Towards Radix Sorting in the Chapel Standard Library

Michael Ferguson

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Outline

- Interface Design for Radix Sort
- Exploring Parallel Radix Sort Algorithms
- Comparing Single-Locale Performance
- Distributed Sorting

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Interface Design for Radix Sort

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Interface Design for Radix Sort

- Programming languages usually offer a sort library
- These normally include the ability to specify a comparison function
  - but that limits implementations to comparison sorting algorithms

- Some sorting libraries also allow specifying a key to sort by
  - easy to sort by a specific field in a structure
  - but no help for variable length keys

- Would like to improve on this situation
  - to enable radix sorting in most cases
  - including the common case of sorting by variable-length strings

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The .key method

```
use Sort;
record MyRecord { var key: int; var value: int; }
record MyKeyComparator {
  proc key(element: MyRecord) {
    return element.key; // now uses radix sorting for integral keys
  }
}
config const n = 10000;
var A: [1..n] MyRecord = [i in 1..n] new MyRecord(i, i*i);
sort(A, new MyKeyComparator());
```

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The .keyPart method

```
use Sort;
record MyRecord { var key: c_string; var value: int; }
record MyKeyPartComparator { }
  proc keyPart(element: MyRecord, i: int) {
    var byte = element.key[i-1]; // compute the current key byte
    // has the end been reached? Note, c_strings have a 0 terminator
    var done = if byte != 0 then 0 else -1;
    return (done, byte);
} }
var A:[1..n] MyRecord = ...;
sort(A, new MyKeyPartComparator());
```

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How .keyPart supports variable length keys

- Say we are sorting strings
- Which comes first?
  - "badminton"
  - "bad"
- keyPart returns a tuple to indicate the ordering here
- Tuple consists of (section, part)
  - (-1, part) ⇢ sort this key before those with more data
  - (0, part) ⇢ sort based on key data in part
  - (1, part) ⇢ sort this key after those with more data

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Exploring Parallel Radix Sort Algorithms

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Algorithms Explored

- Two most-significant digit first counting radix sorts
  - Recursive algorithm with serial bucketize inspired by [1]
  - Two-array algorithm with parallel bucketize

[1] Peter M McIlroy, Keith Bostic, and M Douglas McIlroy. 1993. Engineering radix sort. Computing systems 6, 1 (1993), 5–27.

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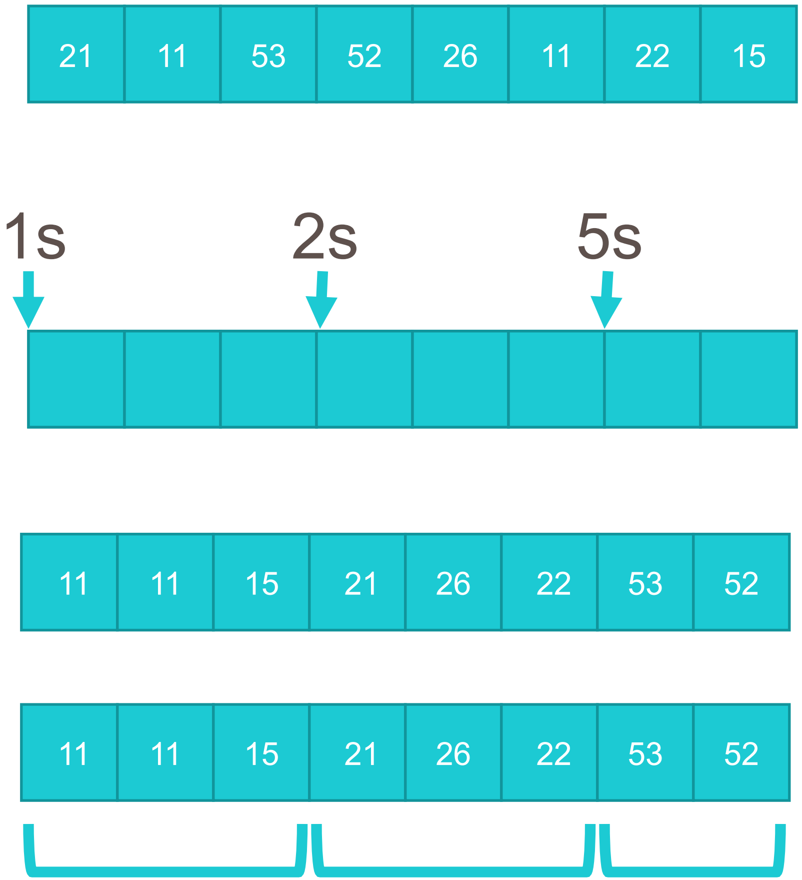

