Open MPI State of the Union
Community Meeting SC '11

November 16, 2011

Jeff Squyres — CISCO

George Bosilca — ICL UT

Shinjii Sumimoto — FUJITSU

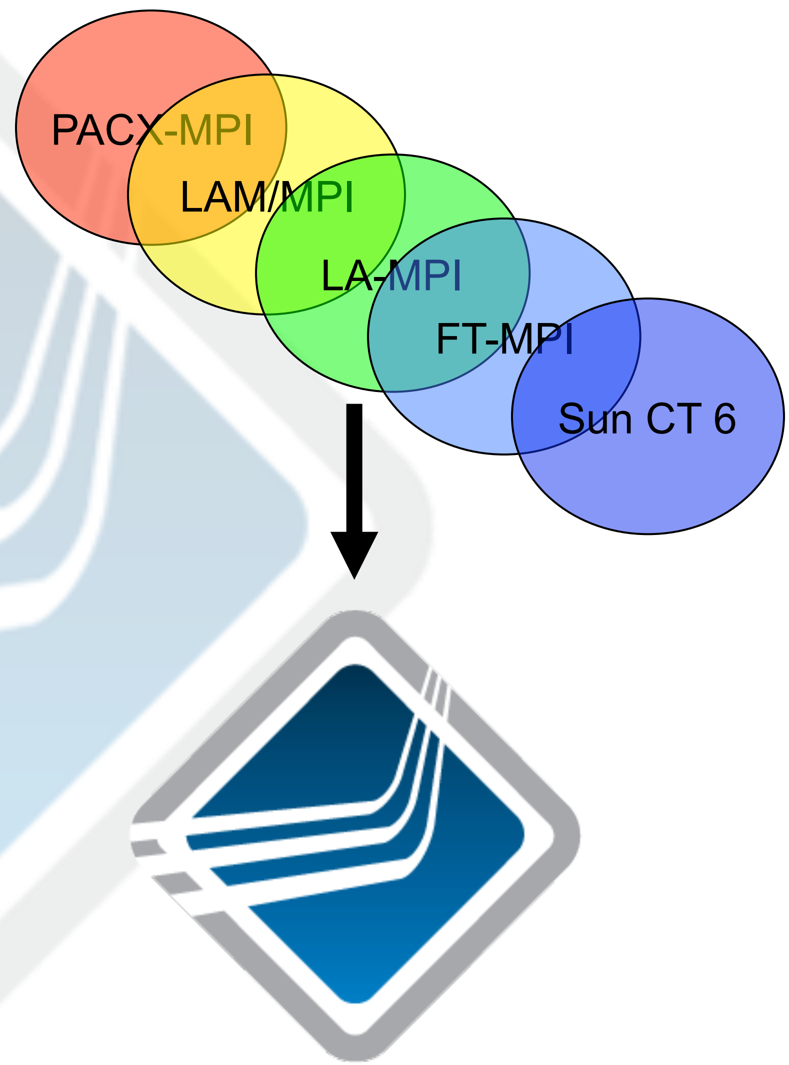
Rolf vandeVaart — NVIDIA

Agenda

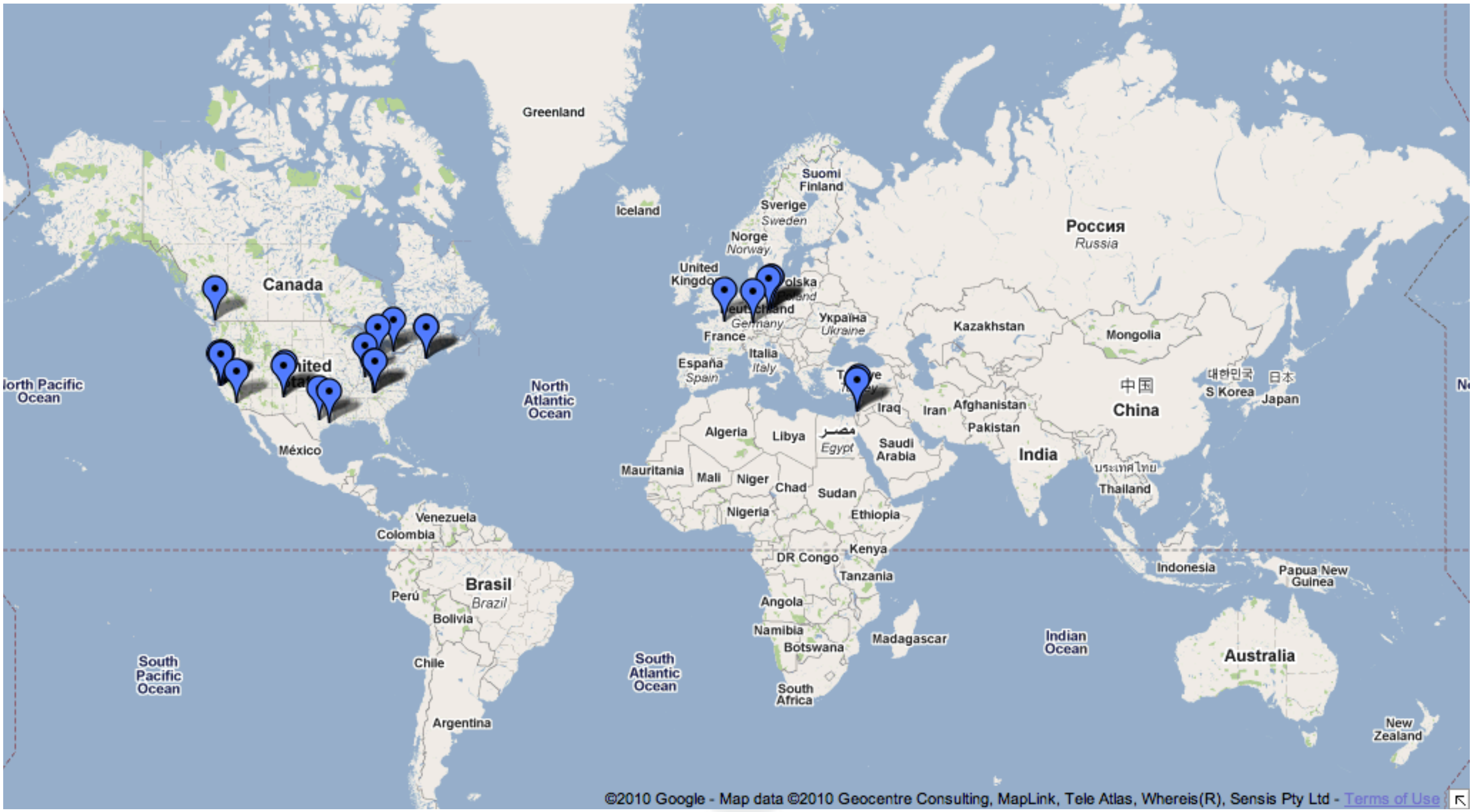
- Open MPI Project / Community
- Roadmap
- Select organization project updates
  - Nvidia, Fujitsu, U. Tennessee, Cisco, others
- The (continuing) road to MPI-3
- Community questions
  - Feedback: http://www.open-mpi.org/sc2011

Open MPI Is…

- Evolution of several prior MPI’s
- Open source project and community
  - Production quality
  - Vendor-friendly
  - Research- and academic-friendly
- MPI-2.1 compliant



Members, Contributors, Partners



Roadmap

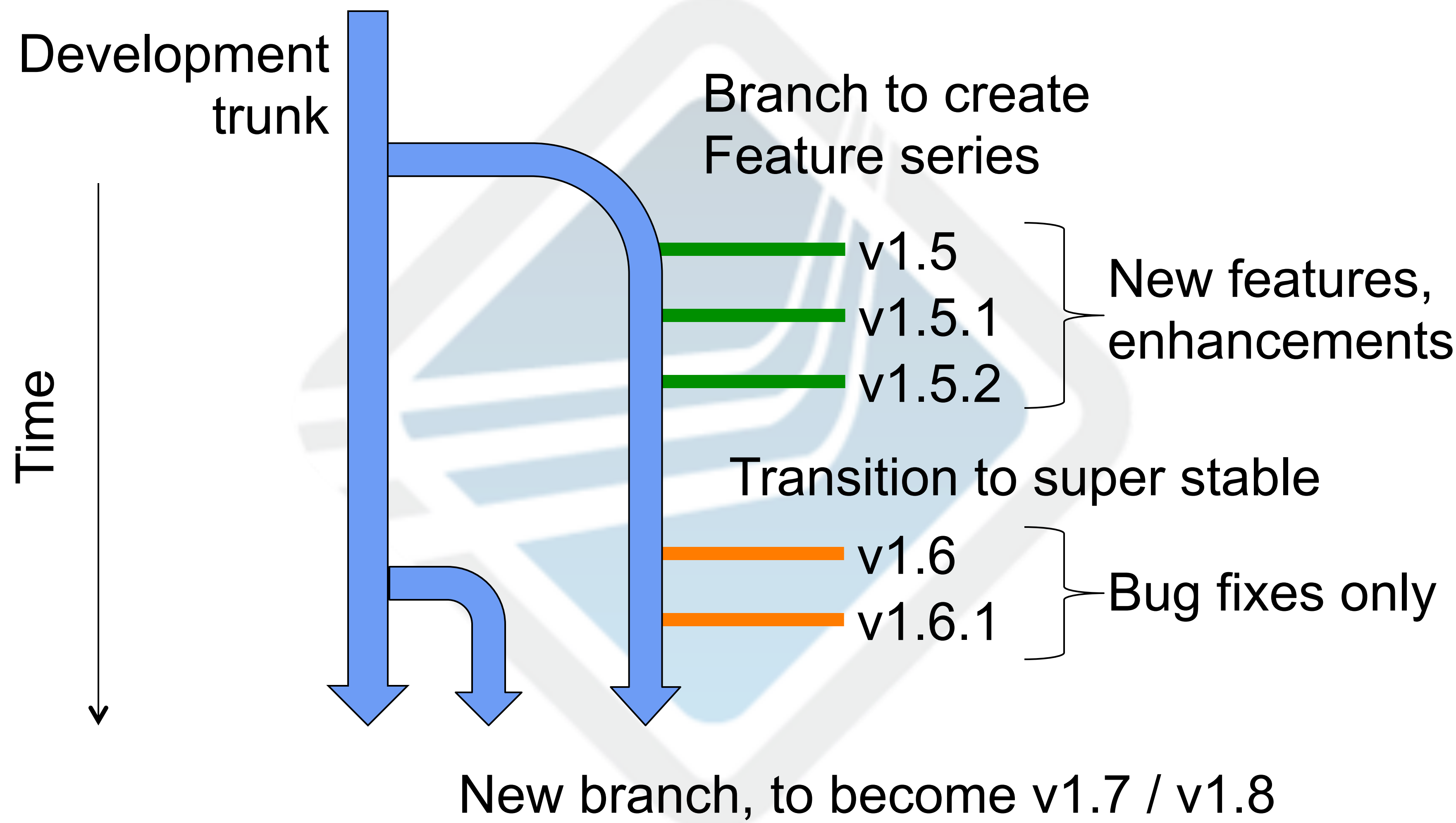
Jeff Squyres

Cisco

Versioning scheme

- Open MPI has 2 concurrent release series
  - "Feature series" → v1.<odd>
  - "Super stable series" → v1.<even>
- Both are tested and QA'ed
  - Main difference between the two is time

