11th Charm++ workshop

Optimizing Charm++ over MPI

Ralf Gunter,
David Goodell, James Dinan, Pavan Balaji
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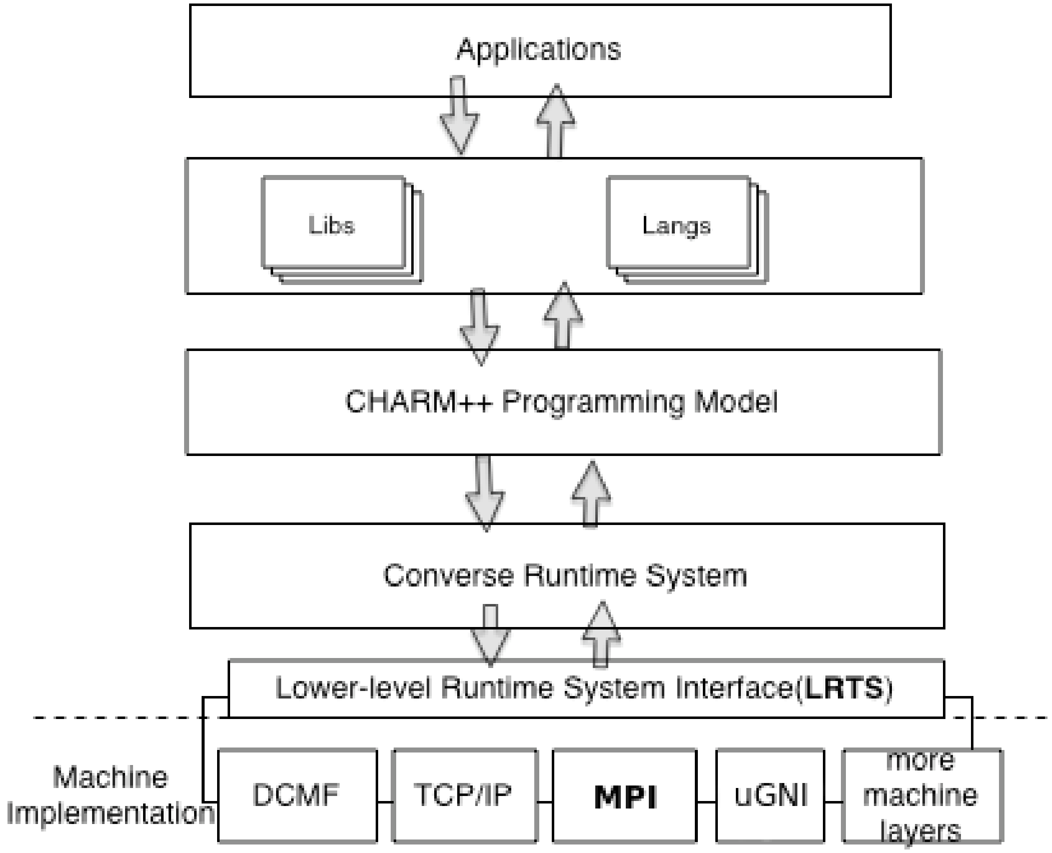
Programming Models and Runtime Systems Group
Mathematics and Computer Science Division
Argonne National Laboratory

rgunter@mcs.anl.gov

The Charm++ stack



(Sun et al., IPDPS '12)

- Runtime goodies sit on top of **LRTS**, an abstraction of the underlying network API.
  - `LrtsSendFunc`
  - `LrtsAdvanceCommunication`
  - Choice of native API (uGNI, DCMF, etc) and MPI.

Why use MPI as the network engine

- Vendor-tuned MPI implementation from day 0.
  - Continued development over machine's life-time.
- Prioritizing development.
  - Charm's distinguishing features sit above this level.
- Reduce resource usage redundancy in MPI interoperability.

Why not use MPI as the network engine

- Unoptimized default machine layer implementation.
  - In non-SMP, communication will stall computation on the rank.
    - Many chares are mapped to the same MPI rank.
  - In SMP, incoming messages are serialized.
- Charm++'s semantics don't play well with MPI's.

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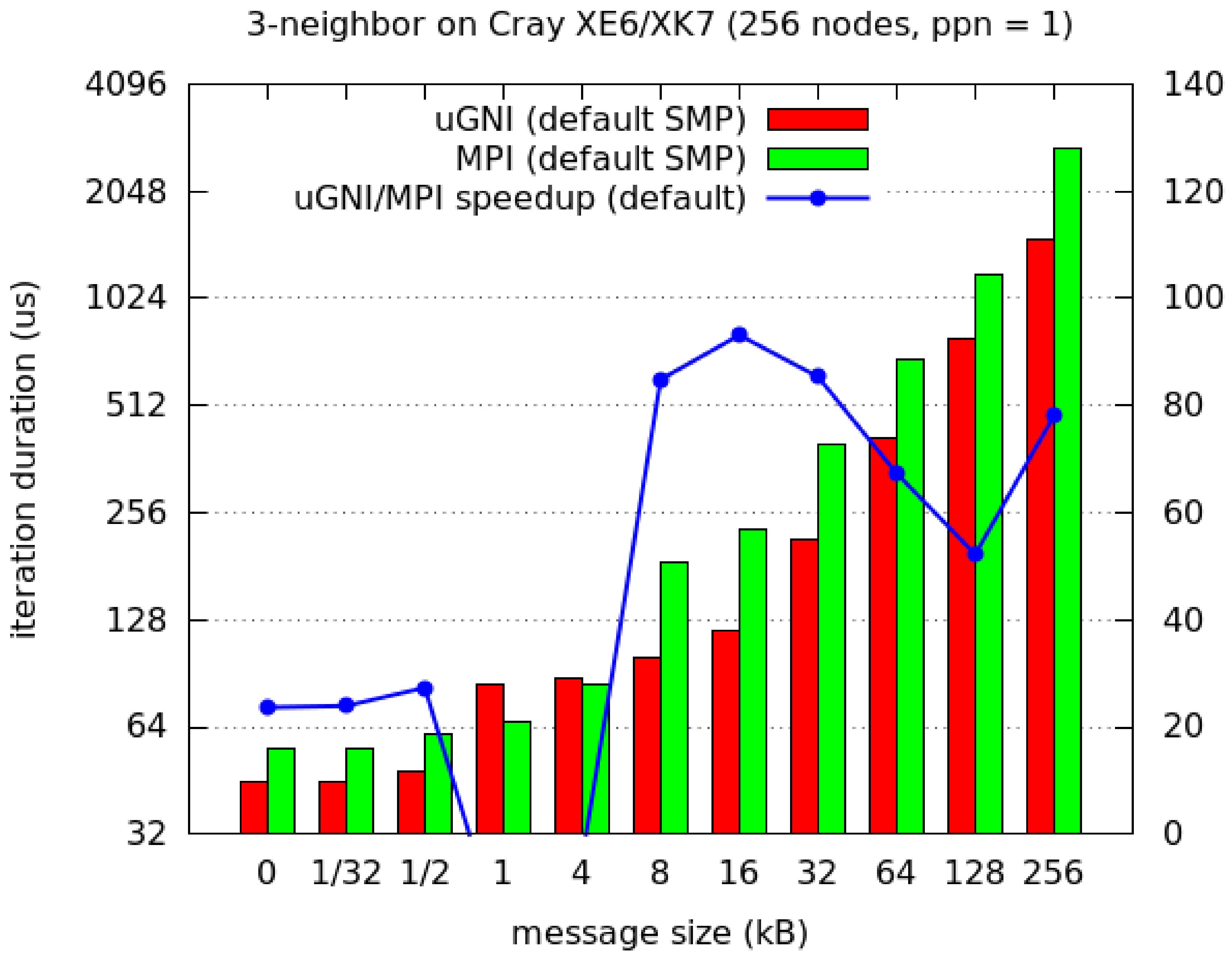
Why not use MPI as the network engine