Count 1st digit:

3x '1' 3x '2' 2x '5'

Scan to find bin starts

Bucketize: move into bins

Continue with next digit within each bin

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Recursive Algorithm

```
proc recursiveSort(start, end, A, digit) {
  // local arrays for byte counts and offsets
  var counts, offsets : [0..#256] int;
  parallelCountAndScan(...)
  sequentialInPlaceBucketize(...);  // repeated swapping of current item
  forall bins do
    // recursively calls algorithm
    recursiveSort(binStart, binEnd,
                  A, digit+1);
}
```

Drawbacks:

- Limited parallel speedup
- Lots of array allocations
- Not a stable sort

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Iterative Algorithm

```
var counts, offsets : [0..#256] int; // just one of each per sort call
proc twoArraySort(start, end, A, Scratch, digit) {
  bigTasks.push( ... );
  while !bigTasks.isEmpty() {
    task = bigTasks.pop();
    parallelCountAndScan(...);
    parallelBucketizeToScratch(...)
    for bins do append task to bigTasks or smallTasks
  }
  forall tasks in smallTasks do baseCaseSort(...)
}
```

Drawbacks:

Uses 2n space

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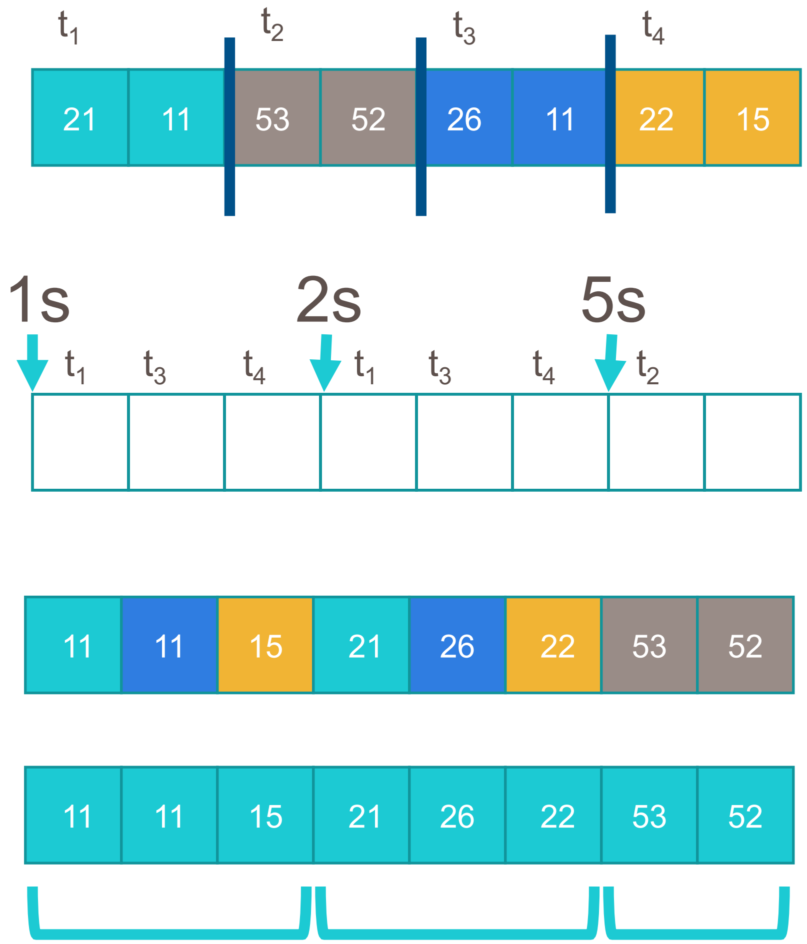

