Hewlett Packard Enterprise

CHAPEL 1.25 RELEASE NOTES: PERFORMANCE OPTIMIZATIONS

Chapel Team

September 23, 2021

OUTLINE

- InfiniBand Optimizations
- Automatic Aggregation Improvements
- Barrier Optimizations
- Bounded Coforall Optimization Improvements

INFINIBAND OPTIMIZATIONS

INFINIBAND
Background

- Memory must be registered with the network in order to do one-sided GETs/PUTs (RDMA)
  - gasnet-ibv supports two registration modes:
    - Static: All memory is registered at startup—fast communication, but hurts NUMA affinity and leads to long startup times
    - Dynamic: Memory is registered at communication time—can add overhead, but good NUMA affinity and fast startup

- Chapel defaults to dynamic registration to get good NUMA affinity and fast startup times
  - We believe this is the right choice for most users
    - Have recommended static registration to some users with certain communication-heavy idioms
  - Ideally, we just want to have one mode with no, or few, downsides

- The 1.24.1 release included significant InfiniBand performance improvements
  - Many of these reduced the gap in communication performance between dynamic and static registration
  - For this release, we wanted to further tune performance and hopefully work towards a single registration mode

INFINIBAND OPTIMIZATIONS

Background and This Effort

Background: Discovered IB verbs completion queues (CQ) were being highly contended

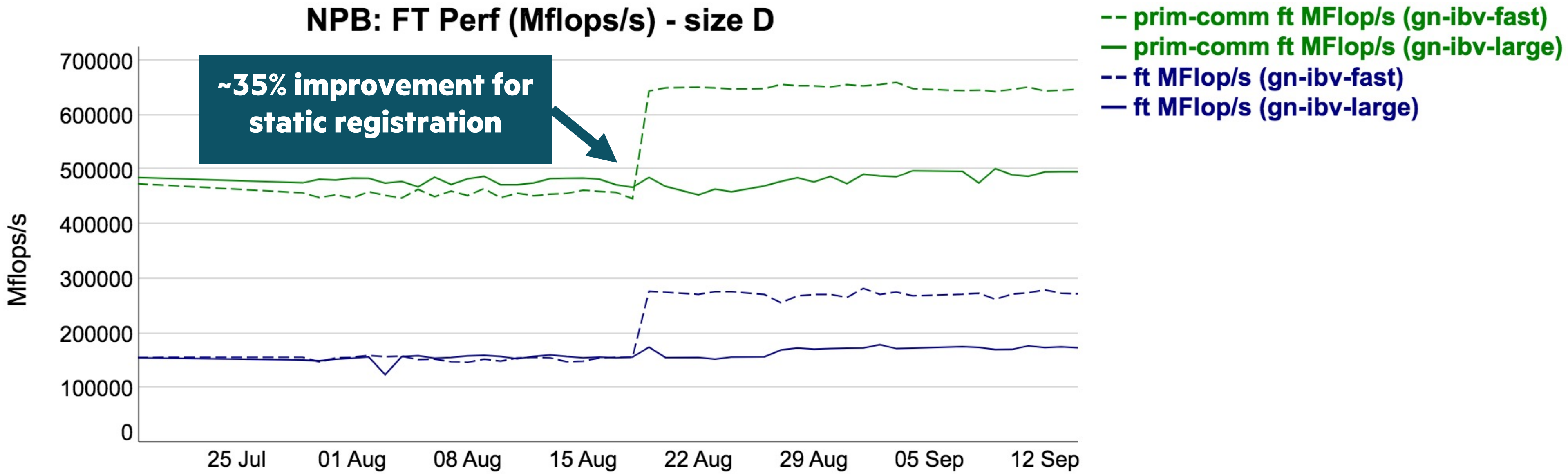
- CQs are polled to track the completion of network operations
- Currently, multiple threads share a single CQ, which leads to concurrent polling and contention
- CQs are protected by an unaligned lock in the verbs API
- Unaligned lock led to false-sharing, which compounded performance penalty
  - Bottleneck was identified with perf-c2c, a tool that helps identify cacheline contention

This Effort:

- Collaborated with GASNet team to serialize CQ polling with an aligned try-lock
  - Try-lock skips polling if the lock is already held, reducing total number of polling calls and contention
  - Alignment eliminates false-sharing

INFINIBAND OPTIMIZATIONS
Impact

- Significant performance improvements for applications with concurrent communication



