ISx in Chapel

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CHIUW @ IPDPS

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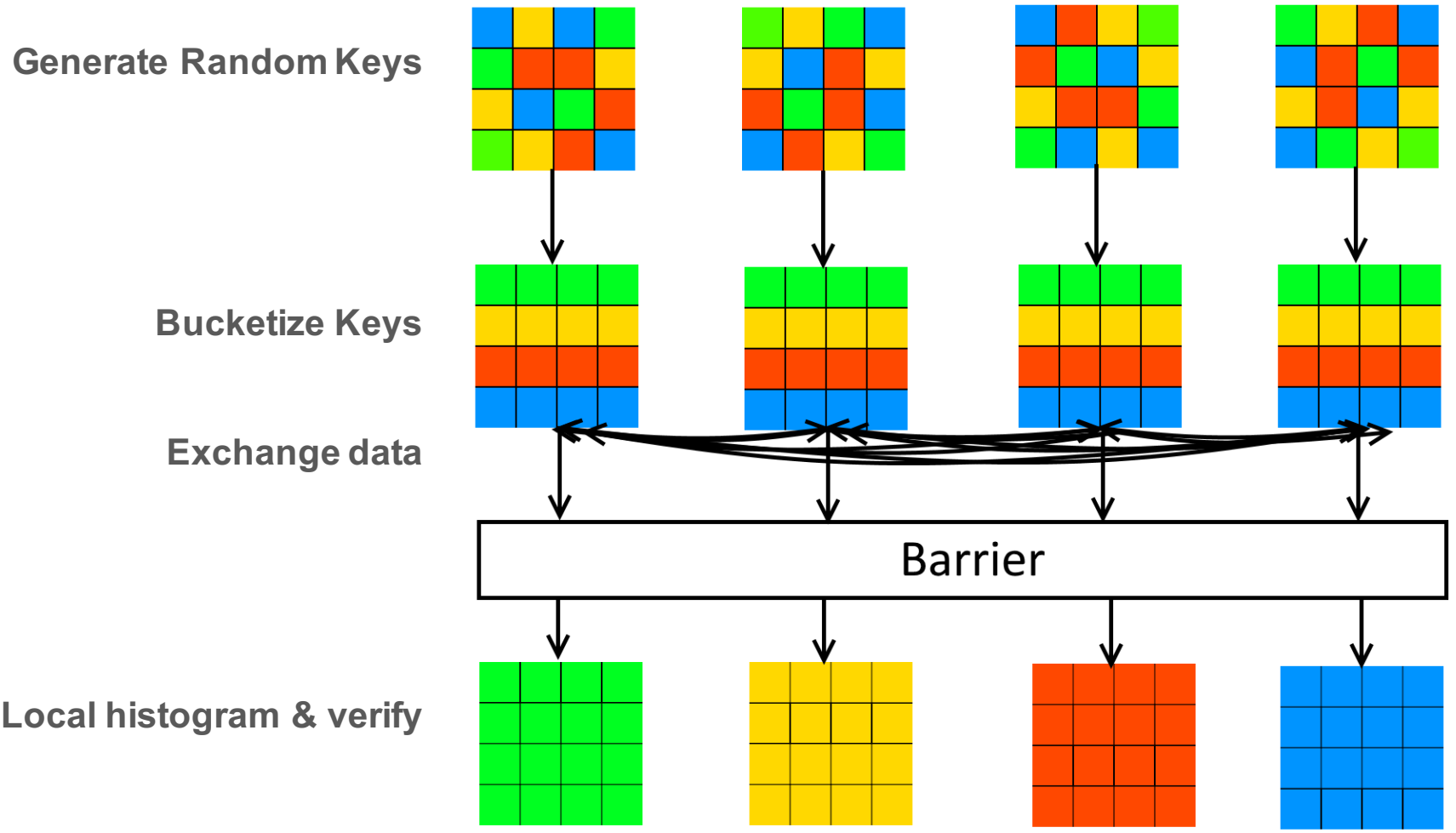
What Is The ISx Benchmark?