Count 1st digit:

3x '1' 3x '2' 2x '5'

Scan to find bin starts

Bucketize: move into bins

Continue with next digit within each bin

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Comparing Single-Locale Performance

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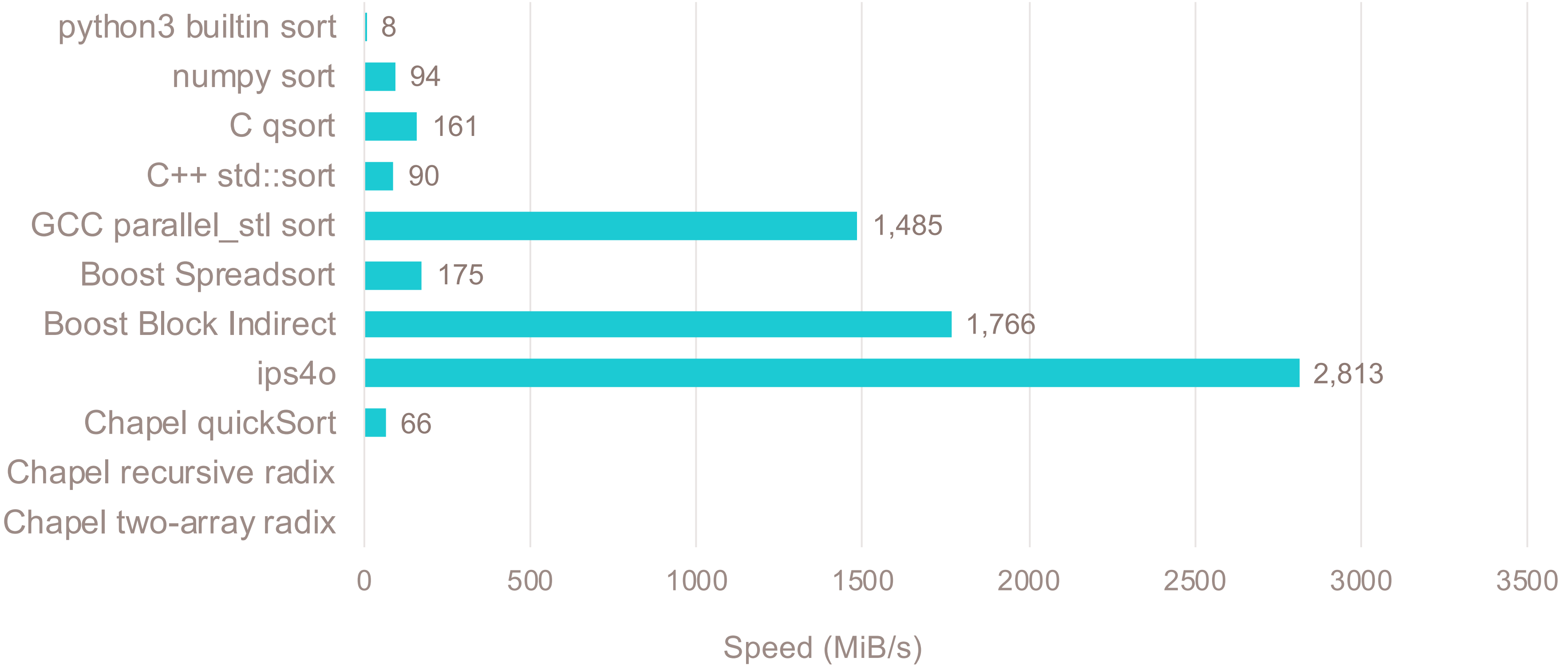
Sorting 1GiB of random uint(64): Broadwell



