Designing, Implementing, and Evaluating the Upcoming OpenSHMEM Teams API

David Ozog, MD. Wasi-ur- Rahman, Gerard Taylor, James Dinan

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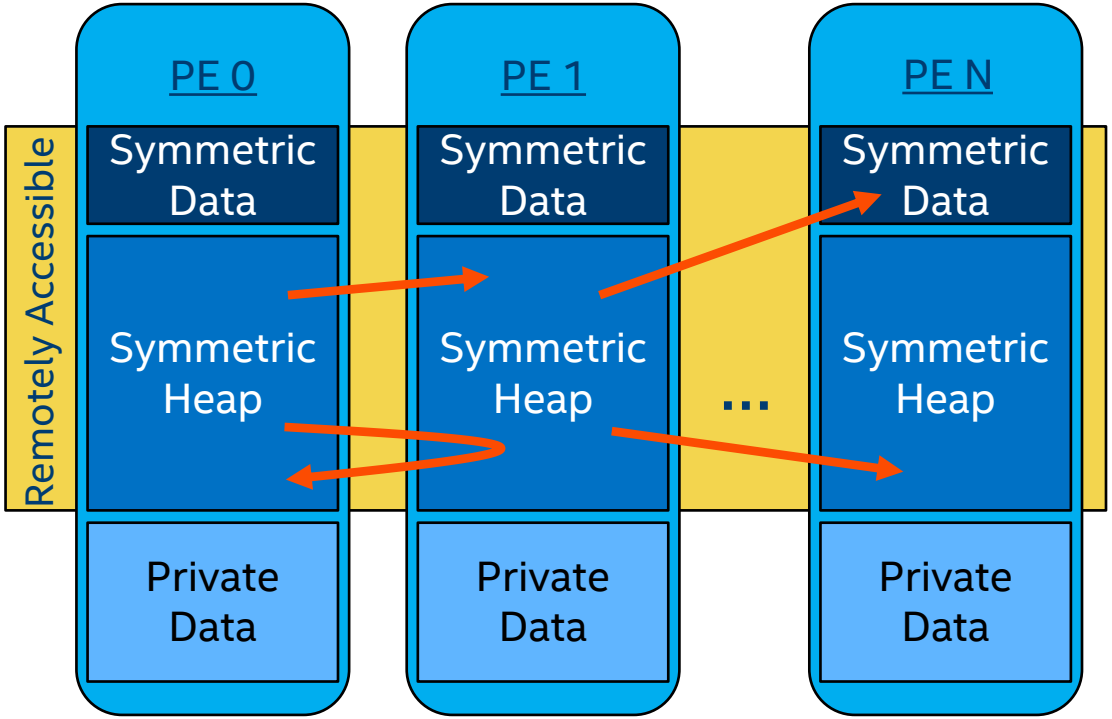
Test and System Configurations: Sandia OpenSHMEM running on Diamond cluster (Intel® Omni-Path 100 Series, Intel® Xeon Platinum 8170 (Skylake), and Cori, Intel®Xeon E5-2698 v3 (Haswell)

Performance results are based on testing as of Sept 19, 2019 and may not reflect all publicly available security updates. See configuration disclosure for details. No component or product can be absolutely secure.

Introduction to OpenSHMEM

- Open standard PGAS model
- Emphasizes one-sided operations (put/get, atomics)
- Symmetric memory exposed for remote access
- Collective Operations:
  - Barrier, broadcast, collect, reductions, all-to-all, etc.



Teams - Motivation

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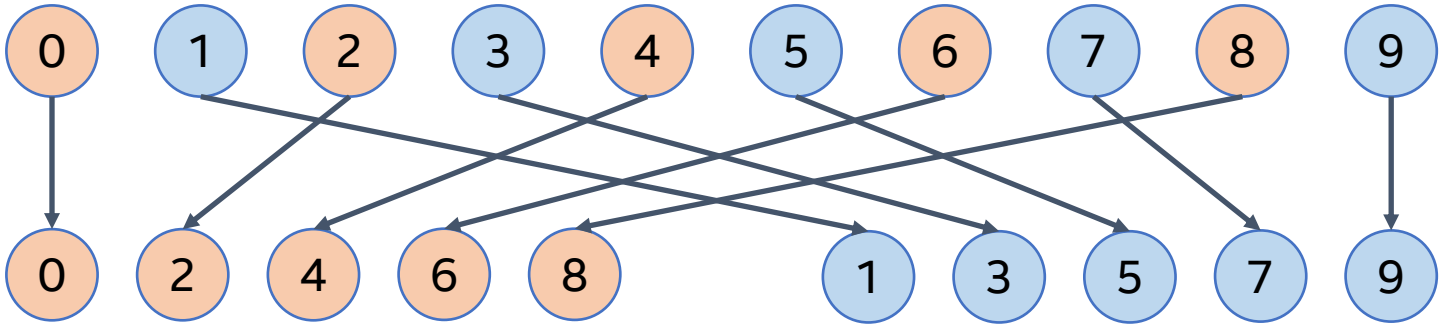

