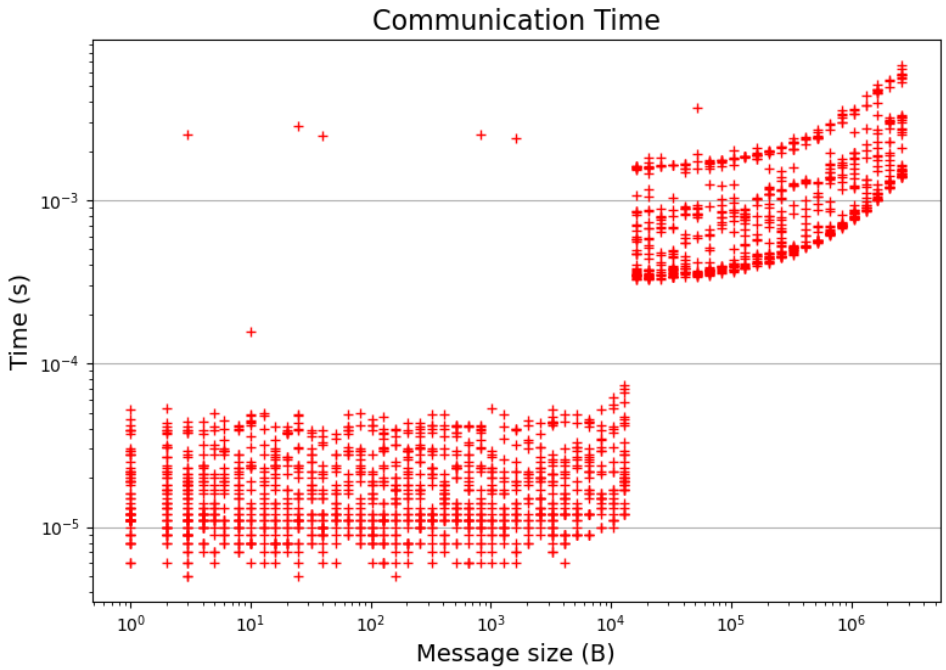

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- Splits message passing into latency and actual communication
- Mathematical expression:

$$t(n) = \alpha + n \cdot \beta = \alpha + \frac{n}{B}$$

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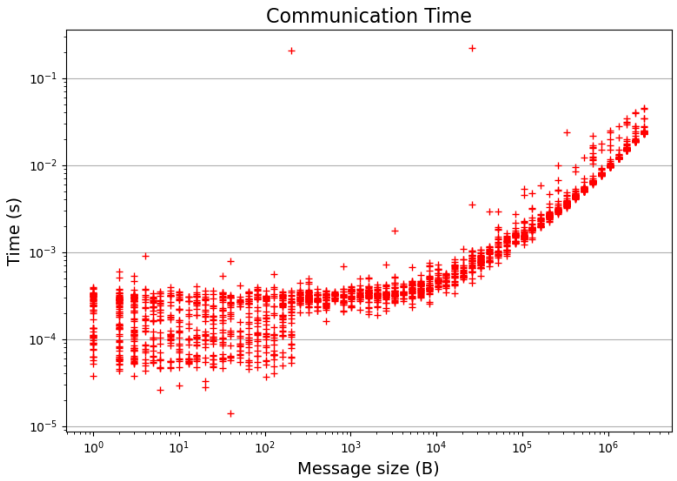
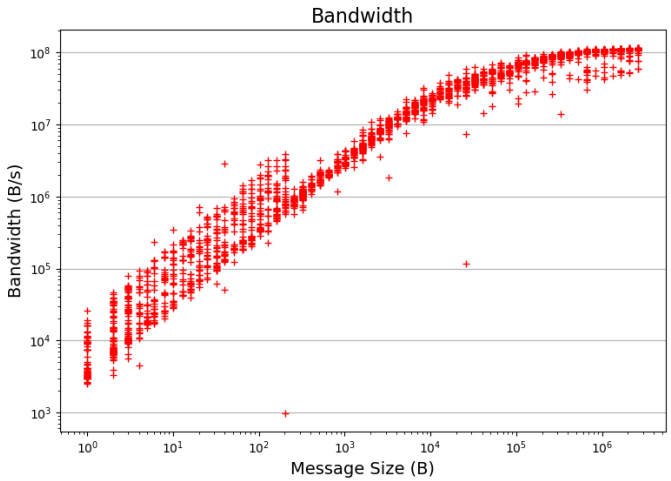
- Fairly accurate, but there are better models
- Sometimes as accurate as noise allows

