Toward Mega-Scale Computing with pMatlab

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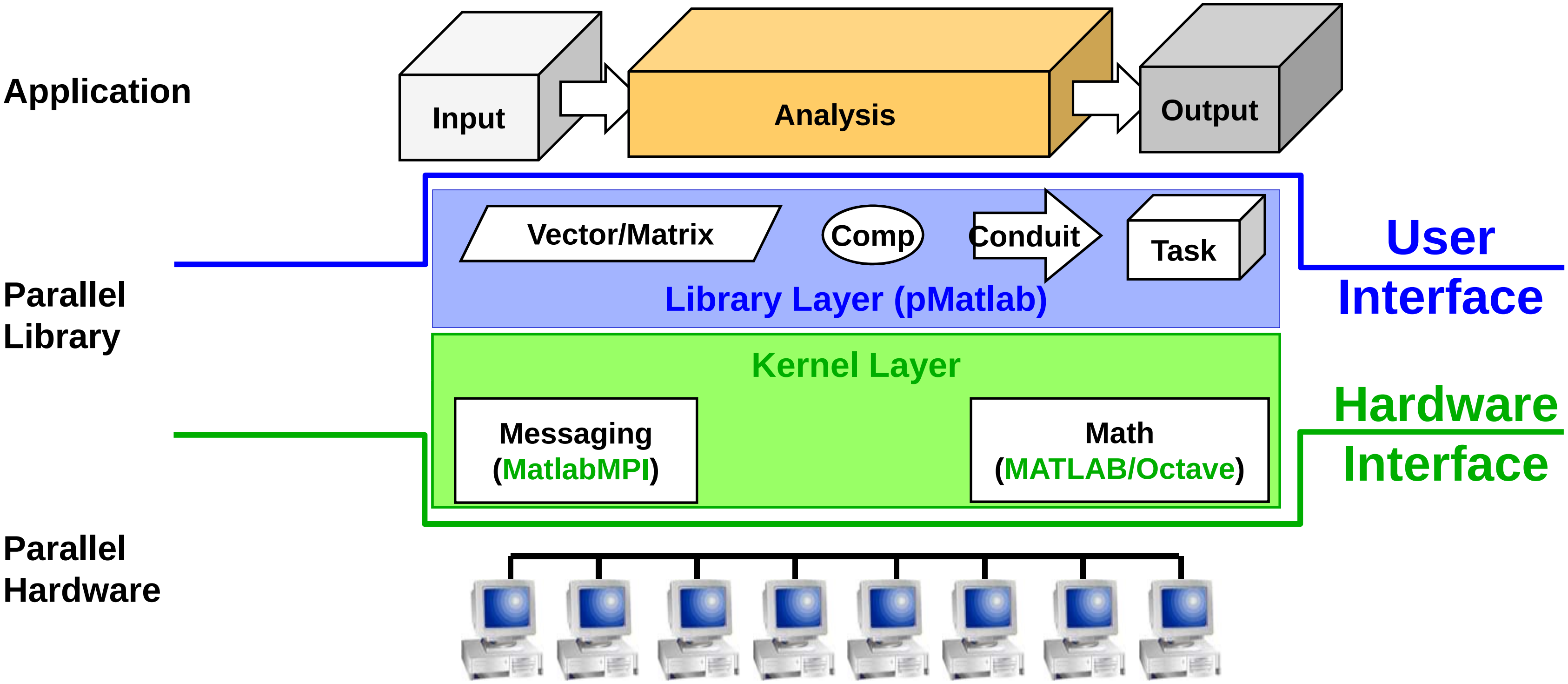
Outline

- **Introduction**
- Performance Studies
- Optimization for Large Scale Computation
- Summary

- ***What is Parallel Matlab (pMatlab)***
- ***IBM Blue Gene/P System***
- ***BG/P Application Paths***
- ***Porting pMatlab to BG/P***

Parallel Matlab (pMatlab)

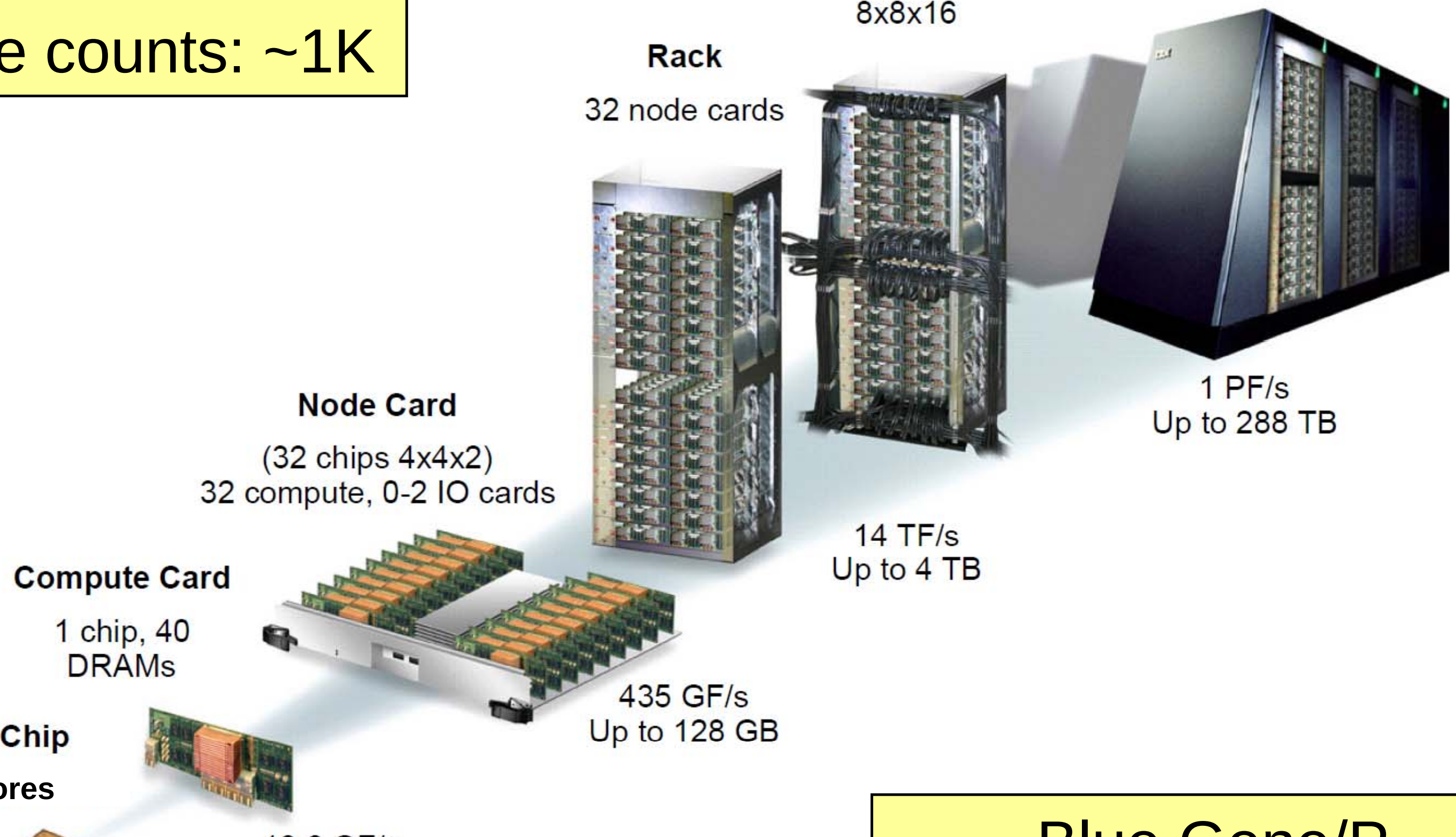


Layered Architecture for parallel computing

- Kernel layer does single-node math & parallel messaging
- Library layer provides a parallel data and computation toolbox to Matlab users