INFINIBAND OPTIMIZATIONS
Impact

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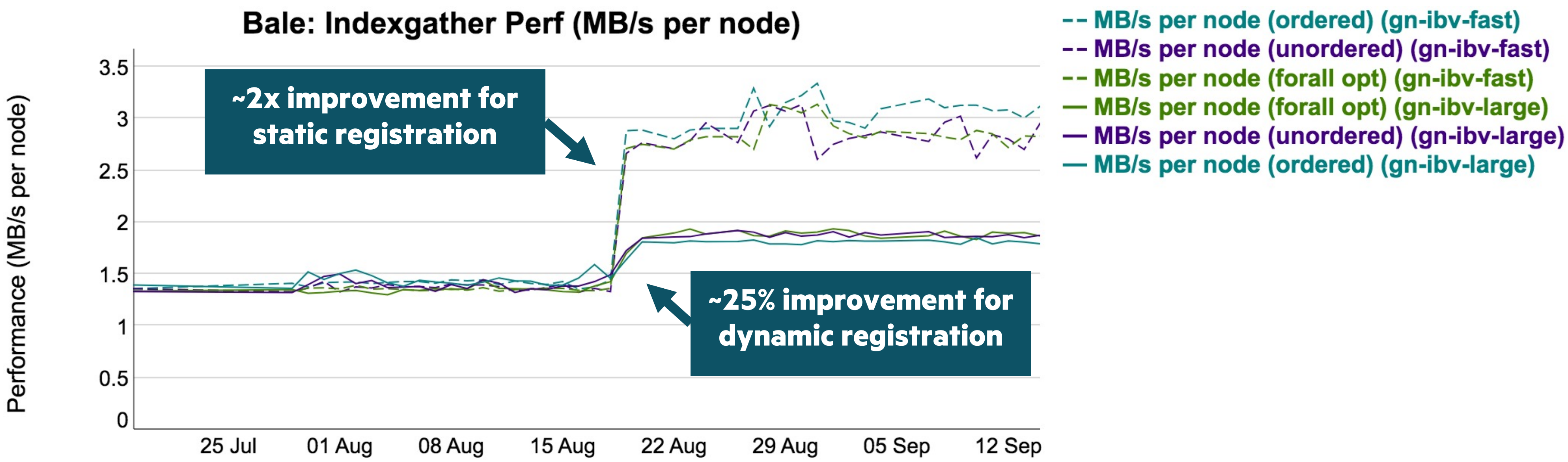
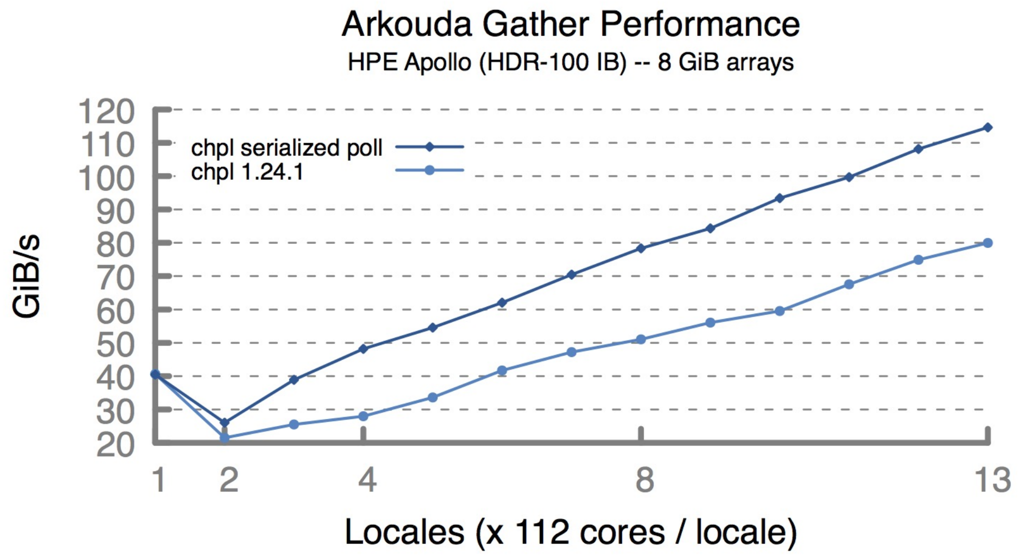
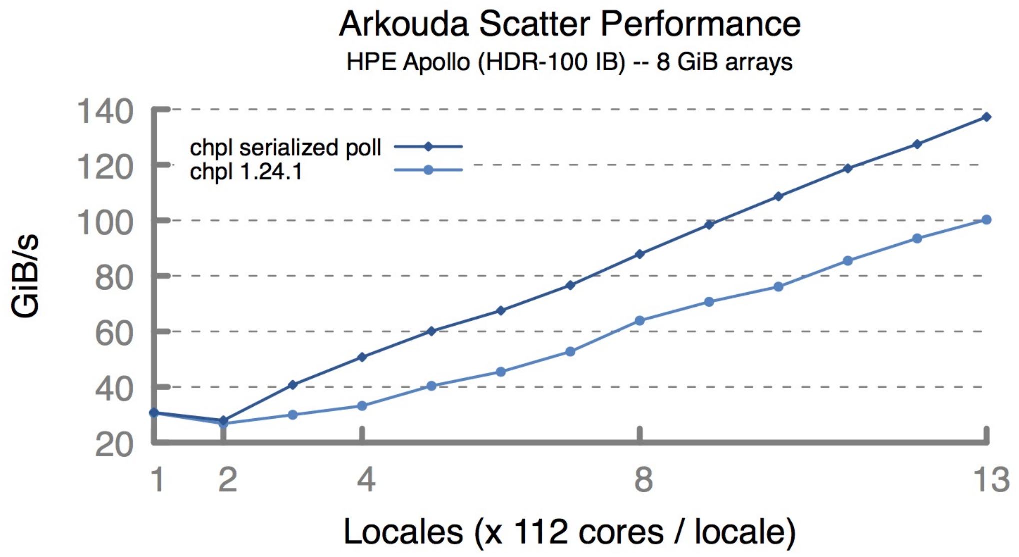


