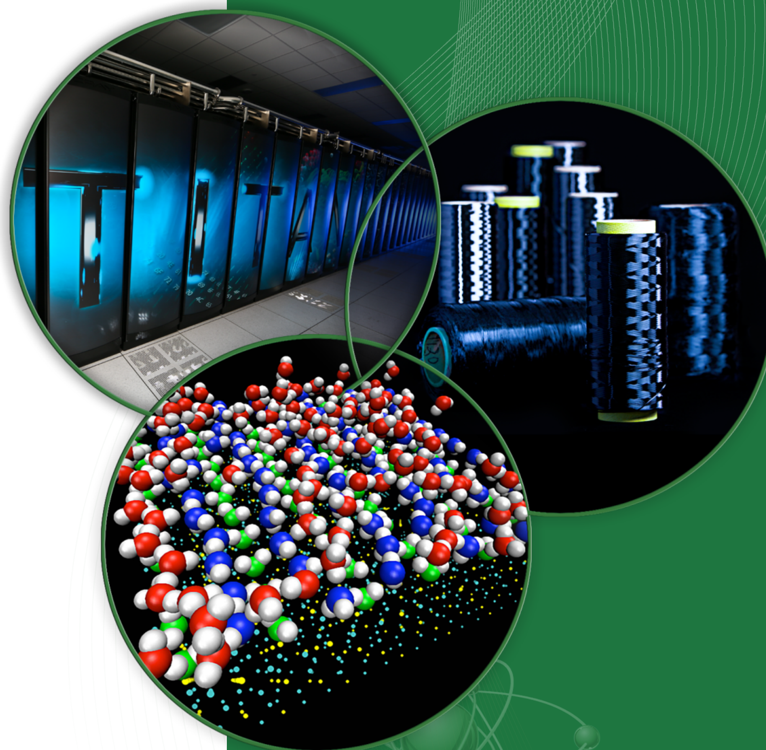
On Synchronisation and Memory Reuse in OpenSHMEM



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Teams and *Spaces*

- Proposed *teams* extention promises greater control over asynchronous processing and ability to handle dynamic problems

- Memory available to *teams* remains globally symmetric, cumbersome, and potentially inefficient

- *Spaces* aim to solve the problem by providing an efficient memory solution for *teams* at minimal cost to the application

Examining Use of pSync Arrays

- New extensions
  - Collectives are being enhanced to work with *teams*
  - Memory allocation within *teams* through *spaces*
- Old ways
  - pSync/pWrk arrays still need to be carefully managed by users
- Allocation within *spaces* prevents headache of managing pSync arrays across *teams*
  - Only partly eliminates management burden

Solution: Implementation Manages pSync Arrays

- Focus on pSync (pWrk tuned to specific operations)
- Ability to move pSync management to implementation depends on:
  - Ability to obtain memory without global synchronisation (solved by *spaces*)
  - Ability to determine when memory can be reused (open problem)
- Thus, need to focus on safe memory reuse
  - Three such implementations were designed

pSync Management Goals

- Don't be intrusive
  - No new interfaces
- Low overhead
  - Avoid additional synchronisation/communication costs
  - Minimise memory footprint
- How to do this?
  - There is no golden goose!

How to Reuse pSync: Strategy 1 (Additional Synchronisation)

- Maintain *n* pSync arrays
- Each collective locks and uses a pSync array from the pool of free arrays
- Introduce additional synchronisation to communicate when particular array can be reused
  - Does not need to block
  - When all PEs agree that a pSync is no longer in use, release lock and put the array back in pool
- If free arrays depleted, wait or allocate more

How to Reuse pSync: Strategy 2 (Unlock on User Barrier)

- Maintain *n* pSync arrays
- Each collective locks and uses a pSync from the pool of free arrays
- On barrier, unlock all arrays except for the current barrier's array
- If free arrays depleted, wait or allocate more

How to Reuse pSync: Strategy 3 (Pairwise Synchronisation)

- No pSync arrays - synchronisation is pairwise and memory is exclusive
  - Each target PE needs a separate piece of memory to synchronise on
- Maintain multiple memory locations for each target to rotate through (similar to before)
- Memory use dependent on synchronisation algorithm(s) used
  - Tree and recursive doubling algorithms are usually sufficient
- Whenever a PE needs to synchronise with another as a part of the chosen algorithm, it selects and locks one of the dedicated locations for that other PE
- Receipt of a synchronisation message from another PE unlocks all buffers for that PE