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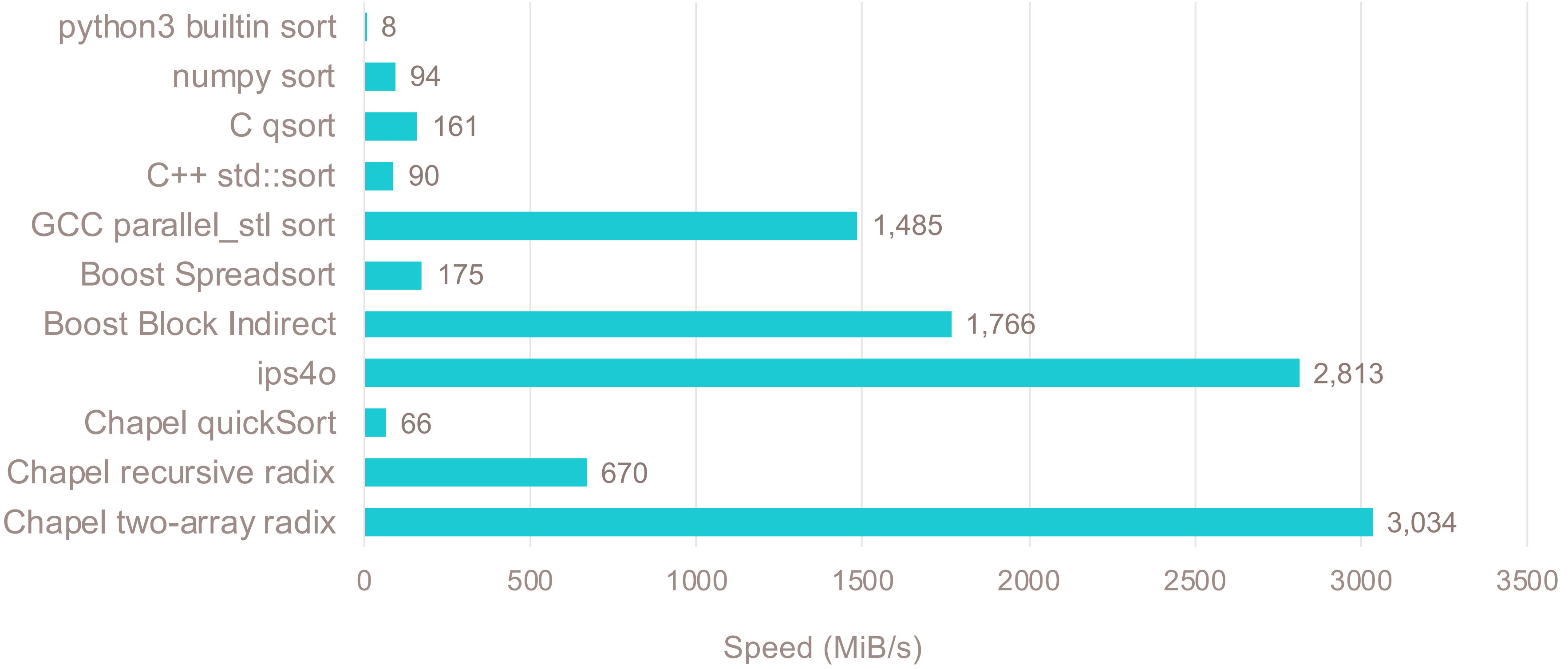
Sorting 1GiB of random uint(64): Broadwell