IBM Blue Gene/P System

LLGrid
Core counts: ~1K



Chip

4 cores

13.6 GF/s
8 MB EDRAM

Compute Card

1 chip, 40
DRAMs

13.6 GF/s
2 or 4 GB DDR

Node Card

(32 chips 4x4x2)
32 compute, 0-2 IO cards

435 GF/s
Up to 128 GB

Rack

32 node cards

14 TF/s
Up to 4 TB

Cabled
8x8x16

System

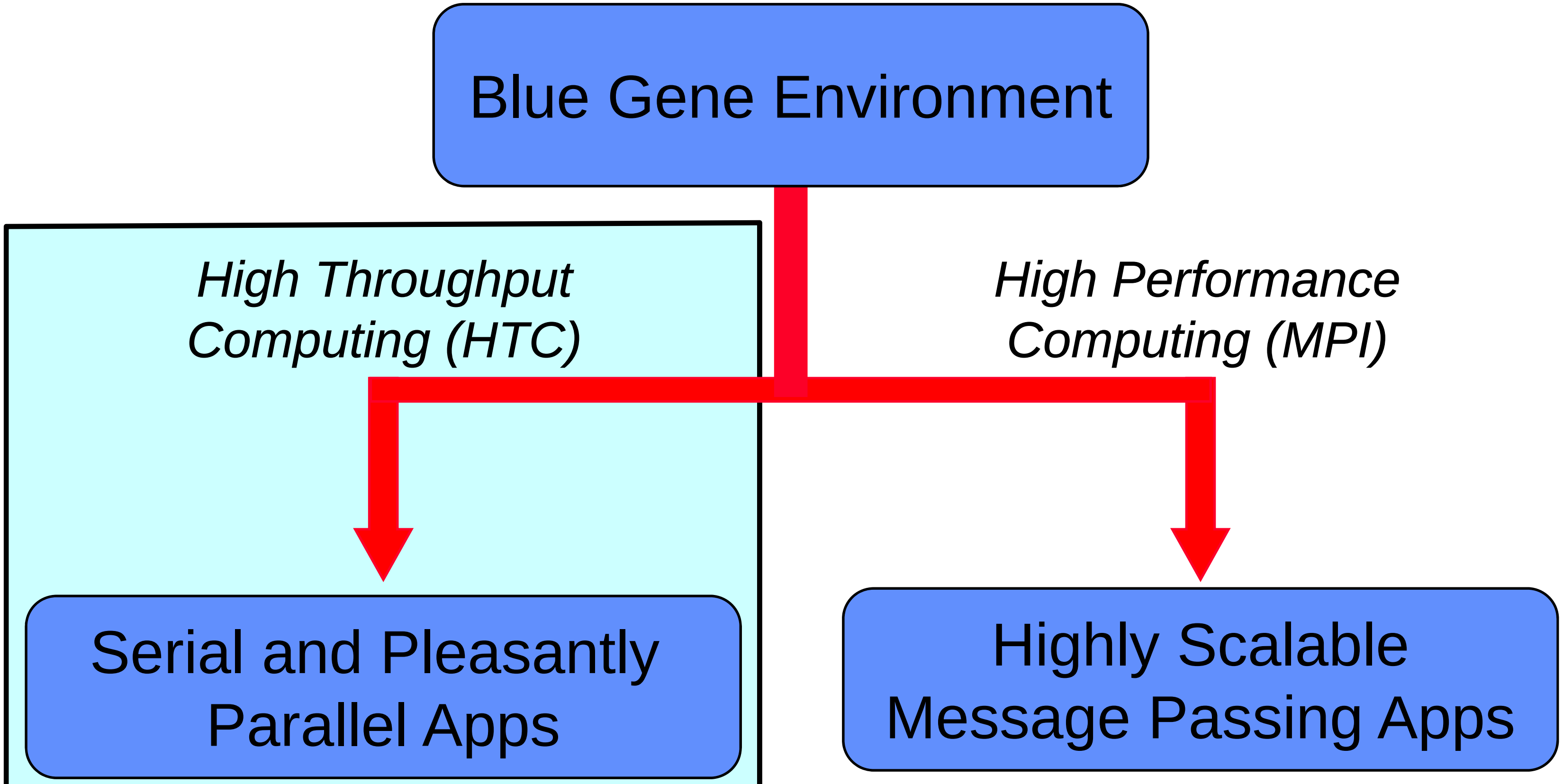
72 racks

1 PF/s
Up to 288 TB

Core speed: 850 MHz

Blue Gene/P
Core counts: ~300K

Blue Gene Application Paths


Blue Gene Environment
High Throughput Computing (HTC)
High Performance Computing (MPI)
Serial and Pleasantly Parallel Apps
Highly Scalable Message Passing Apps

- **High Throughput Computing (HTC)**
  - **Enabling BG partition for many single-node jobs**
  - **Ideal for “pleasantly parallel” type applications**

HTC Node Modes on BG/P

- **Symmetrical Multiprocessing (SMP) mode**
  - One process per compute node
  - Full node memory available to the process
- **Dual mode**
  - Two processes per compute node
  - Half of the node memory per each process
- **Virtual Node (VN) mode**
  - Four processes per compute node (one per core)
  - 1/4th of the node memory per each process

Porting pMatlab to BG/P System

- Requesting and booting a BG partition in HTC mode
  - Execute "qsub" command

    Define number of processes, runtime, HTC boot script (*htcpartition --trace 7 --boot --mode dual \ --partition $COBALT_PARTNAME*)

    ```
    (htcpartition --trace 7 --boot --mode dual \
    --partition $COBALT_PARTNAME)
    ```

    Wait for the partition ready (until the boot completes)
- Running jobs
  - Create and execute a Unix shell script to run a series of "submit" commands including

    ```
    submit -mode dual -pool ANL-R00-M1-512 \
    -cwd /path/to/working/dir -exe /path/to/octave \
    -env LD_LIBRARY_PATH=/home/cbyun/lib \
    -args "--traditional MatMPI/MatMPIdefs523.m"
    ```
- Combine the two steps

  ```
  eval(pRUN('m_file', Nprocs, 'bluegene-smp'))
  ```

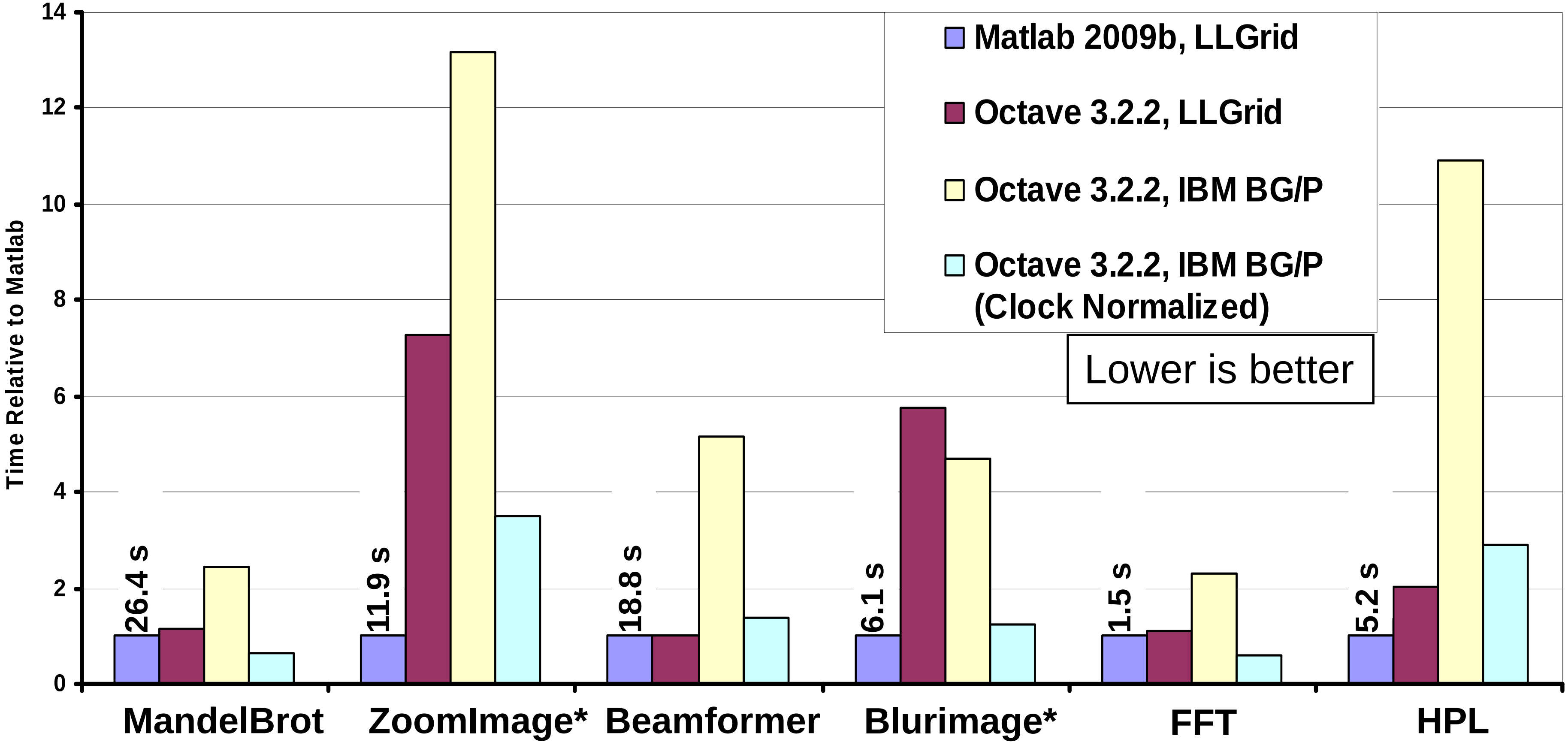
Outline

- Introduction
- **Performance Studies**
  - ***Single Process Performance***
  - ***Point-to-Point Communication***
  - ***Scalability***
- Optimization for Large Scale Computation
- Summary

Performance Studies

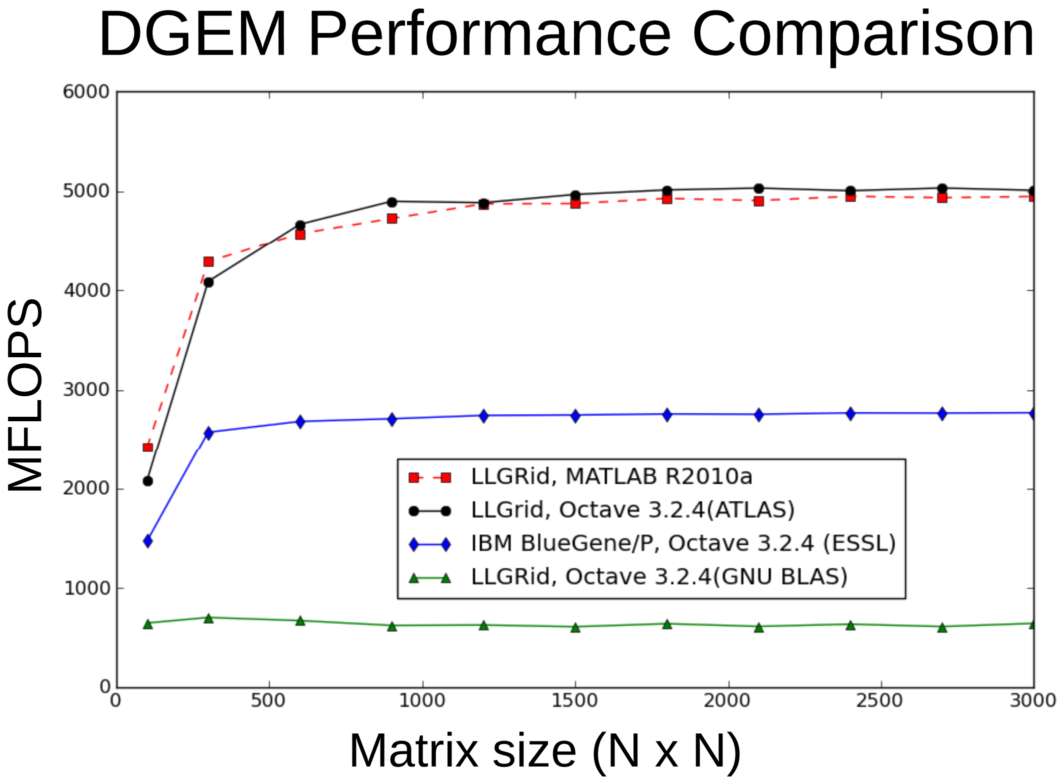
- Single Processor Performance
  - MandelBrot
  - ZoomImage
  - Beamformer
  - Blurimage
  - Fast Fourier Transform (FFT)
  - High Performance LINPACK (HPL)
- Point-to-Point Communication
  - pSpeed
- Scalability
  - Parallel Stream Benchmark: pStream