Feature Series



v1.4 Series Sunset

- v1.4 is the current “super stable series”
- Likely to only have one more release
  - A few more bug fixes have crept in
  - v1.4.5 possibly in December

So long, v1.4 series!

v1.5 → v1.6 Transition

- ABI change since v1.4
- New features over the v1.5 series
  - Support for Mellanox "MXM" and offloaded collectives support (Voltaire)
  - ARM support
  - InfiniBand failover transport
  - WinVerbs support
  - Significant run-time scalability, robustness
  - …oodles of little improvements and fixes

v1.5 → v1.6 Transition

- One more release in v1.5
  - Final MPI-2.2 functionality (no strong demand)
  - hwloc version bump
  - Stronger PMI support
  - Usual array of bug fixes, minor enhancements
- Aiming for December, 2011
  - US holiday schedule may force pushing to Jan
  - Transition to v1.6 a fixed time after that
  - **ESTIMATE:** Q1 2012

v1.7 Sunrise

- Several upcoming v1.7 features discussed later in this presentation
- ABI break from v1.5 / v1.6
- Gating factors for v1.7 branch:
  - v1.6 release
  - Stability of new trunk features
  - Have not yet elected v1.7 release managers
- **ESTIMATE:** Q2 2012

Nvidia Update

Rolf vandeVaart

NVIDIA

NVIDIA and Open MPI

Rolf vandeVaart

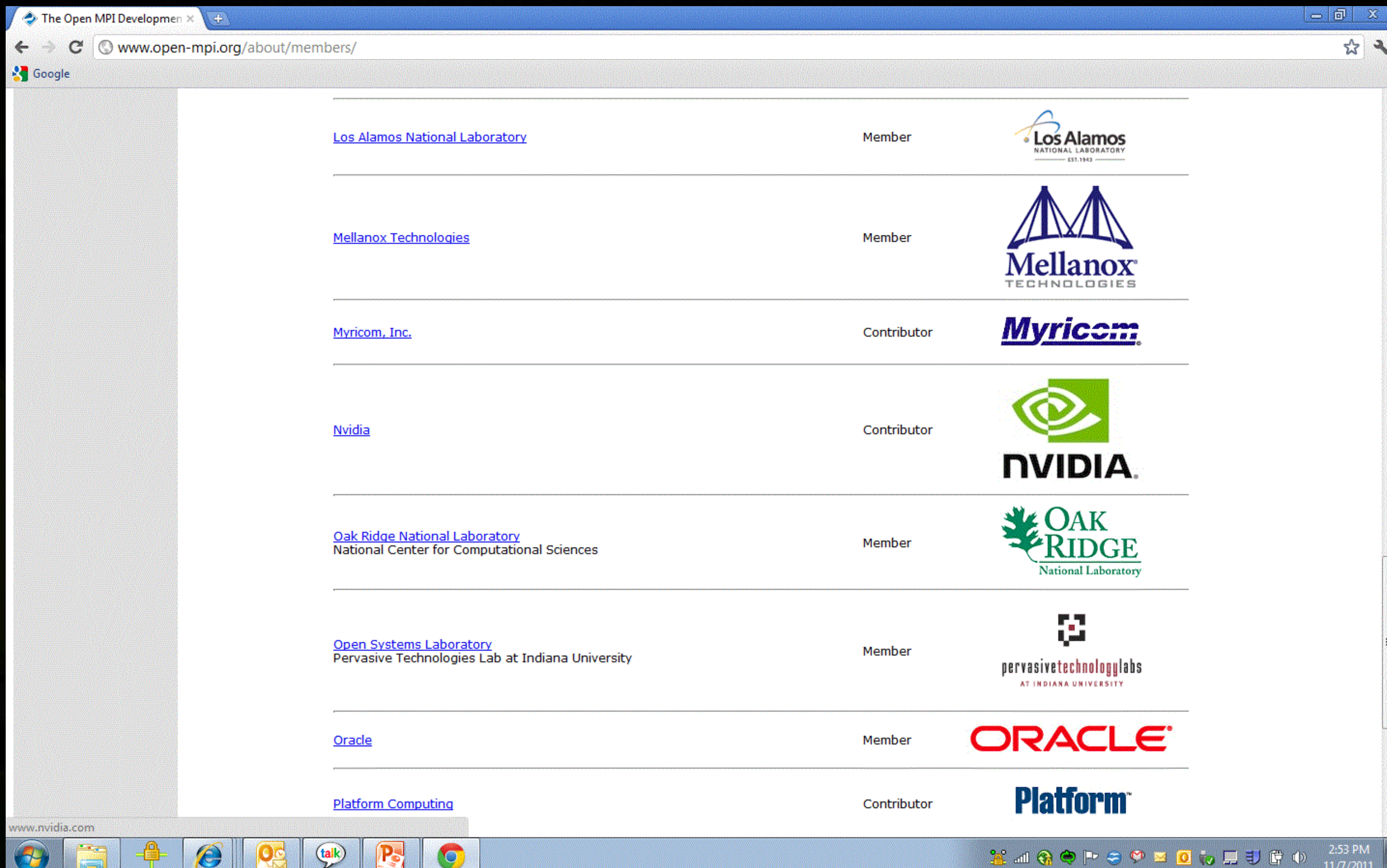
November 16, 2011

NVIDIA

Why

- **Tremendous growth in CUDA adoption**

Joined in April, 2011



The Open MPI Developmen

www.open-mpi.org/about/members/

Google

Los Alamos National Laboratory	Member	Los Alamos NATIONAL LABORATORY EST. 1943
Mellanox Technologies	Member	Mellanox TECHNOLOGIES
Myricom, Inc.	Contributor	Myricom
Nvidia	Contributor	NVIDIA
Oak Ridge National Laboratory National Center for Computational Sciences	Member	OAK RIDGE National Laboratory
Open Systems Laboratory Pervasive Technologies Lab at Indiana University	Member	pervasivetechnologylabs AT INDIANA UNIVERSITY
Oracle	Member	ORACLE
Platform Computing	Contributor	Platform

www.nvidia.com

2:53 PM 11/7/2011

Make Open MPI aware of CUDA

- Allow users to send and receive GPU buffers directly
- Hide complexity with the MPI stack

Make Open MPI aware of CUDA

- Stage data in host memory prior to MPI calls

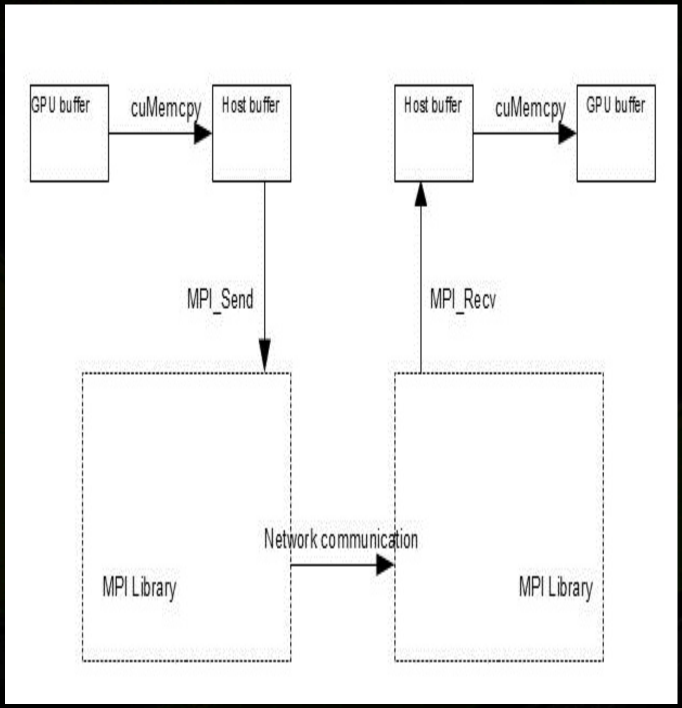
```
cuMemAlloc(devptr, size)
kernel<<grid, block>>(devptr)
hostptr = malloc(size)
cuMemcpy(hostptr, devptr, size)
MPI_Send(hostptr, …)
```

- Access device memory directly from MPI calls

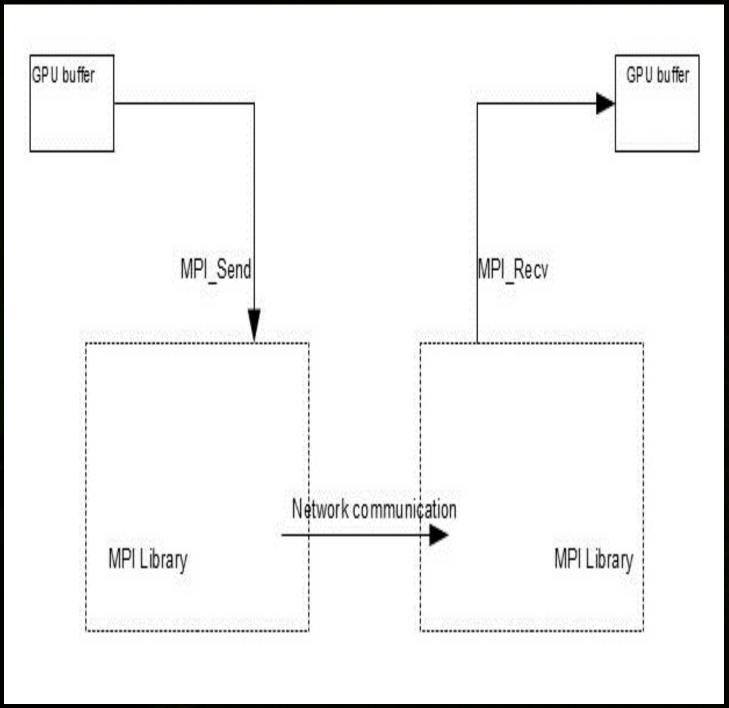
```
cuMemAlloc(devptr, size)
kernel<<grid, block>>(devptr)
MPI_Send(devptr, …)
```

Move GPU buffers within MPI

- **Original**



- **New**



Open MPI Plan

Three Phases

1. Add basic support - Done
2. Add registration of internal buffers - Done
3. Add interprocess memory support within a node – prototype working

Phase 1

- All changes were made in datatype and convertor code.
- Add new pointer in convertor that points to a memcpy routine.
- When MPI request is initialized, input buffer is queried and memcpy routine can be changed to CUDA routine, cuMemcpy
- Modify opal_convertor_need_buffers() to return true if buffer is device memory (special flag added to convertor).

Phase 1 - Continued

- Code is enabled with –with-cuda and –with-cuda-libdir.
- Added to Open MPI trunk April, 2011
- http://www.open-mpi.org/faq/?category=building#build-cuda
- http://www.open-mpi.org/faq/?category=running#mpi-cuda-support

Support

- With these changes, we can support all the following APIs.
  - MPI_Send, MPI_Recv, MPI_Isend, etc.
  - MPI_Bcast, MPI_Gather, MPI_Scatter, etc.
- No support for reductions or one-sided.
- Supports both contiguous and non-contiguous datatypes.