Internode Messages





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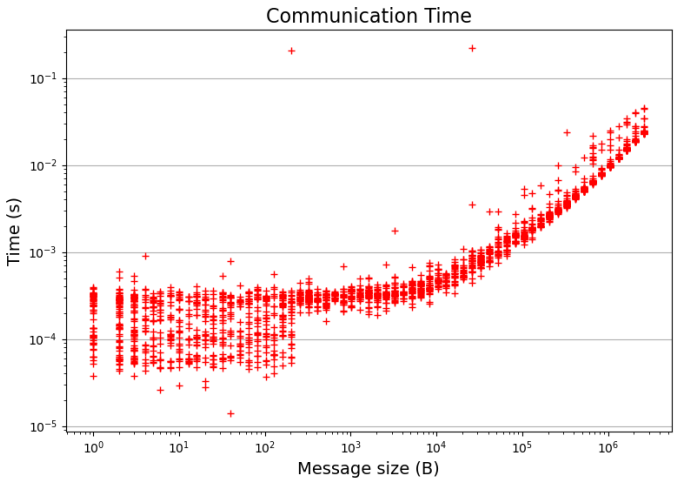
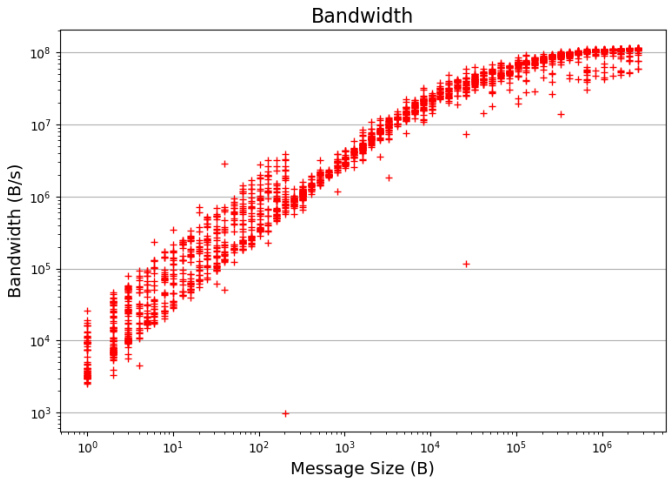
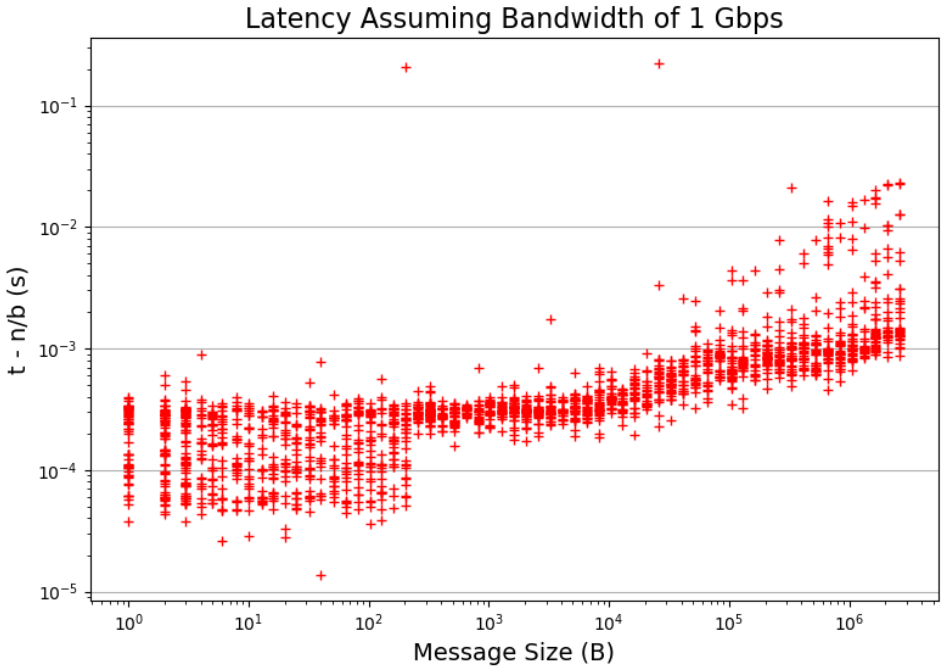




- Messages timed on CSEWS cluster - tree topology, 1 Gbps switches
- Bandwidth converges to 1 Gbps for large messages

Internode Messages



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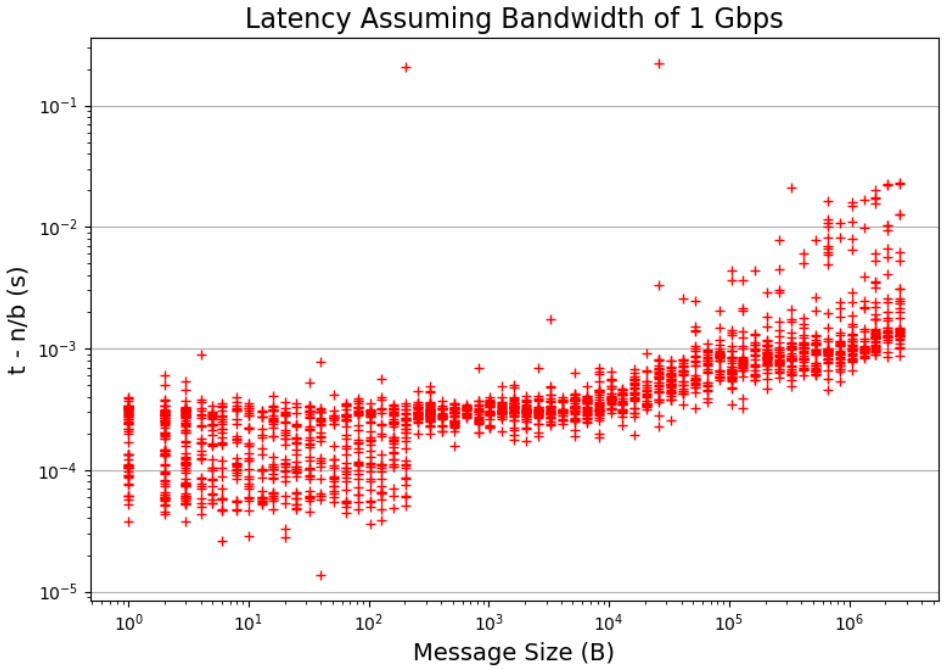
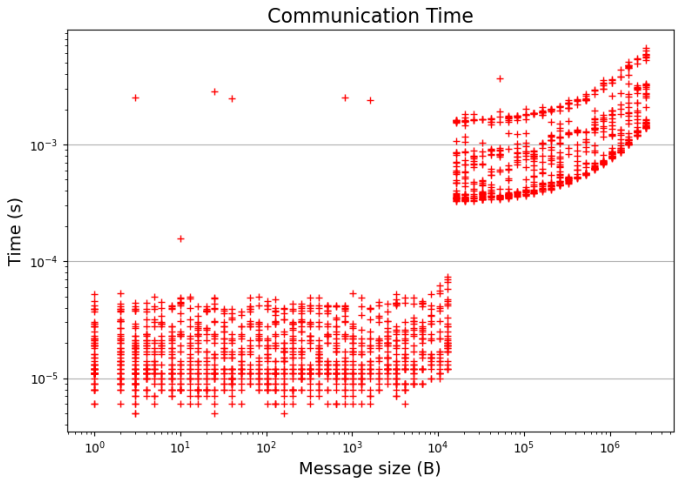
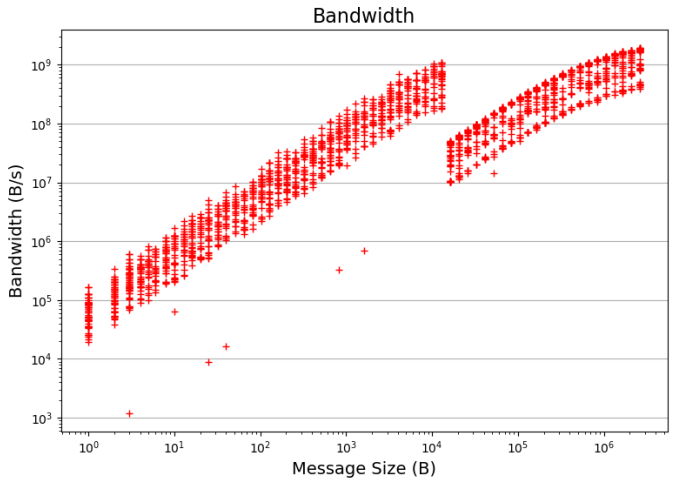