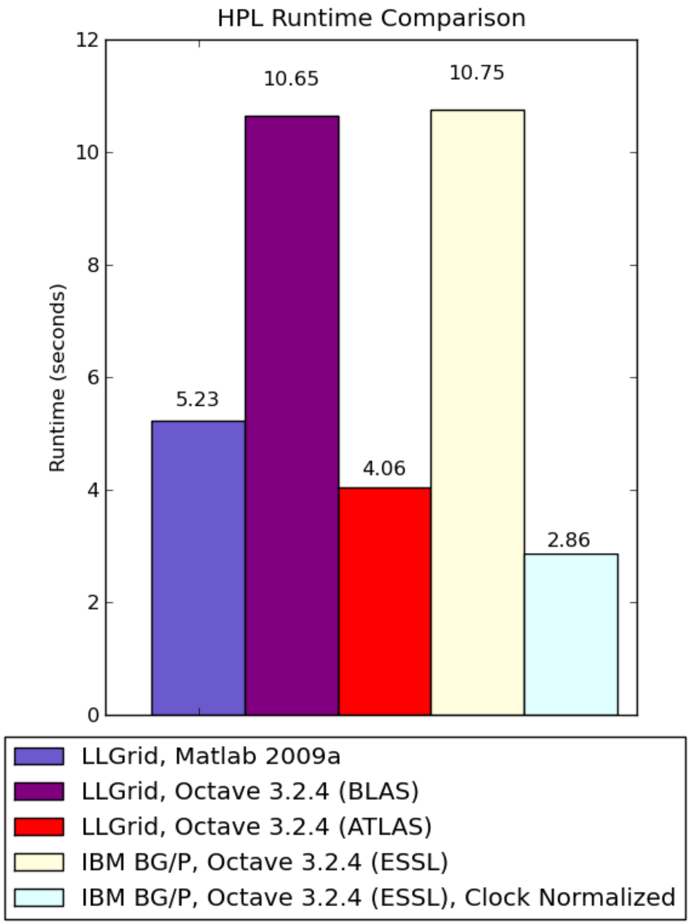
Single Process Performance:
Intel Xeon vs. IBM PowerPC 450



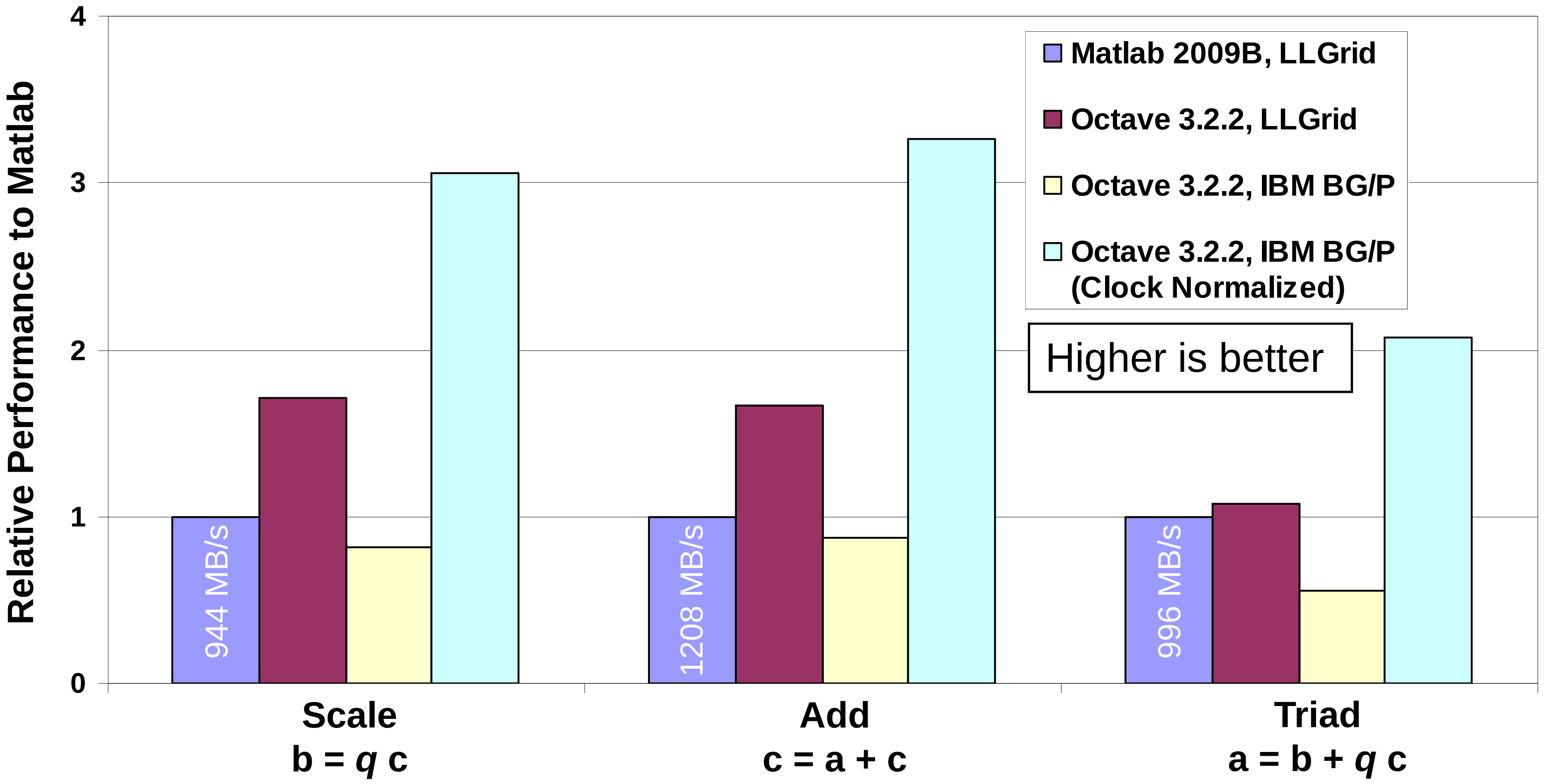
* conv2() performance issue in Octave has been improved in a subsequent release

Octave Performance With Optimized BLAS





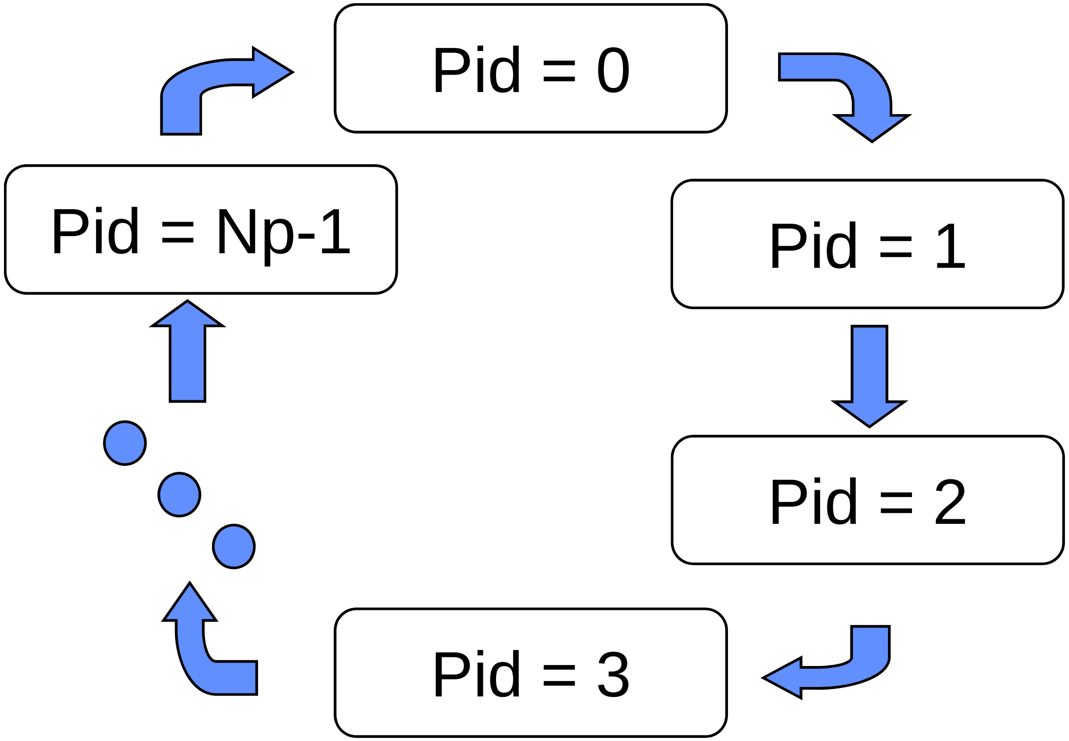
Single Process Performance:
Stream Benchmark



Higher is better

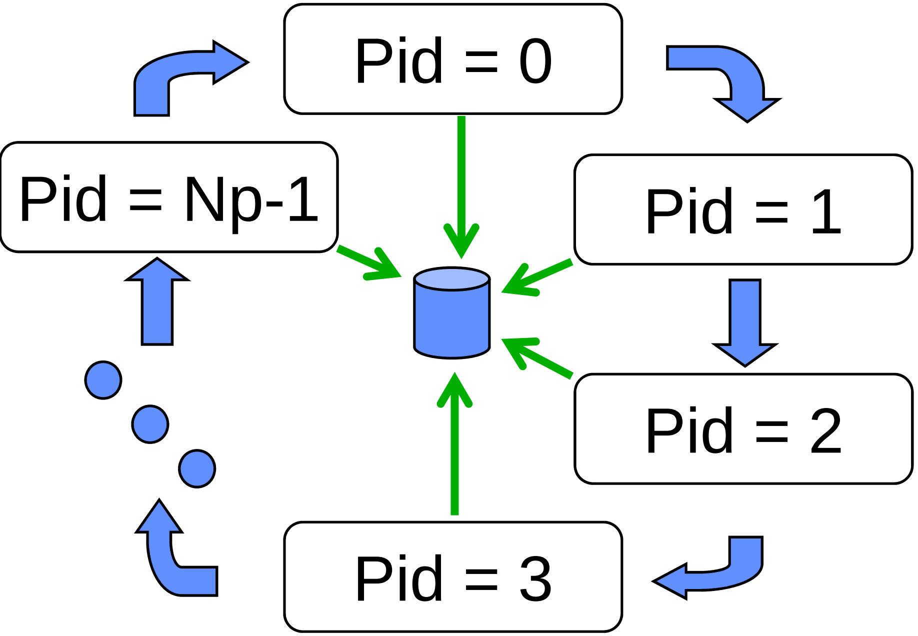
Point-to-Point Communication

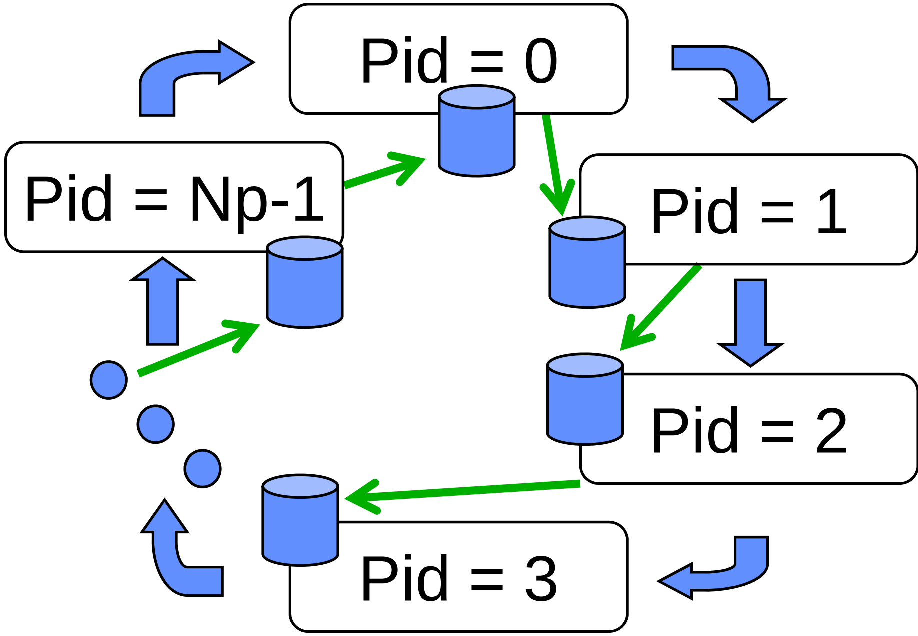
- **pMatlab example: pSpeed**
  - **Send/Receive messages to/from the neighbor.**
  - **Messages are files in pMatlab.**