- **ISx: Scalable Integer Sort benchmark**
  - Modern replacement for NPB IS to address its shortcomings
  - Developed at Intel, published at PGAS 2015
  - Computation style:
    - Local SPMD-style computation with barriers
    - Punctuated by all-to-all bucket exchange pattern

- **SHMEM and MPI reference versions available on GitHub**
  - https://github.com/ParRes/ISx

- **A good case study for Chapel**
  - A common parallel pattern for distributed memory programming

What Is The ISx Benchmark?



Chapel Implementation

```
const BucketSpace = {0..#numBuckets};
const DistBucketSpace = BucketSpace dmapped Block(BucketSpace);

// For each bucket, create an array to receive keys
var allBucketKeys : [DistBucketSpace] [0..#recvBuffSize] int(32);

// Create globally-visible barrier
var barrier = new Barrier(numBuckets);

// Start a task for each bucket, call bucketSort
coforall loc in Locales do on loc {
  coforall tid in 0..#bucketsPerLocale {
    const taskID = (loc.id * bucketsPerLocale) + tid;
    for i in 1..numTrials {
      bucketSort(taskID, i);
    }
  }
}
```

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```

Chapel Implementation

```
// Within bucketSort…

var myKeys = makeInput(taskID);

var myBucketedKeys = bucketizeLocalKeys(taskID, myKeys);

// Exchange step
for i in 0..#numBuckets {
  const transferSize, dstOffset, srcOffset = …

  allBucketKeys[i][dstOffset..#transferSize] =
    myBucketedKeys[srcOffset..#transferSize];
}
barrier.barrier();

var keyCounts = countLocalKeys(taskID);

verify(taskID, keyCounts);
```

SPMD vs. Global-view

- SPMD: bucket per core
  - Serial for-loops
  - Example from 'countLocalKeys'

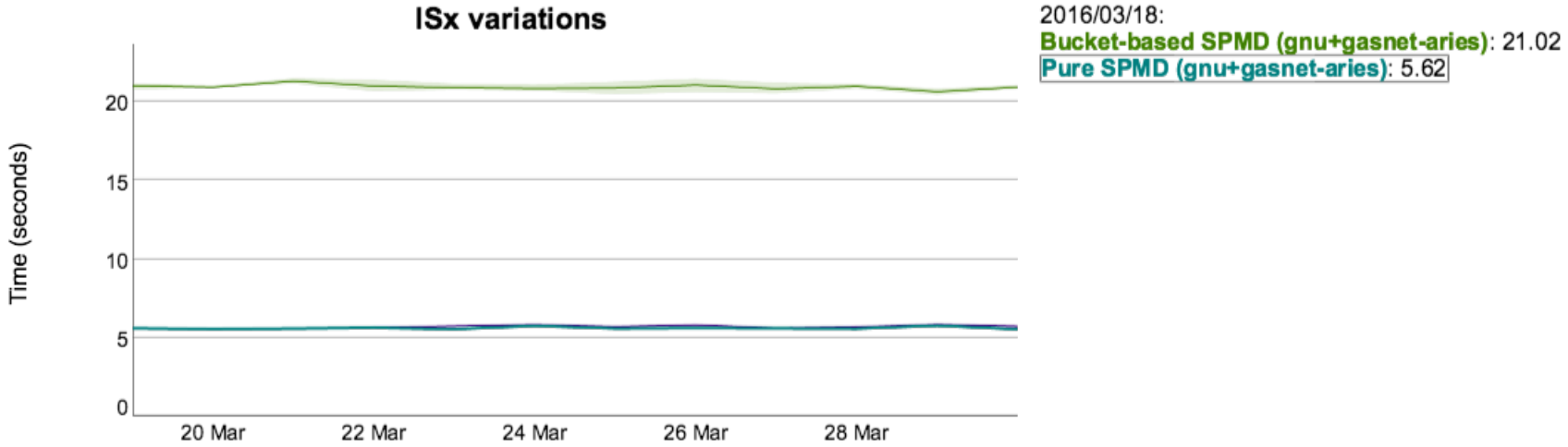
```
var keyCounts : […] int;
for i in 0..#myBucketSize do
  keyCounts[allBucketKeys[taskID][i]] += 1;
```

- Global view: bucket per locale
  - Forall loops for intra-locale parallelism
  - Atomics used to coordinate between loop iterations

```
var keyCounts : […] atomic int;
forall i in 0..#myBucketSize do
  keyCounts[allBucketKeys[taskID][i]].add(1);
```

SPMD vs. Global-view - performance

- **Global-view slower than SPMD version**
  - by up to 4x!



