Parallel Databases

R&G Chapter 22

(slides adapted from content by J.Gehrke, J.Shanmugasundaram, and/or C.Koch)

Creating Parallelism

- Division of Labor:
  - Stages of Execution: Pipeline Parralellism
  - Parts of Data: Partition Parallelism
- Benefits: Speed Up vs Scale-Up
- Architectures:
  - Shared Memory, Shared Disk, Shared Nothing

Creating Parallelism

- Inter-Operator Parallelism
  - (Mostly) Easy: Partition operators between nodes.
- Inter-Query Parallelism
  - Hard: Need to deal with xacts (next lecture)
- Intra-Operator Parallelism
  - Our focus for today.

Partitioning the Data

- Which machine does a data value end up at?
- Range Partitioning:
  - Split data up into N ranges.
- Hash Partitioning
  - Split data up based on hash value.
- Round Robin
  - Value 1 to machine 1, 2 to machine 2, etc…

Parallel Sorts

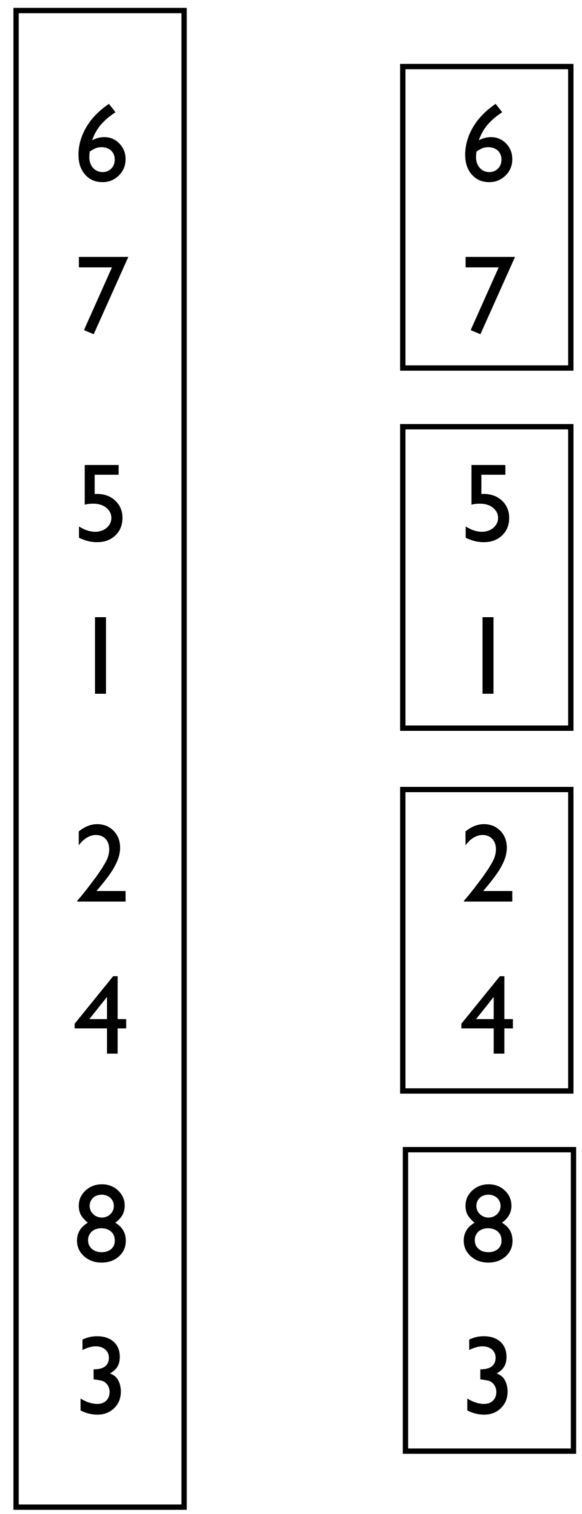
- Record as of March 2013: TritonSort (UCSD)
  - 0.725 TB/Min using 52 nodes
    - 1 Trillion Records in ~2.5 min
  - http://sortbenchmark.org
  - http://sortbenchmark.org/2011_06_tritonsort.pdf