Filesystem Consideration

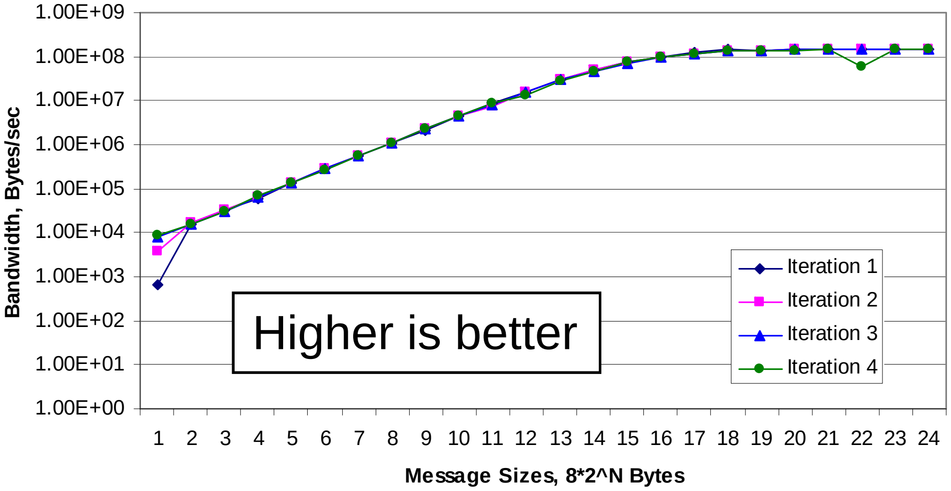
- **A single NFS-shared disk (Mode S)**
- **A group of cross-mounted, NFS-shared disks to distribute messages (Mode M)**