Lower is better



Lower is better for MPI

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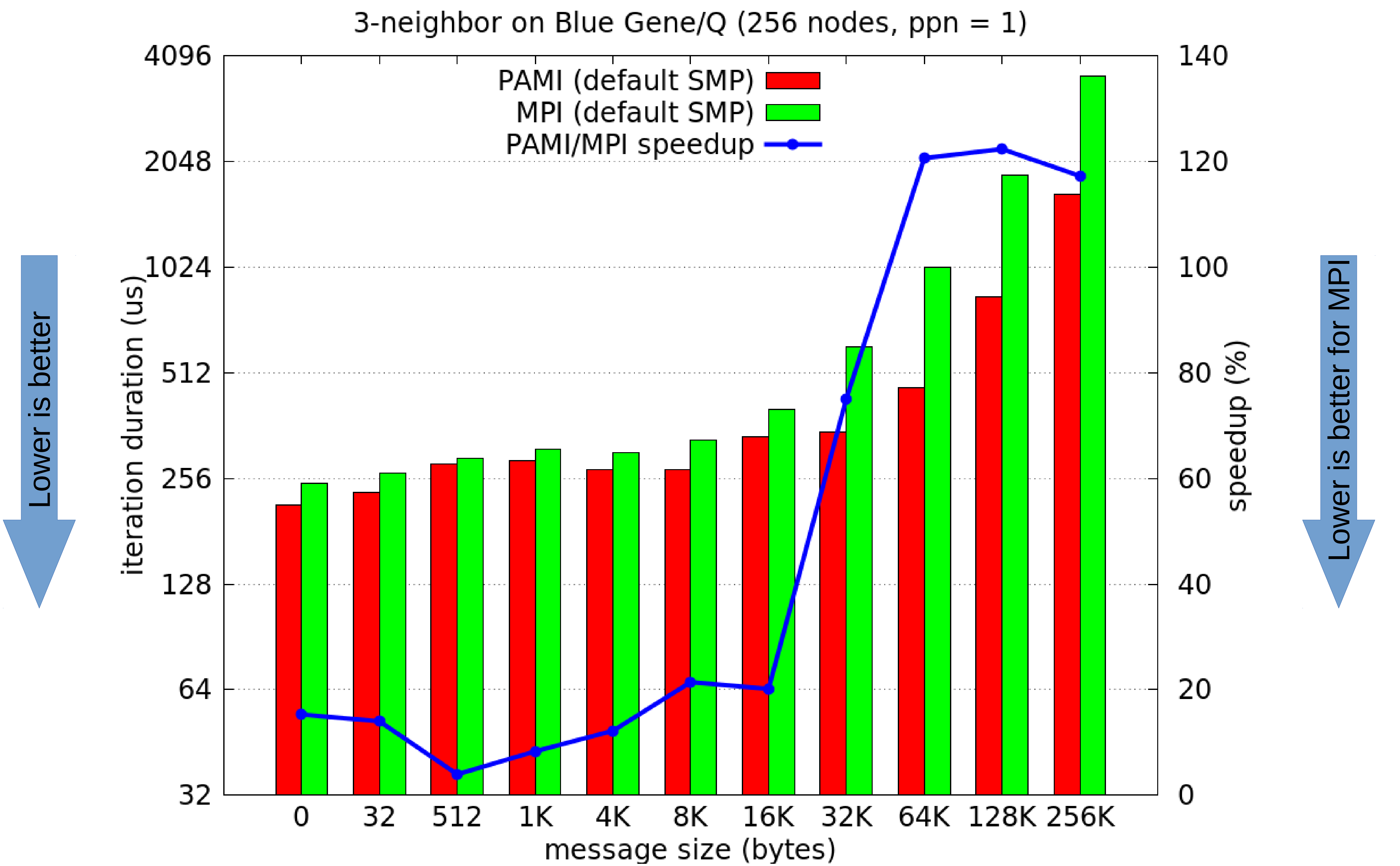
Why not use MPI as the network engine



The inadequacy of MPI matching for Charm++

- Native APIs have no concept of source/tag/datatype matching
  - Neither does Charm, but MPI doesn't know it (if using `Send/Recv`)
  - One-sided semantics avoid matching.
    - Can write directly to desired user buffer.
    - Same for rendezvous-based two-sided MPI, but with a receiver synchronization trade-off.
    - Most importantly, it can happen with little to no receiver-side cooperation.