Parallel Sorts

6
7
5
1
2
4
8
3

Parallel Sorts

Partition



Parallel Sorts

Partition

Local Sort

6	6
7	7
5	1
1	5
2	2
4	4
8	3
3	8

Parallel Sorts

Partition

Local Sort

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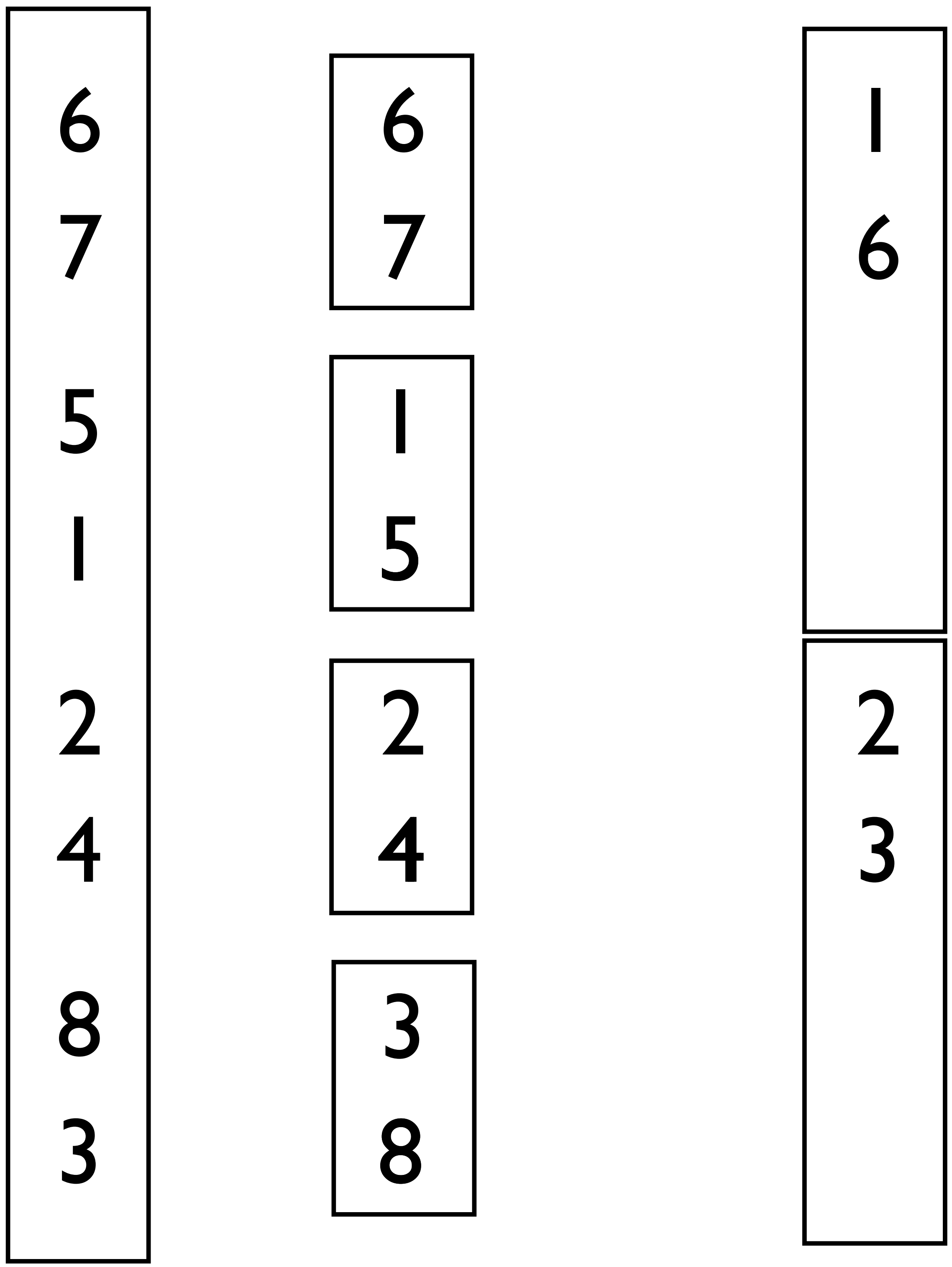
Parallel Sorts