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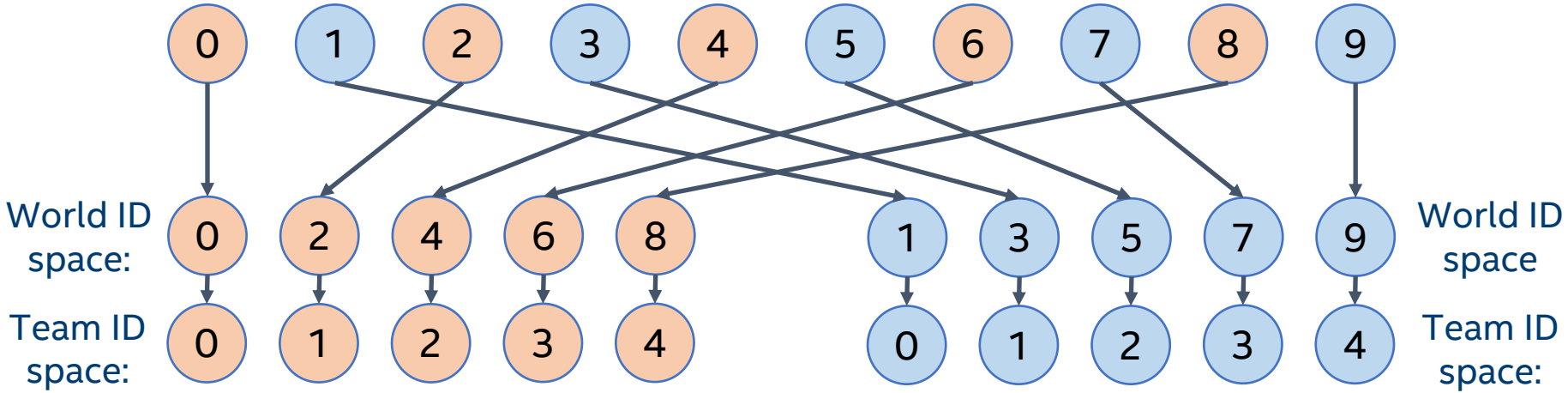

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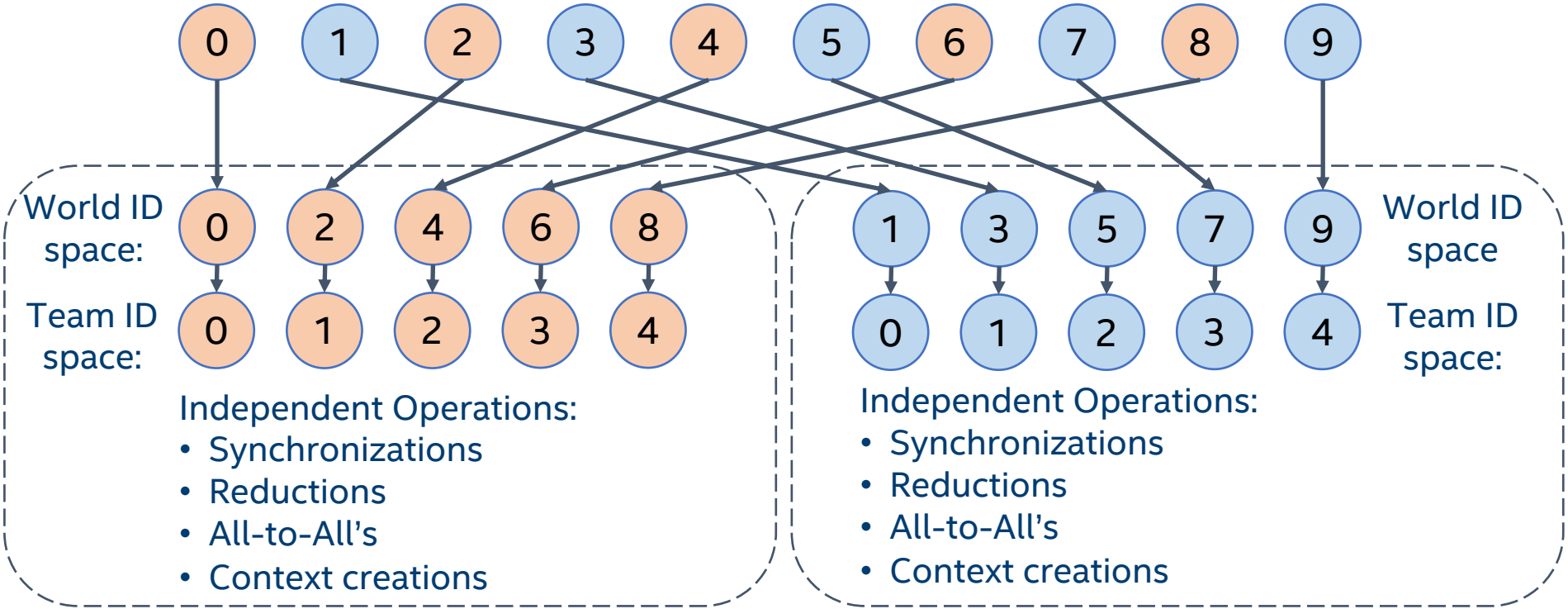
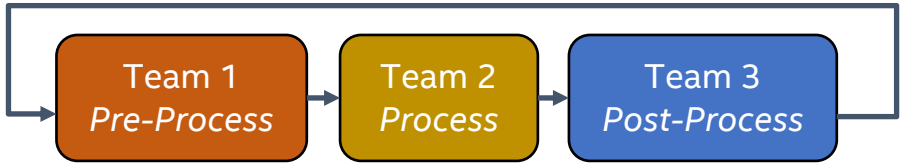
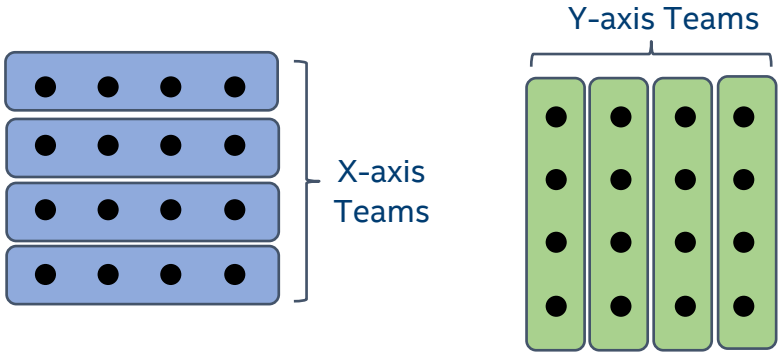