- Latency does not blow up for large messages
- Note the increase in 10 KB - 100 KB range

Intranode Messages





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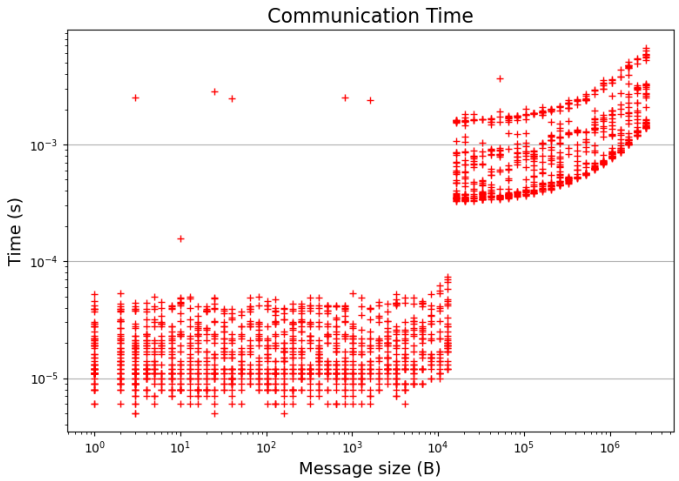

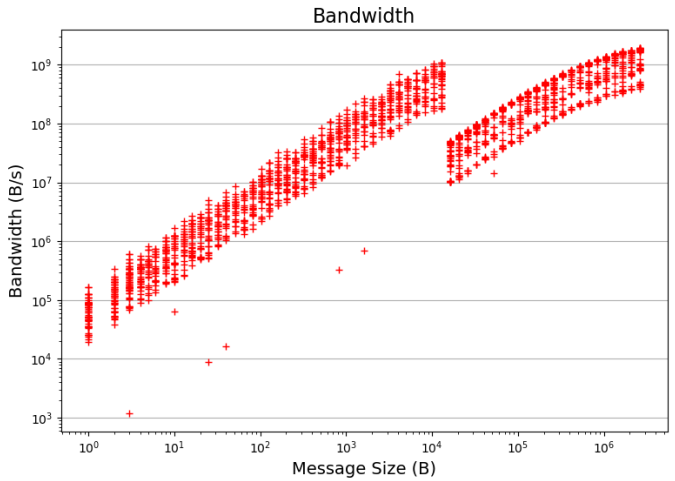

- Altogether different implementation
- Faster by orders of magnitude, not the bottleneck

Variations of the Hockney Model

- Multiple send modes - Blocking, Non-blocking, Synchronous, Ready, etc
- Internally, different modes - short/eager/rendezvous

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- Multiple send modes - Blocking, Non-blocking, Synchronous, Ready, etc
- Internally, different modes - short/eager/rendezvous
- Illustrative example - Kielmann et al. obtained near-full utilisation of WAN links (7×1 Mbps) on interleaving segments across different links [Kie+01]
- Message segmentation is used now
- Hardware and software run concurrently

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- No simple model of contention to date
- We tried timing messages at night/morning/midsem break
- Injected artificial contention to validate models against contention

IPMPI profiler

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- We modify IPMPI to predict execution time

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- Timed P2P messages between 12 nodes - sizes from 512 B to 2 MB
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- Tested on Broadcast, Allgather, Alltoall

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- Slow nodes - large but accurate values predicted
- Not scalable - #messages is quadratic! Supercomputer jobs run on hundreds to thousands of cores

Strategy 2 - Accounting for contention

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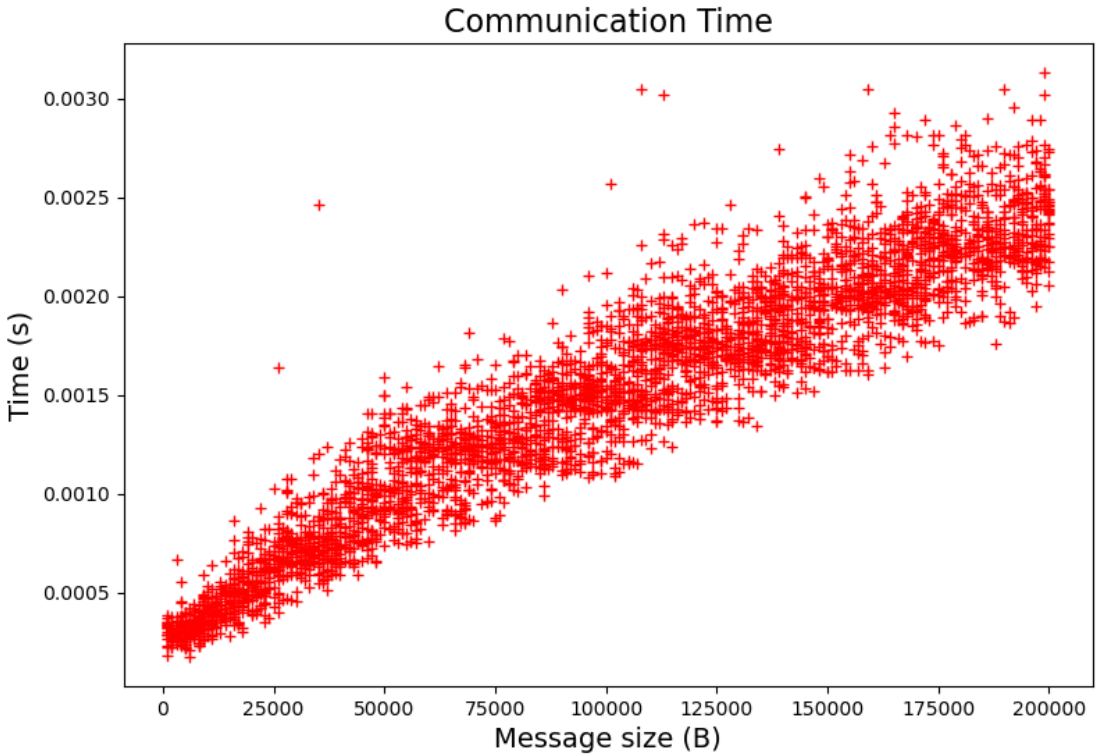
- Linearly interpolate above values to estimate time spent in a message
- Artificial congestion shows up