Partition

Local Sort

Merge Sort



Parallel Sorts

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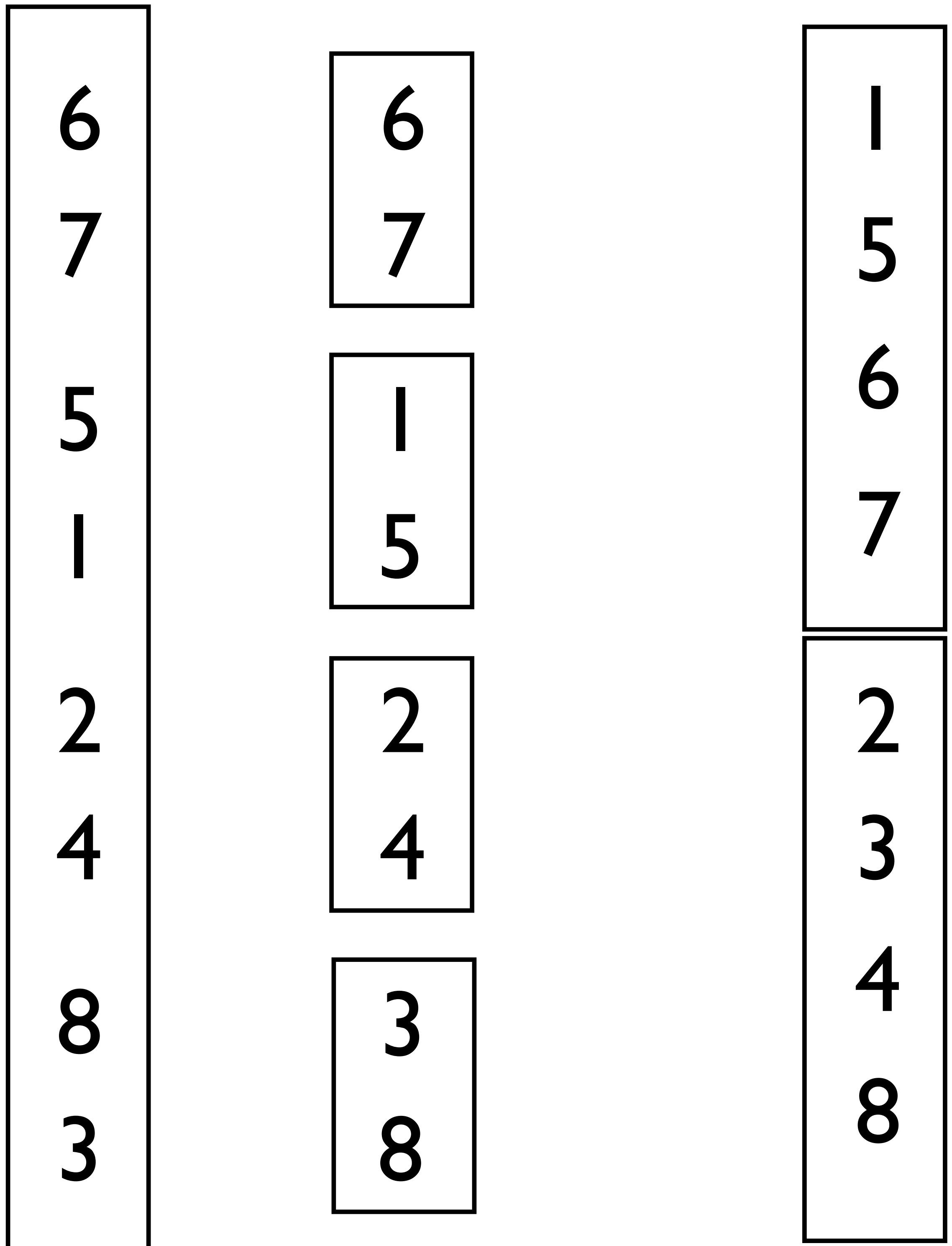
Merge Sort



Parallel Sorts

Partition

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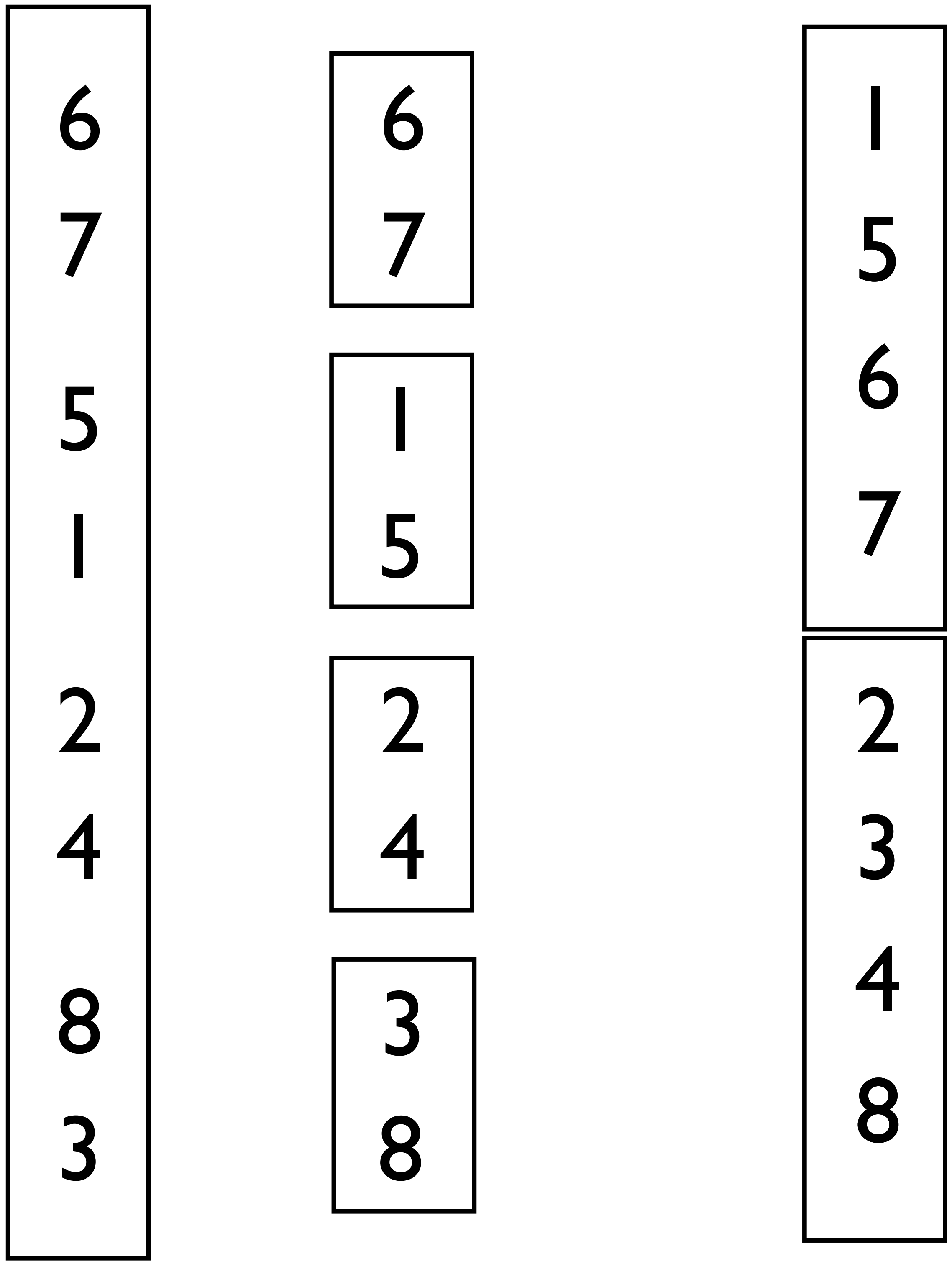
Merge Sort