INFINIBAND OPTIMIZATIONS
Impact

- Significant performance improvements for Arkouda with dynamic registration

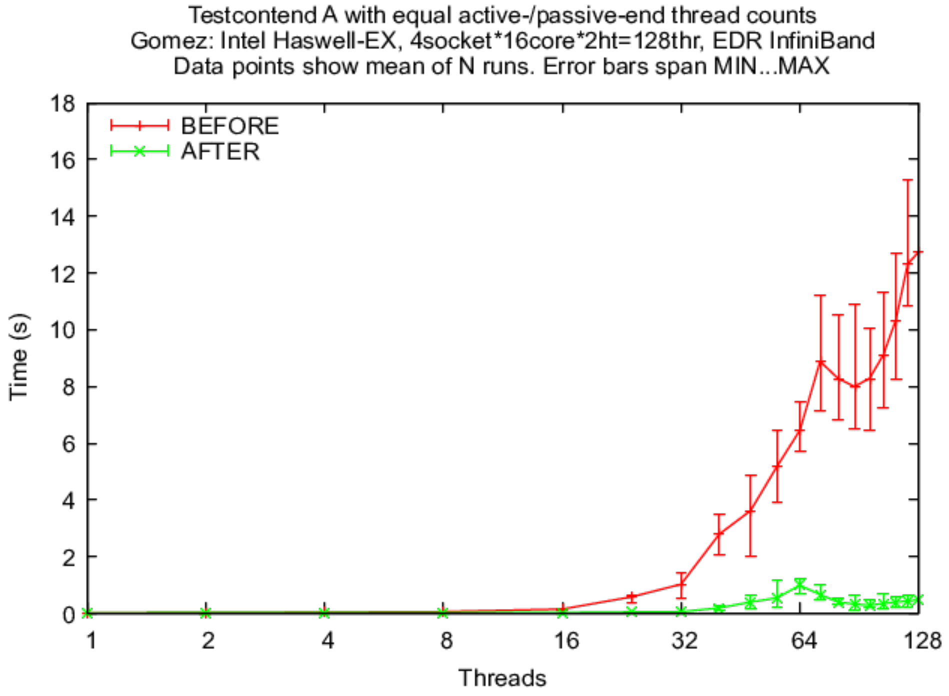


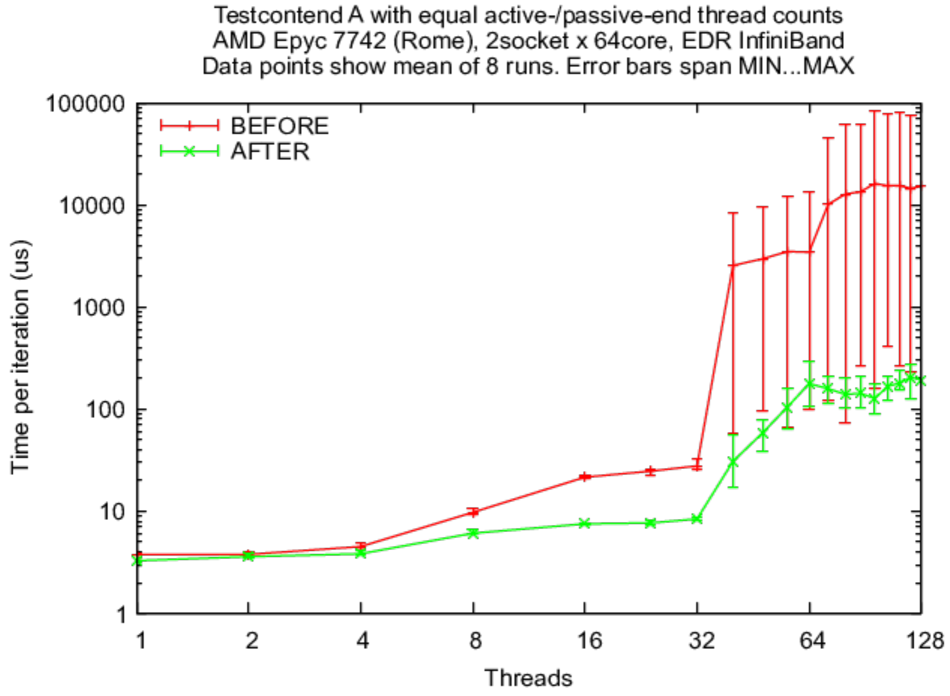


INFINIBAND OPTIMIZATIONS

Impact

- Significant reduction in variability on systems with Address Space Layout Randomization (ASLR)
  - ASLR led to randomized CQ lock addresses, which made the impact of false-sharing variable from run-to-run
  - Our test systems run with ASLR disabled, but many sites have it enabled
    - GASNet results show improved stability on systems with ASLR (L: linear-scale 64-core Intel, R: log-scale 128-core AMD)





INFINIBAND OPTIMIZATIONS

Next Steps

- Further reduce CQ contention by using the GASNet-EX multi-endpoint API
  - Creating an endpoint and CQ per thread can reduce contention

- Improve dynamic registration performance
  - CQ polling optimizations widened the gap between dynamic and static registration performance

- Look at using On-Demand-Paging (ODP) as an alternative registration mechanism
  - Hardware/firmware takes care of registration on demand rather than tracking in software
  - Current prototype hangs
    - Needs more investigation and collaboration with the GASNet team

- Gather performance comparisons between Chapel and reference MPI/SHMEM codes
  - Use this to drive further optimizations