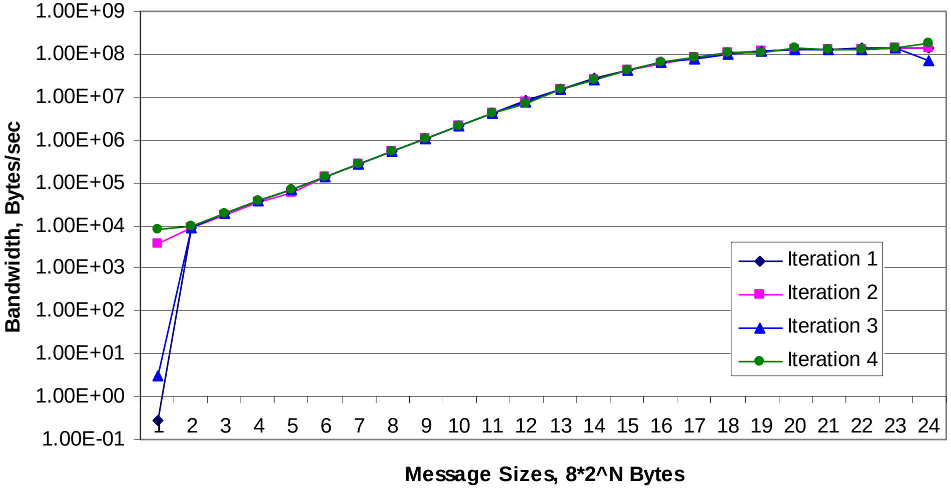
pSpeed Performance on LLGrid:
Mode S

Matlab 2009b, 1x2

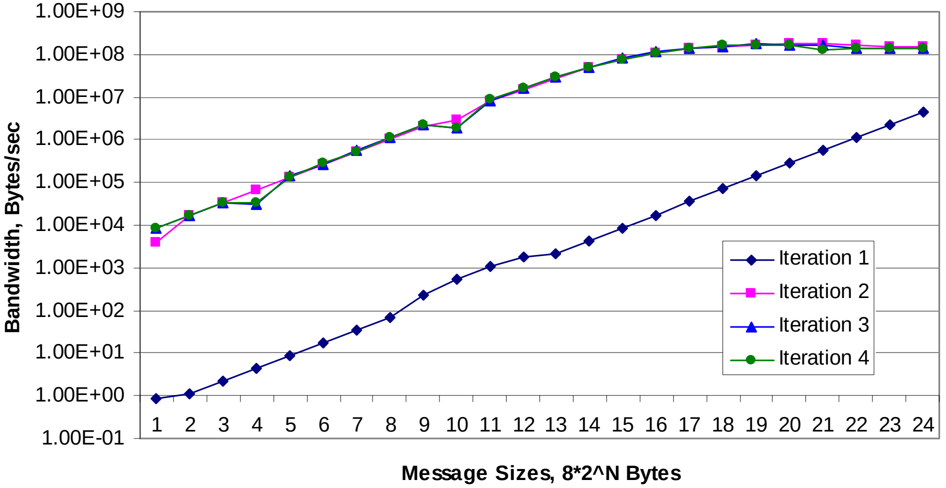


Higher is better

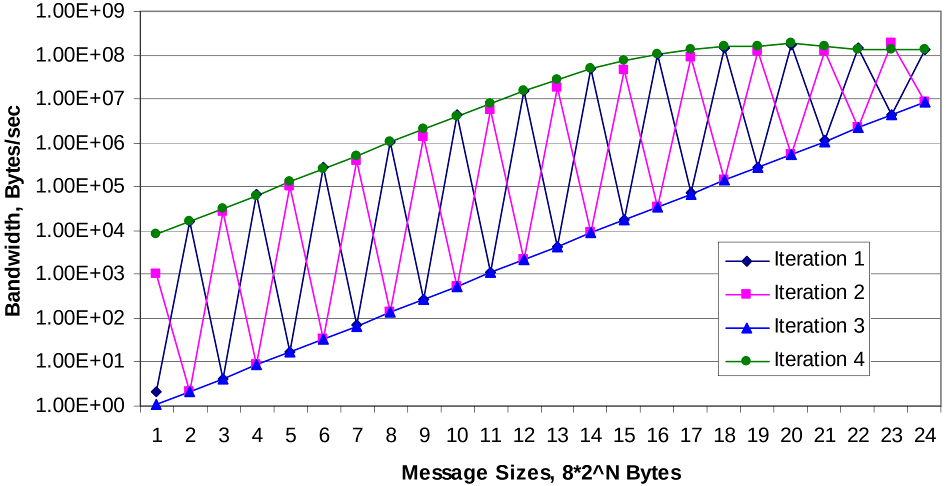
Matlab 2009b, 2x1



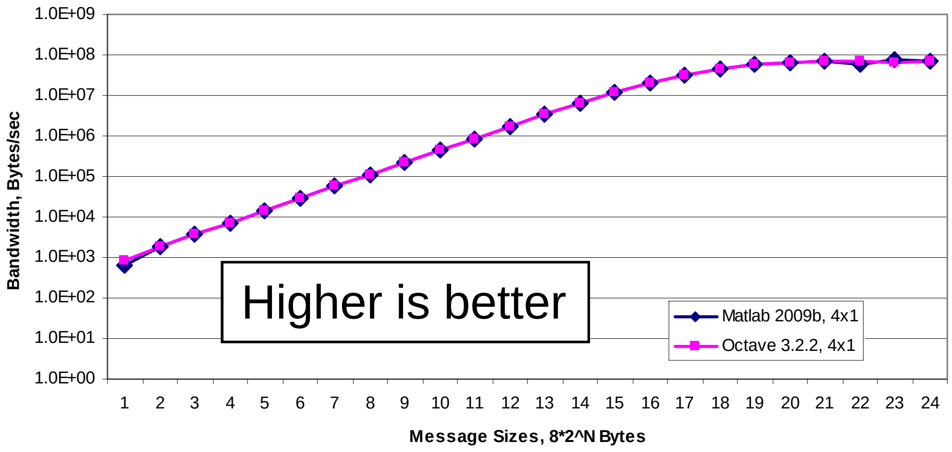
Matlab 2009b, 4x1

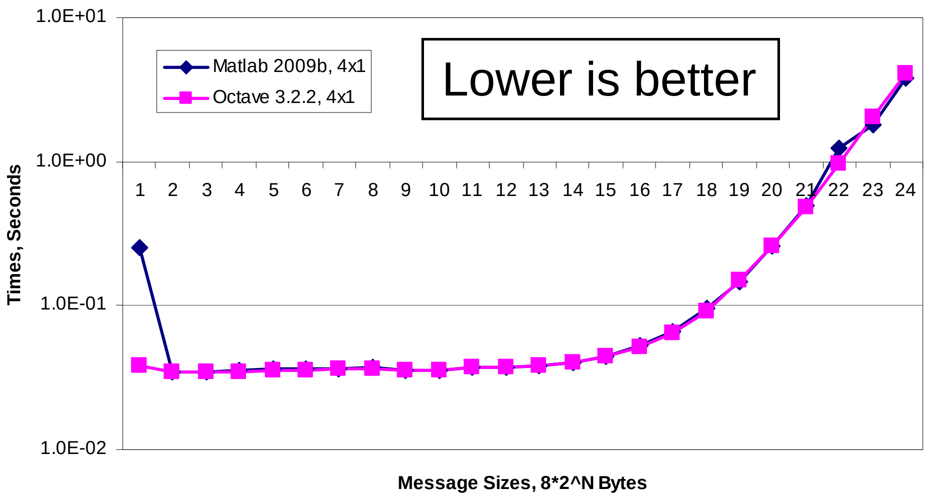


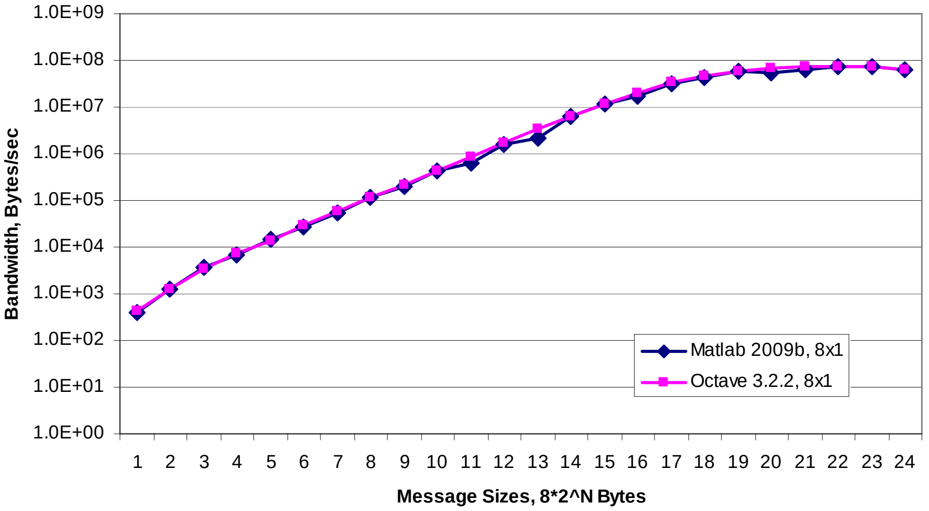
Matlab 2009b, 8x1

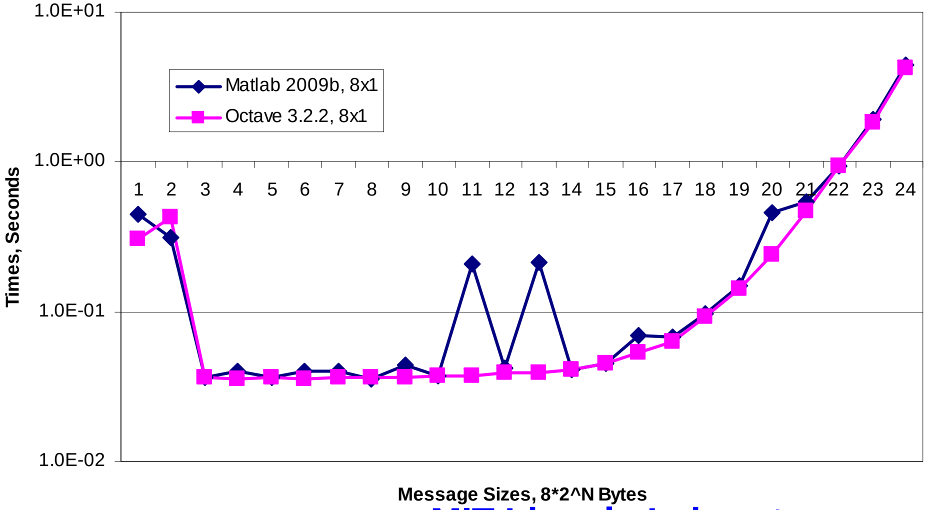


pSpeed Performance on LLGrid:
Mode M

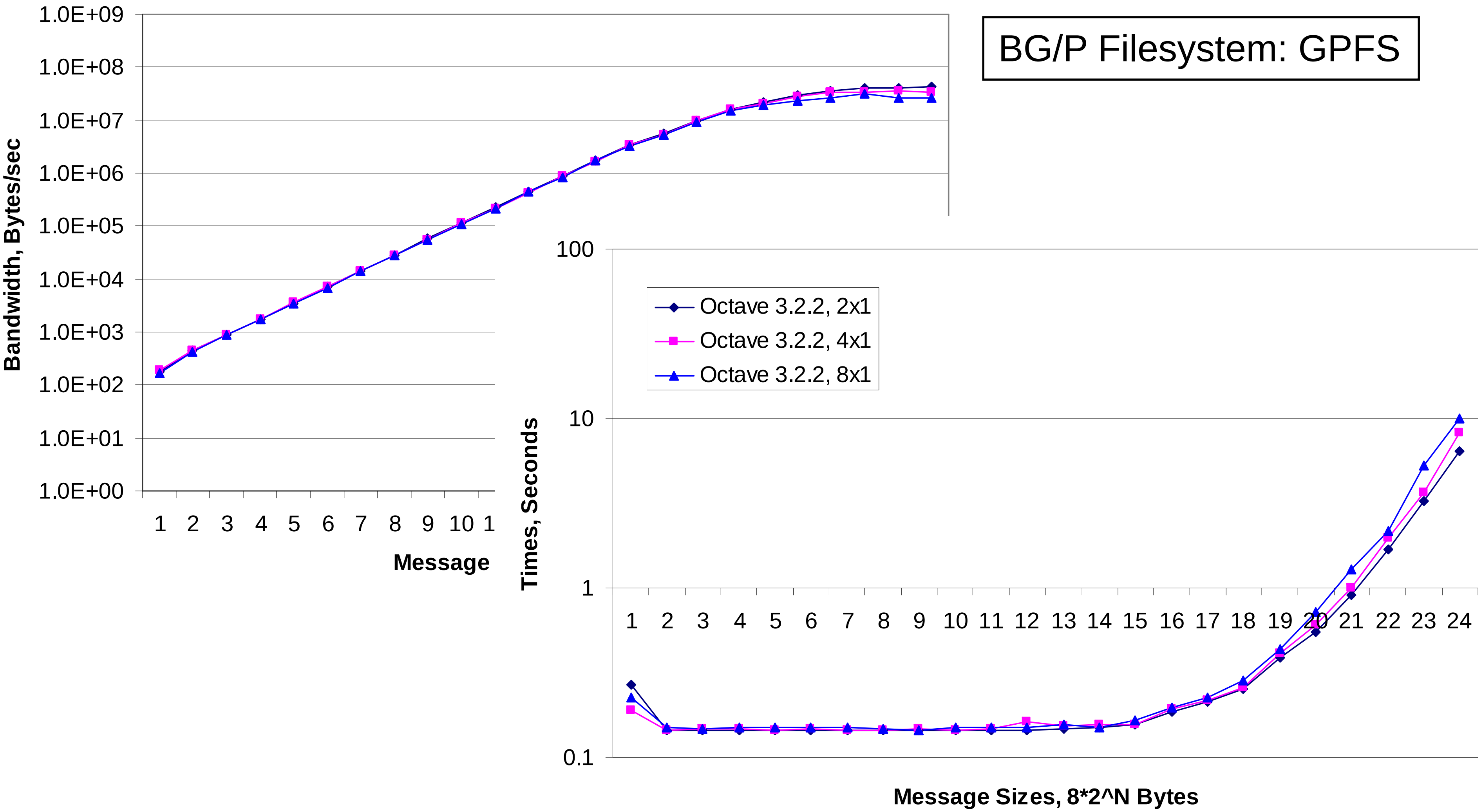

Higher is better


Lower is better





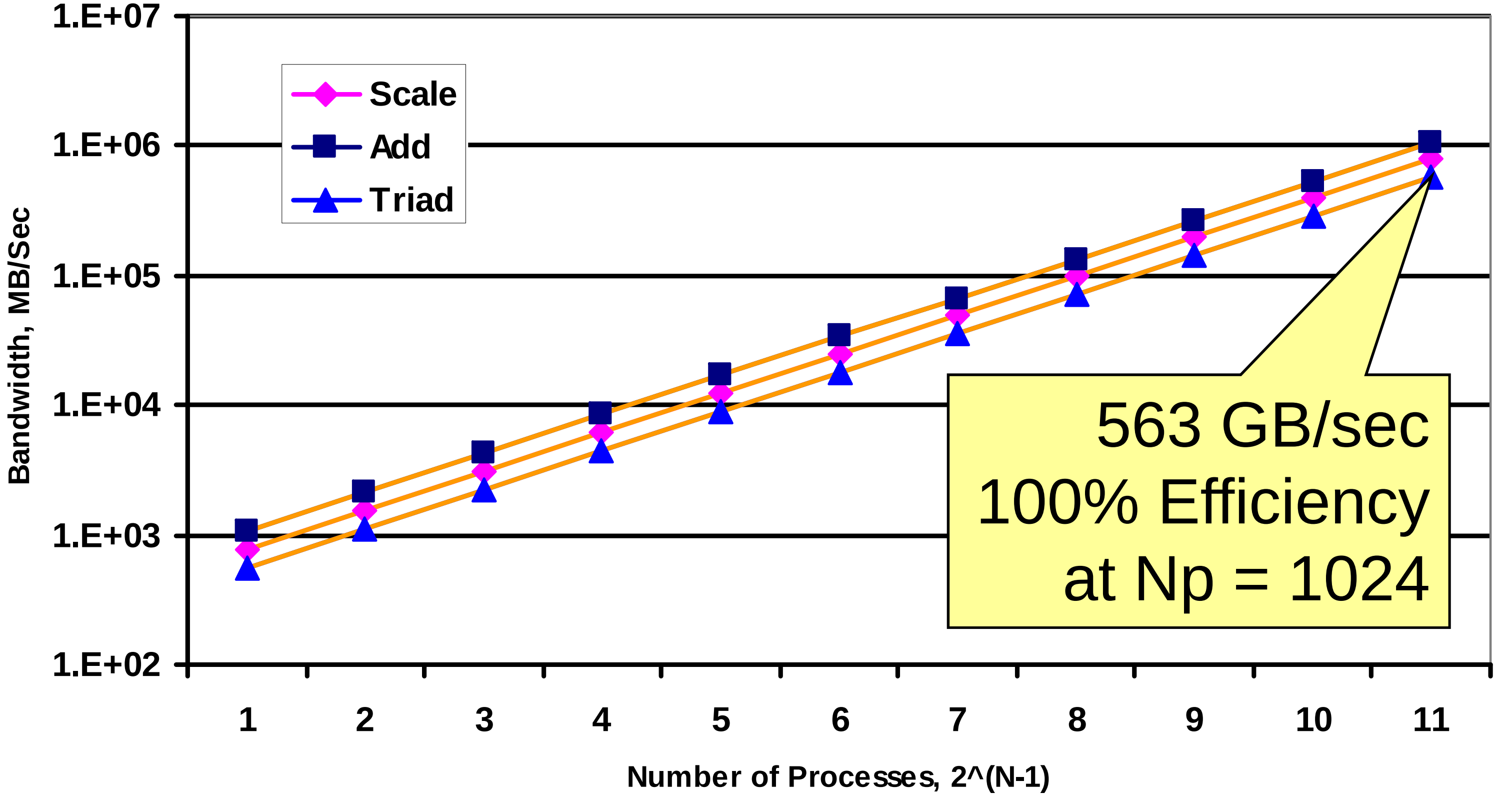
pSpeed Performance on BG/P



BG/P Filesystem: GPFS

pStream Results with Scaled Size

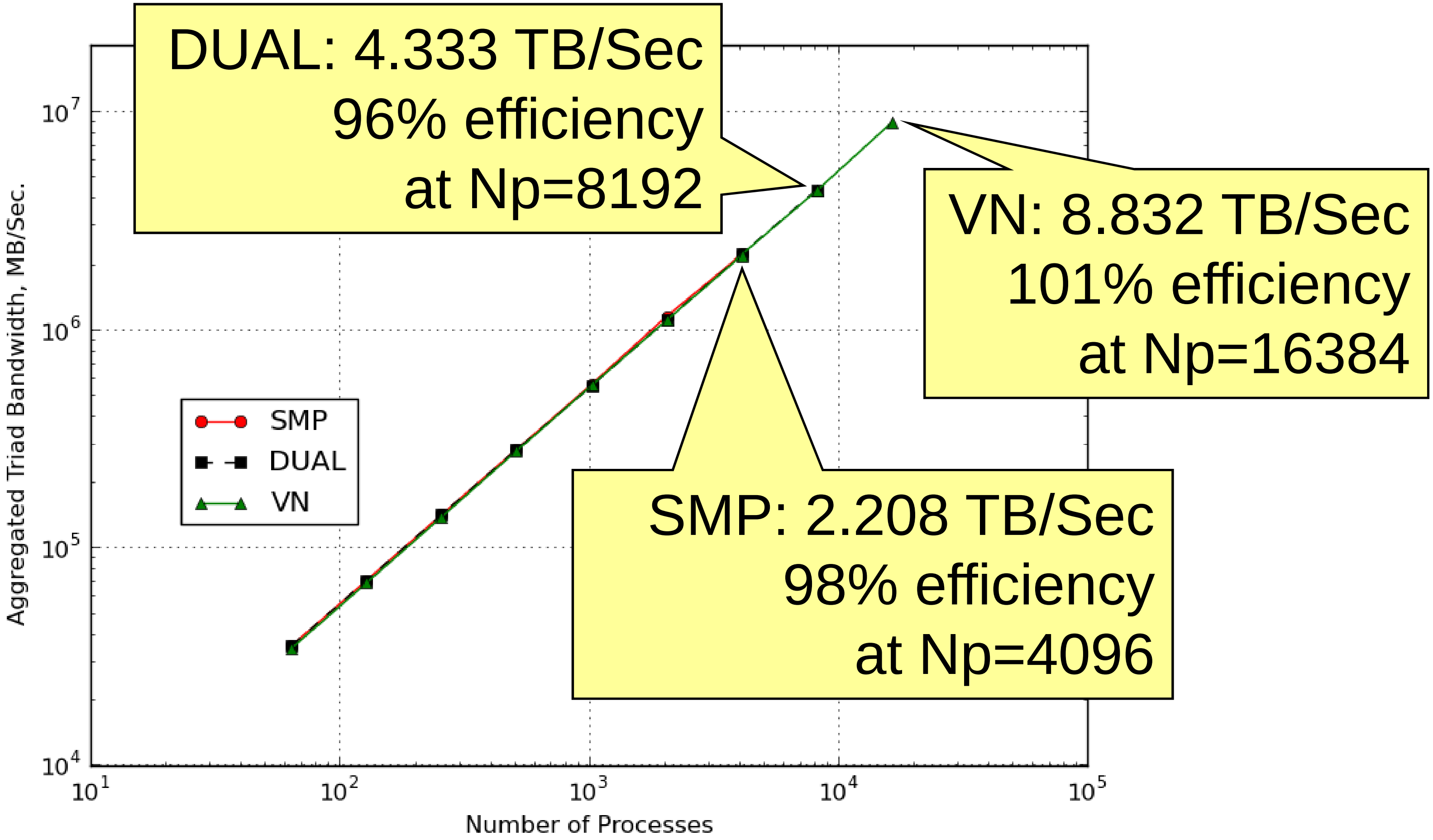
- SMP mode: Initial global array size of 2^25 for Np=1
  - Global array size scales proportionally as number of processes increases (1024x1)