Issues - Performance

- Each call to cuMemcpy incurs a 10us overhead.
- For IB and TCP, forcing usage of the pipelined send protocol can affect large message performance.
- For SM, overhead of cuMemcpy limits performance for large messages also.

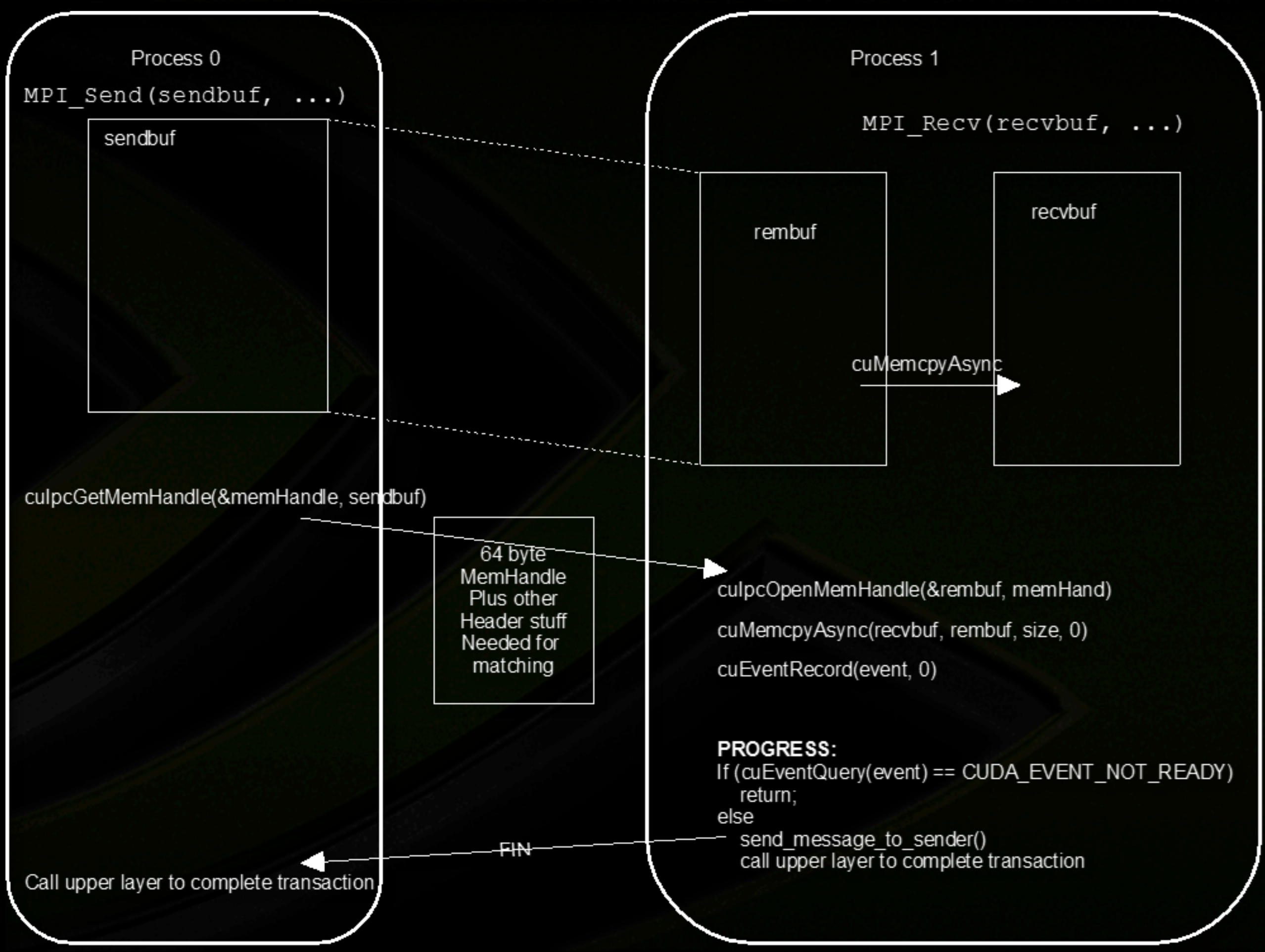
Phase 2

- Register internal host buffers with cuMemHostRegister.
- Improved IB performance
- Allows possible change to asynchronous cuMemcpys in the MPI library.
- Added to Open MPI trunk August, 2011

Phase 3 – Improve on-node performance

- **CUDA 4.1 added new interprocess communication utilities.**
  - `cuIpcGetMemHandle`
  - `cuIpcOpenMemHandle`
  - `cuIpcCloseMemHandle`
  - `cuIpcGetEventHandle`
  - `cuIpcOpenEventHandle`

Remote GET for GPU memory



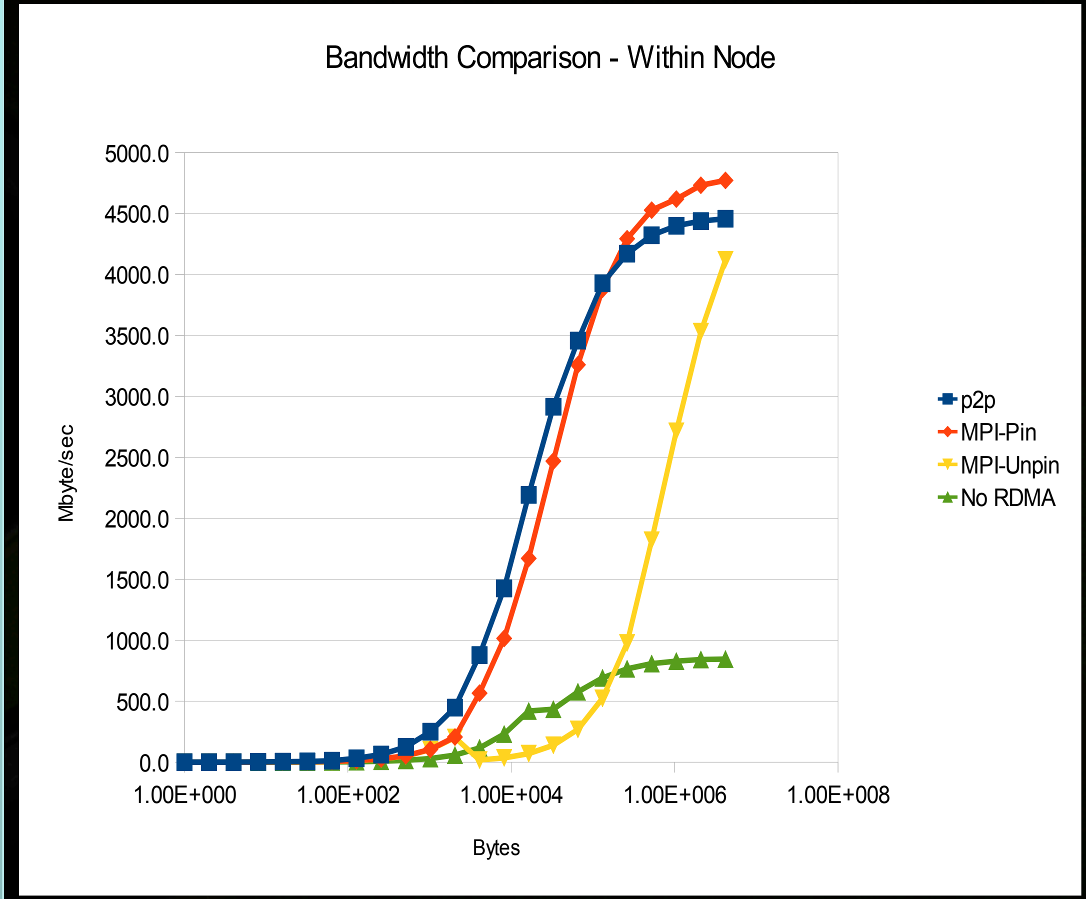
Memory Handles

- cuIpcGetMemHandle – 1 usec
- cuIpcOpenMemHandle – 100 usec
- Therefore, cache the memory handles from remote processes and reuse them if the user reuses them. Similar to IB BTL.
- Great benefit where user buffers are reused.

GPU to GPU within node

Comparison of various protocols

Size	p2p	MPI-Pin	MPI-Unpin	No RDMA
1	1.0	0.1	0.1	0.0
2	1.0	0.2	0.2	0.1
4	1.0	0.4	0.4	0.1
8	2.0	0.9	0.8	0.2
16	4.0	1.7	1.7	0.5
32	6.0	3.4	3.3	0.9
64	12.0	6.7	6.5	1.8
128	32.0	13.3	13.0	3.7
256	63.0	26.5	25.8	7.4
512	125.0	52.7	51.2	14.8
1024	250.0	105.2	102.1	29.7
2048	448.0	206.5	201.8	58.5
4096	879.0	566.0	17.7	117.0
8192	1425.0	1014.7	35.1	230.9
16384	2192.0	1671.4	70.4	419.4
32768	2915.0	2469.3	139.0	434.5
65536	3458.0	3259.2	268.8	577.0
131072	3928.0	3878.5	523.7	691.3
262144	4170.0	4292.8	977.6	765.5
524288	4322.0	4527.3	1820.4	808.2
1048576	4399.0	4618.1	2713.4	829.0
2097152	4438.0	4731.5	3530.7	842.1
4194304	4457.0	4771.3	4119.7	845.6



Future

- More use of CUDA asynchronous copies
- Improved GPU to GPU memory communication between nodes.
- Better noncontiguous datatypes and collectives. (NVIDIA funding university research into this)

Thanks

rvandevaart@nvidia.com

The 'Super' Computing Company

From Super Phones to Super Computers

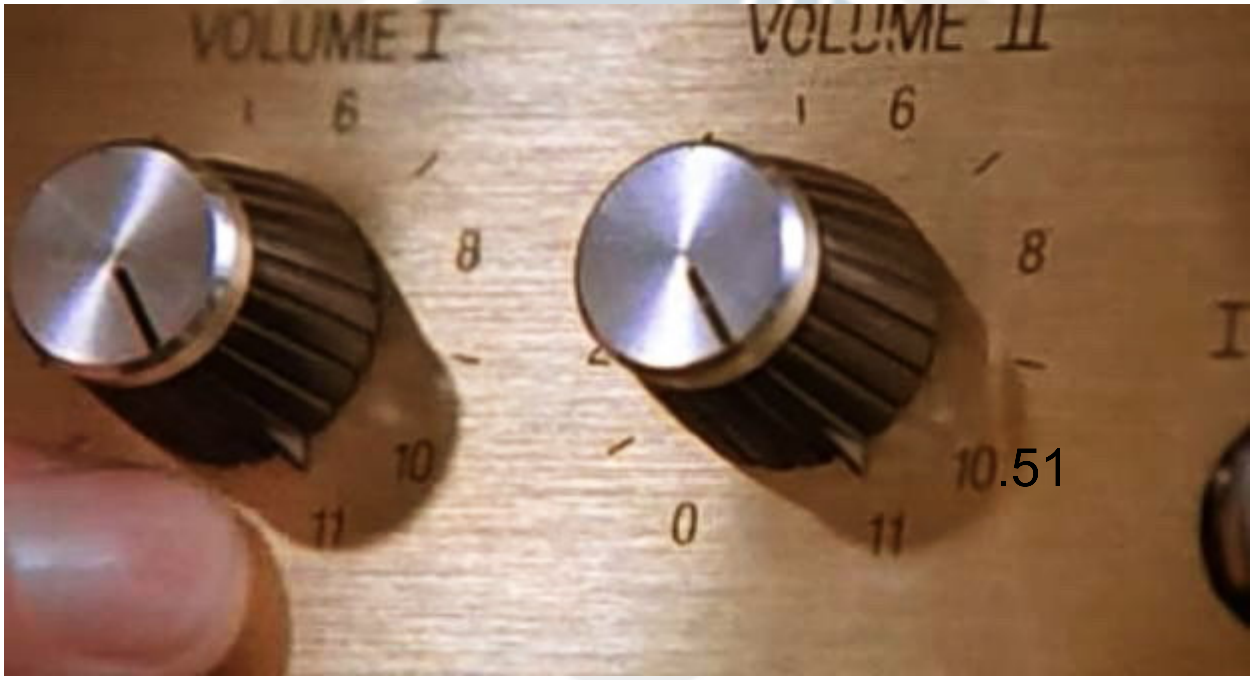
Fujitsu / K Computer Update

Shinjii Sumimoto

FUJITSU

#1, baby!