AUTOMATIC AGGREGATION IMPROVEMENTS

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Background and This Effort

Background:

- In Chapel 1.24, we added a compiler optimization to aggregate remote communication

```
forall i in A.domain do
  A[i] = B[computeIndex(i)];      // accesses to B are aggregated
```

- The optimization is off-by-default and can be enabled with '--auto-aggregation'

This Effort:

- More comprehensive coverage for automatic aggregation
- Performance improvements

AUTOMATIC AGGREGATION IMPROVEMENTS

Impact – Improved Coverage

- Local, non-distributed arrays are recognized as local

```
var A = newBlockArr(1..10, int);
coforall l in Locales do on l {
  var localArr: [1..10] int;
  forall i in localArr.domain do
    localArr[i] = A[computeIndex(i)];
```

Access to a local array that's declared on 'here'

Communication will be aggregated

AUTOMATIC AGGREGATION IMPROVEMENTS

Impact – Improved Coverage

- Local, non-distributed arrays are recognized as local

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var A = newBlockArr(1..10, int);
coforall l in Locales do on l {
  var localArr: [1..10] int;
  forall i in localArr.domain do
    localArr[i] = A[computeIndex(i)];
```

Access to a local array that's declared on 'here'

Communication will be aggregated

- Explicit calls to 'localAccess' recognized as local