563 GB/sec
100% Efficiency
at Np = 1024

pStream Results with Fixed Size

- **Global array size of 2^30**
  - **The number of processes scaled up to 16384 (4096x4)**



DUAL: 4.333 TB/Sec
96% efficiency
at Np=8192

VN: 8.832 TB/Sec
101% efficiency
at Np=16384

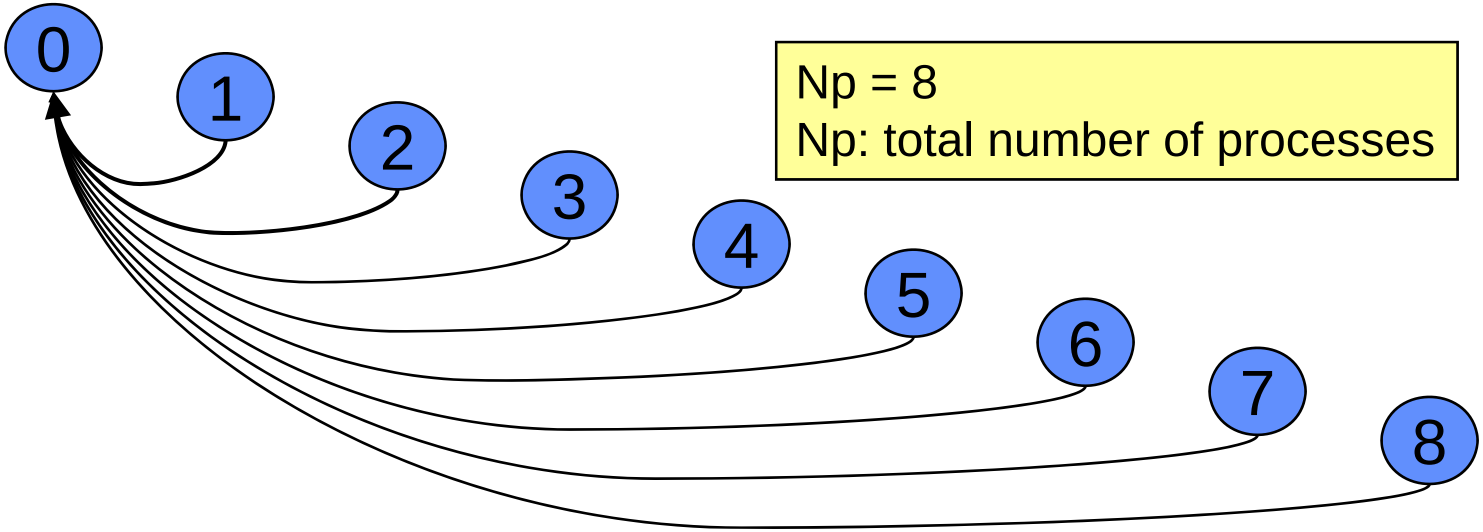
SMP: 2.208 TB/Sec
98% efficiency
at Np=4096

Outline

- Introduction
- Performance Studies
- **Optimization for Large Scale Computation**
  - ***Aggregation***
- Summary

Current Aggregation Architecture

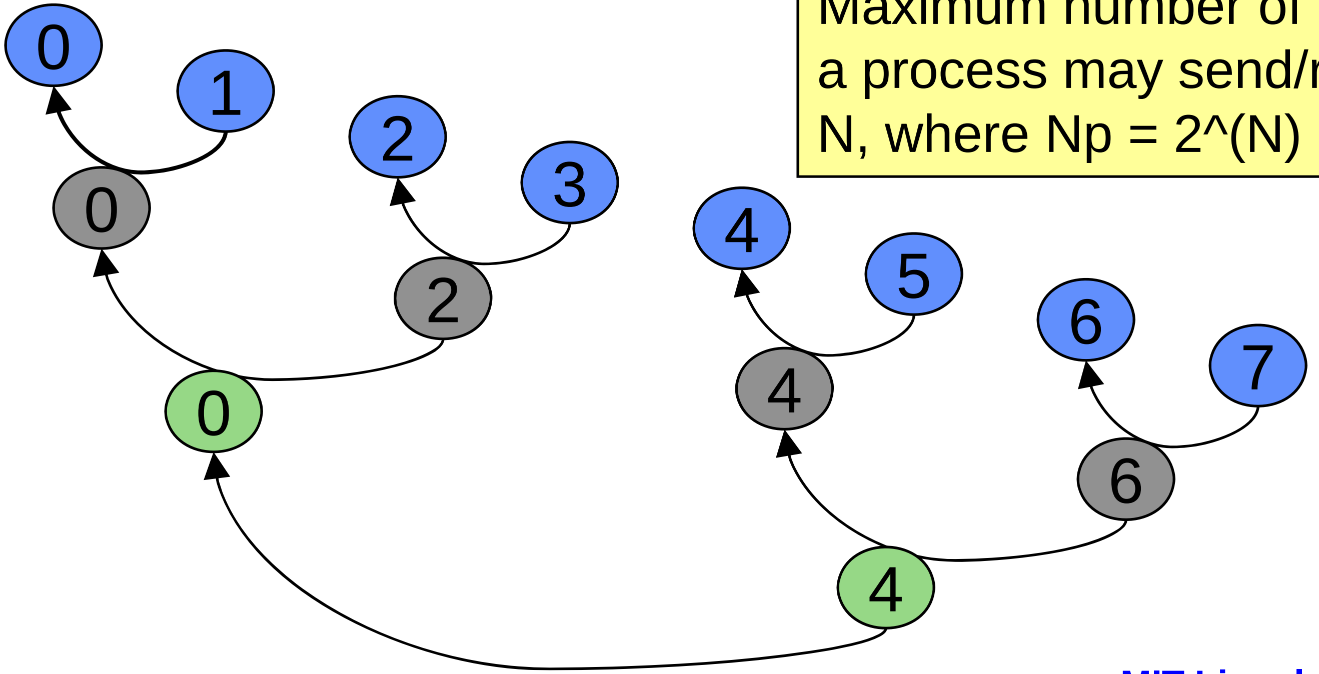
- The leader process receives all the distributed data from other processes.
- All other processes send their portion of the distributed data to the leader process.
- The process is inherently sequential.
  - The leader receives Np-1 messages.