Leveling the field

- Analyzed implementation inefficiencies and semantic mismatches.
  1. MPI implementation issues
     1. MPI's unexpected message queue ✗
  2. Charm++ over MPI implementation issues
     1. MPI Progress frequency ✗
     2. Using MPI `Send`/`Recv` vs. MPI one-sided ✓
  3. Semantics mismatches
     1. MPI tuning for expected vs. unexpected messages ✓

1) Length of MPI's unexpected message queue

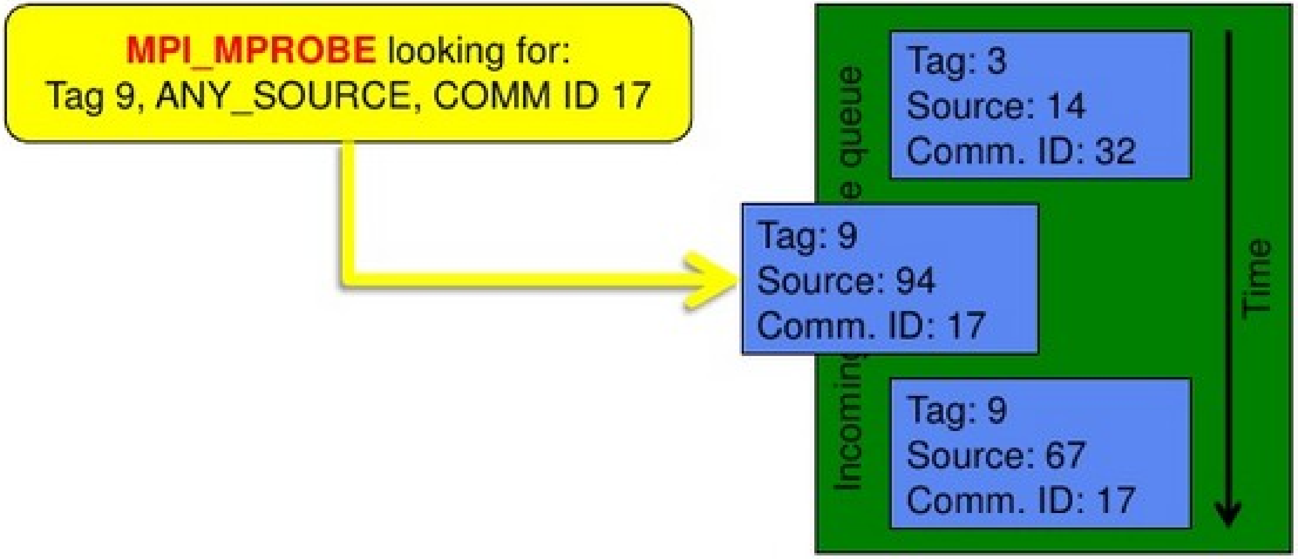
- Unexpected messages (no matching `Recv`) have a twofold cost.
  - `memcpy` from temp to user buffer.
  - Unnecessary message queue searches.
  - Part of why there's an eager and a rendezvous protocol.
- Tested using `MPI_T`, a new MPI-3 interface for performance profiling and tuning.
  - Internal counter keeps track of queue length.
  - Refer to section 14.3 of the standard.

1) Length of MPI's unexpected message queue ✗

- Arguably has no significant impact on performance.
  - Default uses `MPI_ANY_TAG` and `MPI_ANY_SOURCE`, meaning `MPI_Recv` only looks at the head.
  - No need for dynamic tag shuffling (another option in the machine layer).
  - Only affects eager messages.
    - Bulk of rendezvous messages is handled as if expected.

1) Mprobe/Mrecv instead of Iprobe/Recv.

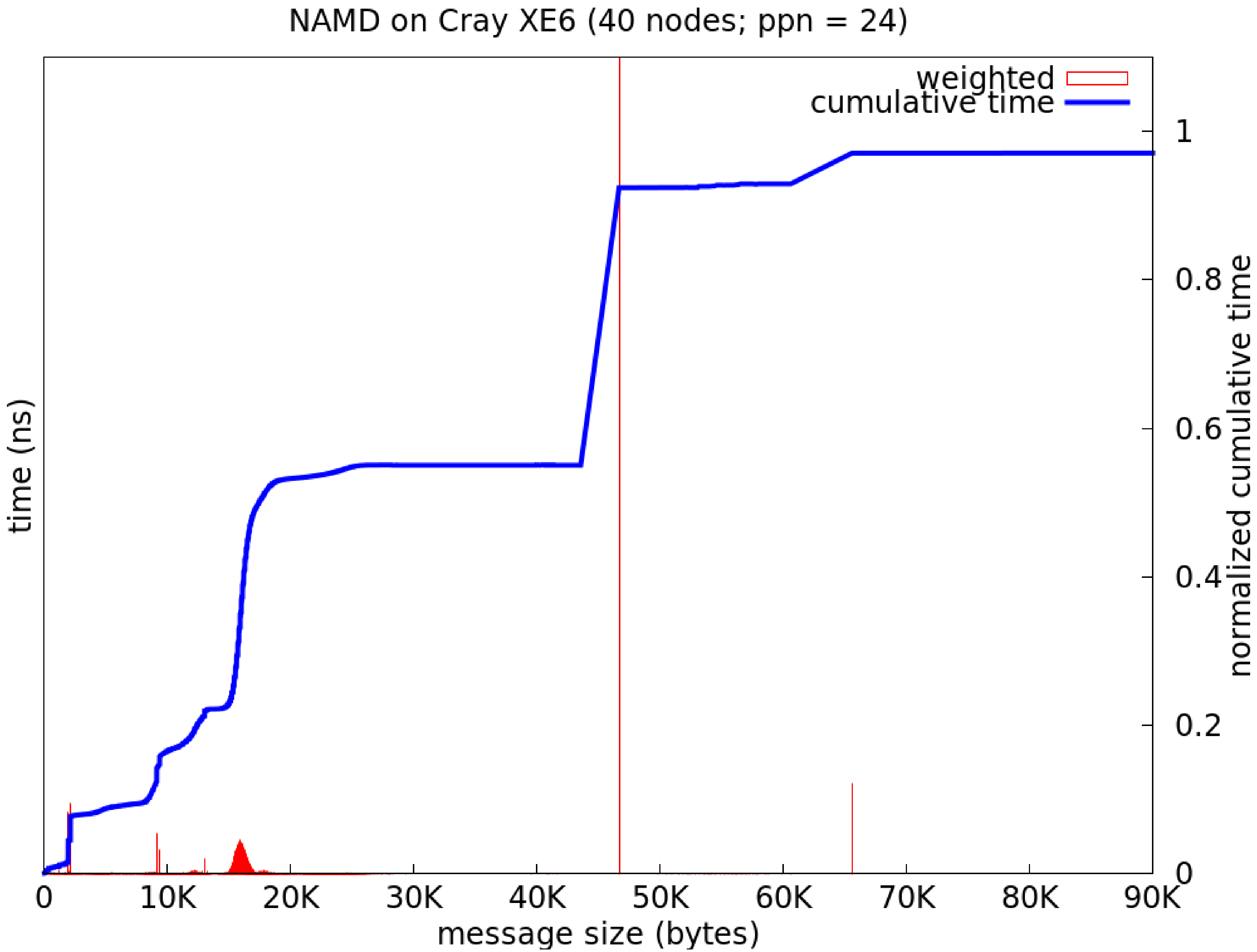
- In schemes with multiple tags, `MPI_Iprobe` + `MPI_Recv` walks the queue twice.
- `MPI_Mprobe` instead deletes entry from queue and outputs a handle to it, used by `MPI_Mrecv`.
- No advantage with double wildcard matching.
- Reduced critical section may help performance with multiple commthreads.