Model for P2P messages



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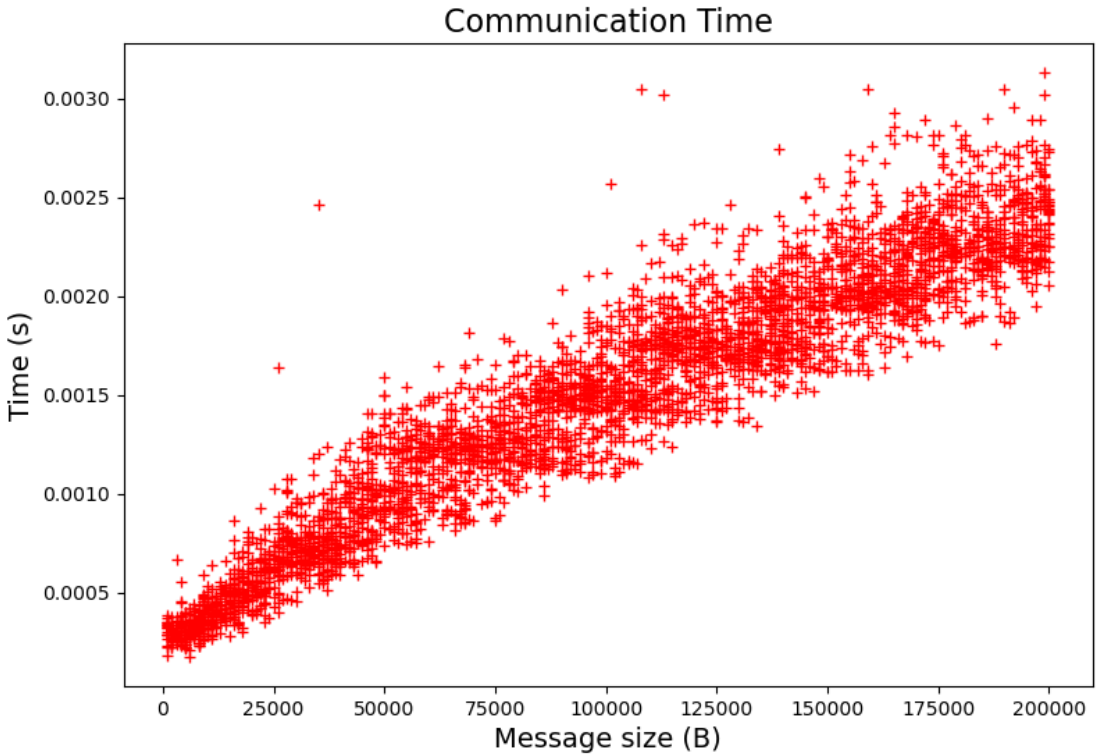

- Two linear parts, threshold 80-100 KB
- Separate Hockney parameters for messages smaller/larger than 128 KB

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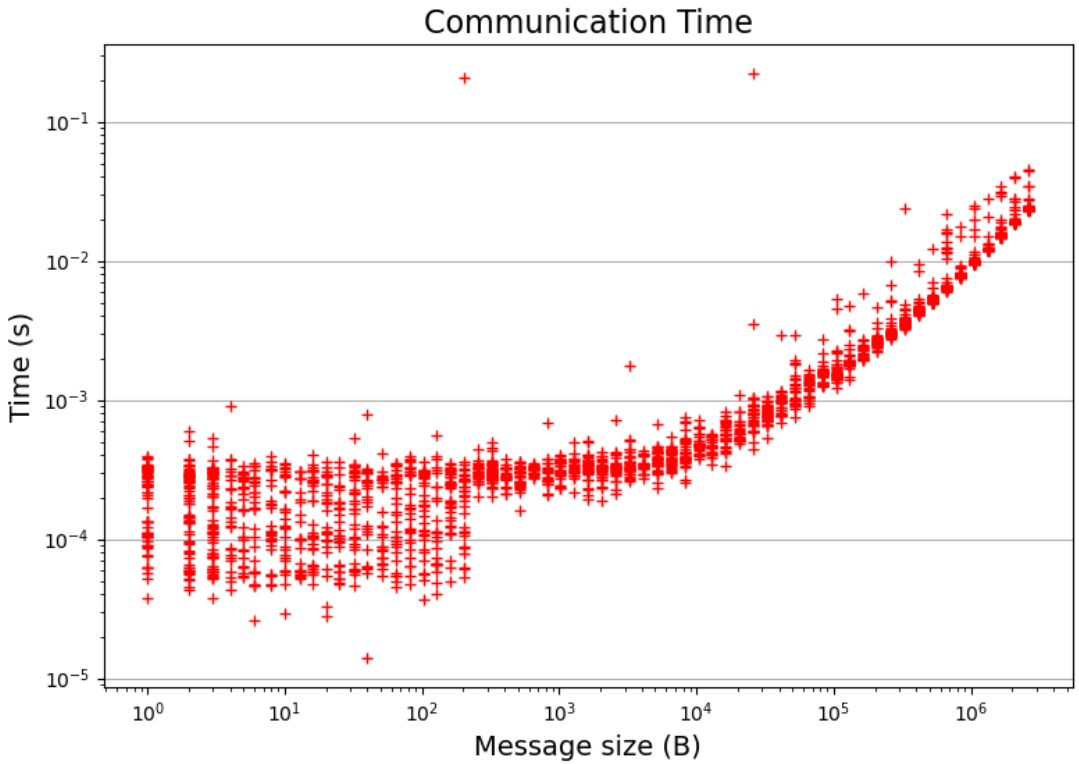