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Distributed Sorting

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Distributed Two-Array Algorithm

```
proc distSort(start, end, A, Scratch, digit) {
  while !distTasks.isEmpty() {
    countAndBucketizeLocalDataToScratch(...) on each locale
    for bins do append task to distTasks or localTasks
  }
  forall tasks in localTasks do twoArraySort(...)
}
```

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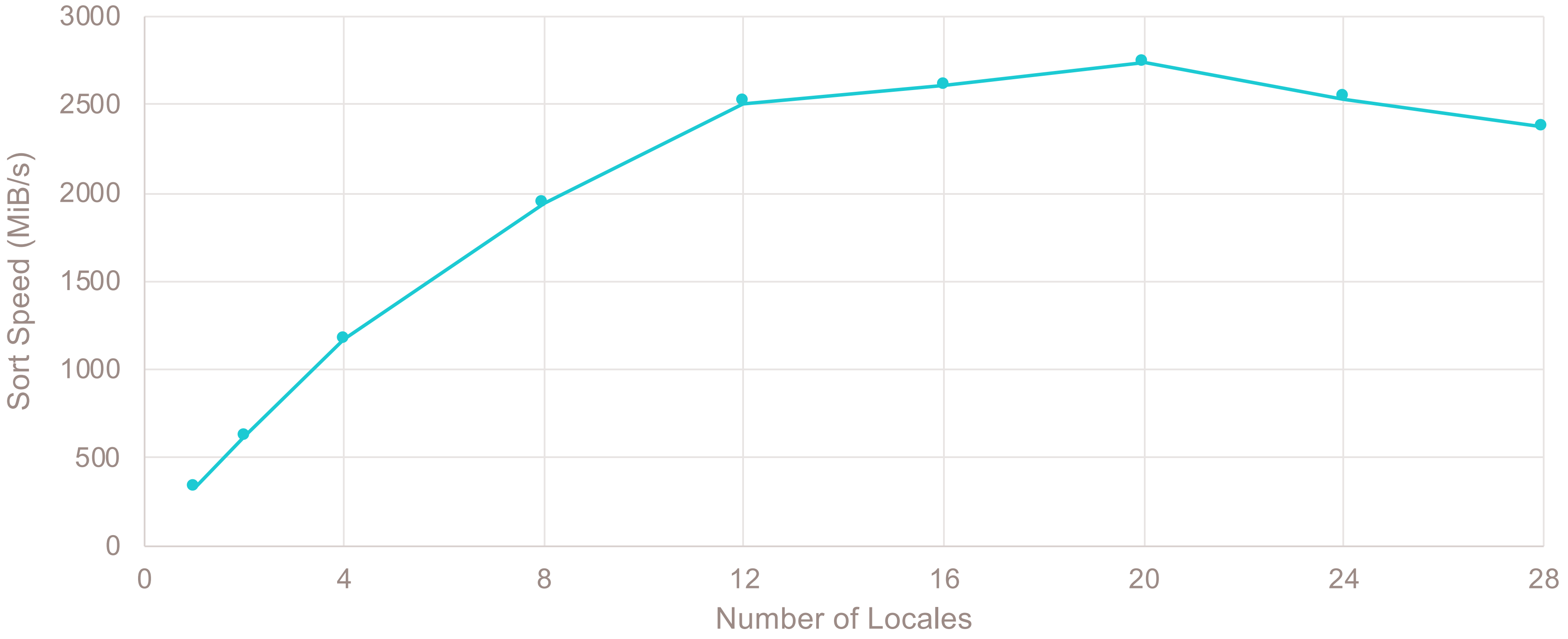
Strong Scaling on Broadwell, sorting 100 M uint