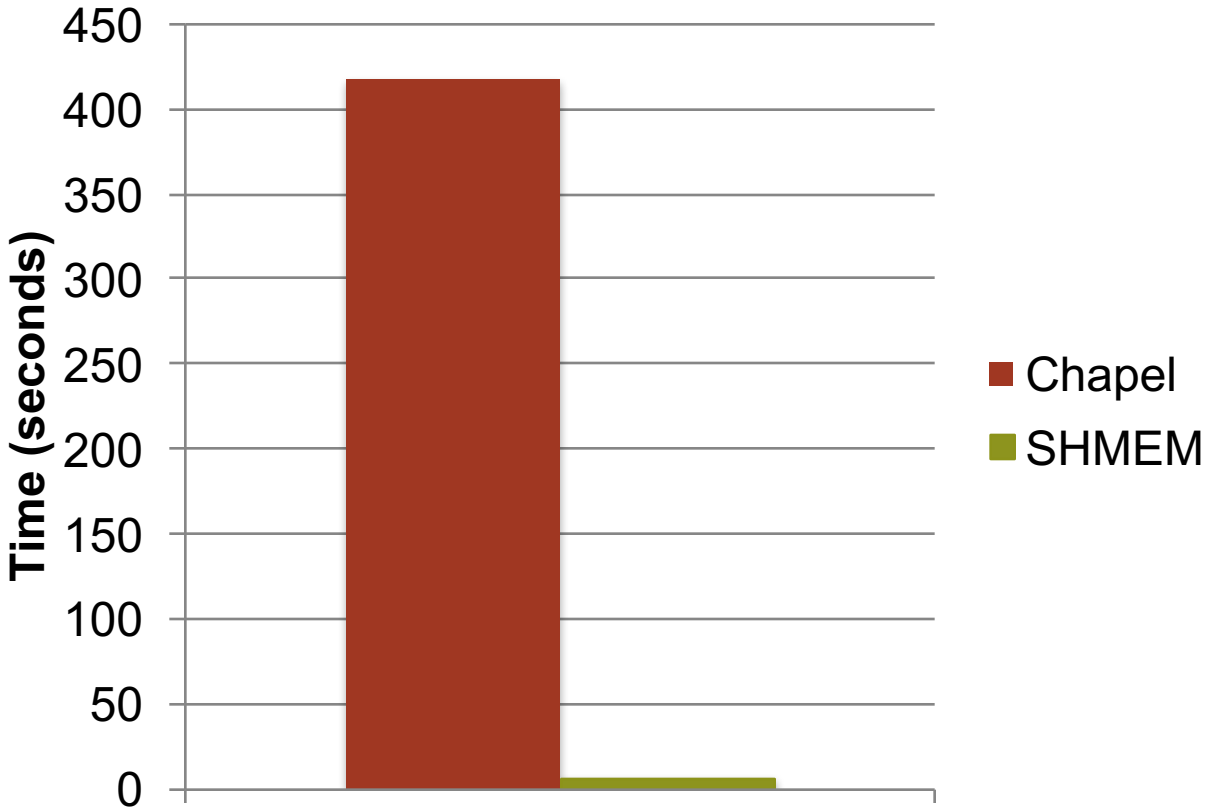
- **Likely due to atomics**
  - Global-view uses atomics to coordinate between forall-loop iterations
  - SPMD uses serial for loops, no atomics

Chapel vs. SHMEM

- **SPMD is faster and a more natural fit**
- **Initial port was much slower than SHMEM reference**
- **Numbers gathered with**
  - ISx reference version 1.1, weakISO scaling
  - Chapel 1.13, ugni-qthreads
  - gcc 5.1.0, -O3
  - cray-shmem/7.3.3
  - Cray XC, 36 broadwell cores per node
  - 134217728 (2^27) keys per bucket

Chapel vs. SHMEM

- **Initial comparison with two XC nodes: yikes!**
  - Nearly 80x worse!