- 10.51 petaflops
  - K “cranked it up to 11” (rounding up ☺)



Bleeding edge research

George Bosilca

RUNTIME

Flexibility

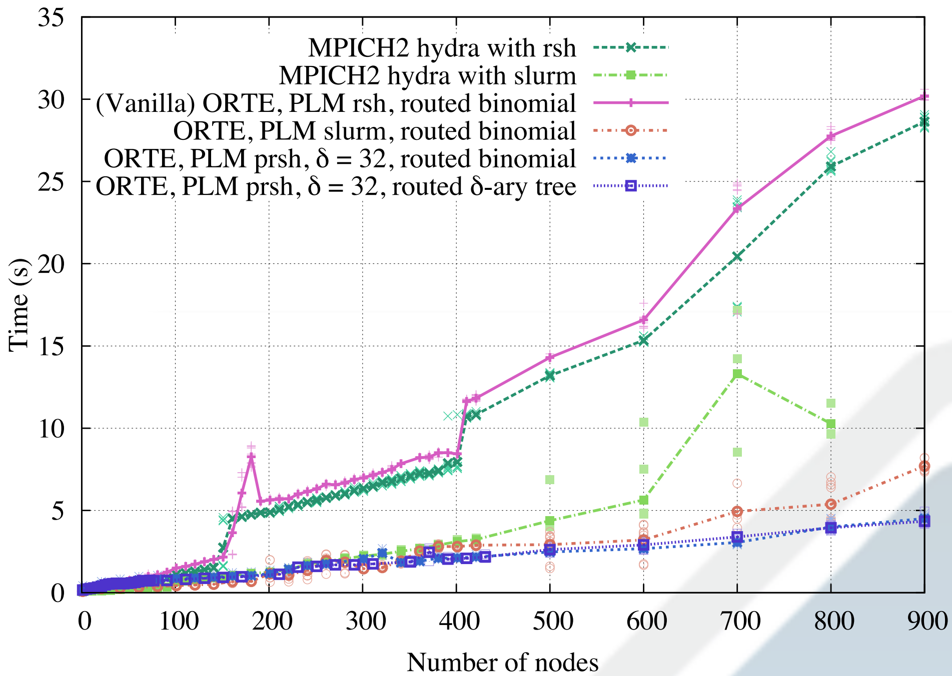
- Support several backend runtimes
  - Eventually with different levels of integrations
    - Notifiers / specialized logging services might not be available everywhere
  - And different capabilities
    - MPI 2 dynamic processing or fault tolerance might be only partially supported in some environments.
- Open RTE, PMI, Hydra, local

Scalability

- Startup
  - Gracefully handle many processes per node
  - Minimize resource consumption while maximizing parallelism: build specialized network overlays

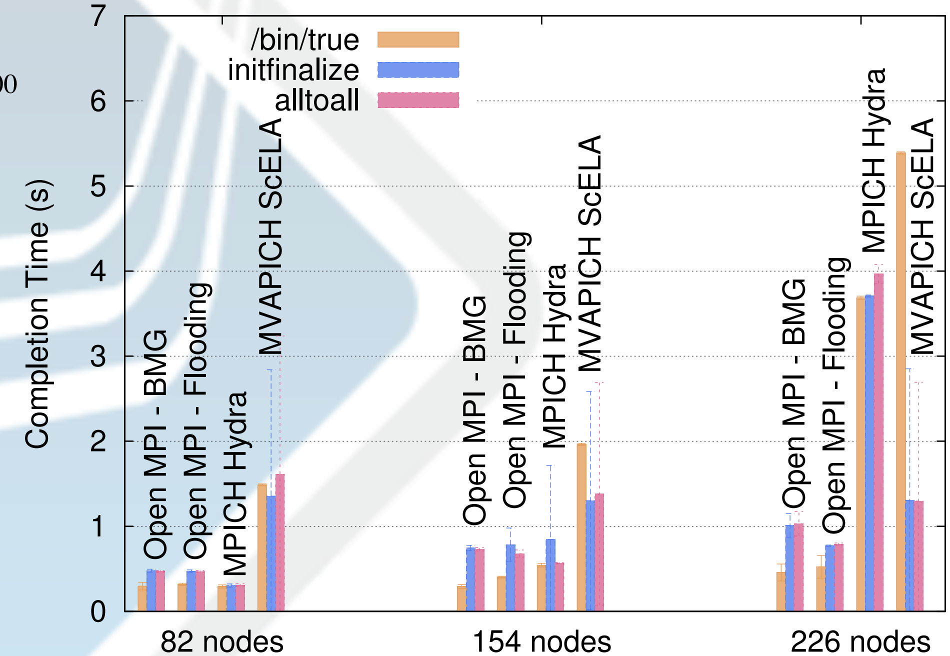
    Bosilca, G., Herault, T., Razmerita, A., Dongarra, Jack J., "**On Scalability for MPI Runtime Systems** ," Cluster 2011.
- Business card (Modex) exchange
  - Use the network overlays to exchange the business cards of the participating processes
  - Keep one single copy per node shared between all local processes
  - Update the data asynchronously

    Bosilca, G., Herault, T., Lemarinier, P., Razmerita, A., Dongarra, Jack J., "**Scalable Runtime for MPI: Efficiently Building the Communication Infrastructure**," EuroMPI 2011 - poster.



Grid'5000

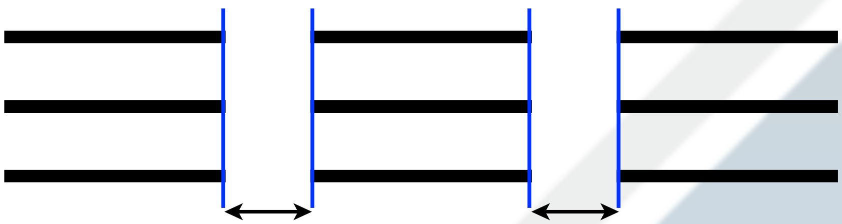
- Self-adapting algorithms to evolve from any type of spanning tree toward BMG
- Good candidate for resilient runtime



Fault Tolerance

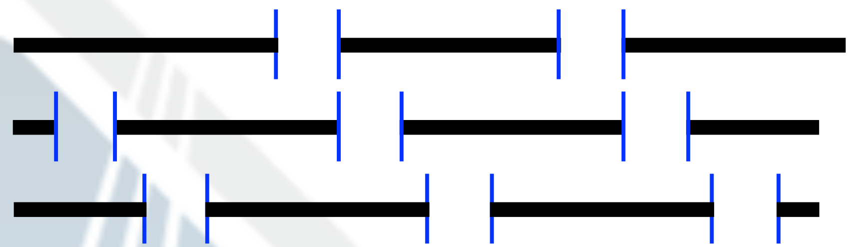
Correlated Set in Message Logging

Coordinated C/R



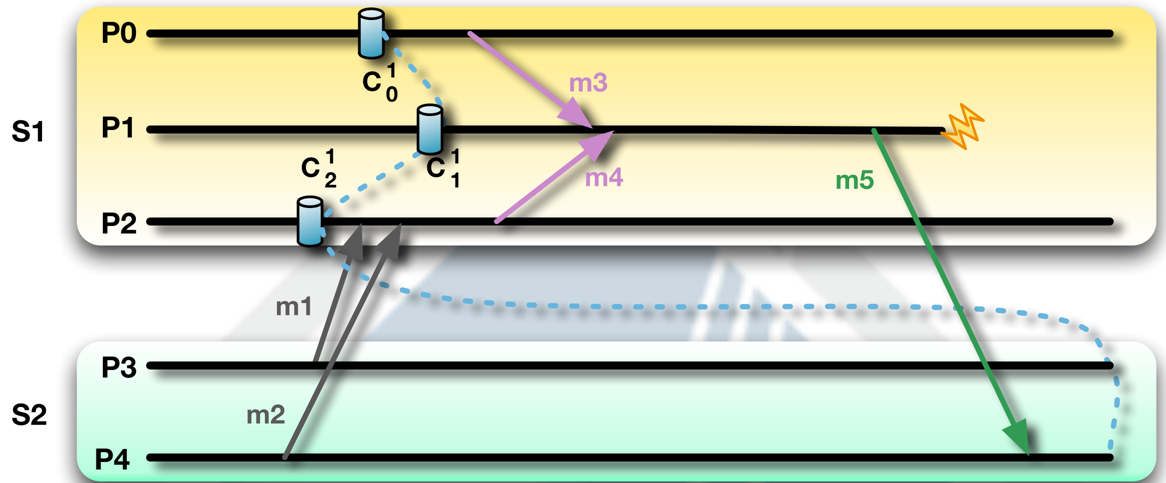
- A complete checkpoint is taken at specified time intervals
- In case of a failure all processes rollback to the last valid checkpoint
- The time to checkpoint strongly depends on the checkpoint support (I/O bandwidth)