```
var A = newBlockArr(1..10, int);
var B = newBlockArr(1..10, int);
forall i in A.domain do
  A.localAccess[computeLocalIndex(i)] = B[computeIndex(i)];
```

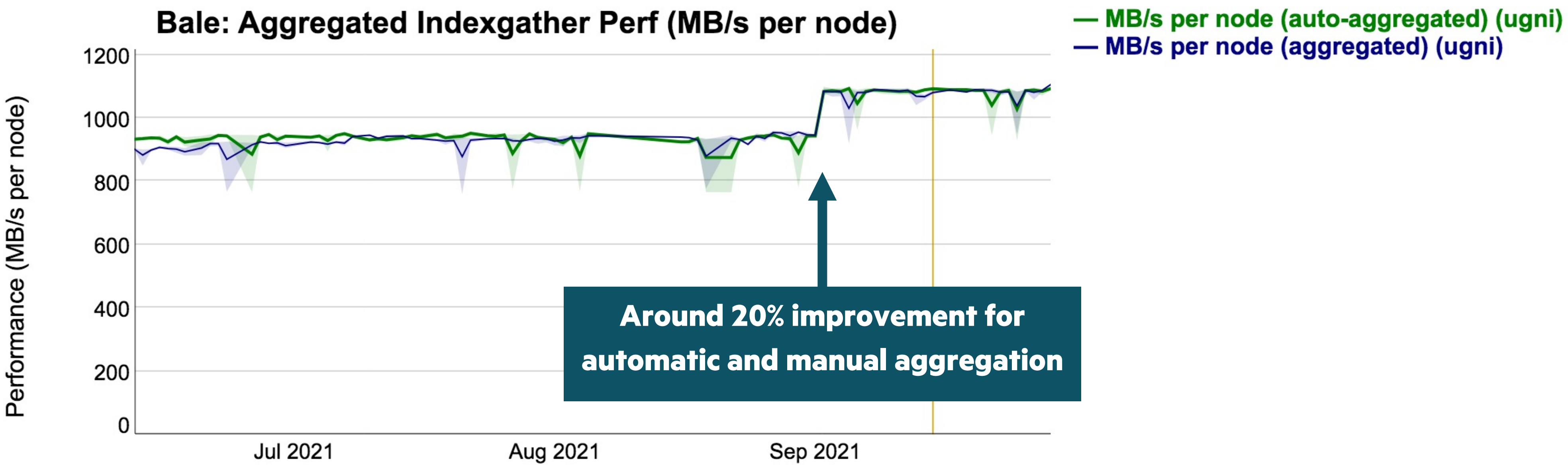
Left-hand side is local because of 'localAccess'

Communication will be aggregated

AUTOMATIC AGGREGATION IMPROVEMENTS

Impact – Improved Performance

- Changes made to improving aggregation in Arkouda were incorporated in upstream Chapel



AUTOMATIC AGGREGATION IMPROVEMENTS

Next Steps

- Provide user-facing aggregation (#16963)
- Port more bale apps for testing aggregation
- Improve all-local aggregation performance
- Extend the coverage to promoted expressions
- Investigate multi-hop aggregators for better memory scalability

BARRIER OPTIMIZATIONS

BARRIER OPTIMIZATIONS

Background and This Effort