2) MPI progress engine frequency ✗

- In Charm, failed `Iprobe` calls drive MPI's progress engine.
  - Pointless spinning around if are no incoming messages.
- Tried reducing calling frequency to 1/16-1/32th of the default rate.
  - Reduces unexpected queue length.
  - Little to no benefit.
    - Network may need it to kickstart communication.

3) Eager/rendezvous threshold ✓



3) Eager/rendezvous threshold ✓

- **Builds on idea of asynchrony.**
  - Rendezvous needs active participation from receiver.
- Forces use of preregistered temp buffers on some machines.
- Environment vars aren't the appropriate granularity.
  - Implemented per-communicator threshold on MPICH.
    - Specified using info hints (section 6.4.4).

    - Each library may tune their communicator differently.
    - Particularly useful with hybrid MPI/charm apps.
    - Available starting from MPICH 3.0.4.

4) Send/Recv vs one-sided machine layer ✓

- **Implemented machine layer** using MPI-3 RMA to generalize what native layers do.
  - Dynamic windows (attaching buffers non-collectively);
  - Multi-target locks (`MPI_Win_lock_all`);
  - Request-based RMA Get (`MPI_Rget`).
  - Based on “control message” scheme.
    - Sends small messages directly; larger ones happen via MPI-level RMA.
  - Handles multiple incoming messages concurrently.
  - Can't be tested yet for performance.
    - IBM and Cray MPICH don't currently support MPI-3.

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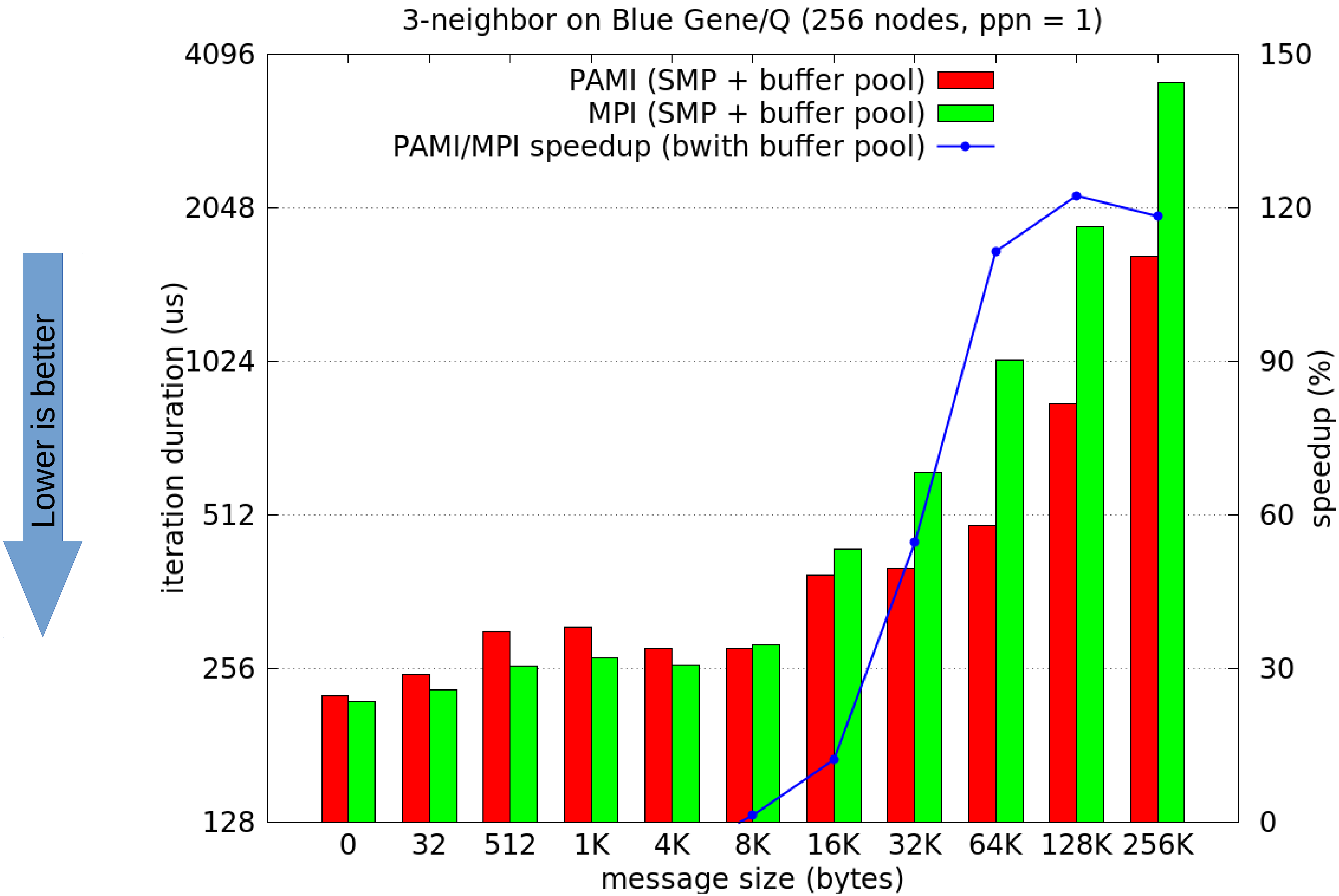
Current workarounds using MPI-2