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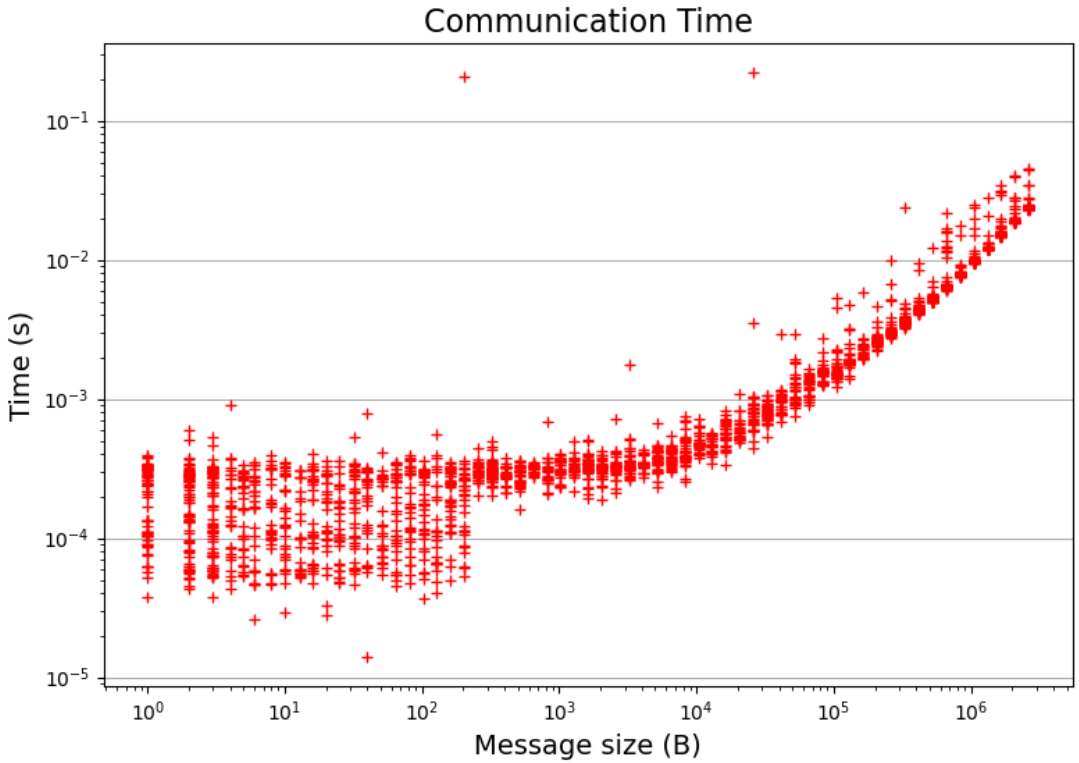
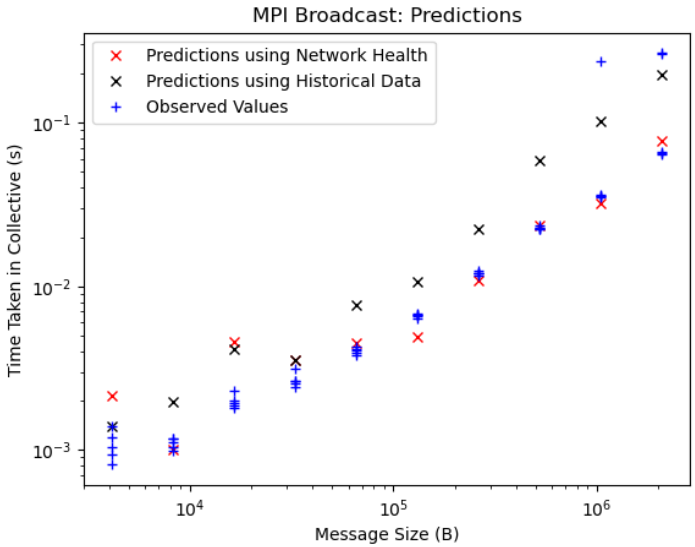
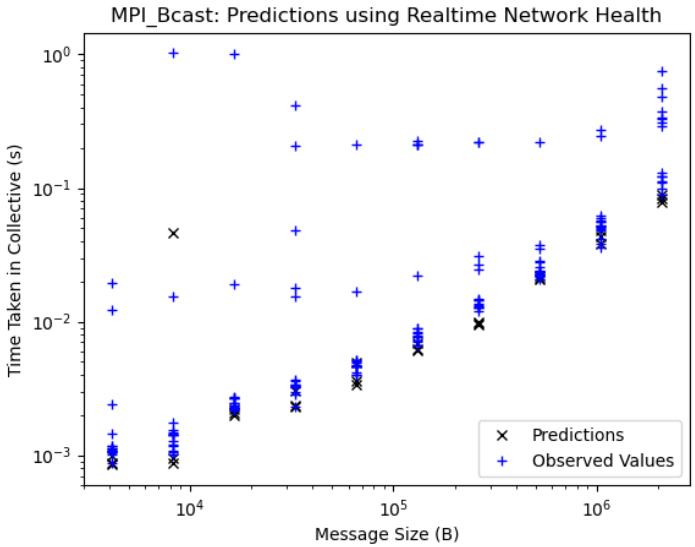


- Small messages take nearly constant time
- Assumed constant time for messages smaller than 8 KB
- Intranode messages - No pattern, used historical data