Teams – Some Motivating Examples

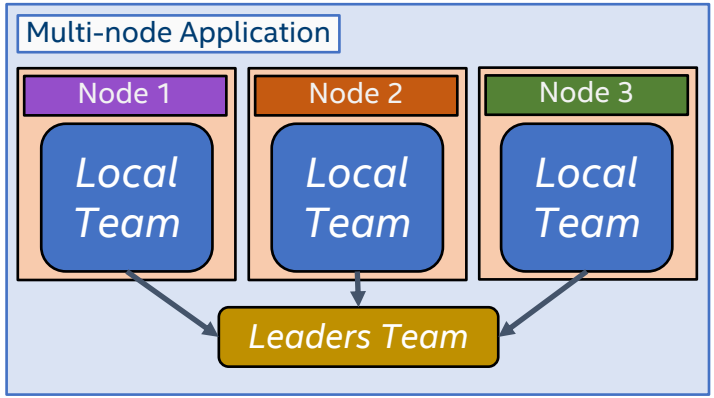
Pipelining / Rings



Useful Topologies (like Cartesian)



Shared Memory Teams



3rd Party Library management

- Parallel HDF5, ADIOS, PETSc, etc.

OpenSHMEM Collectives APIs

Current Version 1.4:

- Active set based: if (*start*, *log_stride*, *size*) == (3, 1, 4), then the active PEs are {3, 5, 7, 9}.
- User supplies a “pSync” array: used for explicit synchronization control.

```
void shmem_broadcast32(void *dest, const void *source, size_t nelems,
int PE_root, int PE_start, int logPE_stride, int PE_size, long *pSync);
```