- **Blue Gene/Q**: use the **pamilrts buffer pool** and **preposted MPI_Irecvs** (toggle `MPI_POST_RECV` on machine.c to 1).
  - Interconnect seems to be more independent from software for RDMA
    - Preposting `MPI_Irecv` help it handle multiple incoming messages.
- **Cray XE6 (and InfiniBand clusters)**: increase **eager threshold** to a reasonably large size.
  - Cray's eager (E1) and rendezvous (R0) protocols differ mostly in their usage of preregistered buffers.

Nearest-neighbors results



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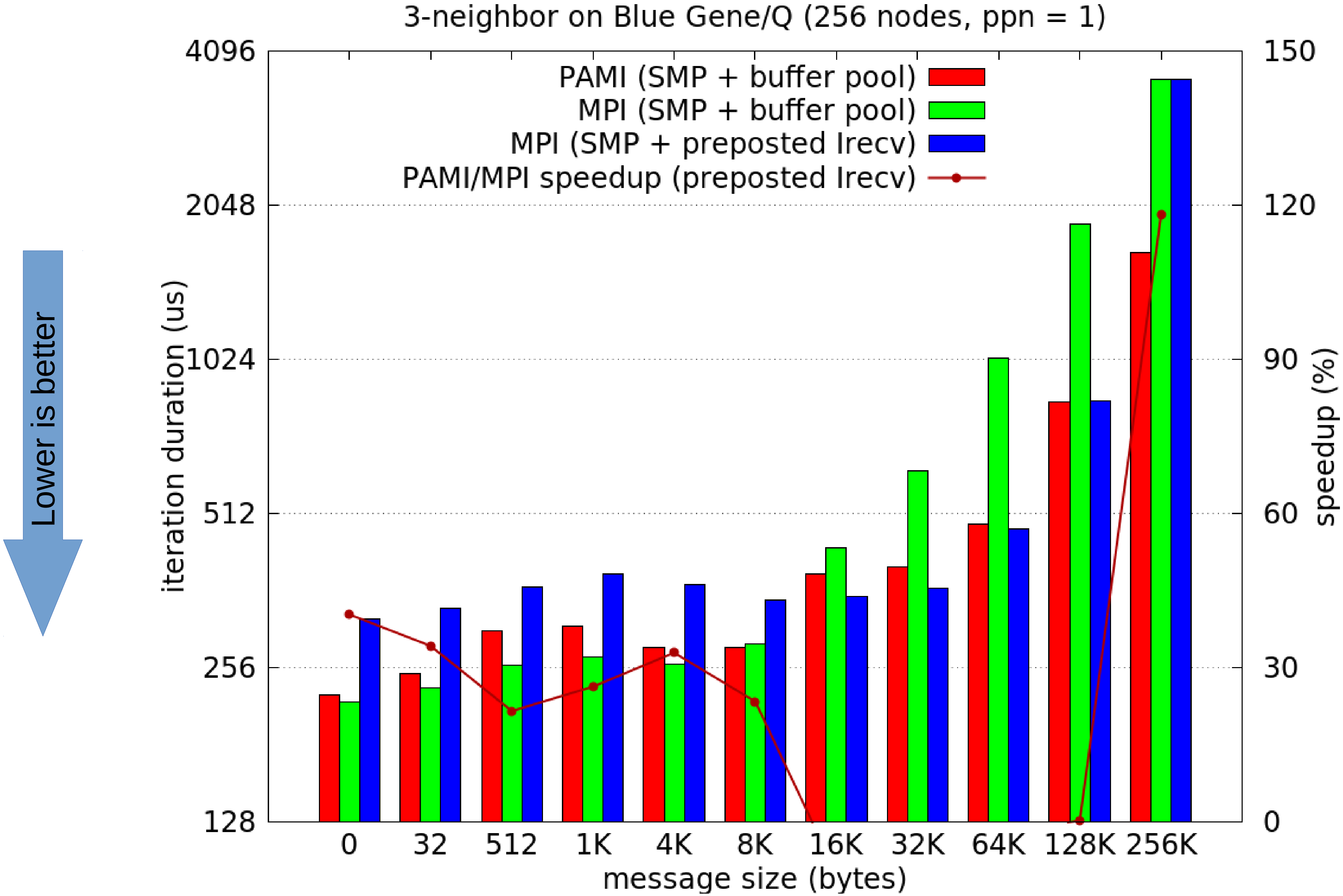
Nearest-neighbors results