Background: At CHIUW 2021, the CHAMPS team reported performance issues in synchronization code

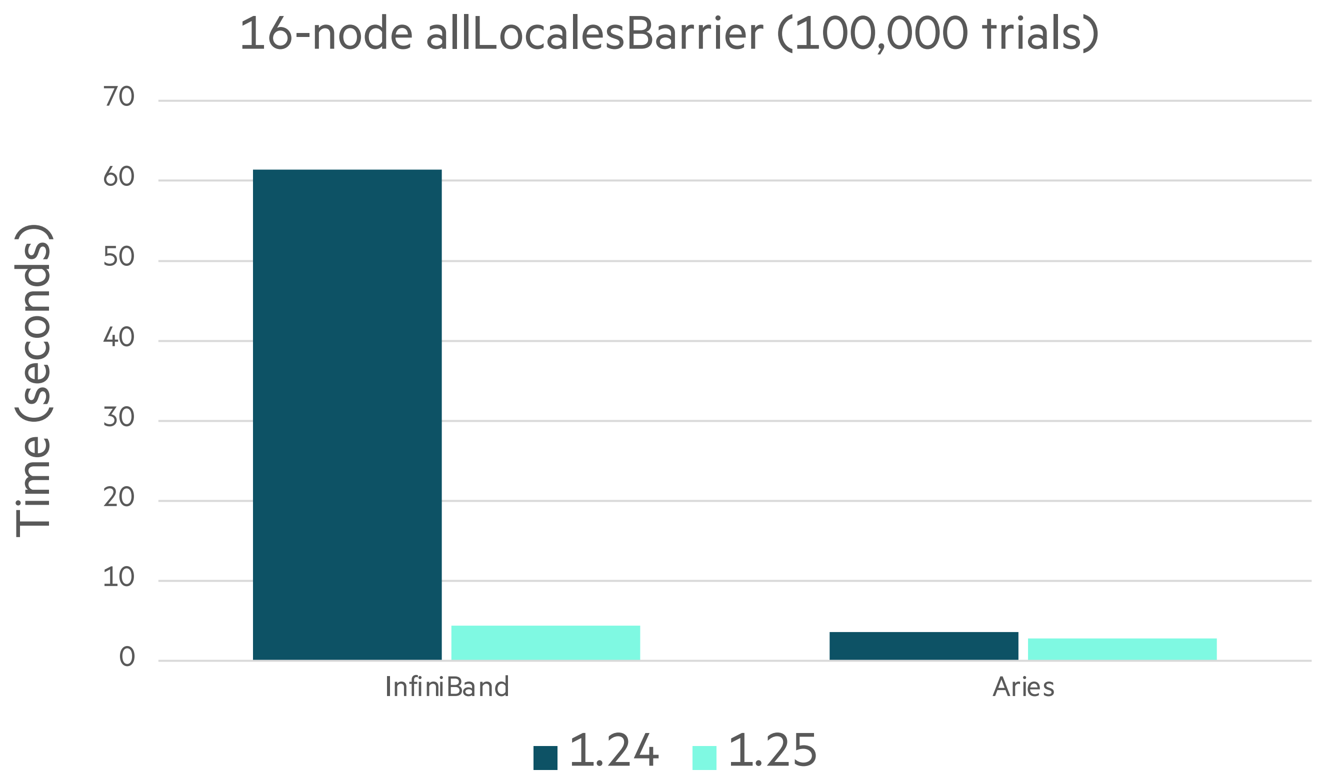
- Synchronization is implemented with a variant of the ‘allLocalesBarrier’
- Discovered excessive communication on every ‘barrier()’ call
  - Due to the implementation using a distributed array in a class, which is a known performance issue (#10160)

This Effort: Optimized ‘allLocalesBarrier’

- Moved distributed array out of the class to eliminate all communication beyond the inter-node barrier itself
  - Workaround until performance issues around distributed array fields are resolved

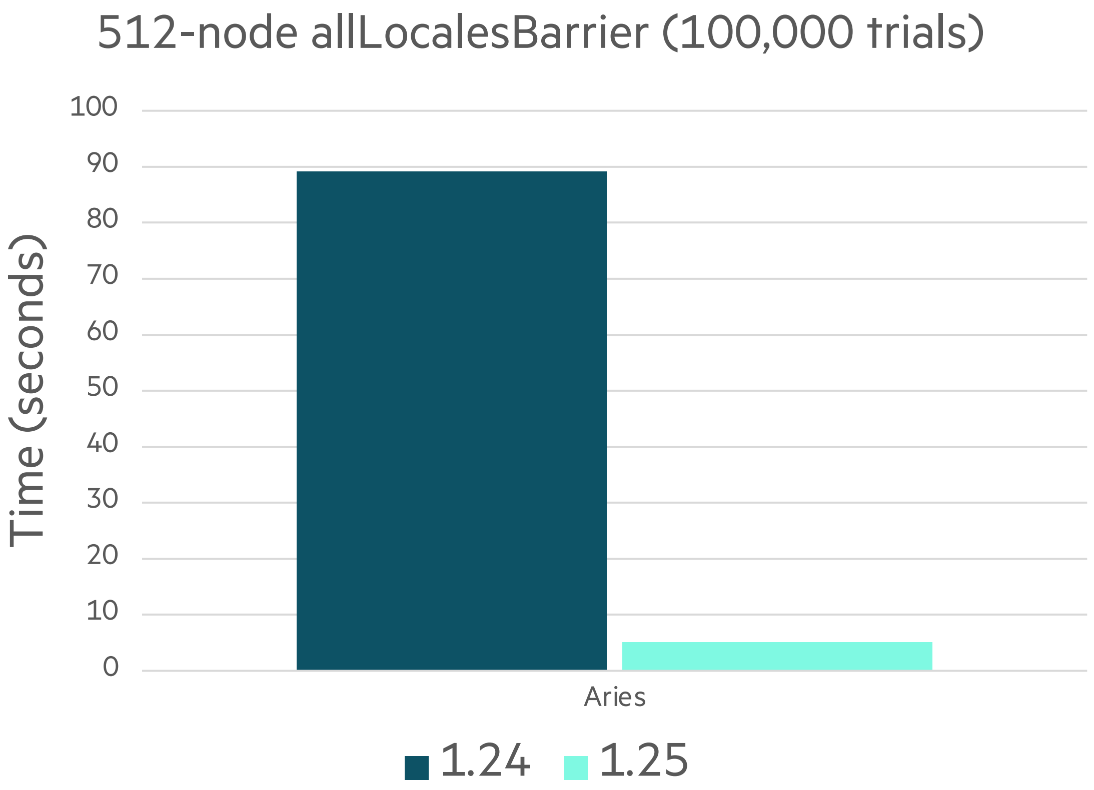
BARRIER OPTIMIZATIONS
Impact

- Significantly faster barrier, especially for configurations where concurrent communication is slow