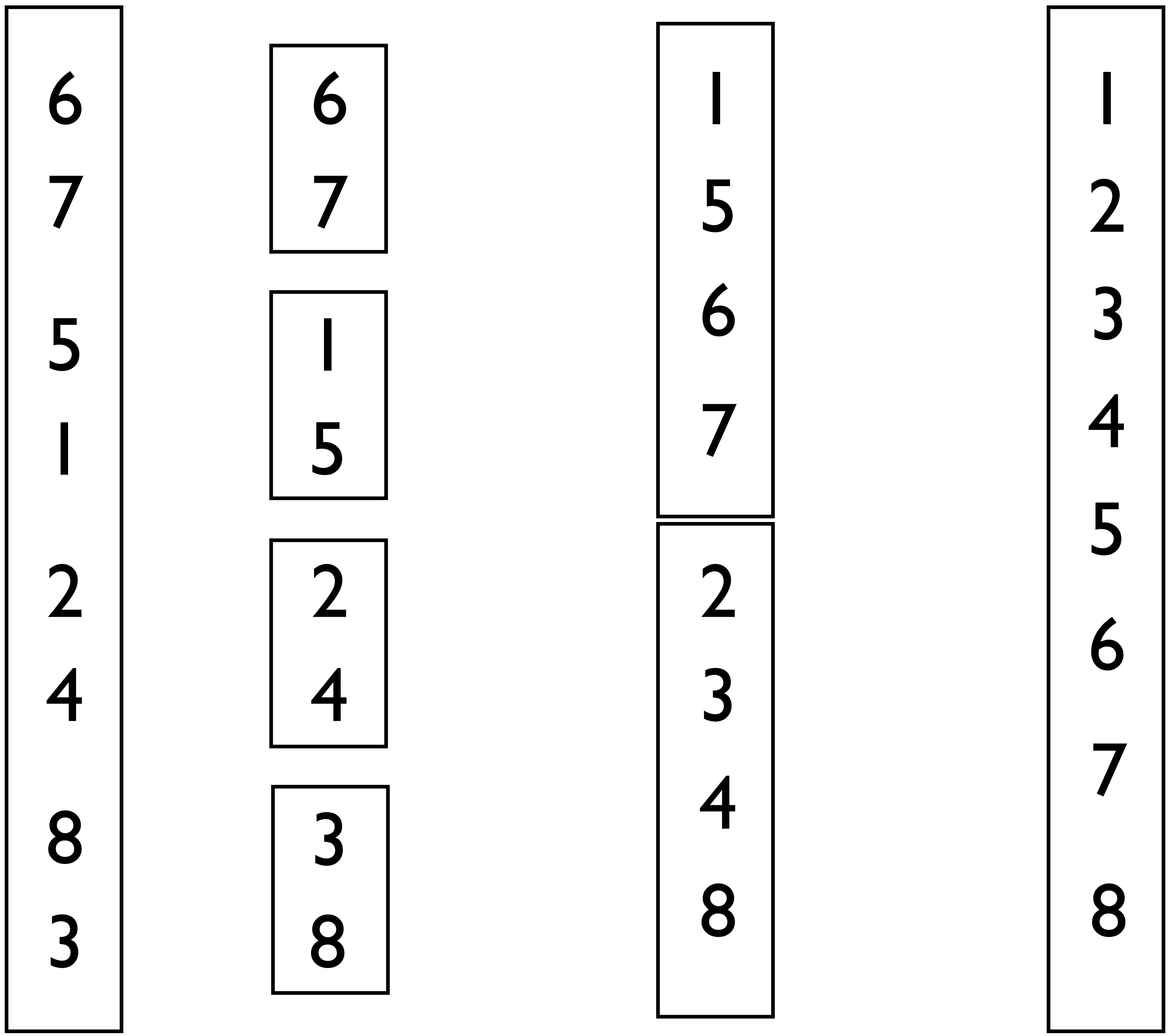
Parallel Sorts

Partition

Local Sort

Merge Sort

Recur



Parallel Sorts

- General Strategy
  - Scan in parallel
  - Range partition to other nodes
  - As tuples come in, sort locally
- Problem: Skew!
  - How do we pick partition boundaries?

Parallel Scans

- Scan the data separately on each machine
- Merge the results together
  - E.g., compute SUM(X) on each machine
  - SUM all computed SUM(X)
- May not need all machines to participate.
- We can build an index at each site.