Results

MPI Broadcast on 8 processes:





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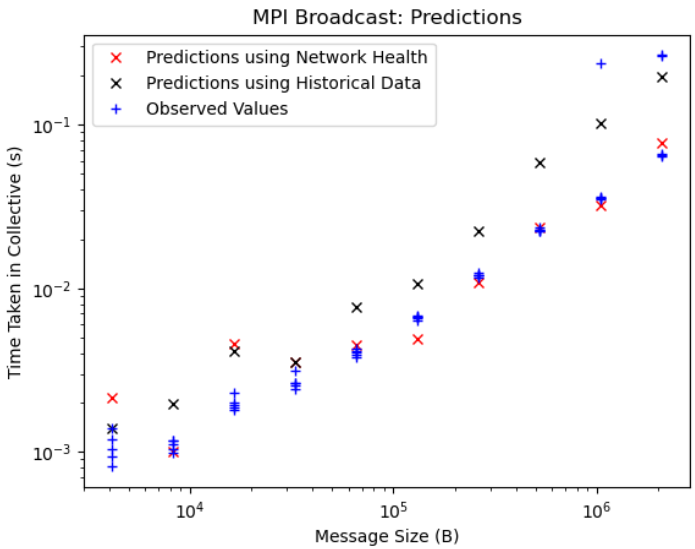
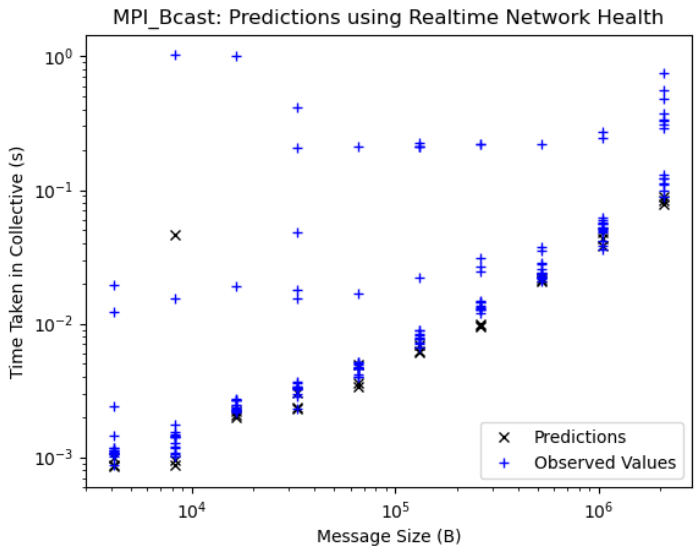
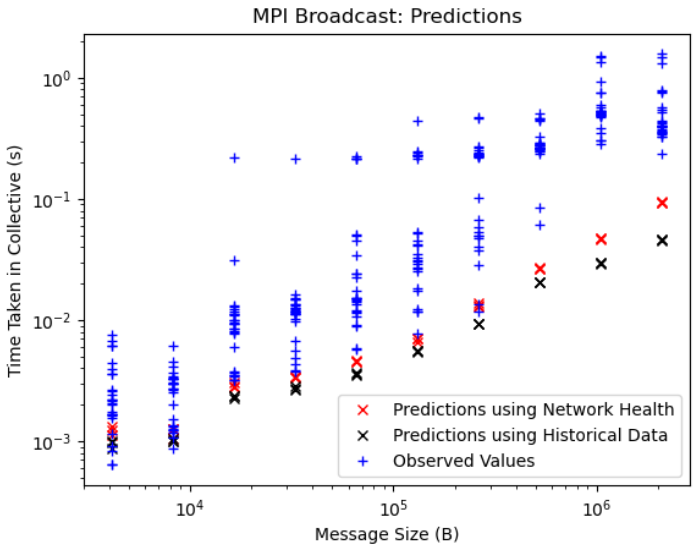


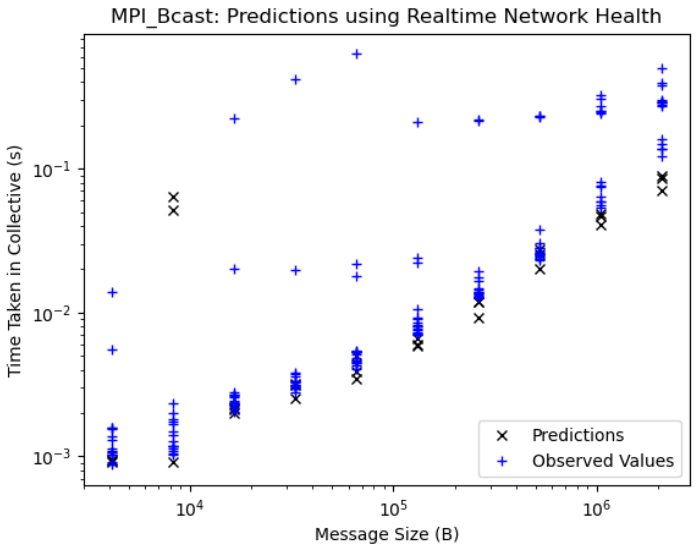


- Programs run on different days
- Noise affects quality of predictions

Results

Broadcast with artificial contention on 8 processes:





- Predictions using realtime data are usually higher

Results

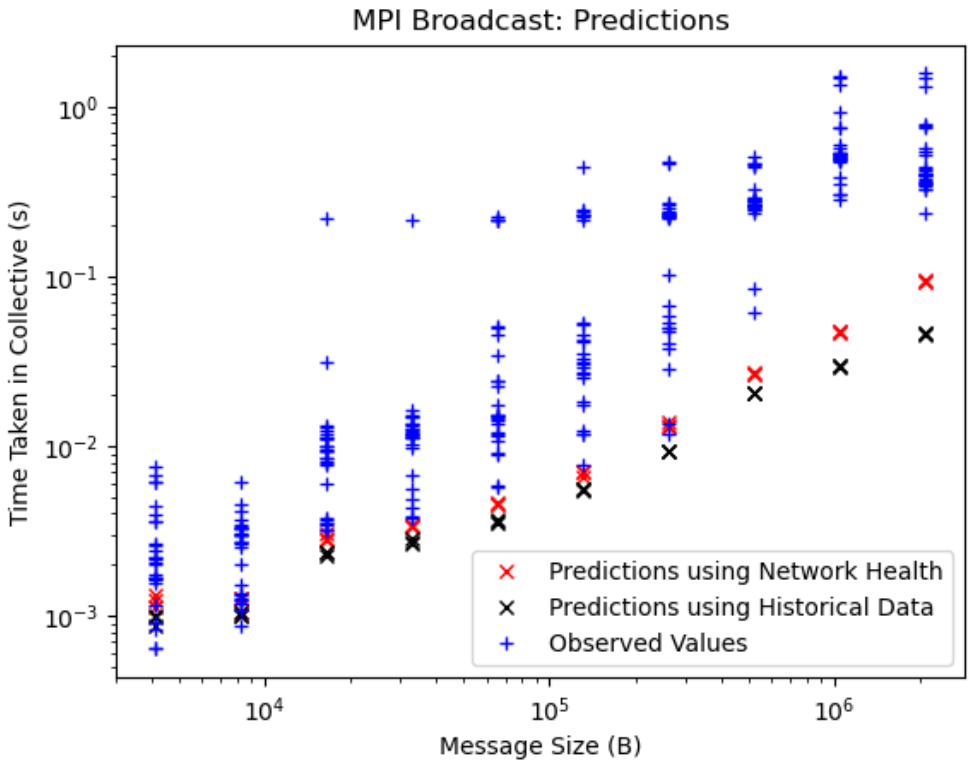


Figure: Broadcast on 16 processes (2 Processes Per Node) with artificial congestion

Results

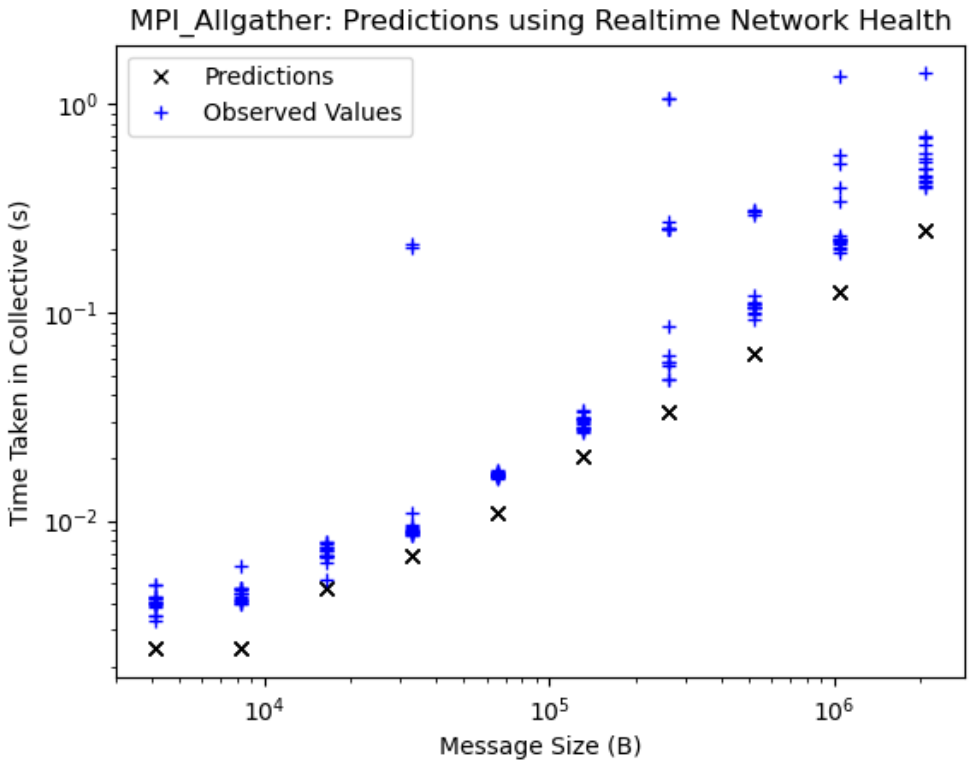


Figure: MPI- Allgather on 8 processes (1 PPN)

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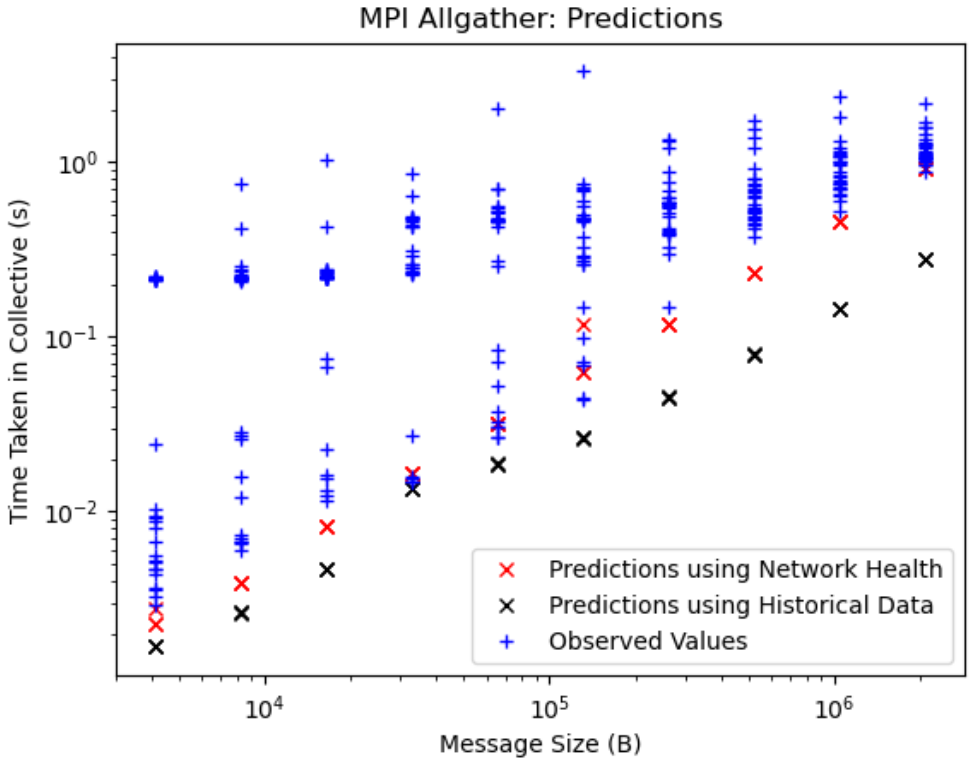