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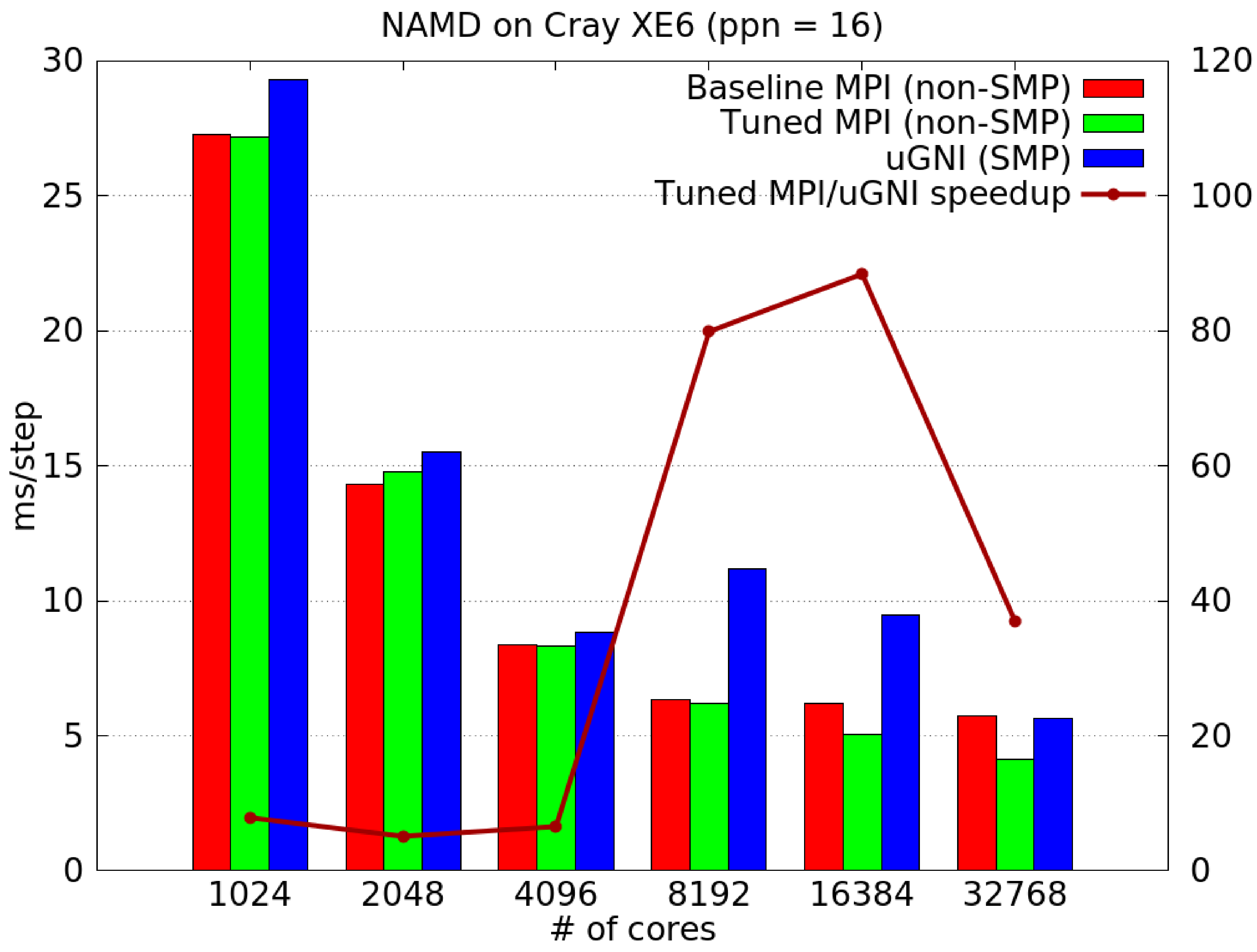
Nearest-neighbors results