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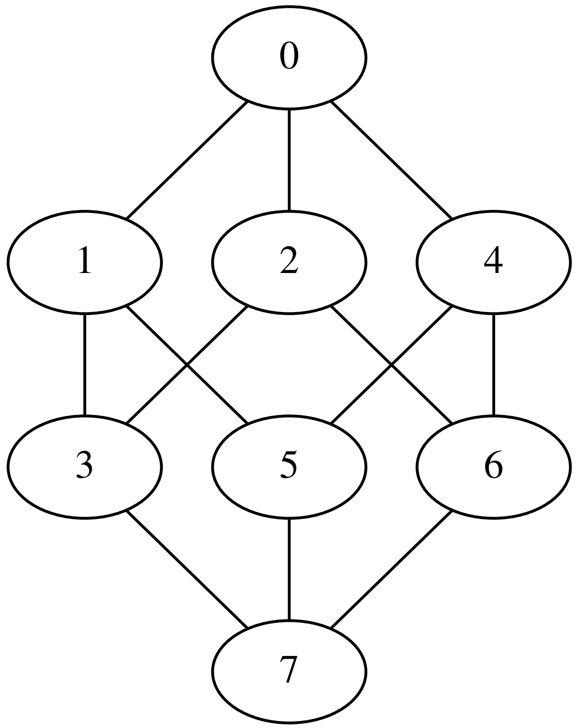
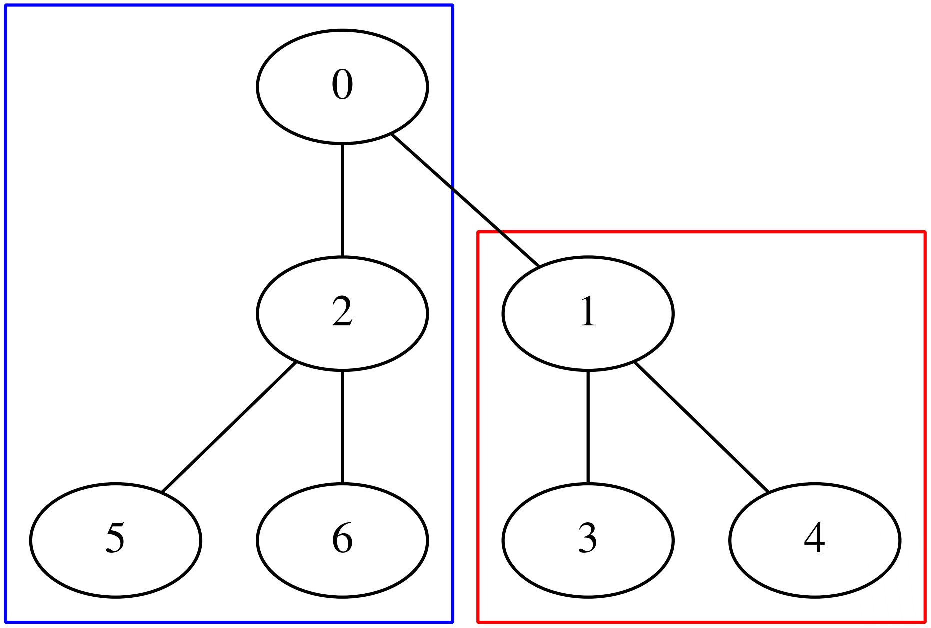
Strategy 3: Recursive doubling



- Edges always remain the same

Strategy 3: Tree (Fixed Structure)



