Introduction to Parallel Computing (CMSC498X / CMSC818X)

Lecture 8: Designing Parallel Algorithms

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Announcements

- Assignment 1 has been released and due on October 5
- Project descriptions are due on September 28
- Quiz on September 30, due on October 1

Writing parallel programs

- Decide the serial algorithm first
- Data: how to distribute data among threads/processes?
  - Data locality: assignment of data to specific processes to minimize data movement
- Computation: how to divide work among threads/processes?
- Figure out how often communication is needed

Prefix sum

- Calculate partial sums of elements in array
- Also called a “scan” sometimes

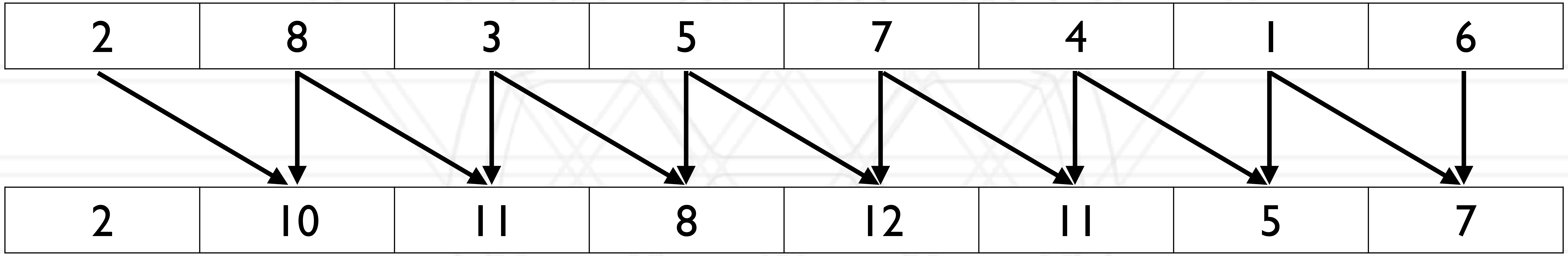
```
pSum[0] = A[0]

for(i=1; i<N; i++) {
    pSum[i] = pSum[i-1] + A[i]
```