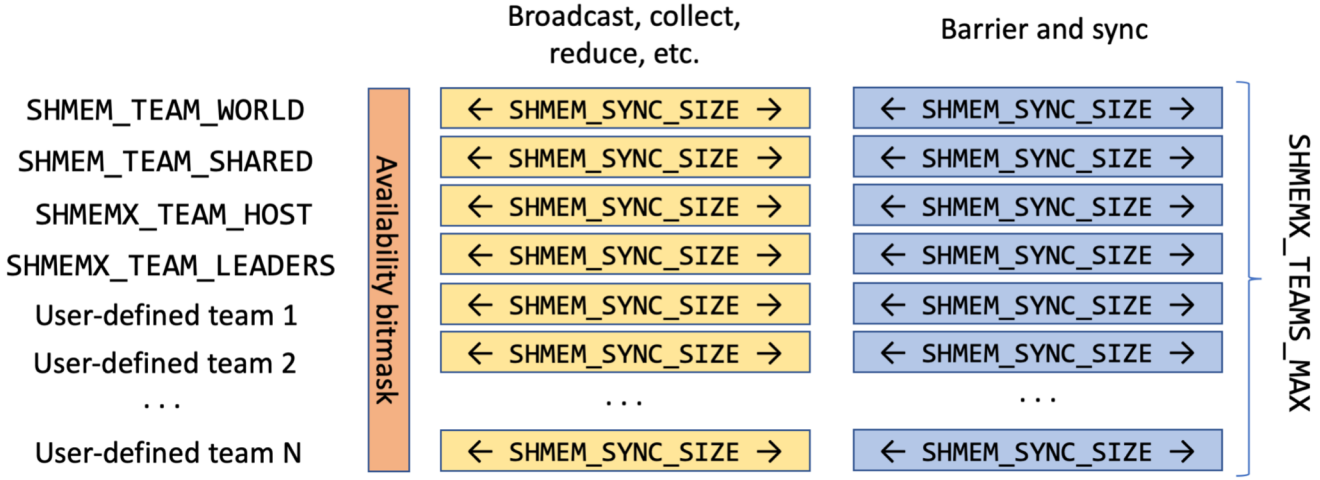
OpenSHMEM Teams proposal (version 1.5):

- The “active set” is specific to a team – defined during team creation.
- No more pSync exposure – managed by the implementation.

```
int shmem_broadcast(shmem_team_t team, TYPE *dest, const TYPE *source,
size_t nelems, int PE_root);
```

pSync Allocation and Management

- pSync/pWrk allocation done at initialization.
- A bitmask dictates which teams utilizes a particular pSync/pWrk region.
- Team creation bottleneck becomes an AND reduction across the bitmask.
- Can have any number of psyncs for back-to-back collectives)



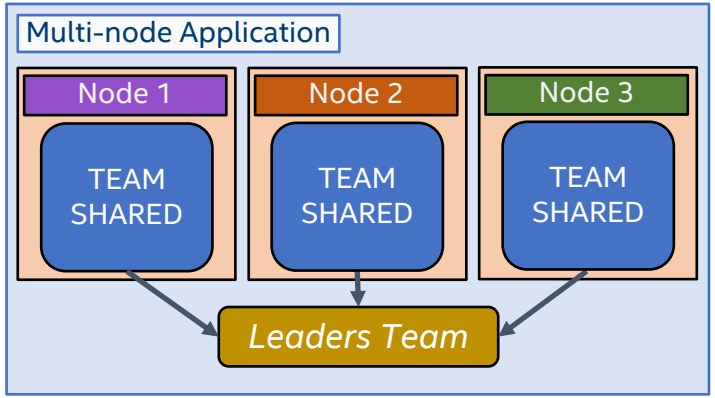
Team creation via `team_split_strided`

```
int shmem_team_split_strided(shmem_team_t parent_team,
                             int start, int stride, int size,
                             shmem_team_config_t *config, long config_mask,
                             shmem_team_t *new_team);
```

- Always collective on the parent team.
- If a PE is outside the (child) active set, call an internal barrier.
- If PE is inside the (child) active set, agree on a pSync via an AND reduction.
- Set the determined pSync reservation bit to 1, update team pool pointer.
- Finish parent barrier.

Teams Sharing Memory

- Iterate over all PE numbers and check `shmem_ptr()`
  - `shmem_ptr()` returns NULL if PE's address is inaccessible.
- For each PE, check that the stride stays *consistent*.
  - Certain teams not representable via a triplet, like {0, 1, 2, 4}.
  - If inconsistent, we give up and set `SHMEM_TEAM_SHARED` to the self PE.
- Various alternative teams possible:
  - PEs sharing a hostname
  - PEs sharing a NUMA domain
  - PEs within a topological fabric group