Np = 8
Np: total number of processes

Binary-Tree Based Aggregation

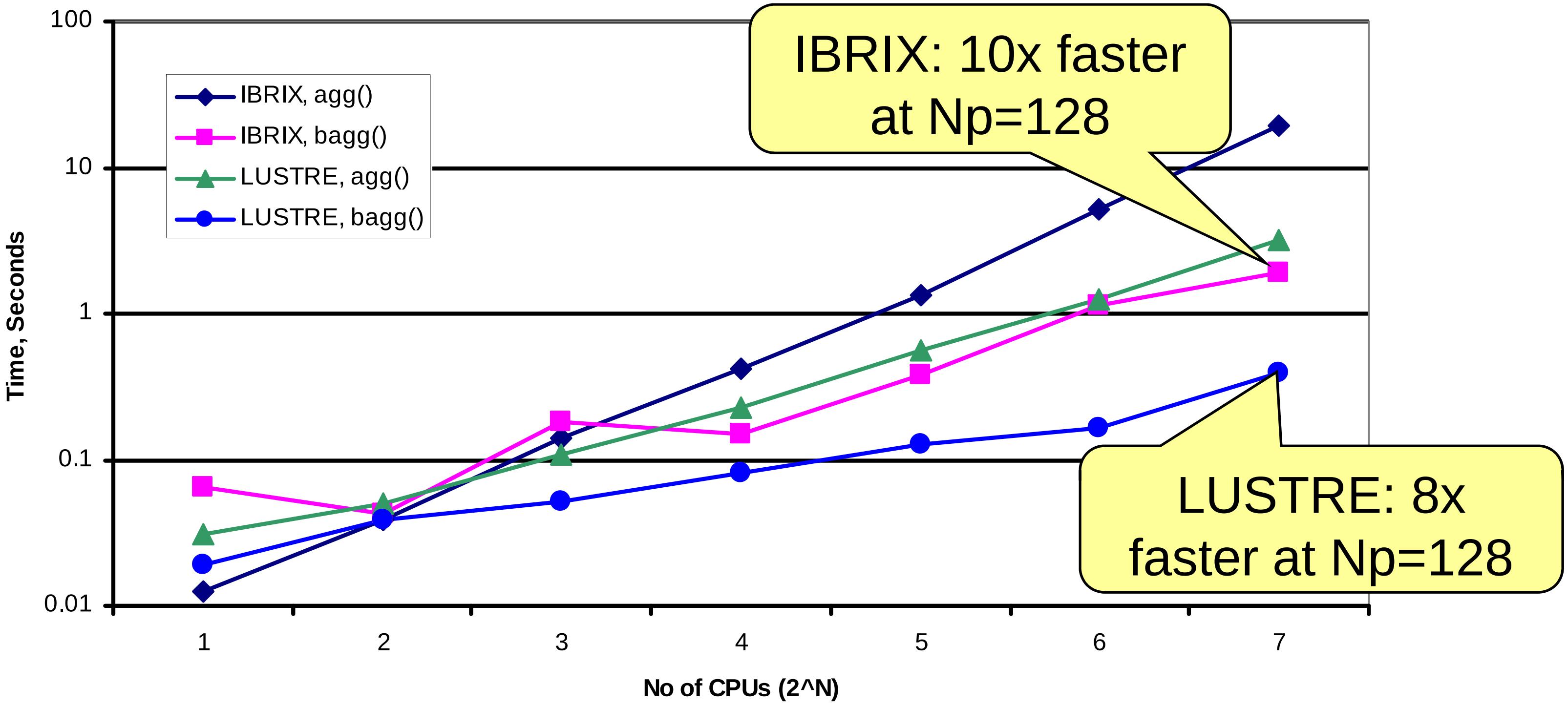
- **BAGG: Distributed message collection using a binary tree**
  - **The even numbered processes send a message to its odd numbered neighbor**
  - **The odd numbered processes receive a message from its even numbered neighbor.**



Maximum number of message a process may send/receive is N, where Np = 2^(N)

BAGG() Performance

- **Two dimensional data and process distribution**
- **Two different file systems are used for performance comparison**
  - **IBRIX: file system for users' home directories**
  - **LUSTRE: parallel file system for all computation**

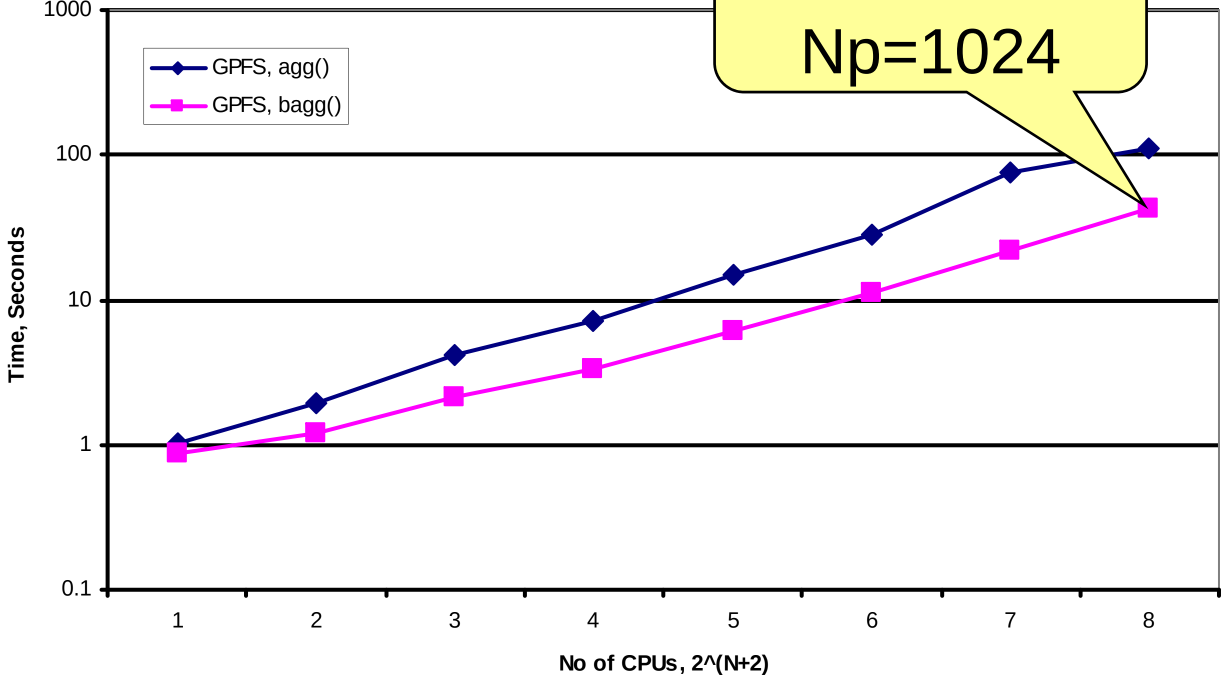


IBRIX: 10x faster at Np=128

LUSTRE: 8x faster at Np=128

BAGG() Performance, 2

- Four dimensional data and process distribution
- With GPFS file system on IBM Blue Gene/P System (ANL's Surveyor)
  - From 8 processes to 1024 processes