1	2	3	4	5	6	…
1	3	6	10	15	21	…

Parallel prefix sum

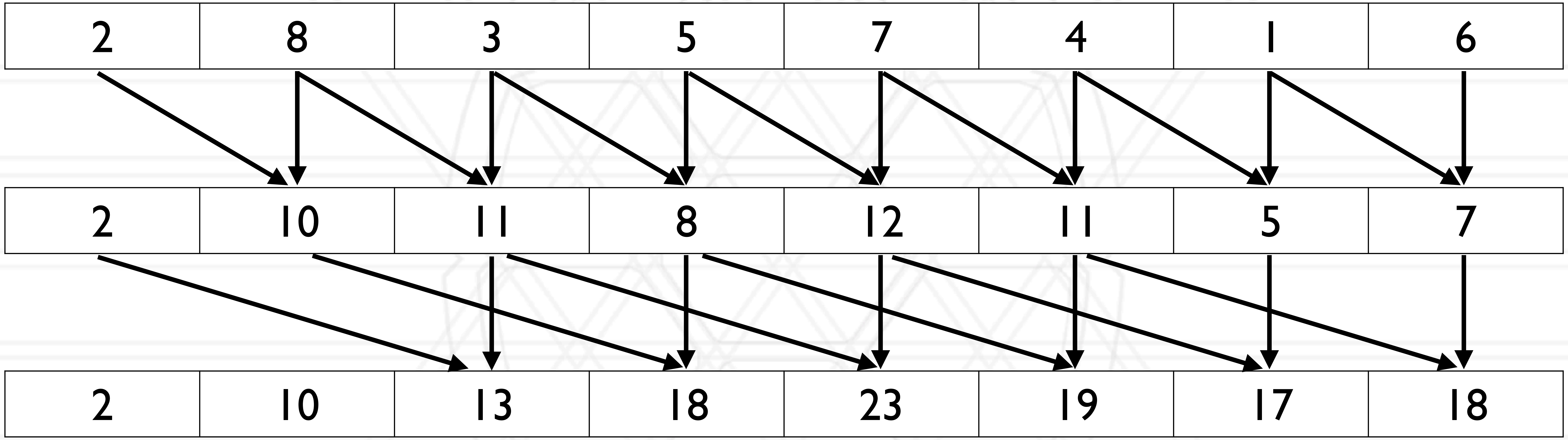
2	8	3	5	7	4	1	6

Parallel prefix sum



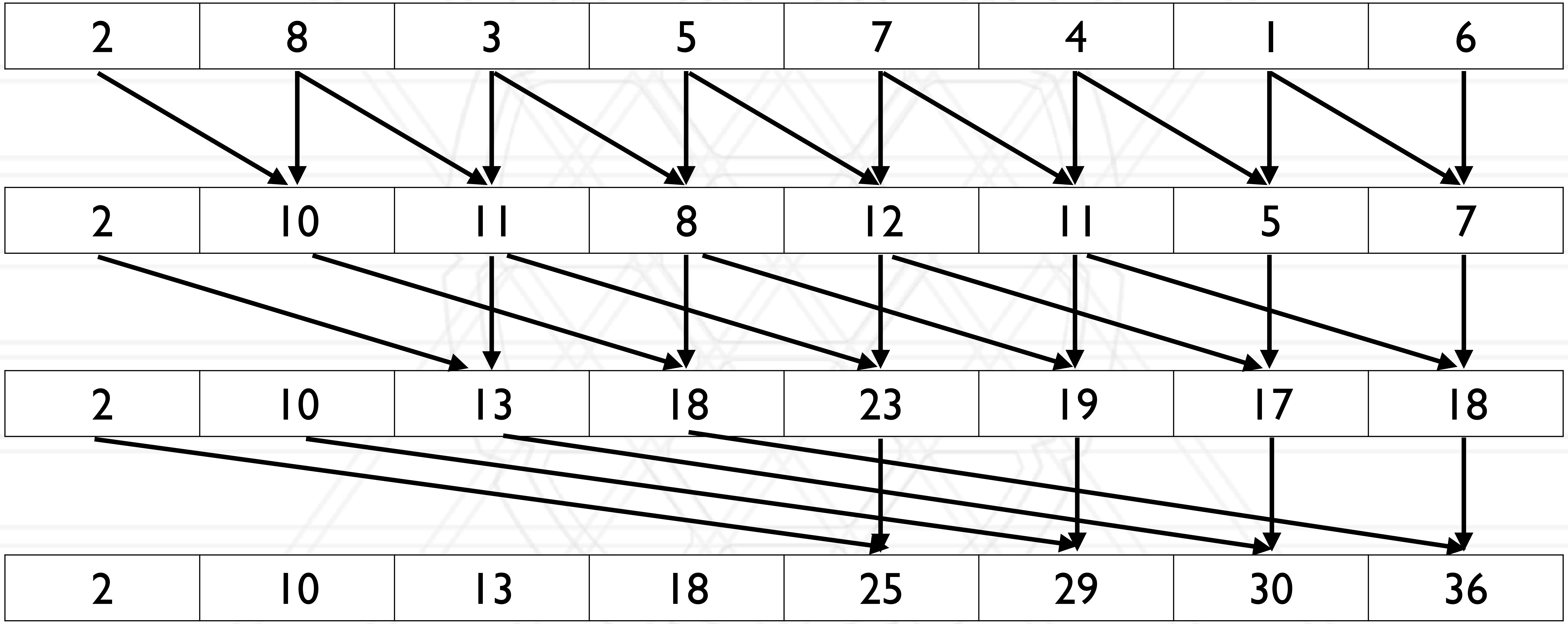
2	8	3	5	7	4	1	6
2	10	11	8	12	11	5	7

Parallel prefix sum



2	8	3	5	7	4	1	6
2	10	11	8	12	11	5	7
2	10	13	18	23	19	17	18

Parallel prefix sum



2	8	3	5	7	4	1	6
2	10	11	8	12	11	5	7
2	10	13	18	23	19	17	18
2	10	13	18	25	29	30	36

In practice

- You have N numbers and P processes, N >> P
- Assign a N/P block to each process
  - Do calculation for the blocks on each process locally
- Then do parallel algorithm with partial prefix sums

Parallel Sorting

- Sorting is used in many HPC codes
- For example, figuring out which particles/atoms are within a cutoff radius
- Two broad categories of parallel sorting algorithms:
  - Merge-based
  - Splitter-based

Review QuickSort

- Choose a pivot element from the unsorted list
- Move all elements < pivot before the pivot and all elements > pivot after the pivot
- Recursively apply this to the sublists before and after pivot

Sample Sort

- Generalization of QuickSort
- Instead of selecting one pivot, we select s-1 samples randomly
  - This provides us with s-1 "splitters"
- Once sorted, these s-1 splitters create s buckets
- Keys are then placed in the appropriate bucket
- Call sample sort or quick sort recursively

Parallel Sample Sort

- Assumption: keys are distributed across all processors in the beginning
- Sample s keys randomly from each process
- Bring all keys s * p keys to one process
  - select p-1 splitters from this sorted sample
- Send all splitters to all processes
- Processes exchange data based on buckets
- Call some fast sorting algorithm locally

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