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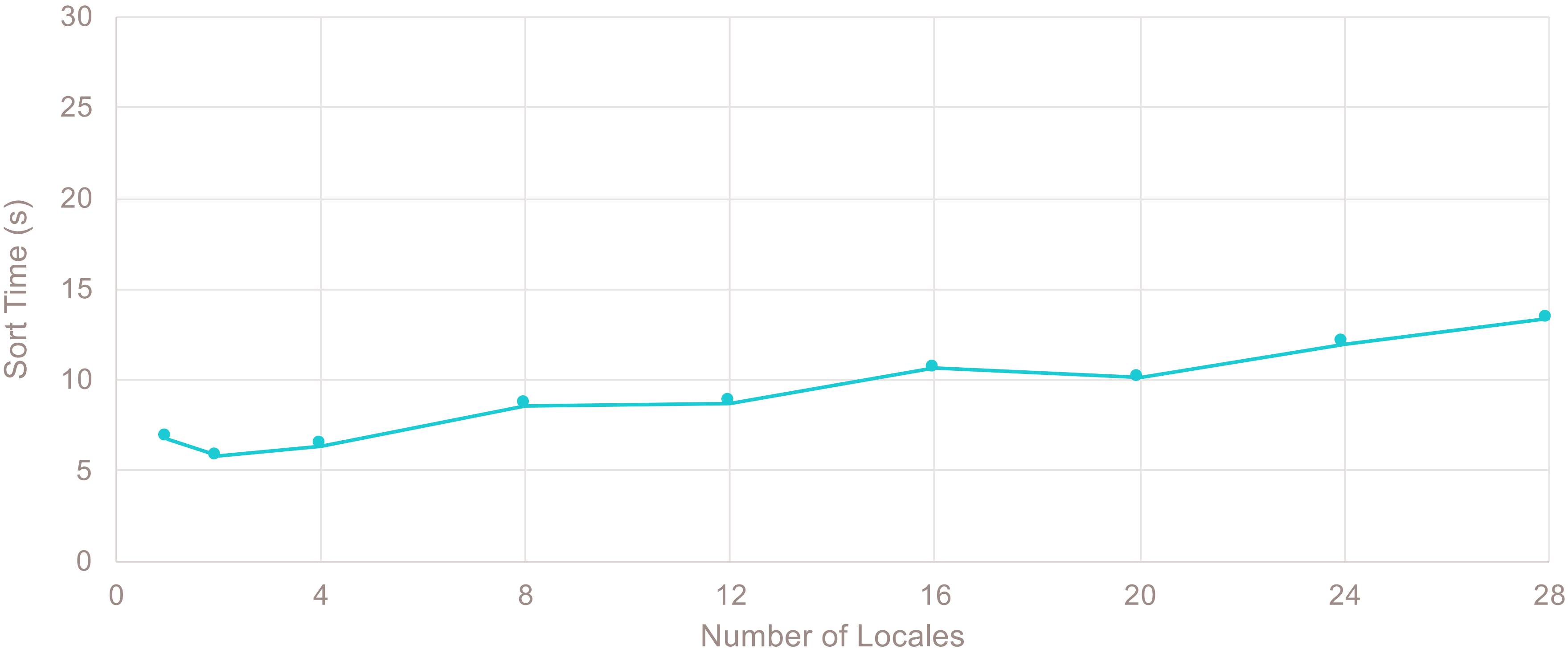
Weak Scaling on Broadwell sorting numLocales*100 M uint



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Future Work

- Put two-array sorting and distributed sorting on master
- Explore in-place one-pass parallel bucketizer as with ips4o [2]
- Support sample sort
  - when only comparison function is provided
  - for very data with skewed data distribution

Thanks to: Rupal Jain and Avneet Kaur (Rails Girls Summer of Code 2018)

References:

[1] Peter M McIlroy, Keith Bostic, and M Douglas McIlroy. 1993. Engineering radix sort. Computing systems 6, 1 (1993), 5–27.

[2] Michael Axtmann, Sascha Witt, Daniel Ferizovic, Peter Sanders. In-Place Parallel Super Scalar Sample Sort. arXiv:1705.02257v2 [cs.DC] 29 Jun 2017

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chapel_info@cray.com
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