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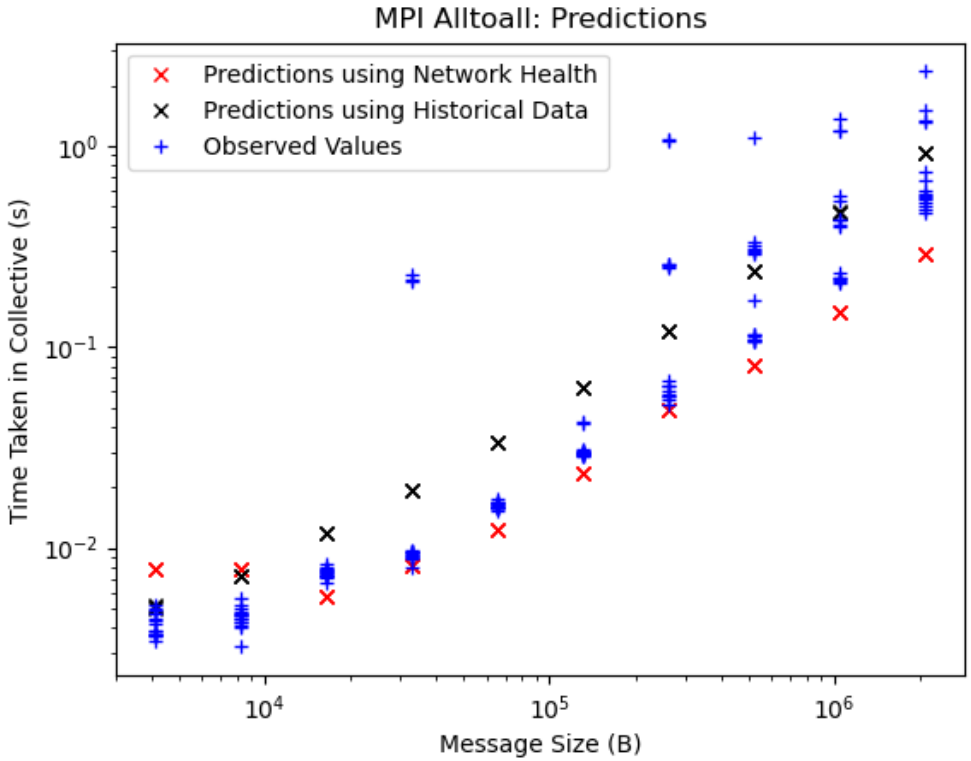

Figure: Alltoall on 8 processes (1 PPN)

Results - Alltoall

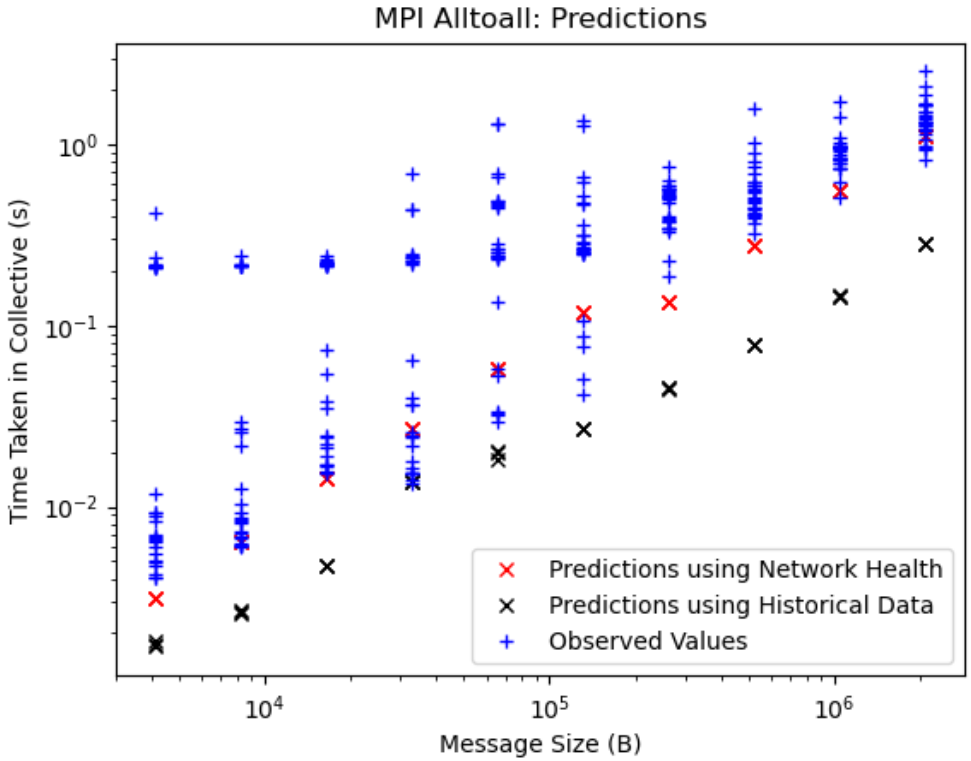

Figure: Allgather on 16 processes (2 PPN)

Tokenization Overhead

- Realtime communication parameters are found with 140 explicitly synchronised messages
- Takes under 1.5 s without contention, < 4 s with artificial congestion (8 nodes at a time, but can be increased)

IPMPI Overheads

- Our extensions to IPMPI read files and generate lookup tables
- File I/O requires significant time, but once for each run
- Typically < 1.5 s (both predictions) for one collective

Thank you

Questions?