Parallel Aggregates

- Aggregate Functions:
  - Distributive: F(A,B,C,D) = F(F(A,B),F(C,D))
  - Algebraic: F(A,B,C,D) = G(H(A,B),H(C,D))
  - Holistic: Can't decompose F.
- What are some examples of each?
- How do we exploit this for ||ism?

Parallel Group By

- Compute partial aggregates locally for each group.
- Use hash group-by columns to partition groups.
- Send partial aggregate to a site for each group.
- Each group's site merges partial aggregates.

Parallel Joins-NLJ

- Analogous to Block-NLJ
- One site computes each block-pair.

image credit: openclipart.org

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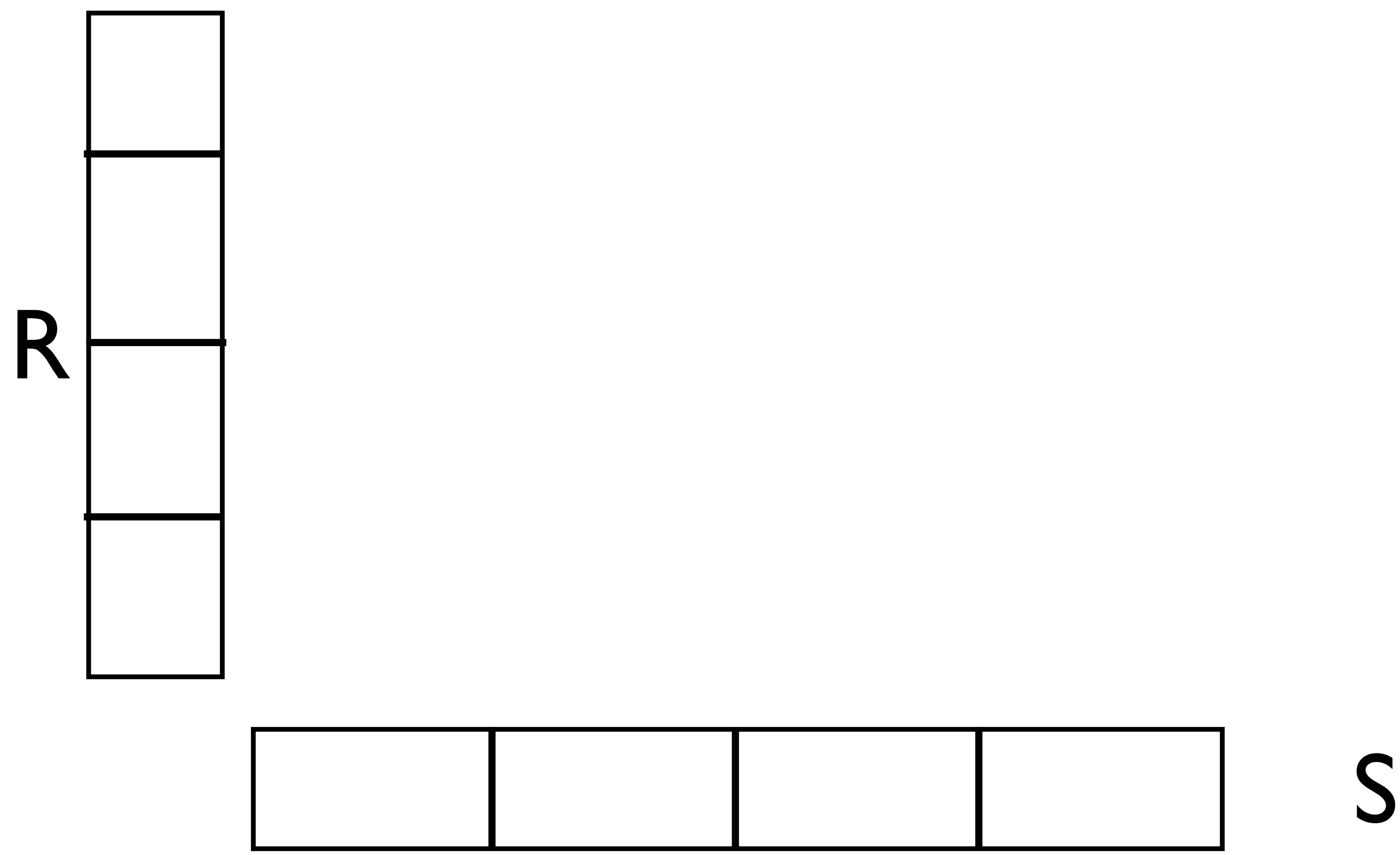