  - On 16 nodes of a Cray CS with InfiniBand, barrier is roughly 14x faster



BARRIER OPTIMIZATIONS
Impact

- Significantly faster barrier at scale, even for configurations where concurrent communication is fast
  - On 512 nodes of a Cray XC with Aries, barrier is roughly 18x faster



BOUNDED COFORALL OPTIMIZATION IMPROVEMENTS

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Background and This Effort

Background: Chapel 1.15 added a bounded coforall optimization

- Reduces task-tracking overhead for coforalls with a known trip-count (ranges, domains, arrays)
- During 1.25 we discovered this optimization did not fire for zippered coforalls
  - Identified while optimizing 'Block' array creation communication
  - Used zippered iteration to reduce communication, but execution time suffered due to slower task-tracking

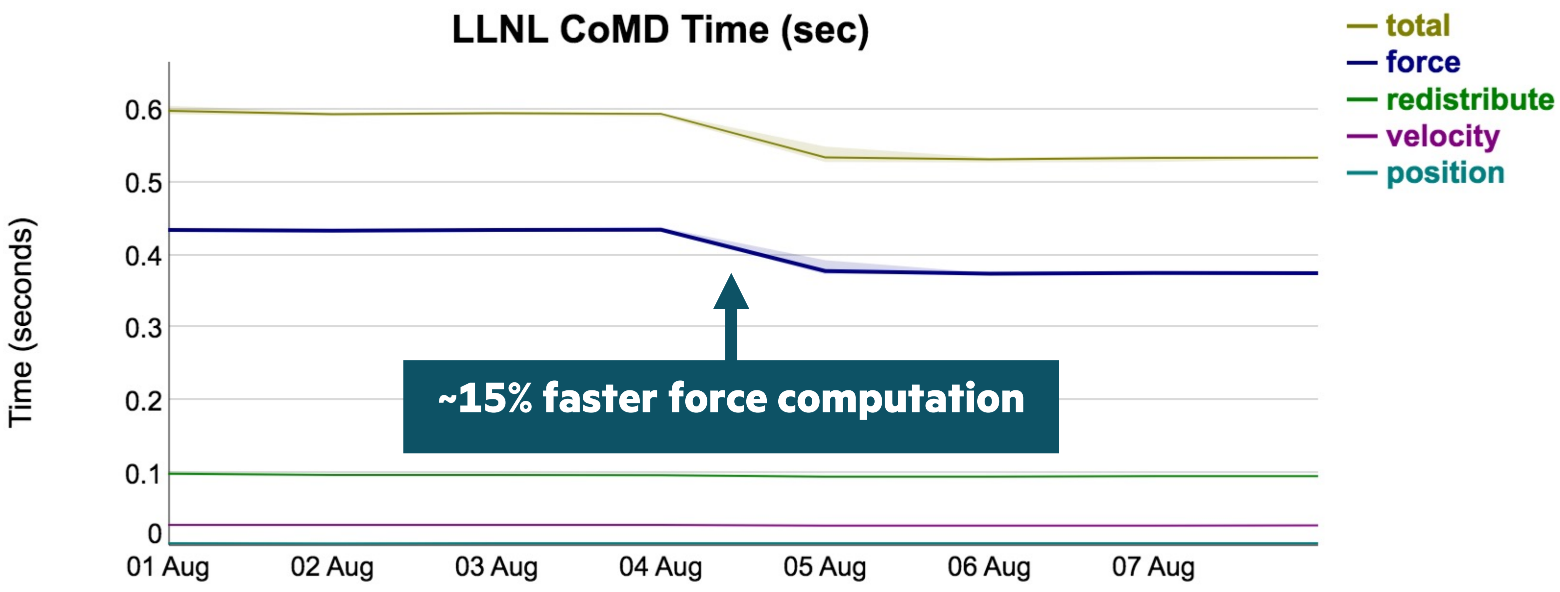
This Effort: Extended the bounded coforall optimization to include zippered iteration

- This enabled optimizing communication for BlockDist array creation

BOUNDED COFORALL OPTIMIZATION IMPROVEMENTS

Impact

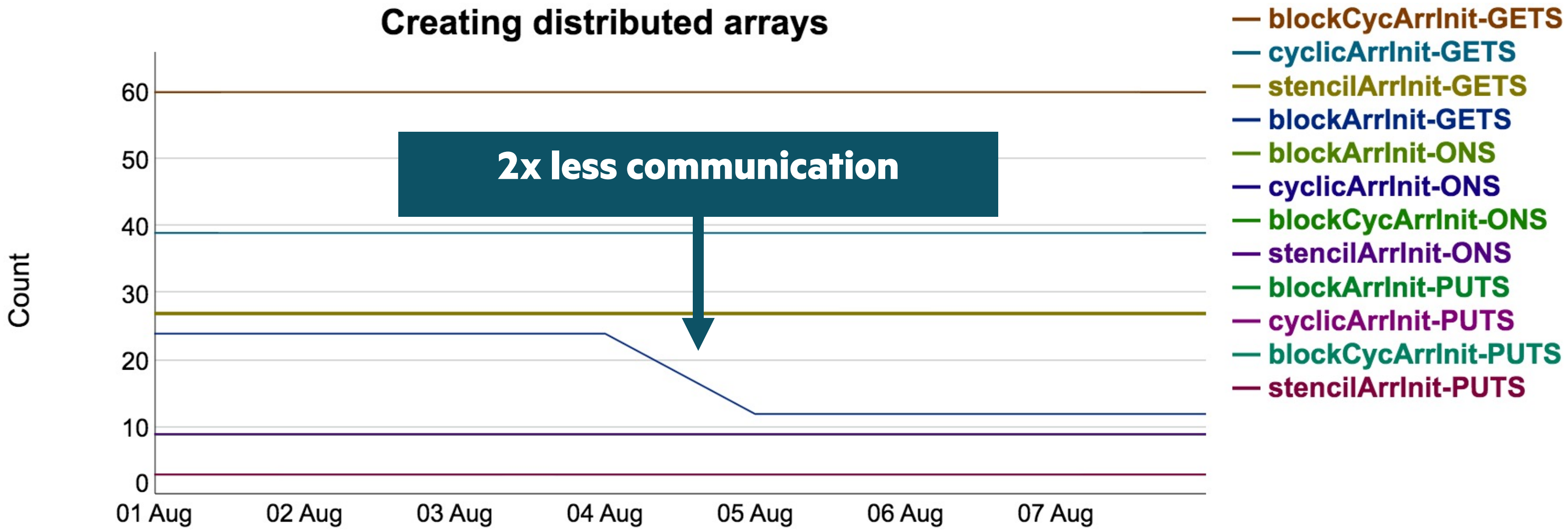
- Performance improvements for codes using bounded zippered coforalls



BOUNDED COFORALL OPTIMIZATION IMPROVEMENTS

Impact

- Communication count reduction for BlockDist array creation



OTHER PERFORMANCE IMPROVEMENTS

OTHER PERFORMANCE IMPROVEMENTS

For a more complete list of performance changes and improvements in the 1.25 release, refer to the following section in the CHANGES.md file:

- ‘Performance Optimizations/Improvements’

THANK YOU

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