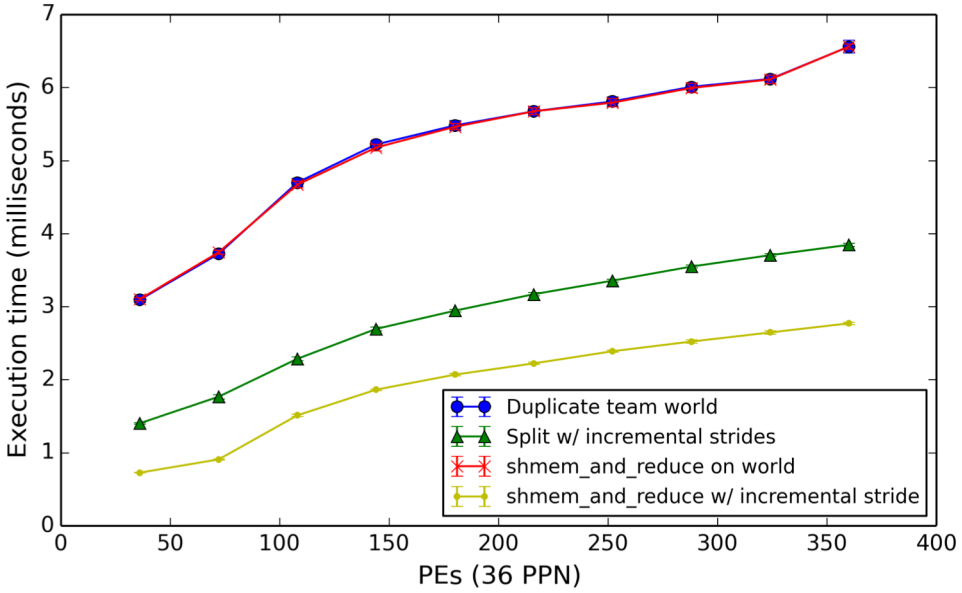


Performance Experiments

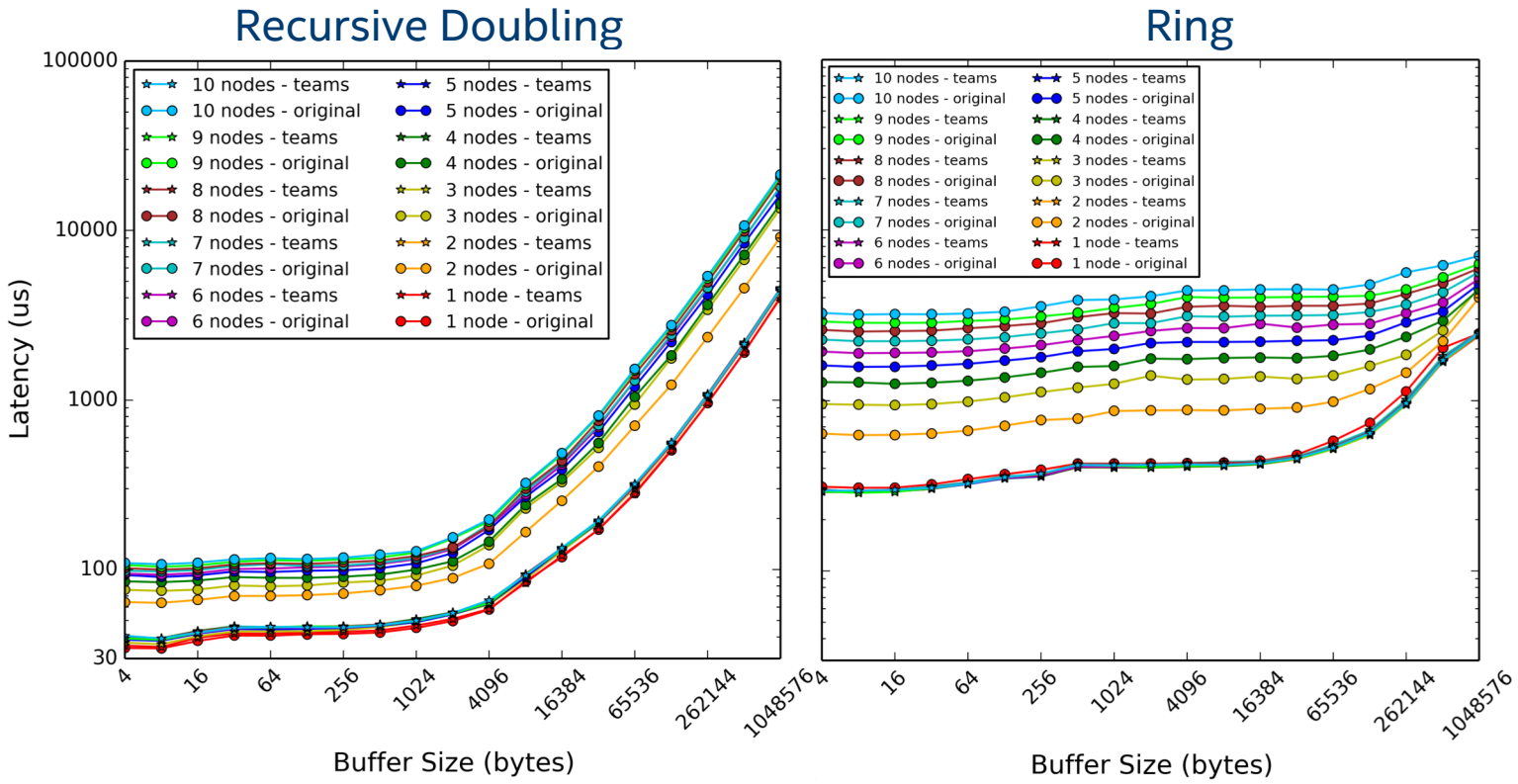
- Cori at NERSC:
  - Cray XC40, Intel®Xeon E5-2698 v3 (Haswell), 64 Hyper-Threaded cores per node, Aries fabric with dragonfly, GNU GCC version 8.2.0, libfabric version 1.8.x with the GNI provider.
- Diamond at Intel:
  - Intel® Xeon® Platinum 8170 (Skylake), 104 Hyper-Threaded cores per node, Intel® Omni-Path 100 series fabric with fat-tree, GNU GCC 4.8.5, libfabric version 1.7.0 with the PSM2 provider.
- OSU sum reduction microbenchmark
  - Reduce across SHMEM_TEAM_SHARED, then across SHMEM_TEAM_LEADERS.
- Ring
  - Reduce-Scatter followed by all-gather
  - Bandwidth optimized
- Recursive Doubling
  - Series of pairwise transfers between PE's with powers of 2
  - Latency optimized