Chapel vs. SHMEM

- Timing output indicated some problem areas

```
exchange = 355.502 (349.506..386.19)
count keys = 56.406 (16.9024..124.789)
```

- Exchange step ~350s, compared to SHMEM's 1.6s

- Counting step ~56s, compared to SHMEM's .2s

Chapel vs. SHMEM - Bulk Transfer

- **Exchange looks something like this:**
  - Slice and assign between two arrays

```
allBucketKeys[i][dstOffset..#transferSize] =
  myBucketedKeys[srcOffset..#transferSize];
```

- **We expect this to use Chapel's bulk transfer optimization**
  - One large GET/PUT/memcpy better than element-by-element

- **Investigation revealed bulk transfer not firing correctly**

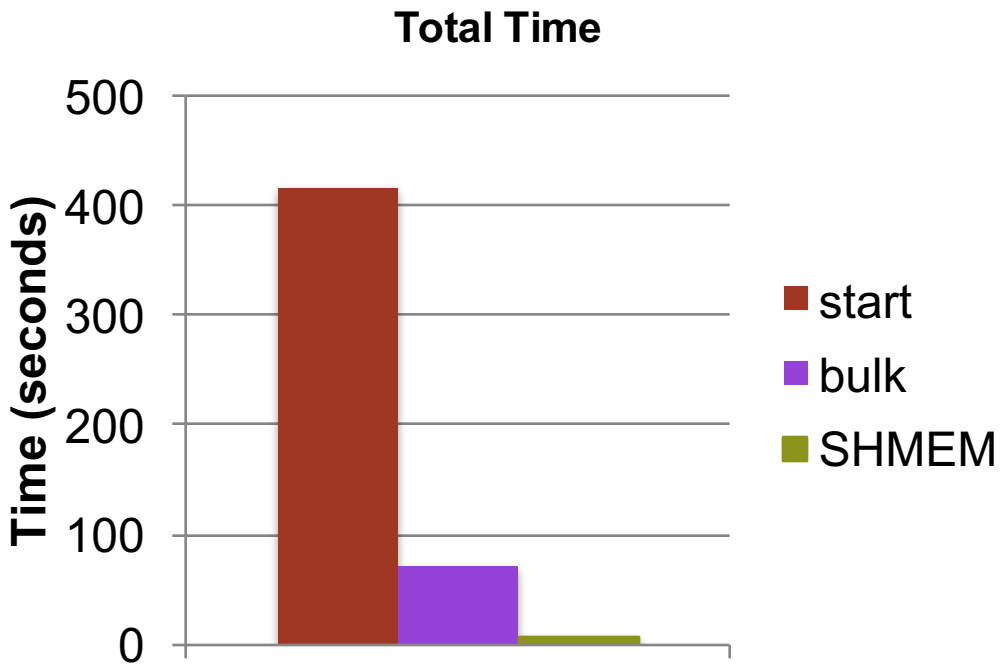
Chapel vs. SHMEM - Bulk Transfer

- **Solution: remove overly-conservative runtime check**
  - Prevented bulk transfers when slicing from the middle of an array
  - Near 6x improvement!

```
var A, B :[1..20] int;

// optimization works!
A[1..10] = B[1..10];

// Failed to bulk transfer!
// Fixed in 1.13 release
A[1..10] = B[5..15];
```



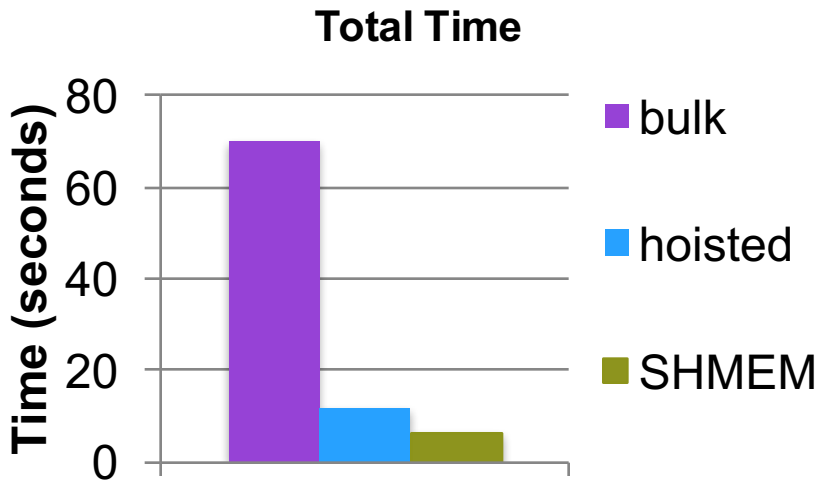
Chapel vs. SHMEM: Loop Hoisting

- Counting step slow (56s vs .2s)
- Solution: Manually optimize source code

```
for i in 0..#myBucketSize do
  keyCounts[allBucketKeys[taskID][i]] += 1; // loop-invariant
```