Uncoordinated C/R



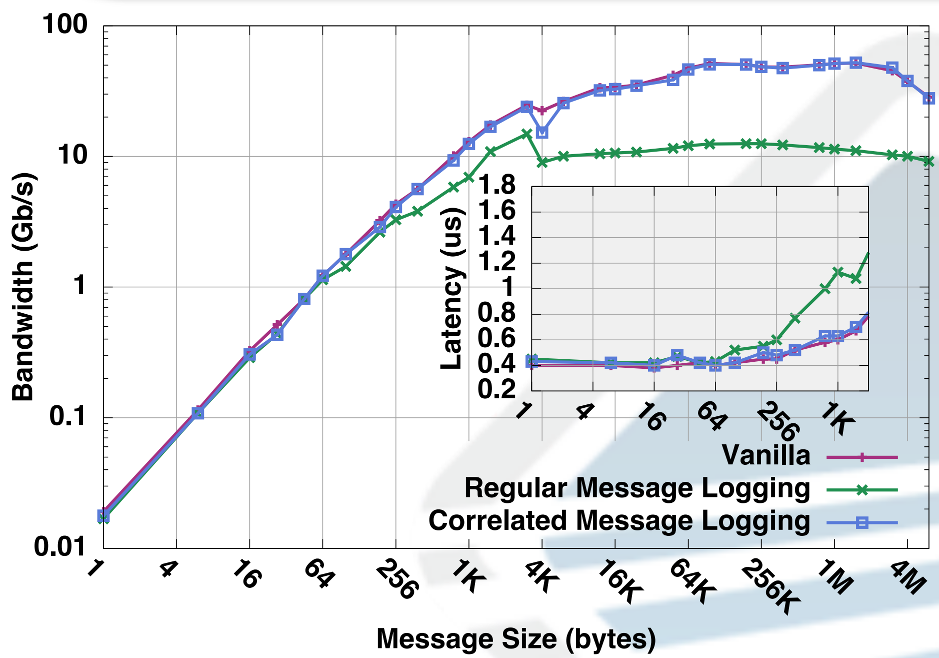
- A single checkpoint is taken at specified time intervals
- In case of a failure one process rollback to the last valid checkpoint
- The time to checkpoint barely depends on the checkpoint support (I/O bandwidth)

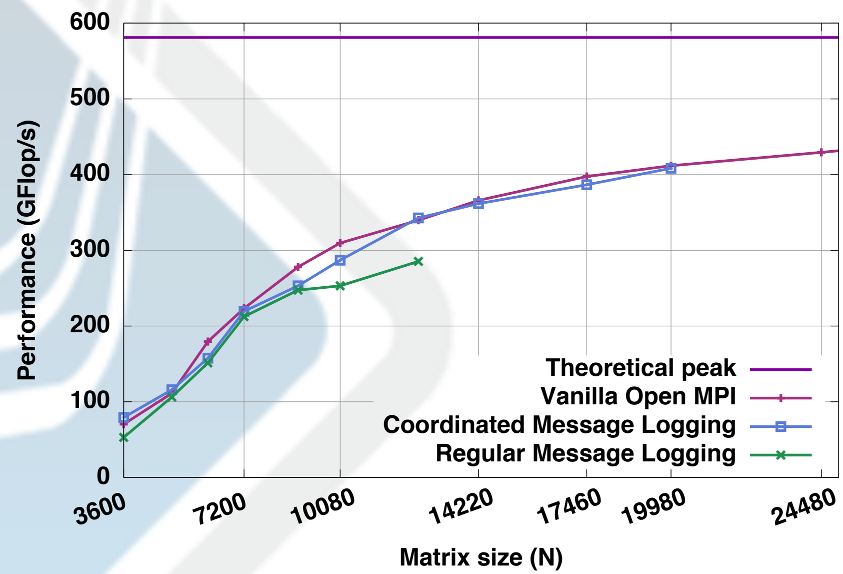
Correlated Set Coordinated Message Logging



- **Hybrid** between **coordinated** and **uncoordinated**
- **Codependent failures** are defined as sets of processes prone to fail simultaneously (cores of a same node)
- Codependent processes use coordinated checkpoint: relieves the need for expensive sender-based logging
- Non codependent processes are still uncoordinated and benefit from faster recovery

Correlated Set in Message Logging





Non deterministic events are still logged, but payload in a correlated set is not

MPI Forum Fault Tolerance Working Group

Define a set of semantics and interfaces to enable fault tolerant applications and libraries to be portably constructed on top of MPI.

- Application involved fault tolerance (not transparent FT)
  - Natural & Algorithm Based Fault Tolerance (ABFT)
- Fail-stop process failure:
  - MPI process permanently stops communicating with other processes.
- Two Complementary Proposals:
  - Run-Through Stabilization: (*Target: MPI-3.0*)
    - Continue running and using MPI even if one or more MPI processes fail
  - Process Recovery: (*Target: MPI-3.1*)
    - Replace MPI processes in existing communicators, windows, file handles
- Prototype in Open MPI is guiding proposal development

MPI Forum Fault Tolerance Working Group:
https://svn.mpi-forum.org/trac/mpi-forum-web/wiki/FaultToleranceWikiPage

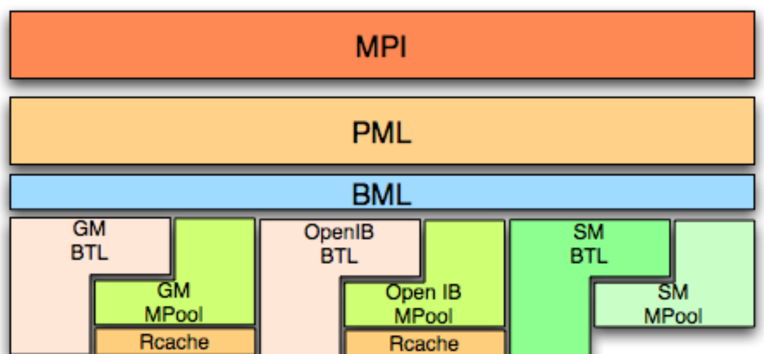
Open MPI Prototype of the Run-Through Stabilization Proposal*

- Pt2Pt Overhead: NetPIPE over shared memory
  - Latency: 0.84 to 0.85 microseconds (1.2%)
  - Bandwidth: 8957 to 8920 Mbps (0.4%)
- Fault Aware Collective Performance
  - MPI_Barrier & MPI_Bcast:
    Within 1% of fault-unaware, regardless of # failures

    Hursey, J., Graham, R., "*Analyzing Fault Aware Collective Performance in a Process Fault Tolerant MPI*," Elsevier Journal of Parallel Computing Special Issue, 2011 (in press).
  - MPI_Comm_validate_all: New fault tolerant agreement collective
    Within 3% of MPI_Allreduce() collective, log-scaling

    Hursey, J., Naughton, T., Valle, G., Graham, R., "*A Log-Scaling Fault Tolerant Agreement Algorithm for a Fault Tolerant MPI*," EuroMPI, 2011.
- Prototype available to interested application developers
  - Contact: Josh Hursey jjhursey@open-mpi.org

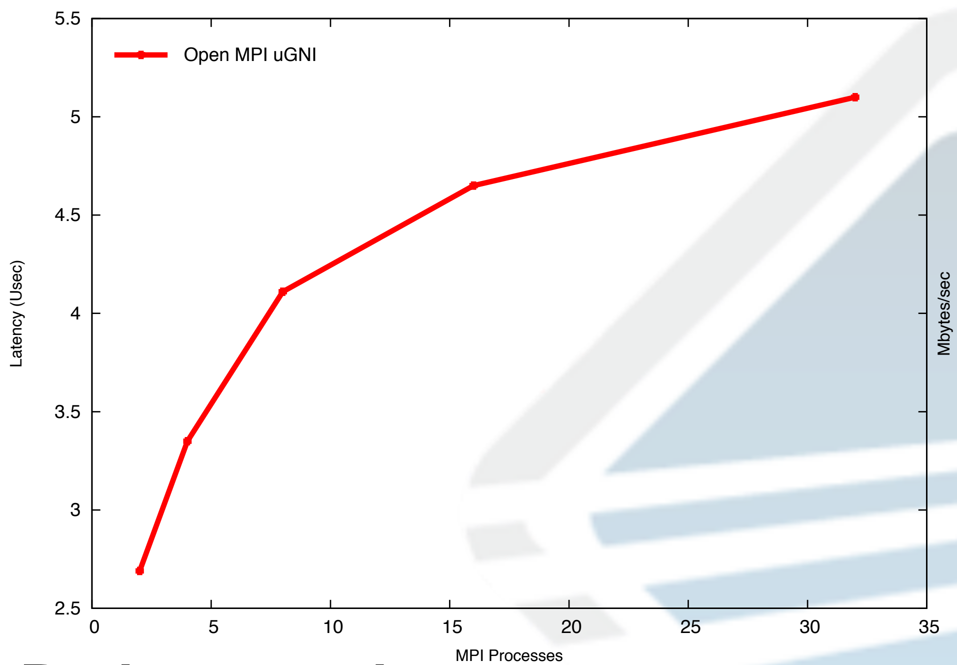
Point-to-point communications

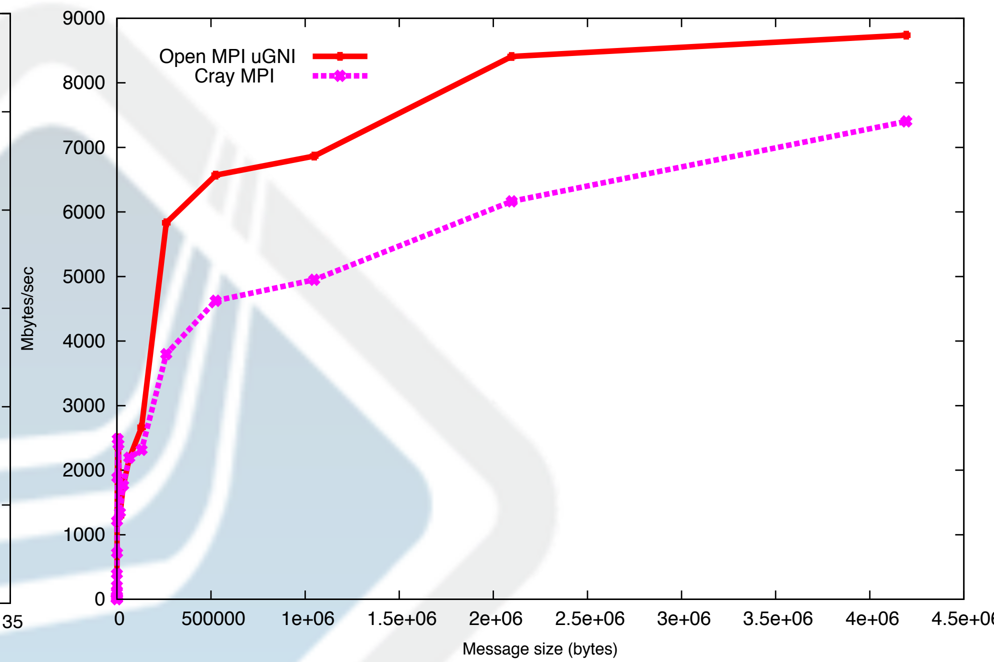


Open MPI for Cray XE Systems

- uGNI and Vader BTLs provide point-to-point and shared-memory communication functionality
- uGNI BTL implements three protocols for Internode communication
  - Eager protocol for short message transfer
    - Send/Recv for short message (SMSG)
  - Rendezvous protocol for long message transfer
    - RDMA Read/Write for medium message (FMA)
    - Offloaded RDMA/Write for long message (BTE)
- Vader BTL provides protocols for Intranode communication
  - Single copy between source and destination buffers using Cray xpmem
  - Nemesis-style lock free fifos for small message delivery