Team Creation Latency Experiment

- 64 team creations (max supported) per iteration
- 1000 iterations – average time measured
- Blue – `TEAM_WORLD` "duplicate" split
- Red – *reduction* across `TEAM_WORLD`
- Green – `TEAM_WORLD` "halve" split
  - 1st split = {0, 1, 2, 3, …, N} (size=N)
  - 2nd split = {0, 2, 4, …, ~N}. (size=N/2)
  - 3rd split = {0, 4, 8, …, ~N} (size=N/4) etc.
- Yellow – *reduction* across the "halved" teams



Diamond Sum-Reduction Measurements



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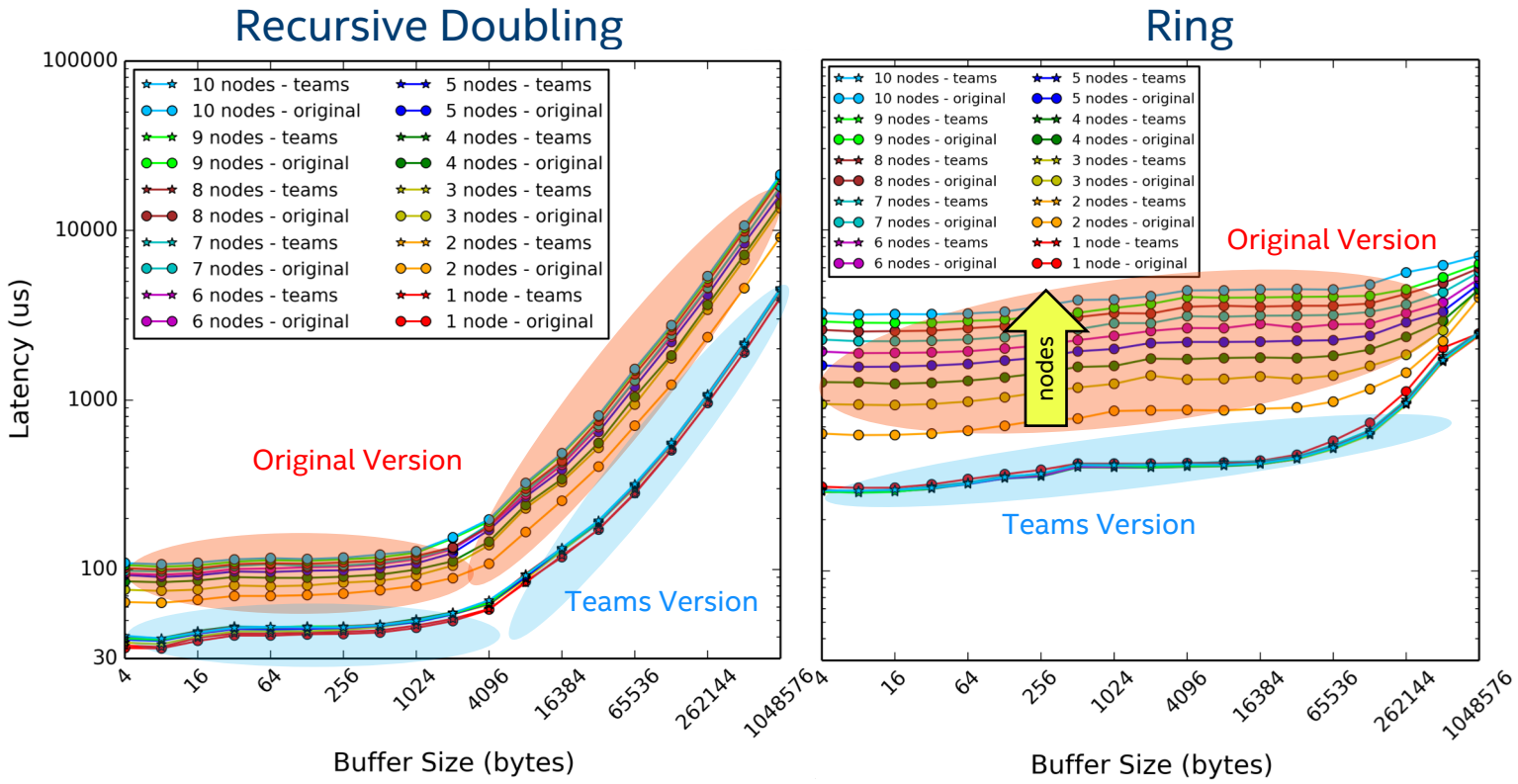
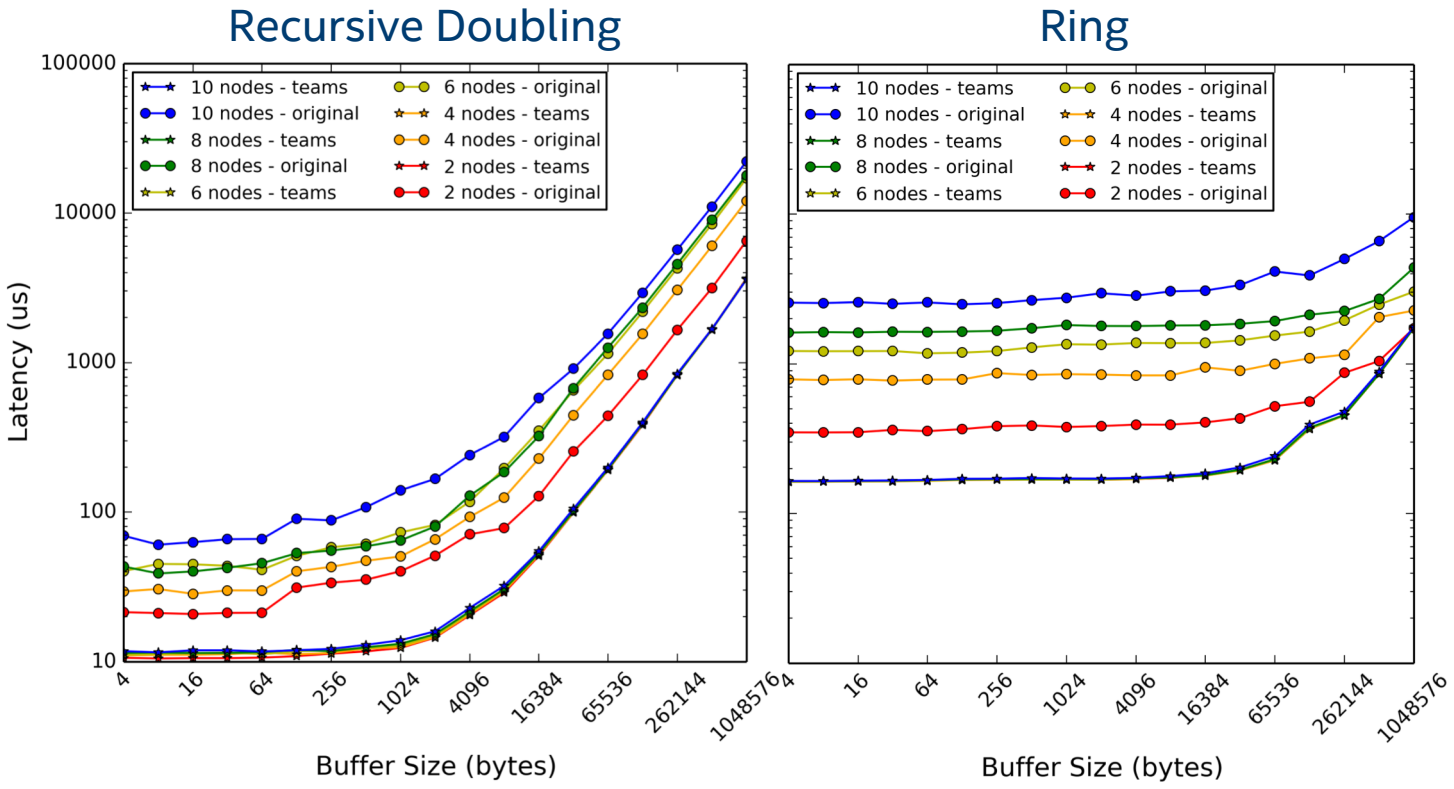
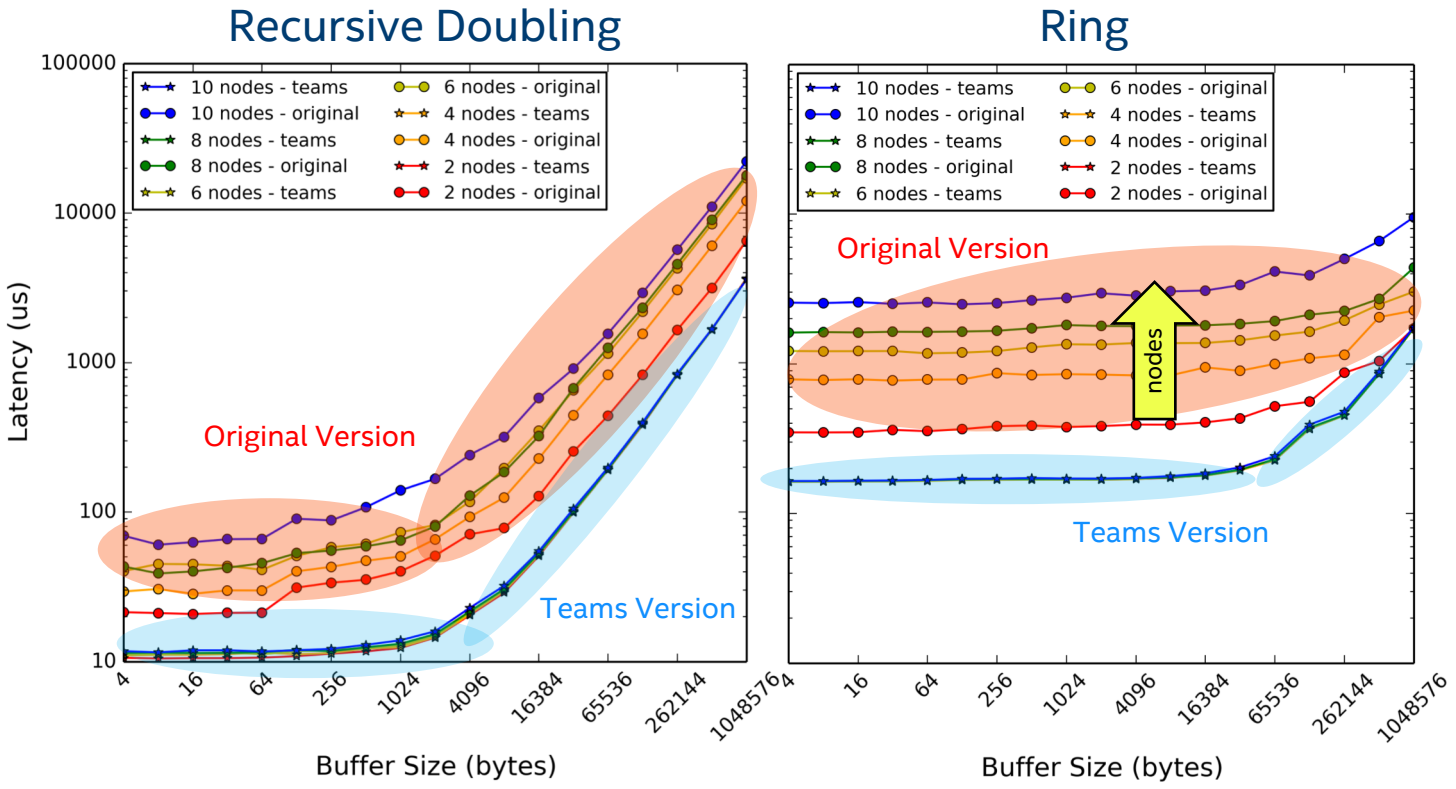