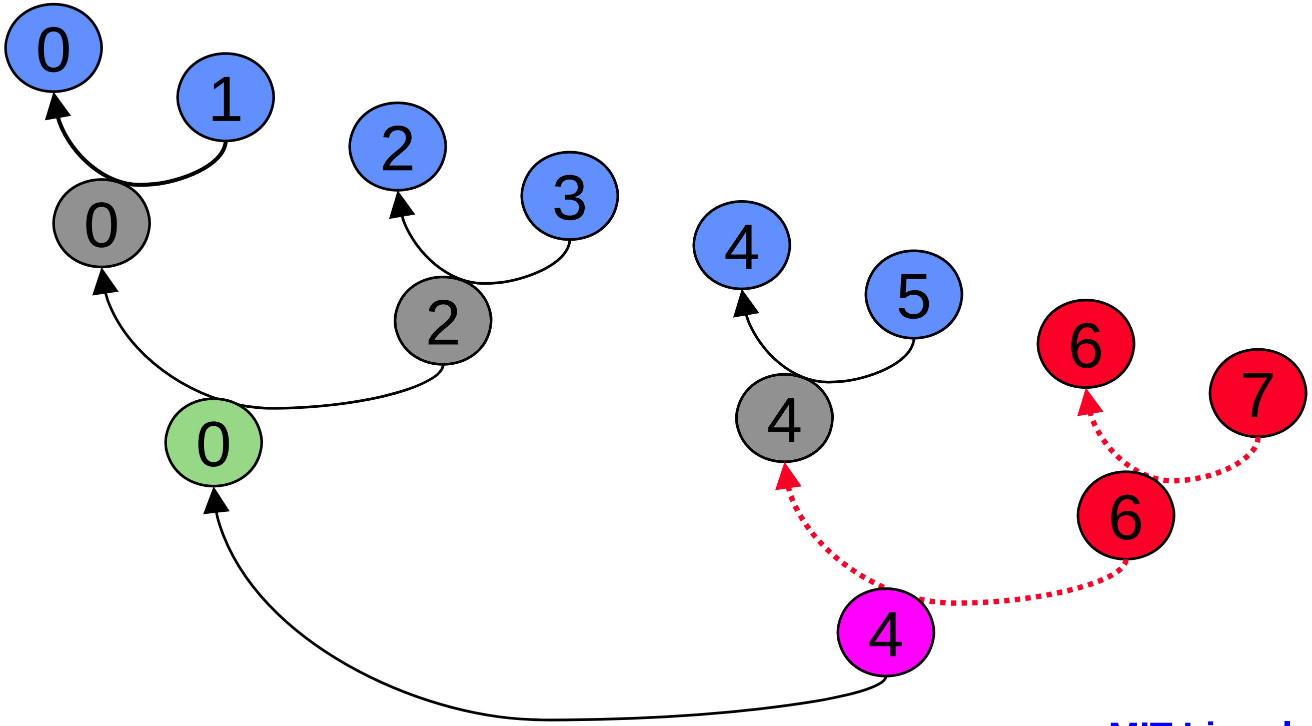


2.5x faster at Np=1024

Generalizing Binary-Tree Based Aggregation

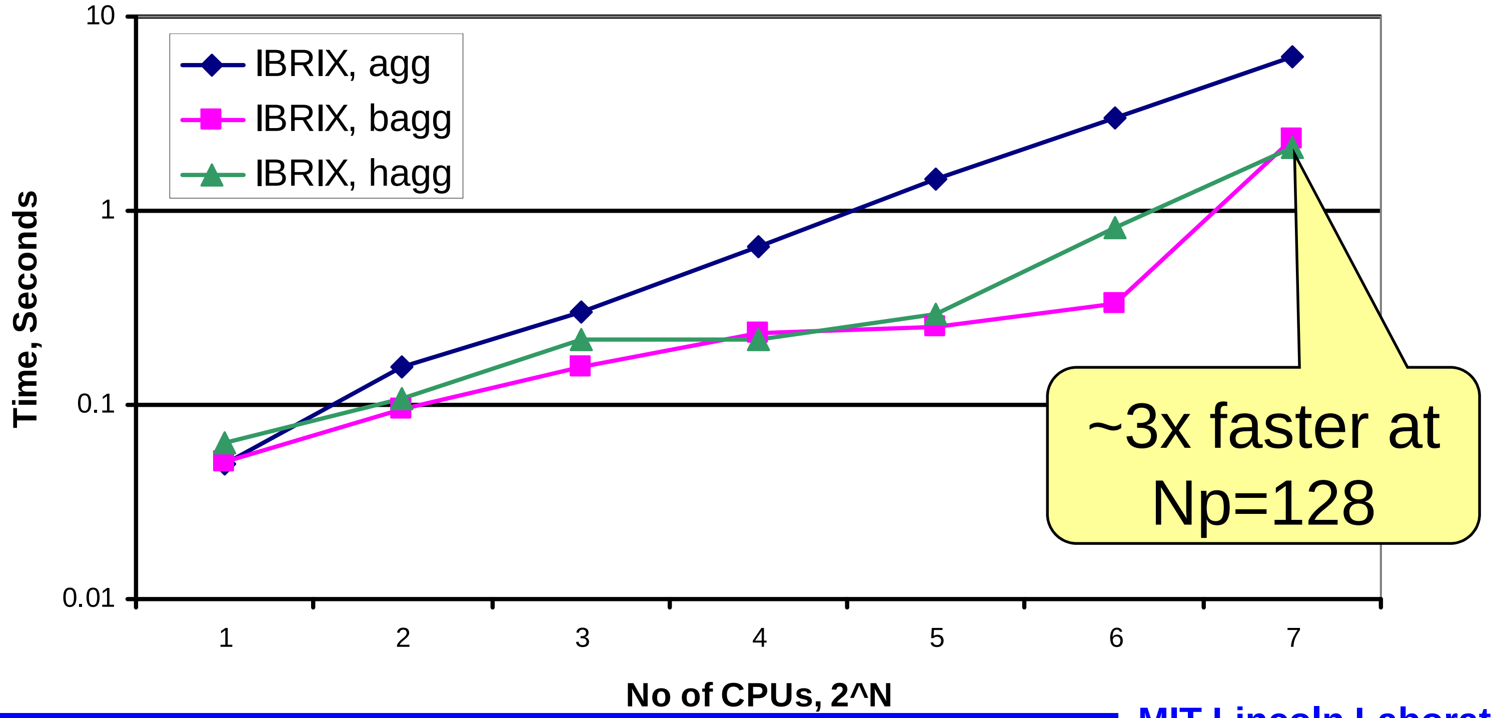
- **HAGG: Extend the binary tree to the next power of two number**
  - **Suppose that Np = 6**

    The next power of two number: Np* = 8
  - **Skip any messages from/to the fictitious Pid's.**



BAGG() vs. HAGG()

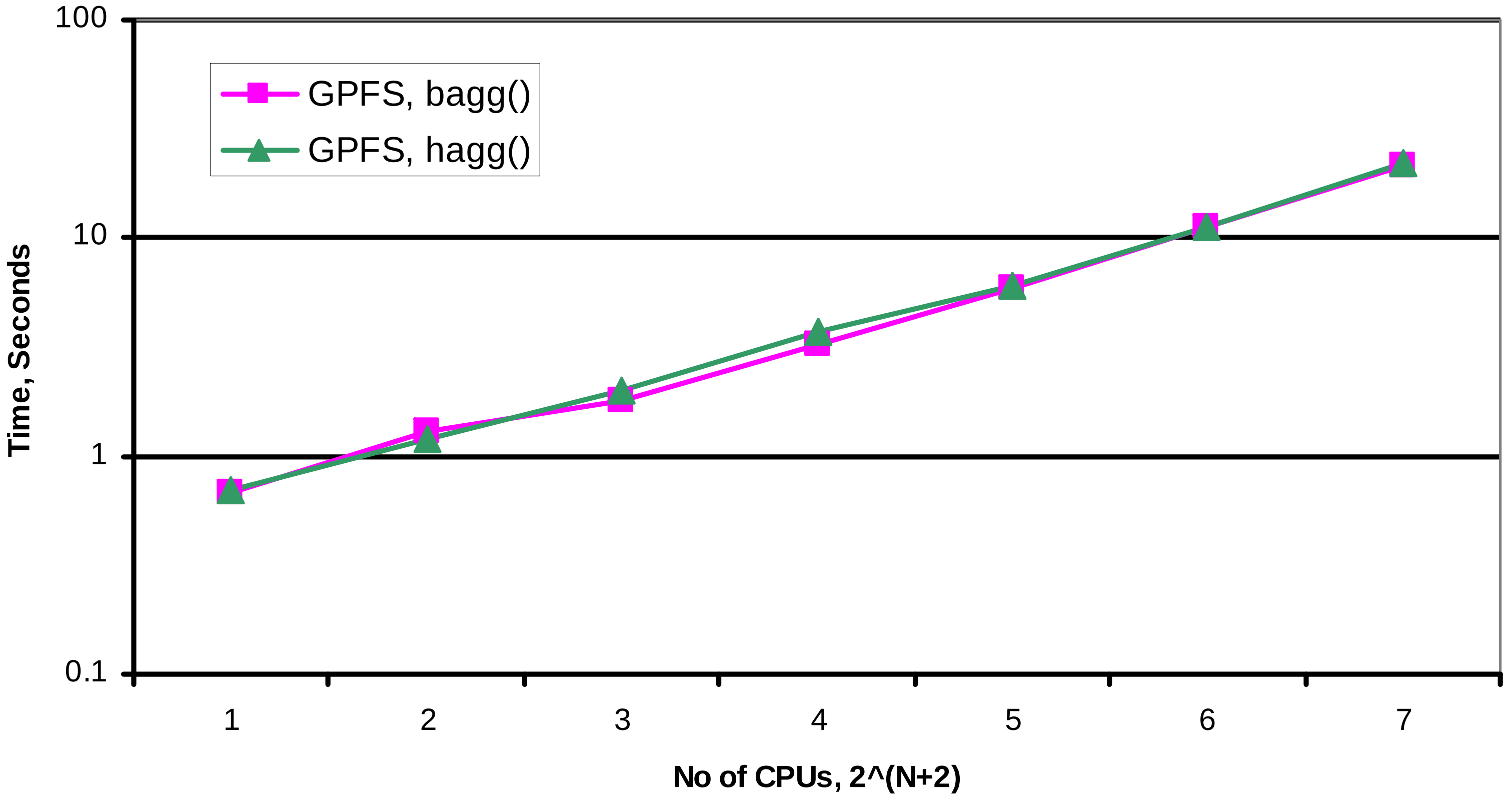
- **HAGG() generalizes BAGG()**
  - **Removes the restriction (Np = 2^N) in BAGG()**
  - **Additional costs associated with bookkeeping**
- **Performance comparison on two dimensional data and process distribution**



~3x faster at Np=128

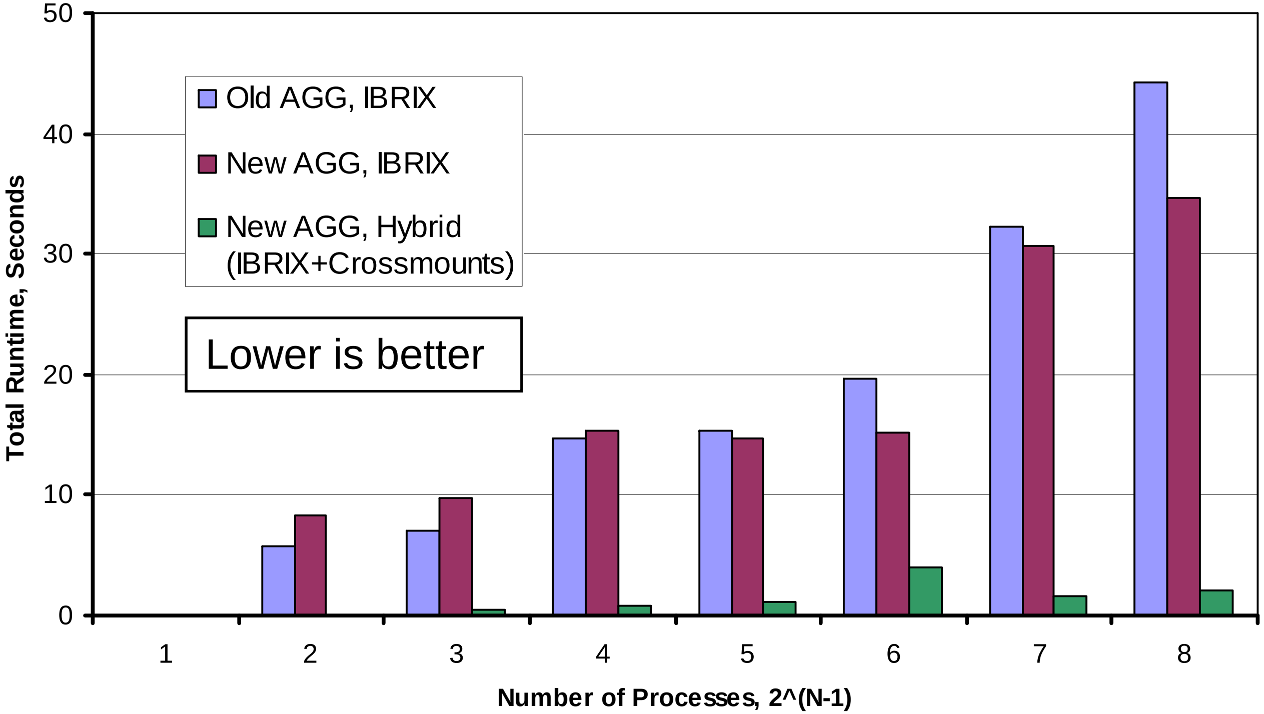
BAGG() vs. HAGG(), 2

- Performance comparison on four dimensional data and process distribution
- Performance difference is marginal on a dedicated environment
  - SMP mode on IBM Blue Gene/P System



BAGG() Performance with Crossmounts

- **Significant performance improvement by reducing resource contention on file system**
  - **Performance is jittery because production cluster is used for performance test**



Summary

- pMatlab has been ported to IBM Blue Gene/P system
- Clock-normalized, single process performance of Octave on BG/P system is on-par with Matlab
- For pMatlab point-to-point communication (pSpeed), file system performance is important.
  - Performance is as expected with GPFS on BG/P
- Parallel Stream Benchmark scaled to 16384 processes
- Developed a new pMatlab aggregation function using a binary tree to scale beyond 1024 processes