- Maintaining balanced tree results in edges changing based on root

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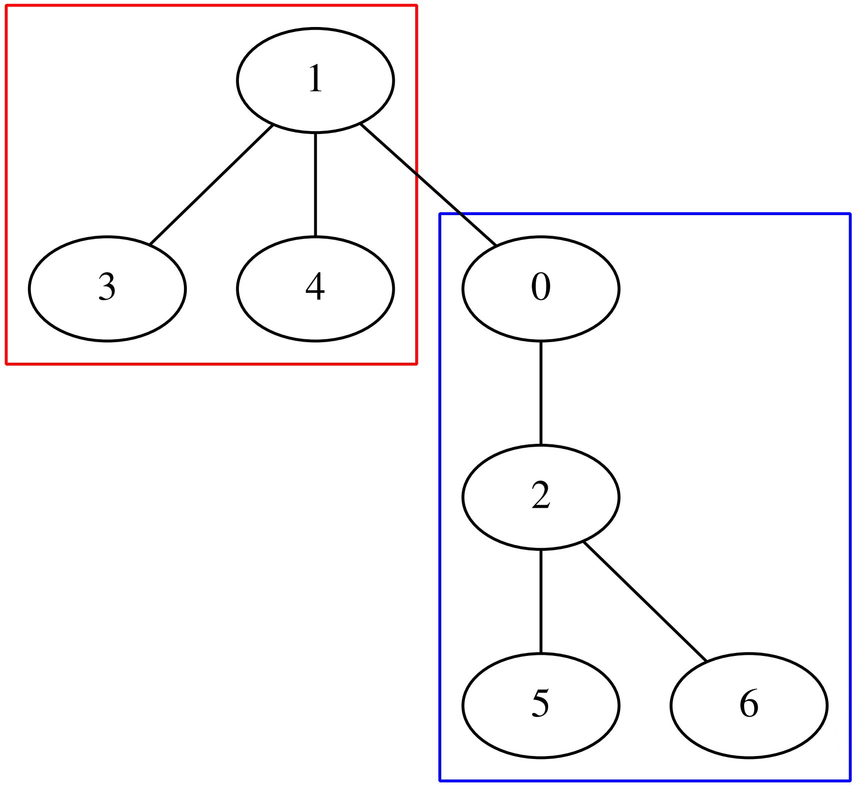
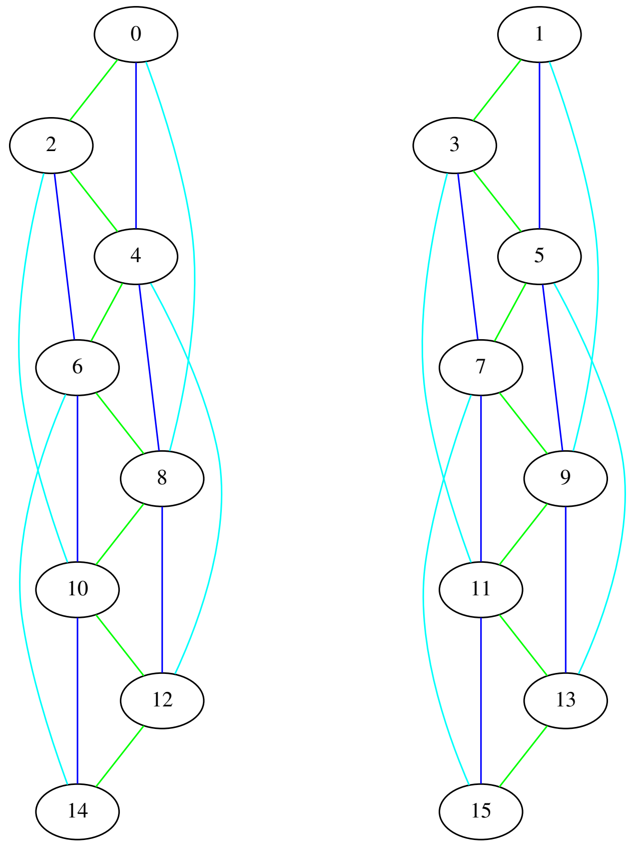
Strategy 3: Tree (Fixed Edges)