Open MPI uGNI BTL Latency and Bandwidth (Preliminary Results)





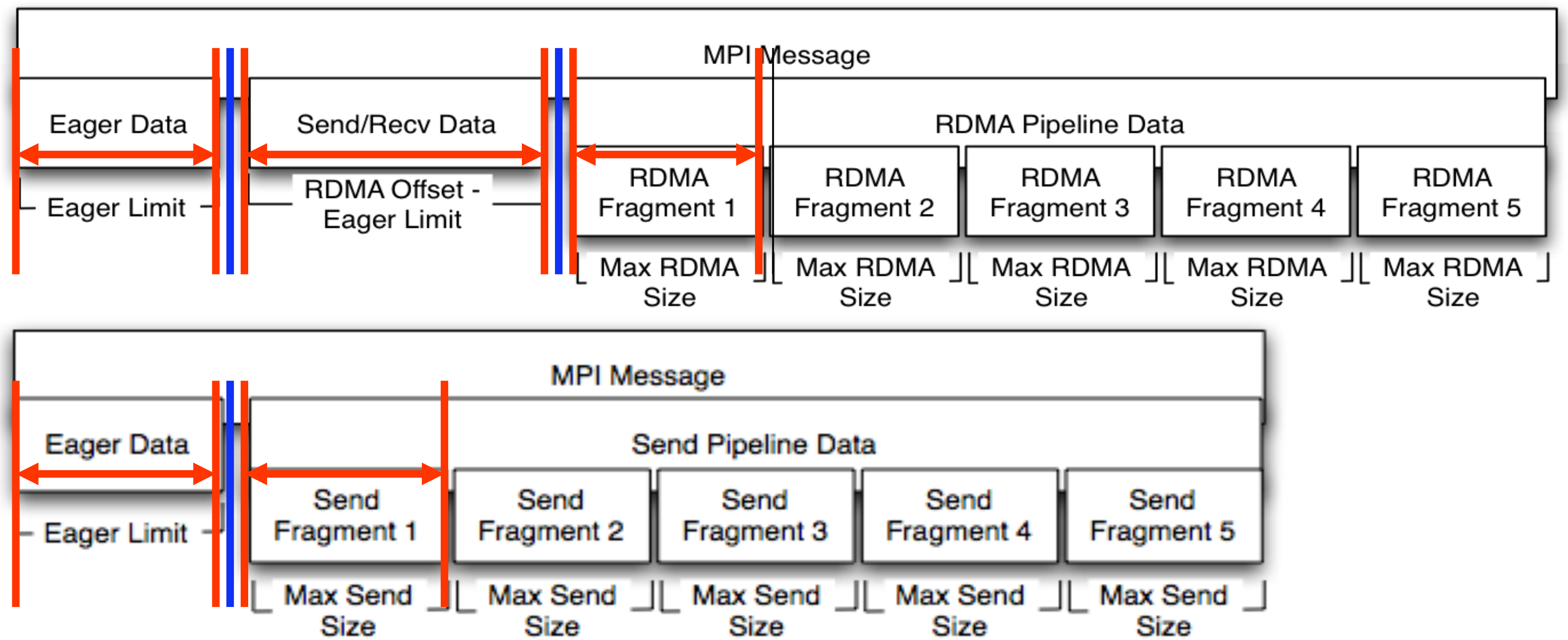
Project members :

ORNL : Richard Graham, Manjunath Gorentla Venkata

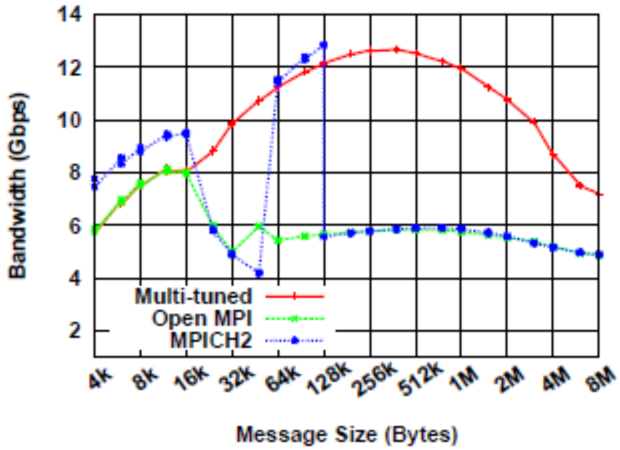
LANL : Samuel Gutierrez, Nathan Hjelm

SNL : Brain Barrett

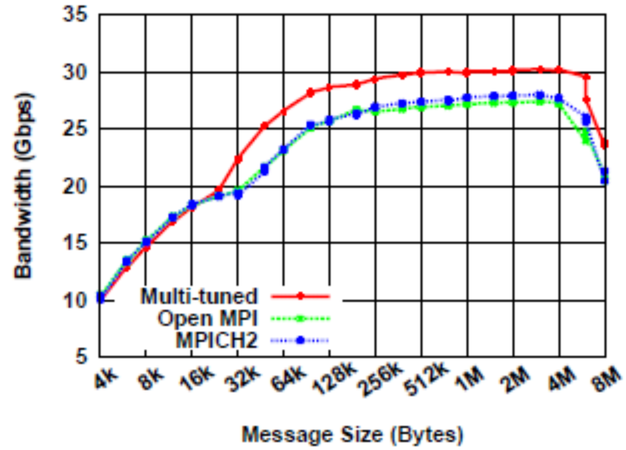
Adapting to NUMA architectures



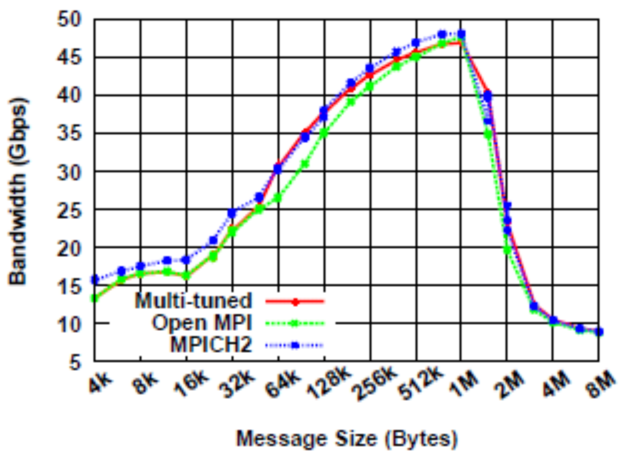
CPU	locality	btl_eager_limit	pipe_size	use_knem	DMA_min
Tigerton	No shared L2	2k	0.5 * L1 size	true	2MB
Nehalem EP	No shared L2	4k	0.5 * L1 size	false	0
Tigerton	Shared L2	2k	L1 size	true	4MB



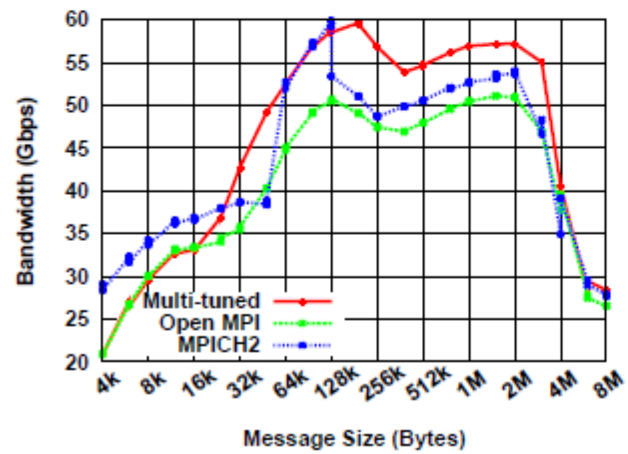
(a) Tigerton, inter-socket $C_0 \rightleftharpoons C_2$