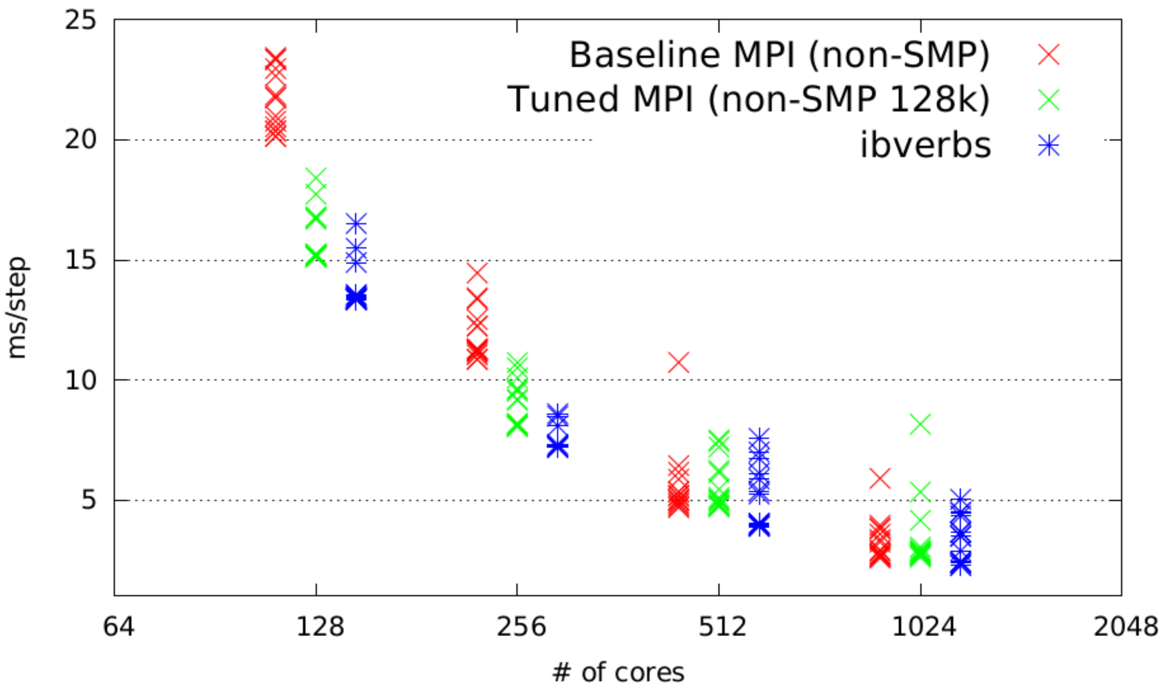


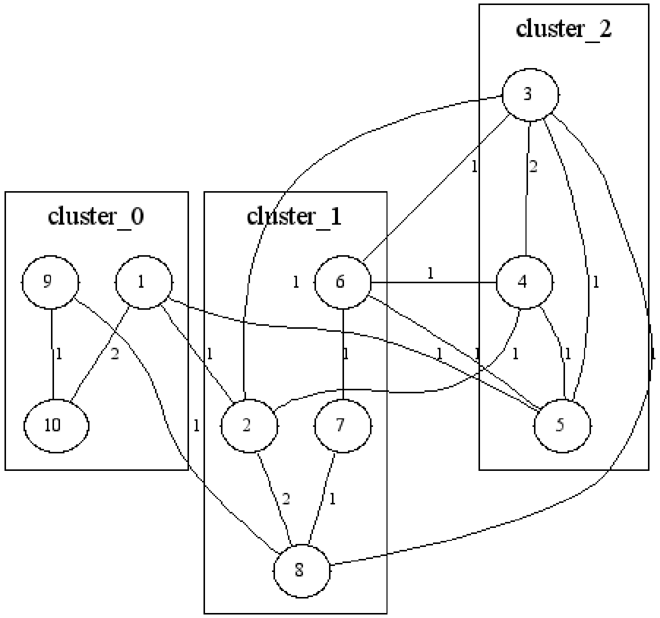
Lower is better

Higher is better for MPI

Future work.

- Fully integrate one-sided machine layer with charm.
- No convincing explanation yet for **ibverbs**/MVAPICH difference.
- **Hybrid benchmark** for per-communicator eager/rendezvous threshold on Cray.





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Conclusions

- There's more to MPI slowdown than just “overhead”.
  - Mismatch of **MPI** with **Charm semantics** is a better story.
- Specific MPI-2 techniques per machine.
  - May not be portable, like eager/rendezvous threshold for Cray XE6 vs preposted `Irecv` for Blue Gene/Q.
- `Send`/`Recv` **machine layer** should be replaced with **one-sided** version once MPI-3 is broadly available.

R. Gunter, D. Goodell, J. Dinan, P. Balaji

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Group Lead

- Pavan Balaji (scientist)

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- James S. Dinan (postdoc)
- Antonio Pena (postdoc)
- Wesley Bland (postdoc)
- David J. Goodell (developer)
- Ralf Gunter (research associate)
- Yuqing Xiong (visiting researcher)

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- Huiwei Lu (postdoc)
- Yan Li (visiting postdoc)

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- Darius T. Buntinas (developer)

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- Marc Snir (director)
- Rajeev Thakur (deputy director)

External Collaborators (partial)

- Ahmad Afsahi, Queen's, Canada
- Andrew Chien, U. Chicago
- Wu-chun Feng, Virginia Tech
- William Gropp, UIUC
- Jue Hong, SIAT, Shenzhen
- Yutaka Ishikawa, U. Tokyo, Japan
- Laxmikant Kale, UIUC
- Guangming Tan, ICT, Beijing
- Yanjie Wei, SIAT, Shenzhen
- Qing Yi, UC Colorado Springs
- Yunquan Zhang, ISCAS, Beijing
- Xiaobo Zhou, UC Colorado Springs

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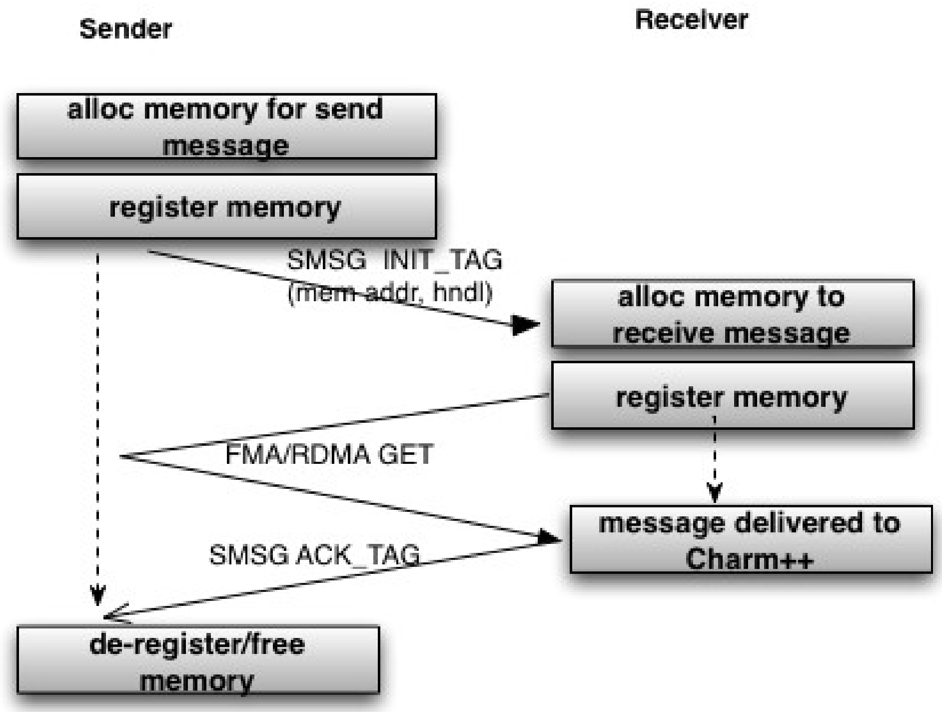
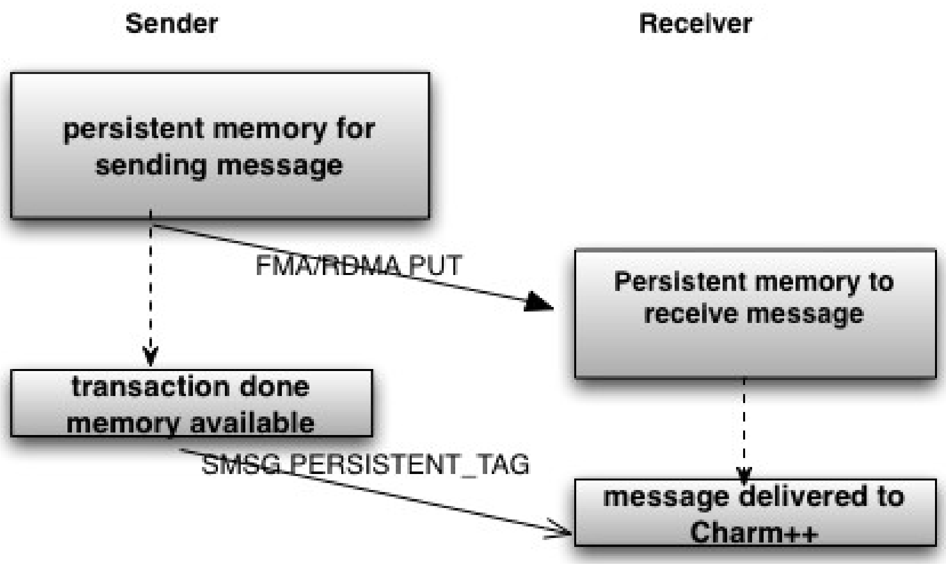
3) Send/Recv vs one-sided machine layer