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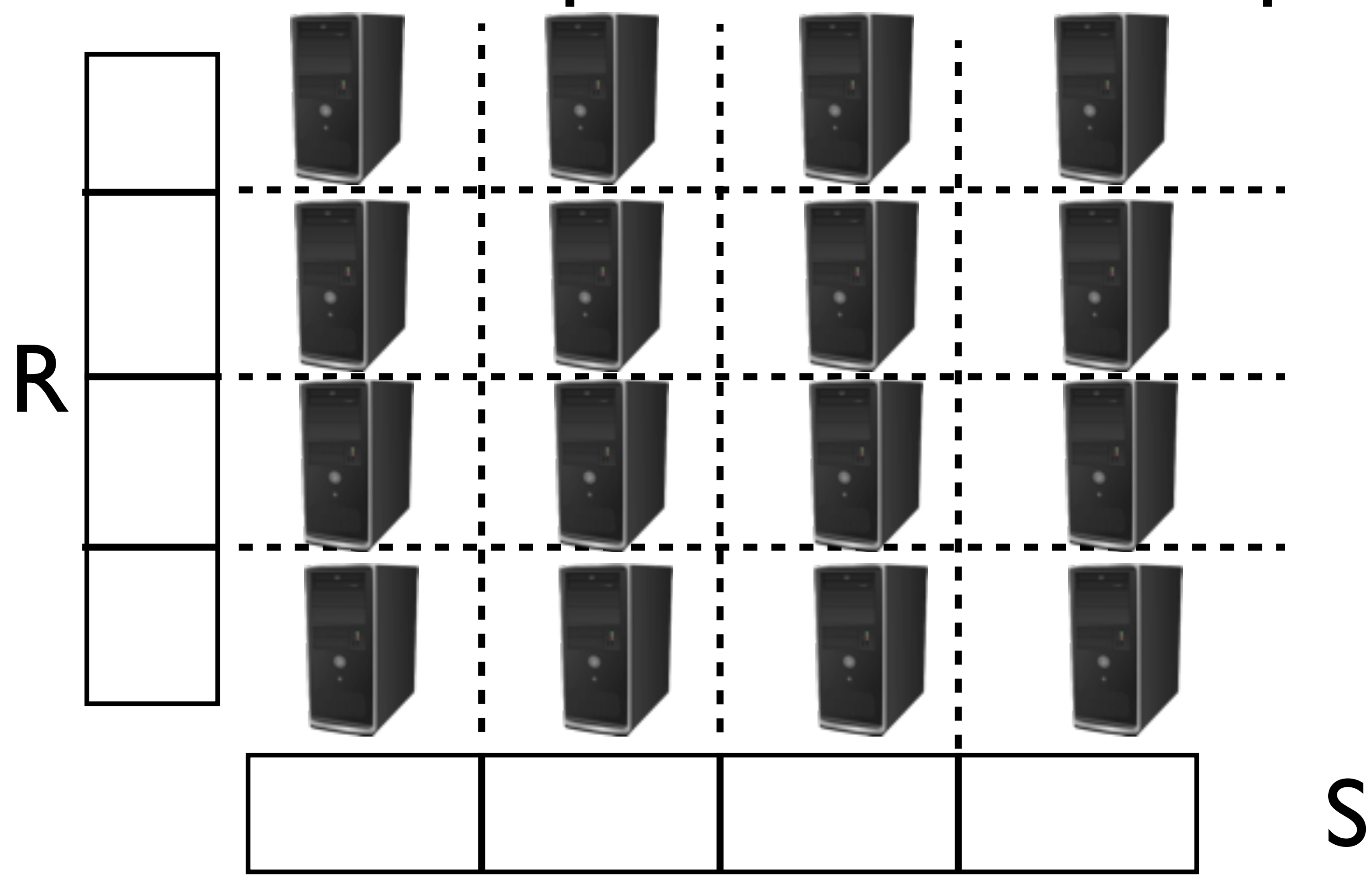