(b) Nehalem, inter-socket $C_0 \rightleftharpoons C_1$



(c) Tigerton, intra-socket $C_0 \rightleftharpoons C_8$

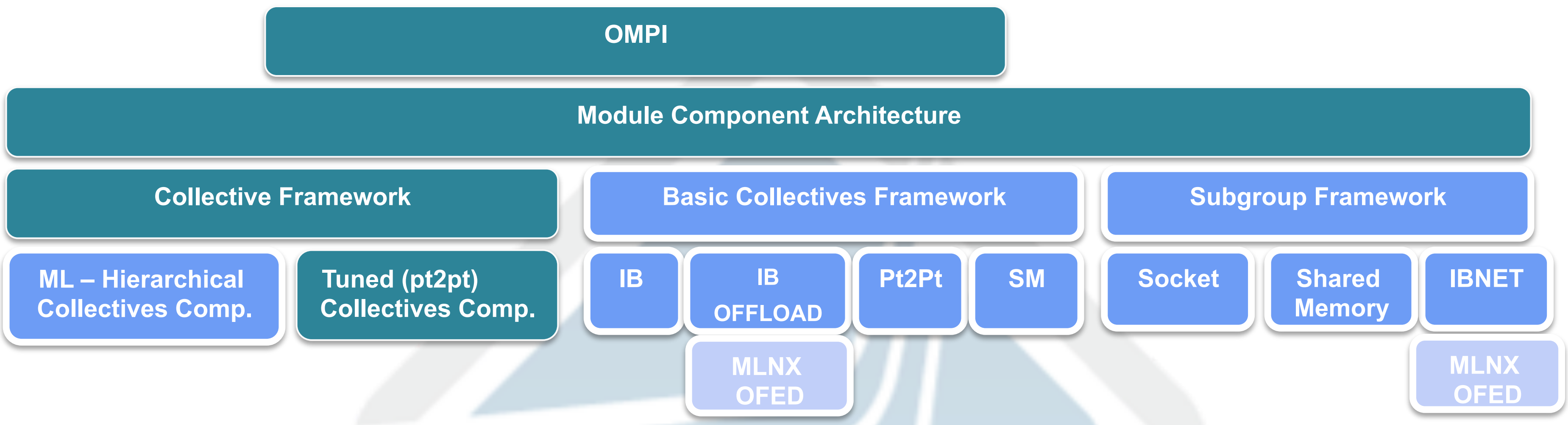


(d) Nehalem, intra-socket $C_0 \rightleftharpoons C_2$

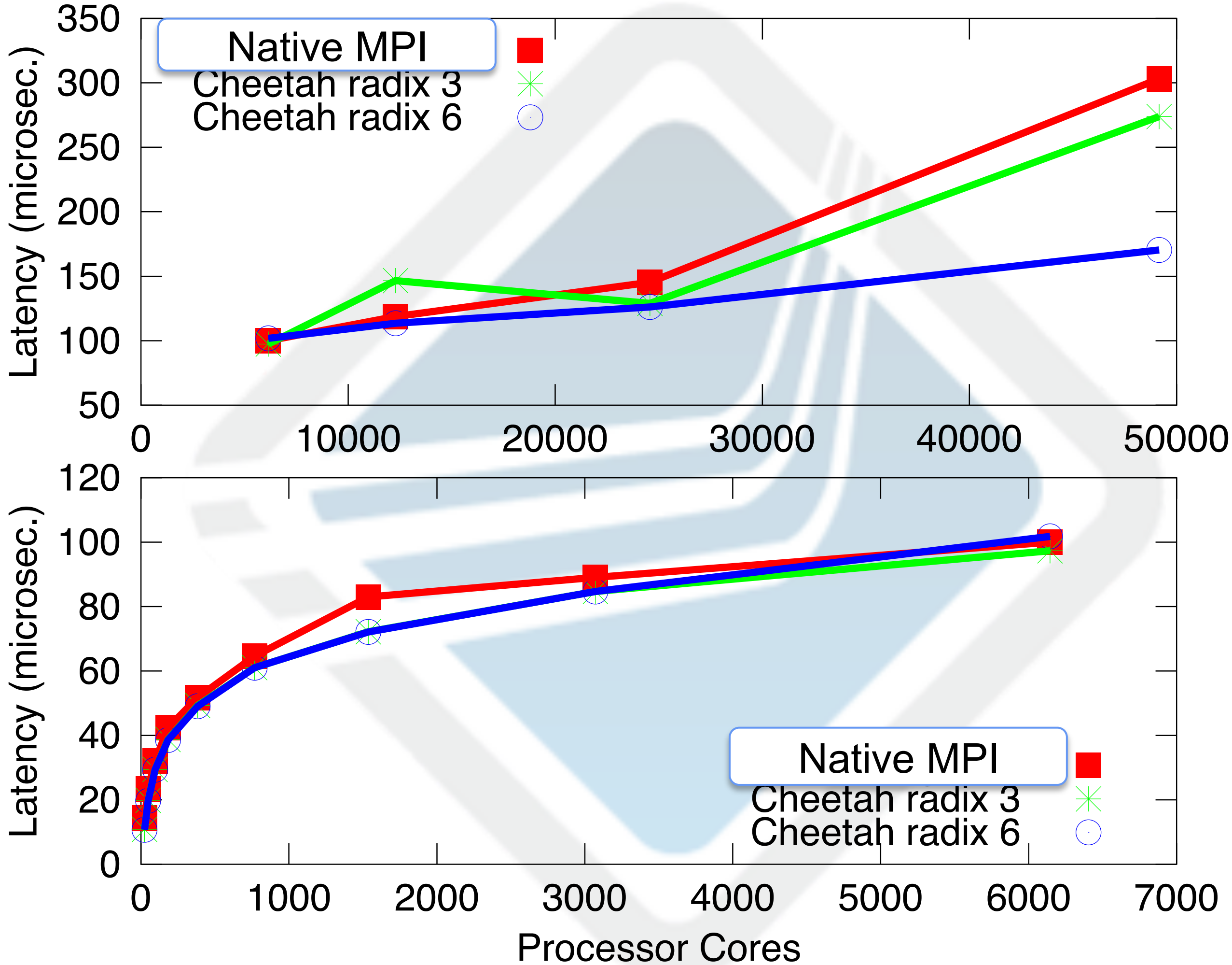
Fig. 3. Bandwidth of the ping-pong test for vanilla MPICH2, vanilla OpenMPI and multi-tuned Open MPI

Collective communications

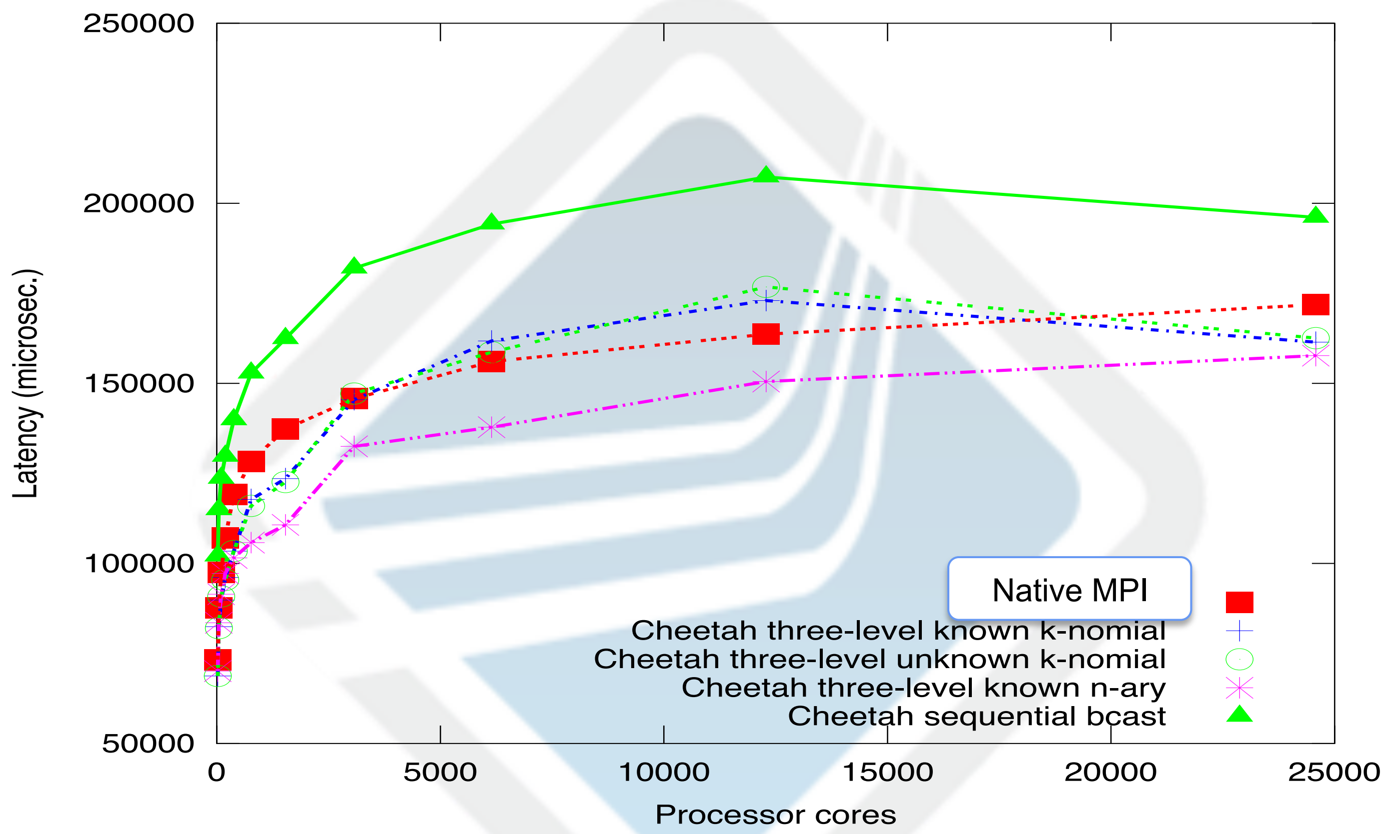
Hierarchical Collectives Software Layers - Cheetah