- One-sided communication better suits charm's asynchrony.
  - `Send`/`Recv` puts too much burden on receiver.
  - All native machine layers take advantage of this.

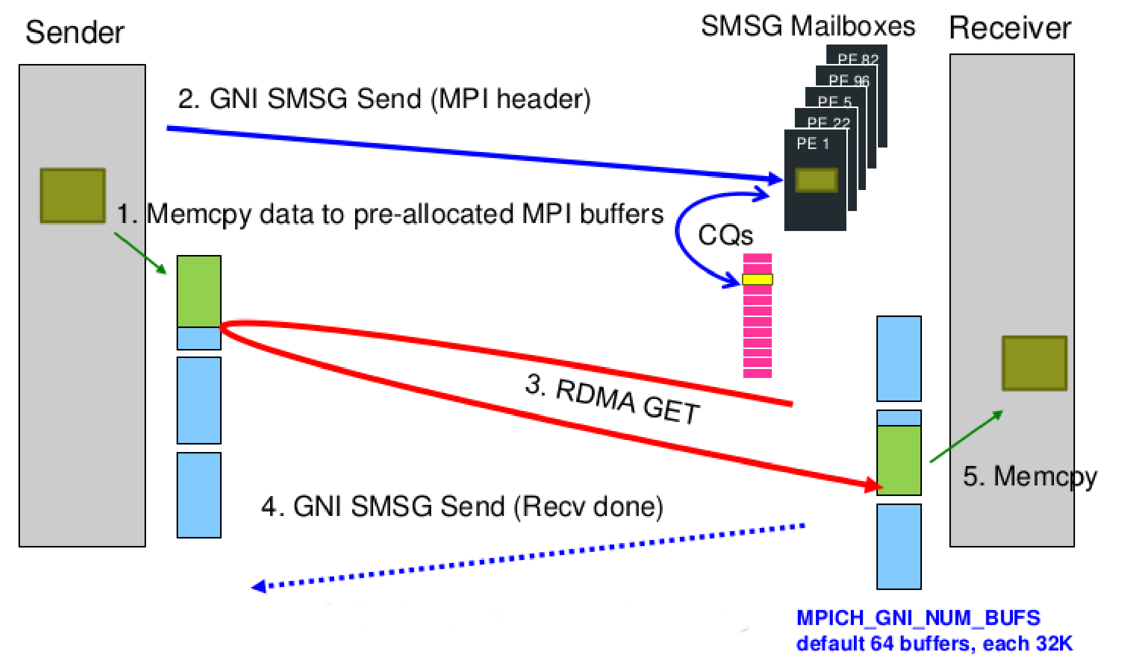


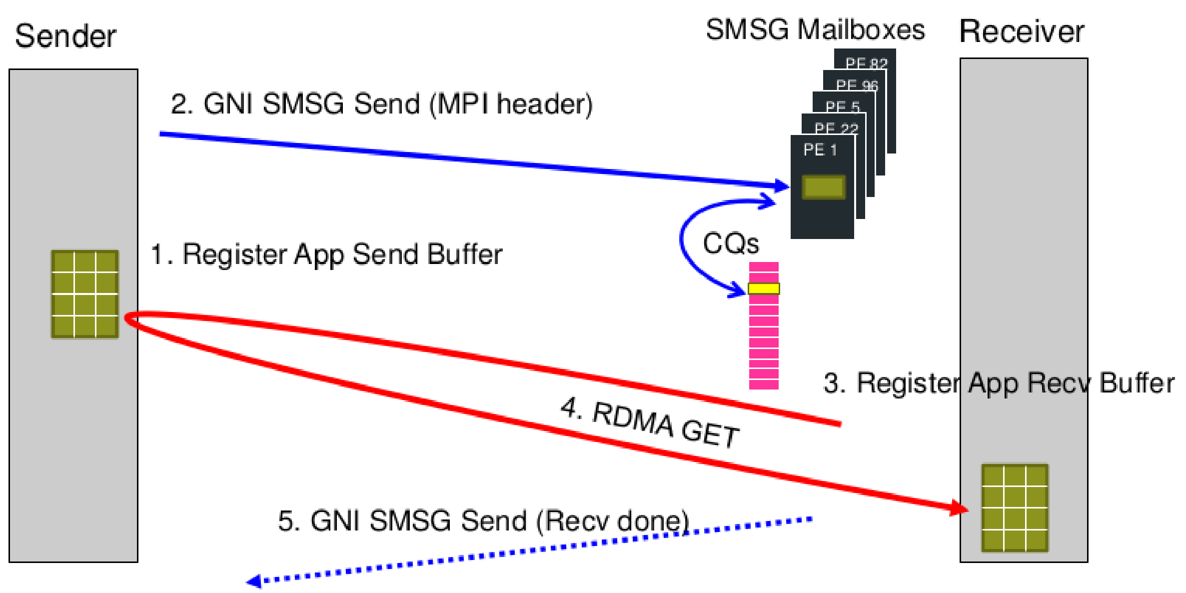


(Sun et al., IPDPS '12)

3) Send/Recv vs one-sided machine layer

- Vendor-supplied MPI implementations already do this internally.
- Two-sided matching semantics are just inappropriate.
  - "Tuned" for expected messages.
  - Blue Gene/Q suffers from serialization because of `Send`/`Recv`.





(Cray Inc., PRACE '12)