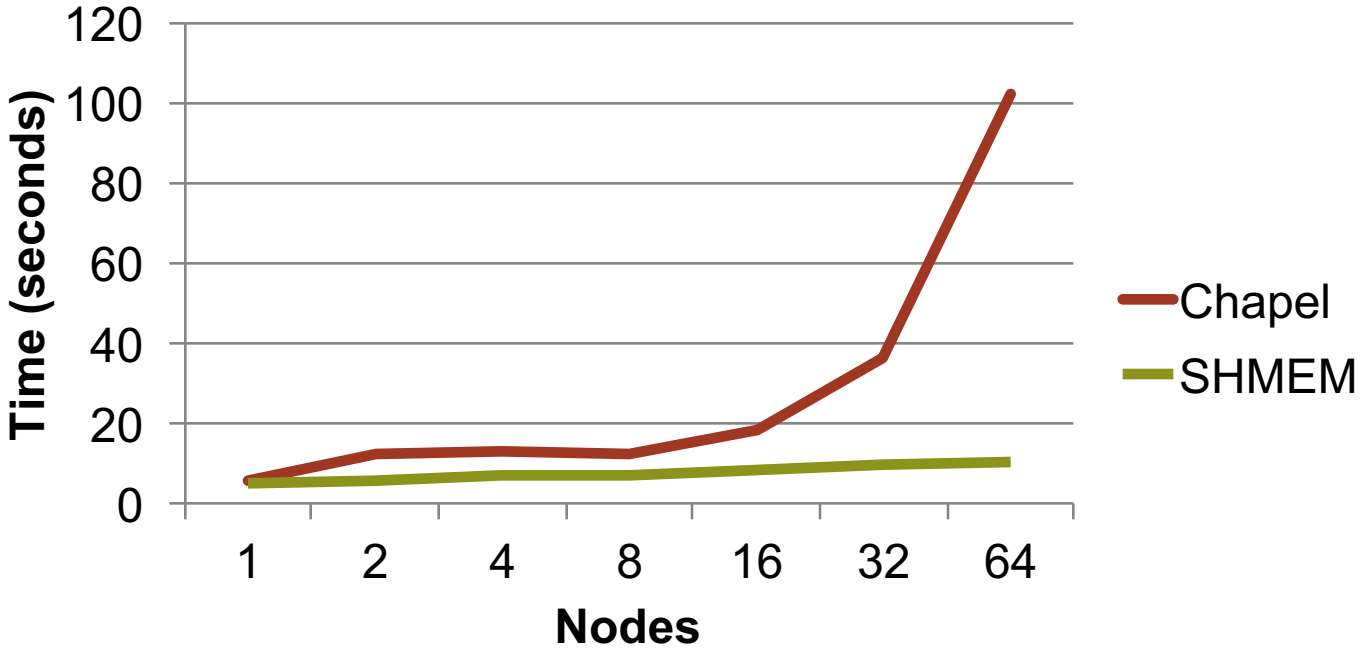
  - Manually hoisting helps tremendously
  - Compiler should perform this optimization in the future