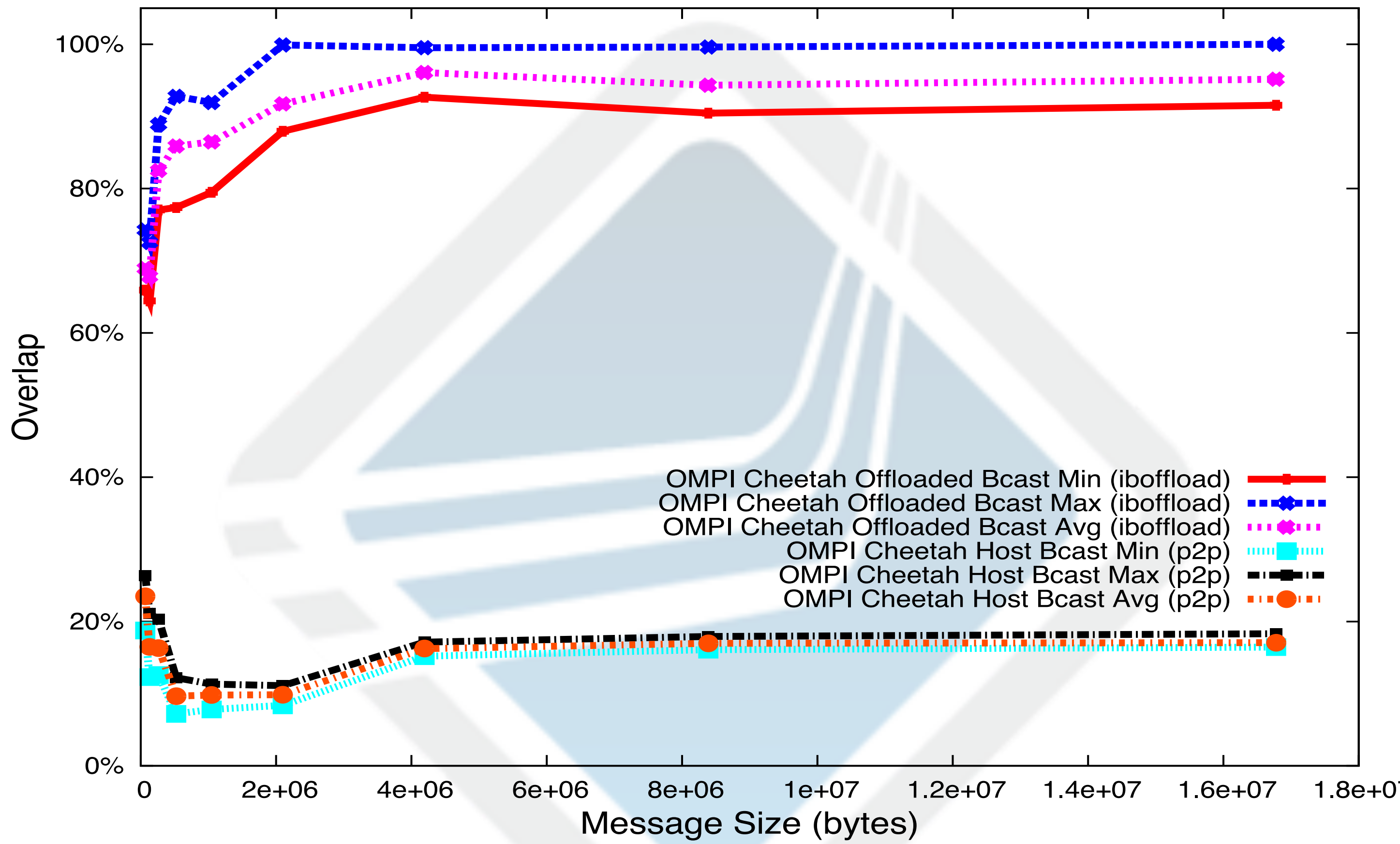
Barrier – Comparison with Native MPI



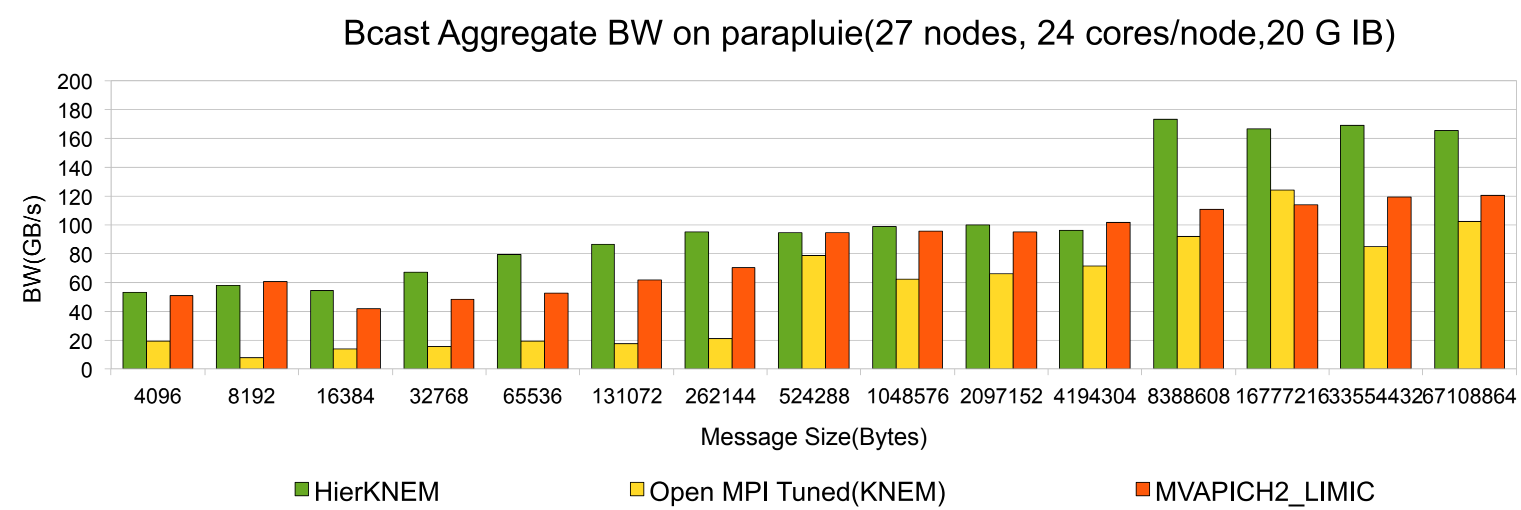
Large-Scale Broadcast Performance: OMPI vs Native MPI large message 16 MBytes

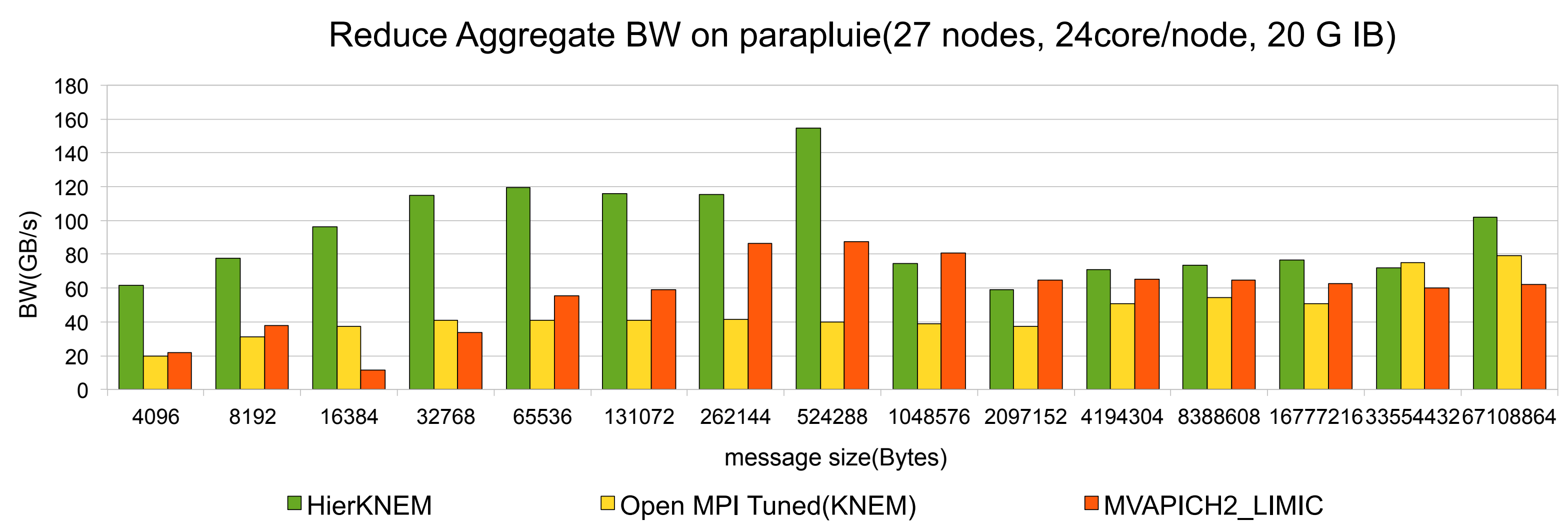


Non-blocking Bcast Overlap – IB CORE-Direct



Architecture aware collective





Cisco

Jeff Squyres

CISCO

Cisco 1st Gen. Ethernet MPI Transport Technology Preview

- Demo in Cisco booth (#1317)
  - New Open MPI BTL (point-to-point transport)
  - Ethernet NetPIPE latency: 5.17us
- Using Linux VFIO technology
  - **NOTE:** VFIO is not upstream yet
- **This is not RoCE, not iWARP**
- Cisco 2nd generation NIC coming "soon"
  - Latency will be significantly lower than 5.17us

Processor Affinity

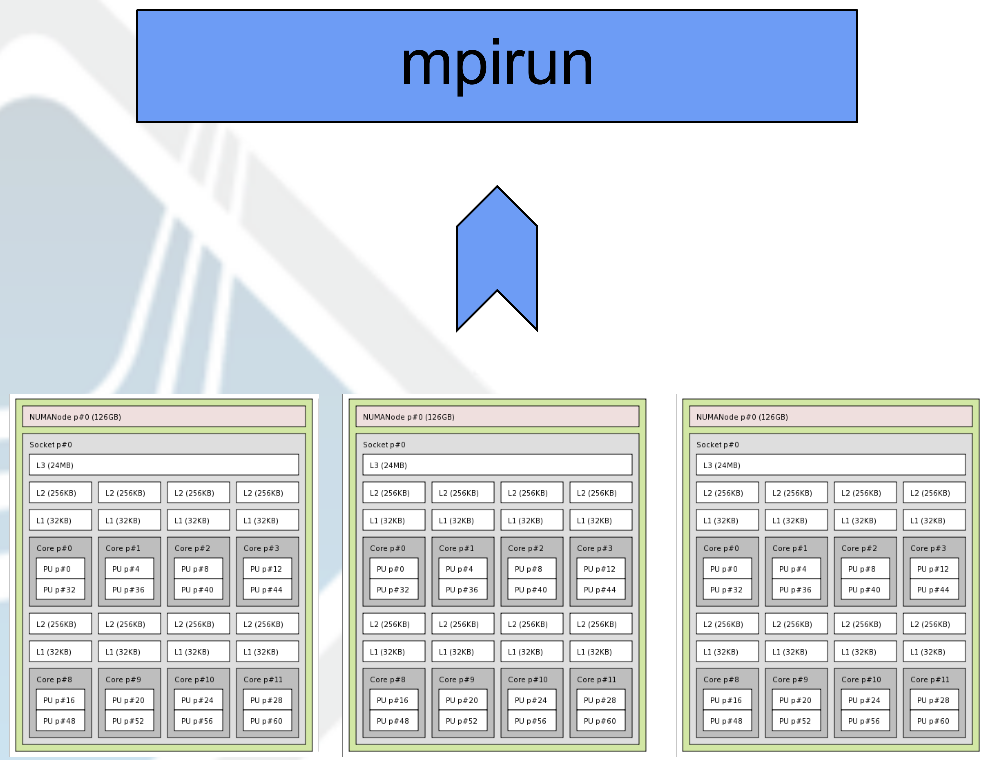
- Core counts are rising
- Users are asking for powerful, flexible affinity controls
  - Bind processes to an entire sockets
  - Bind processes to half the cores in a socket
  - Bind processes to a NUMA locality
  - …etc.
- Joint work between Cisco, Oracle, ORNL

Processor Affinity

- Processor affinity revamp
  - Overview presented at SC’10 SoU BOF
  - Took a looooong time to implement
- Branched for this work last year
  - Just folded first major part back to SVN trunk
  - More coming soon (still testing)
- Slated for v1.7
  - We need real-world feedback

Processor Affinity

- mpirun reads from compute nodes
  - Sockets, cores, threads, caches, NUMA, etc.
  - Maps MPI processes according to what exists
- Useful for:
  - Dissimilar head node
  - Heterogeneous



Compute nodes

Processor Affinity

- Clarified, fixed mpirun affinity options
  - `--map-by <entity>`
  - `--bind-to <entity>`
- New options for flexible mapping / binding
  - Inspired by Blue Gene XYZ specification
  - `--map <letter sequence>`
  - `--bind <letter sequence>`
  - Letters for thread, core, socket, NUMA node, caches, server node

The (Continuing) Road to MPI-3

Jeff Squyres

CISCO

MPI-3 Prototyping Work

- MPI-3 has a “freely available implementation” requirement
  - Much work being prototyped in Open MPI
  - Will help speed our final implementation

MPI-3 Prototyping Work

- New Fortran '08 bindings
  - Compile-time sub. parameter type safety
  - Unique types for MPI handles
  - Safe non-blocking MPI functionality (when compilers support it)
- Better "use mpi" implementation
  - …except for gfortran ☹
- Craig Rasmussen (Los Alamos National Labs), Jeff Squyres (Cisco)

MPI-3 Prototyping Work

- MPI_MPROBE
  - Matched probe
  - Helpful for threaded MPI apps
  - Helpful for upper-level bindings (e.g., Python)
- Almost ready to be folded back to SVN trunk
- Brian Barrett (Sandia National Labs)

MPI-3 Prototyping Work

- Run-through stabilization prototype
  - Gracefully allow for process failure(s)
  - New MPI API functions
  - Adapt underlying MPI run-time to not automatically kill the entire job
  - Define what happens in the MPI layer
- Josh Hursey (Oak Ridge National Labs)

MPI-3 Prototype Work

- New one-sided / RMA chapter
  - Implementation on Portals
  - Tweaking of infrastructure for other underlying transports
- Almost ready to be folded back to SVN trunk
- Brian Barrett (Sandia National Labs)

MPI Forum = Needs Feedback

- MPI Forum BOF tonight
  - 5:30pm, TCC 301/302
  - Slides to be posted on meetings.mpi-forum.org
- PLEASE send your feedback
  - Many of the Forum are implementers
  - Need real world user feedback
- Next face-to-face meeting:
  - Cisco, San Jose, CA, USA, Jan. 9-11, 2012

Community Questions

George Bosilca

- Community questions
  - Feedback: http://www.open-mpi.org/sc2011

Come Join Us!

http://www.open-mpi.org/