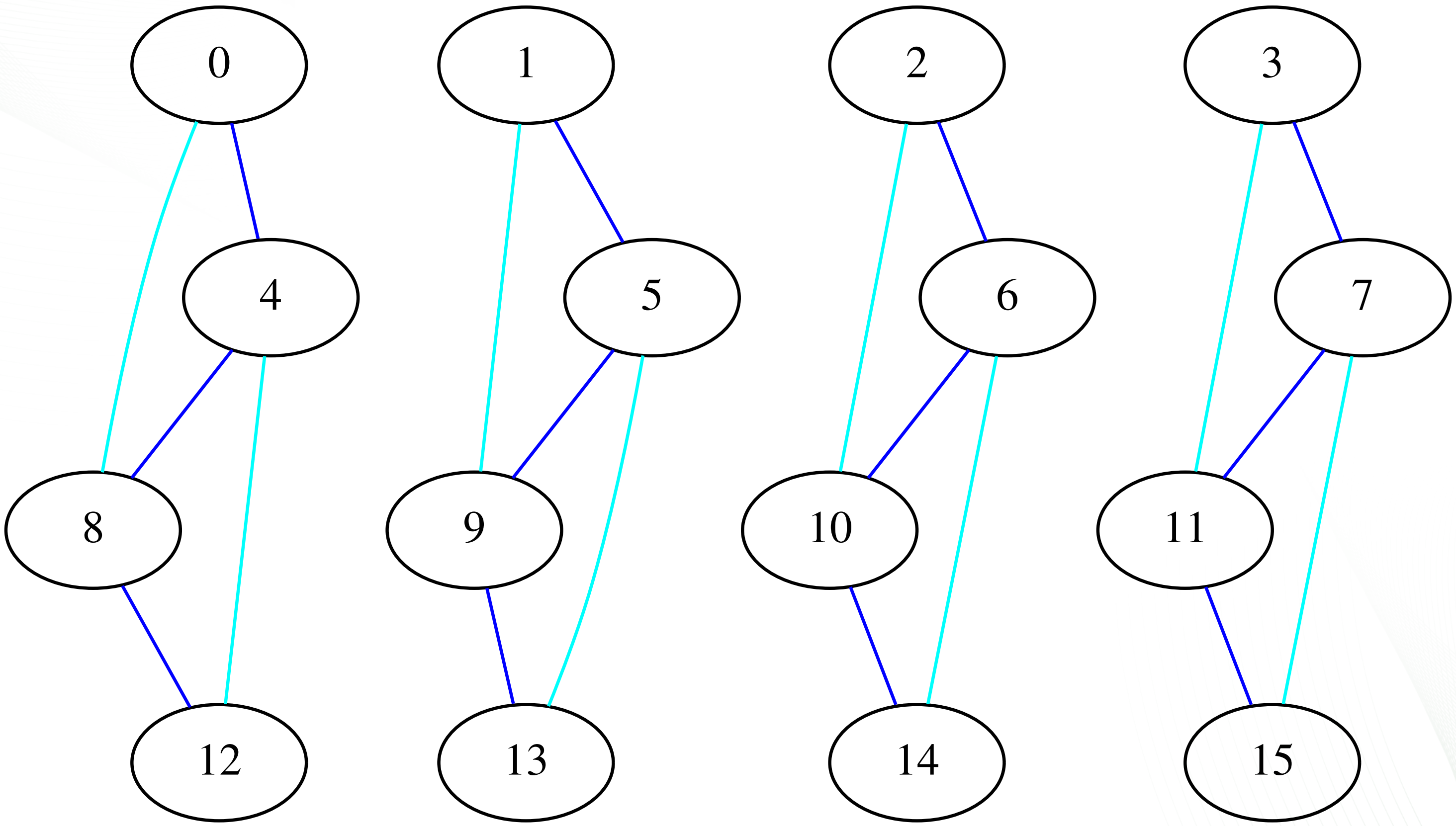


- Maintaining edges results in unbalanced tree

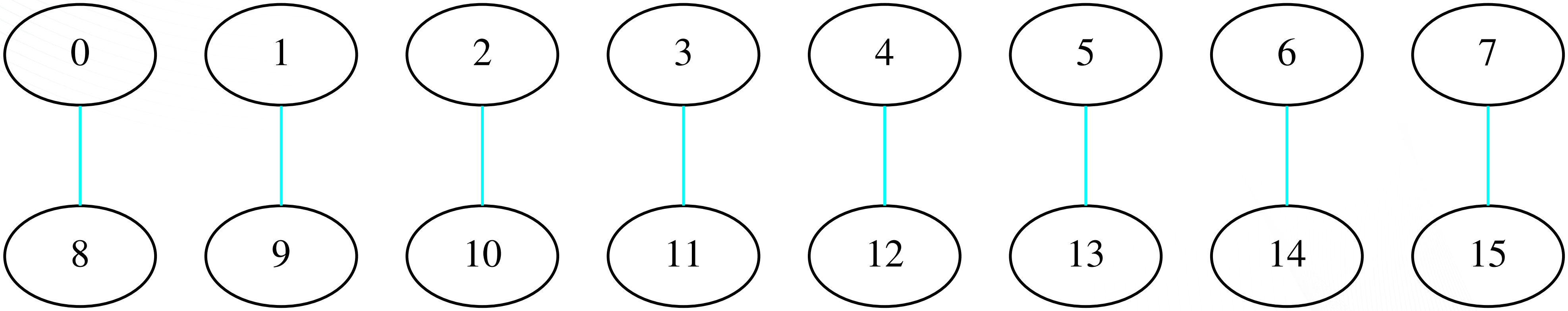
Connectivity Graph: Stride 2



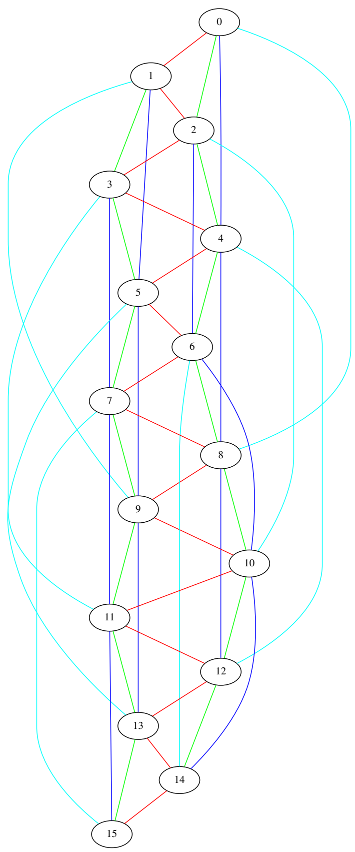
Connectivity Graph: Stride 4



Connectivity Graph: Stride 8



Connectivity Graph: All Strides



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Theoretical Analysis

- Strategy 1 - Additional Synchronisation
  - Communication cost: $\mathcal{O}(3 \log n)$ (worst case)
  - Memory Cost: $\mathcal{O}(n \log n)$
- Strategy 2 - Unlock on User Barrier
  - Communication cost: $\mathcal{O}(2 \log n)$ (worst case)
  - Memory cost: $\mathcal{O}(cn \log n)$, where c is the average distance (in collective operations) between barriers

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Theoretical Analysis

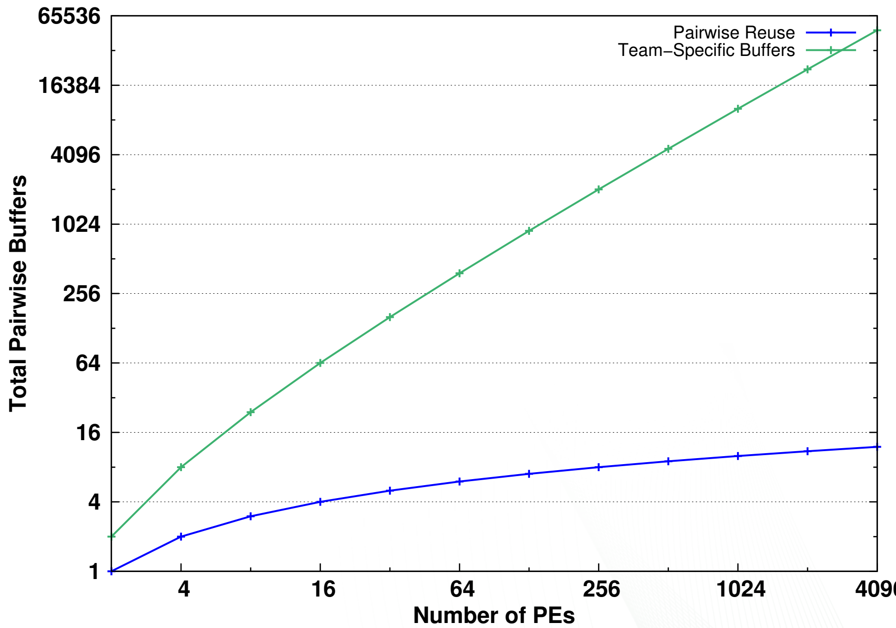
- Strategy 3 - Pairwise Synchronisation
  - Recursive doubling
    - Communication cost: $\mathcal{O}(\log n)$
    - Memory cost: $\mathcal{O}(n \log n)$
  - Tree (fixed structure)
    - Communication cost: $\mathcal{O}(\log n)$
    - Memory cost: $\mathcal{O}(n^2)$
  - Tree (fixed edges)
    - Communication cost: $\mathcal{O}(2 \log n)$
    - Memory cost: $\mathcal{O}(3)$

SHOC Benchmark Suite: QTC

- Scalable Heterogeneous Computing (SHOC) benchmark suite
  - Collection of benchmark programs testing the performance and stability of systems using computing devices with non-traditional architectures for general purpose computing, and the software used to program them
  - Initial focus is on systems containing graphics processing units (GPUs) and multi-core processors
- SHOC: quality threshold clustering (QTC)
  - Clustering algorithm like *k*-means
  - Instead of finding points near *k* centroids, group points based on some distance threshold
    - Variable number of clusters
  - As remaining free points decreases, excess PEs are pruned from working group

QTC Results

- Memory use for pairwise strategy
- Memory requirement: log *n*
- Memory use with unique, traditional pSync arrays for each *team*: *n* log *n*



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Conclusion

- Moving synchronisation buffer management to implementation shown to be possible with set degrees of overhead
- Possible to scale linearly with respect to the number of PEs in the system
- May involve making decisions on acceptable tradeoffs

Future Work

- Investigate when it may make sense to destroy old buffers
- Consider implications and potential benefits for applying tags to collective operations
- Analyse other potential synchronisation algorithms that may be used
- Further study optimal connectivity graphs

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