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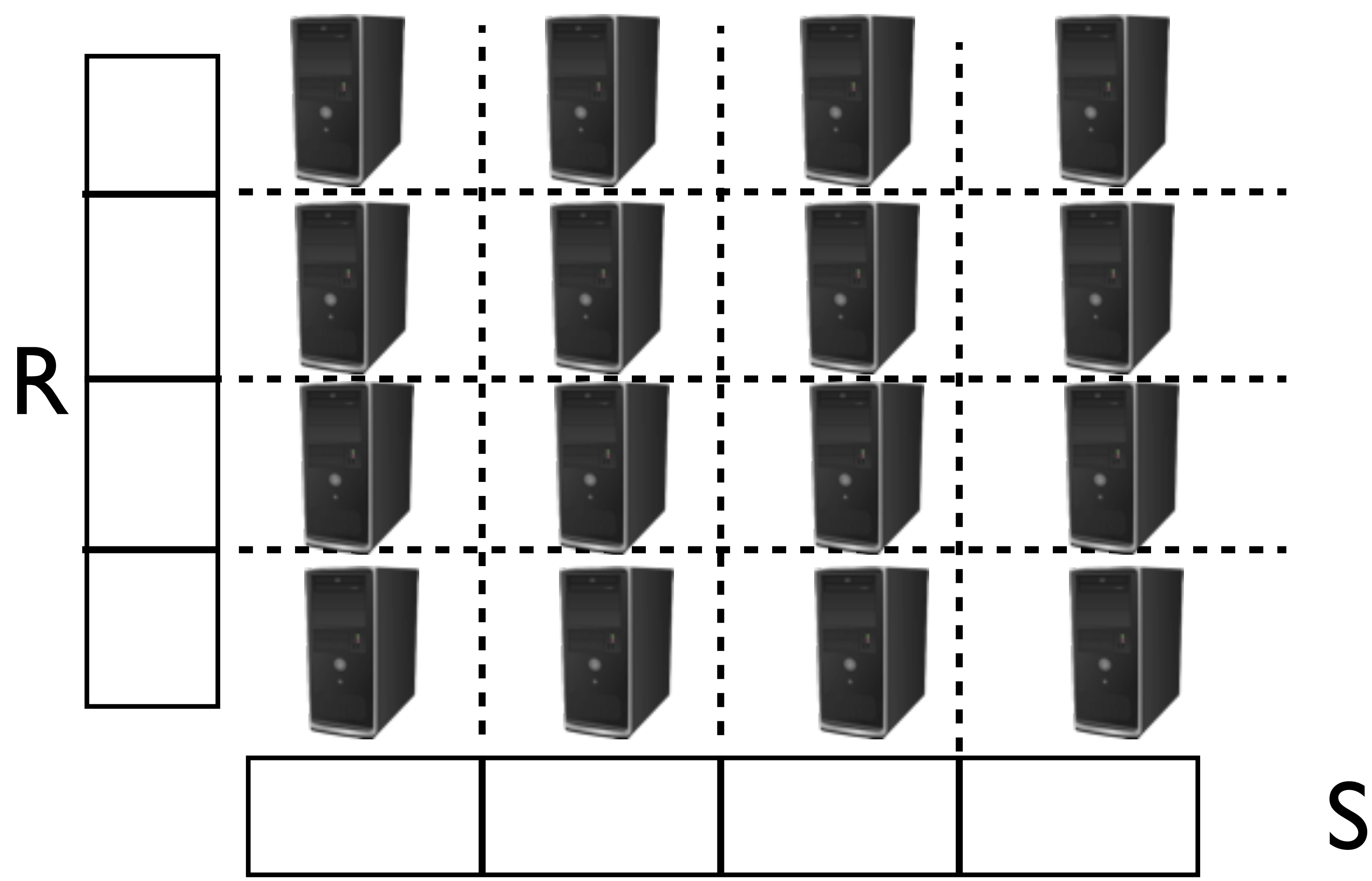
Parallel Joins-NLJ

- **Optimization**: Skip blocks that are guaranteed to be empty



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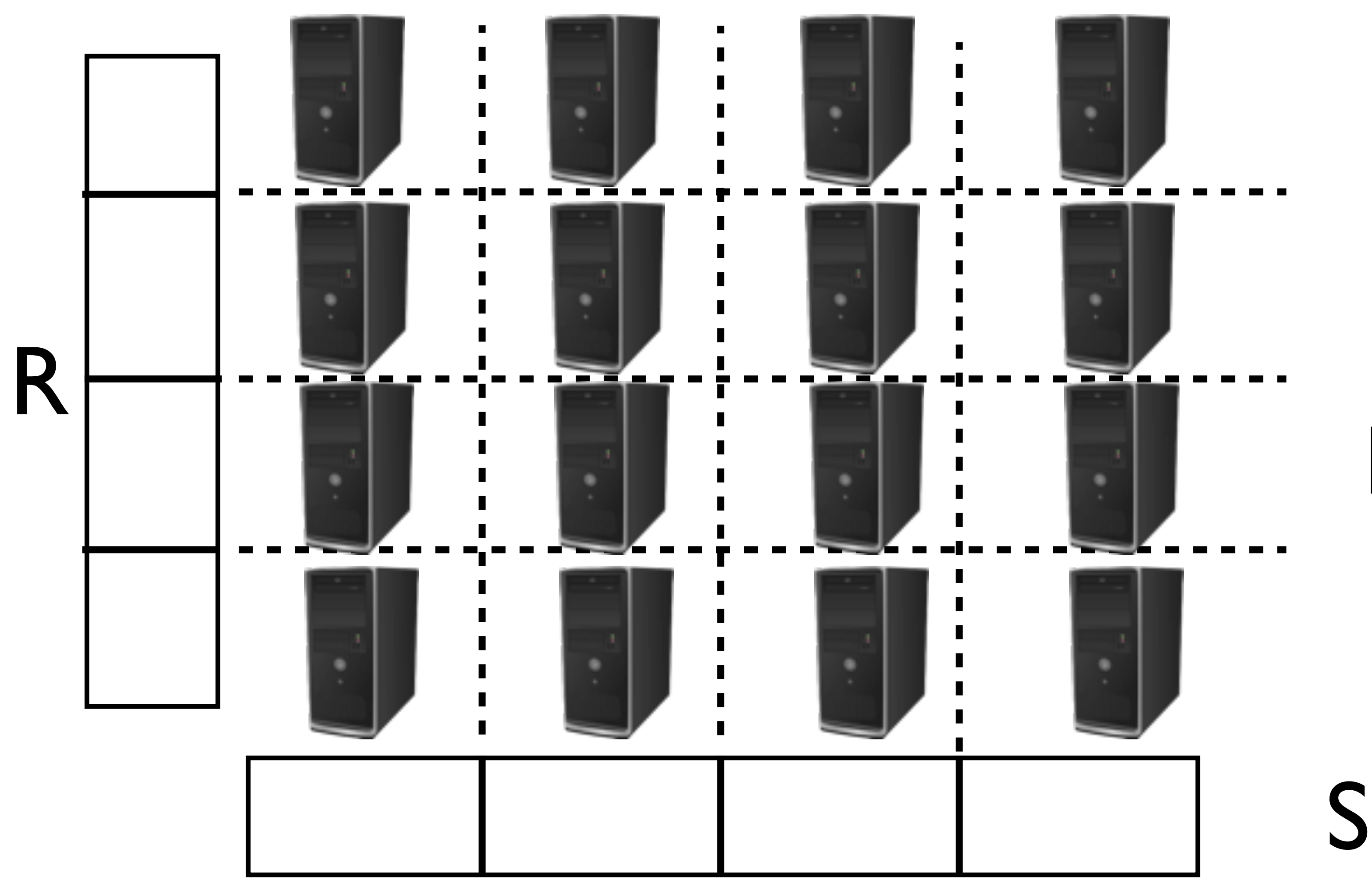


```
SELECT …
FROM R,S
WHERE R.A>S.B
```