Cori Sum-Reduction Measurements



Cori Sum-Reduction Measurements

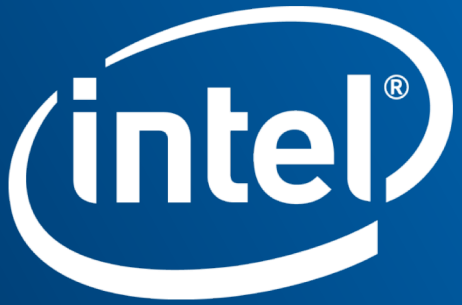


Conclusion

- The OpenSHMEM Teams API is impactful for applications: easier decomposition, better locality, simpler collectives usage.
- The latest API is implementable and shows good performance characteristics.
- From the experiments:
  - Team creation is dominated by a reduction.
  - Both bandwidth-optimized (ring) and latency optimized (rec. dbl.) algorithms benefit from team-based shared memory reduction.
- This code is under review within the SOS topic/teams branch:
  - https://github.com/Sandia-OpenSHMEM/SOS/pull/886
- Status:
  - Recently ratified by the specification committee – will be released in v1.5.

Future Work

- Support non-triplet (set-based) teams?
  - More general support for `SHMEM_TEAM_SHARED`.
  - May enable topological optimizations.
- Various teams-related extensions:
  - Memory Spaces
    - Teams-based memory allocation
    - Different traits for different memories
  - Atomicity domains
    - Isolate atomic operations to within a team (or team hierarchy)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