- Result: immensely better
  - ~7x improvement
- Now, let's look at scaling…



Chapel vs. SHMEM: Scaling

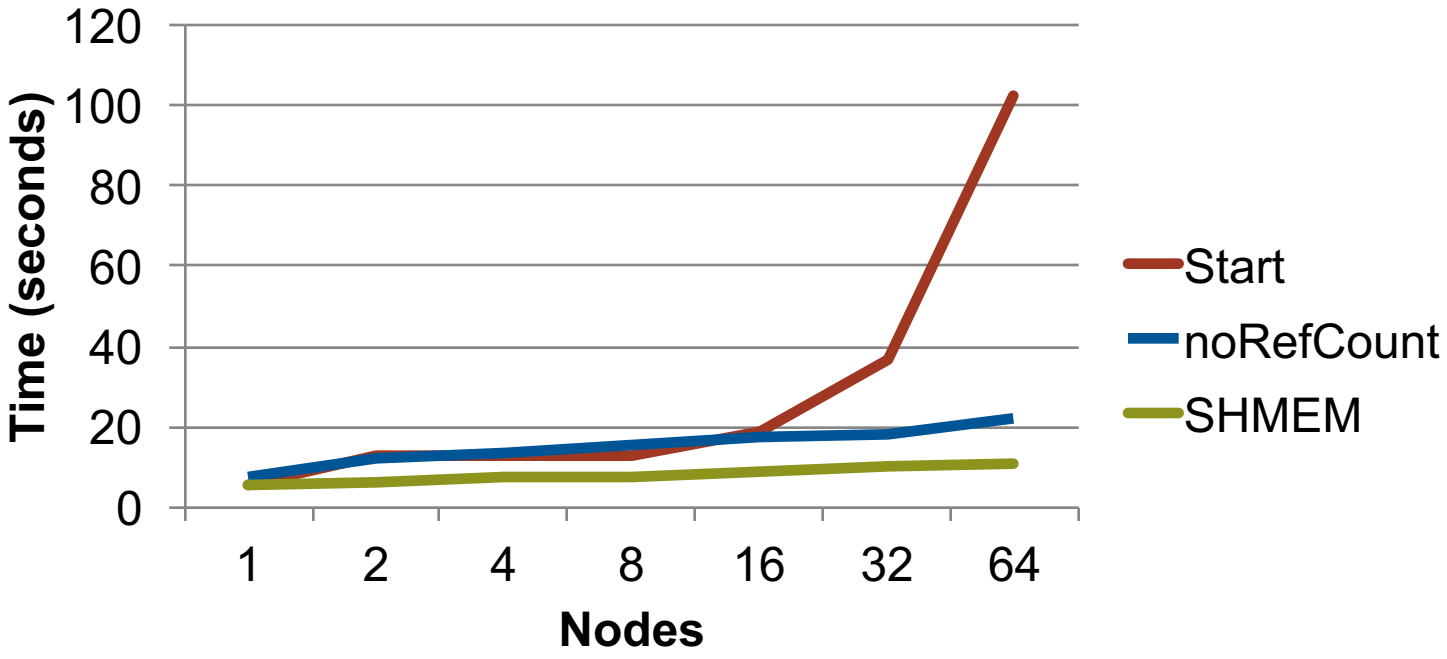
- Starts out OK, then goes off the rails…



- Exchange step still too long
  - ~96s vs SHMEM's ~8s

Chapel vs. SHMEM: Scaling

- **Bulk transfer is firing, what gives?**
- **Reference counting is a known source of overhead**
  - Especially for array/domain slicing…
  - Can be disabled with '–snoRefCount'



Chapel vs. SHMEM: Array Slicing

- **Observation: exchange is still slower than reference**
- **Suspicion: array slicing is at fault**
  - DefaultRectangular array slicing uses an on-statement
    - Ensures slices lives on same locale as actual array
  - # of ons equals numBuckets**2
- **Currently not a simple task to remove the on-statement**
  - Other optimizations rely on the existing semantics
- **Idea: avoid doing a full slice for bulk tranfers**
  - Recognize the slice is short-lived
  - Bulk transfer really only needs the slice's offset information

Conclusions

- **Easy to write in Chapel**
- **Without reference counting, about 2x worse**
  - Relatively good for Chapel, today
- **Future work for performance**
  - Improve reference counting
  - Better loop hoisting
  - Improve slicing performance

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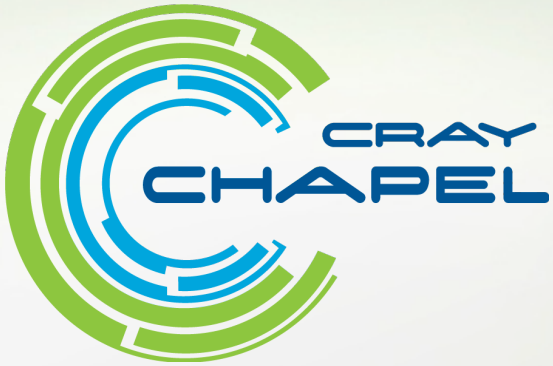

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