R: Range on A

S: Range on B

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Parallel Joins-NLJ

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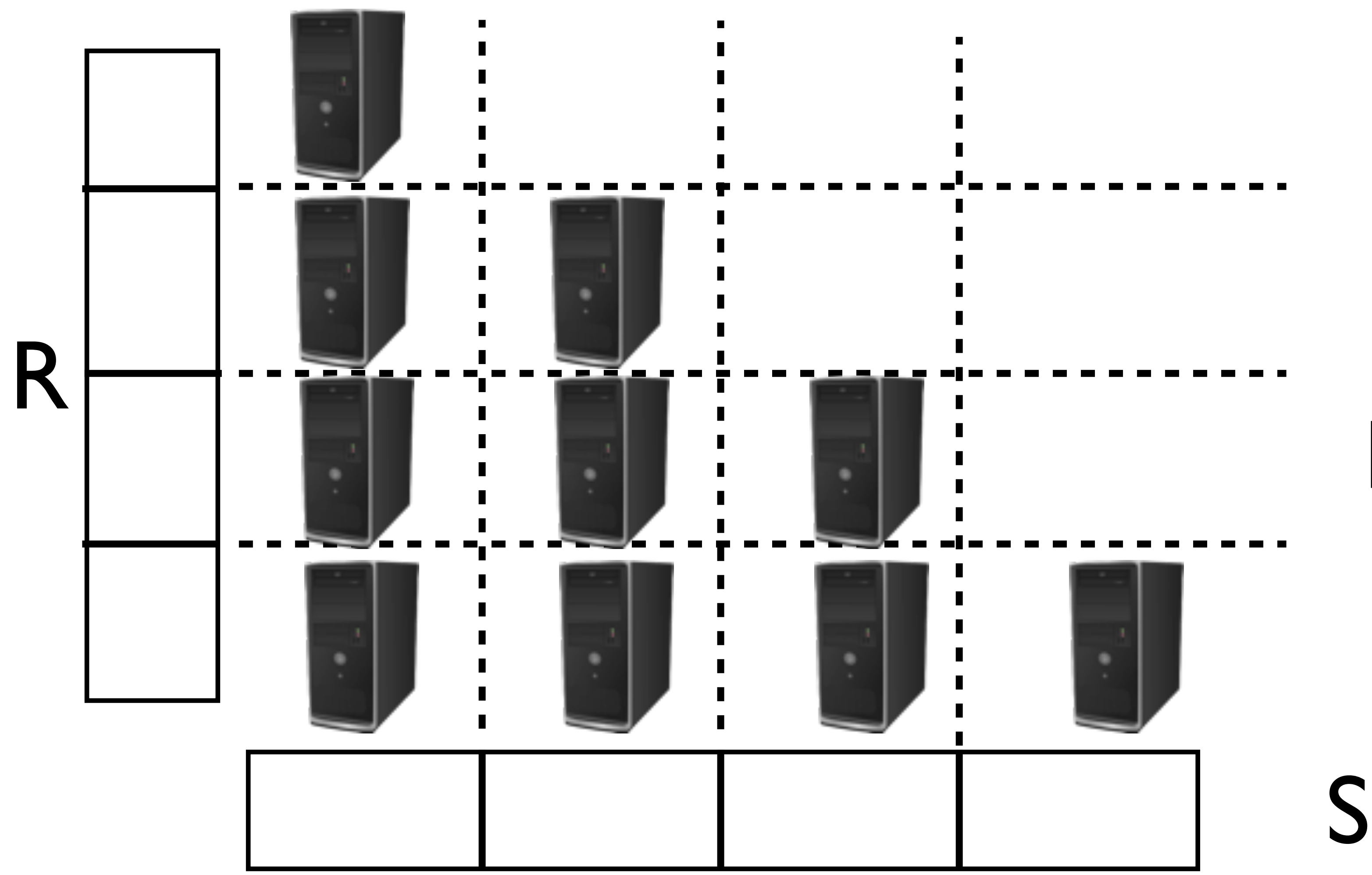


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R: Range on A

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Parallel Joins-NLJ

- **Limitation**: Requires a large amount of network communication.
  - Why does this happen?
  - Why is this a problem?
  - What can be done about it?

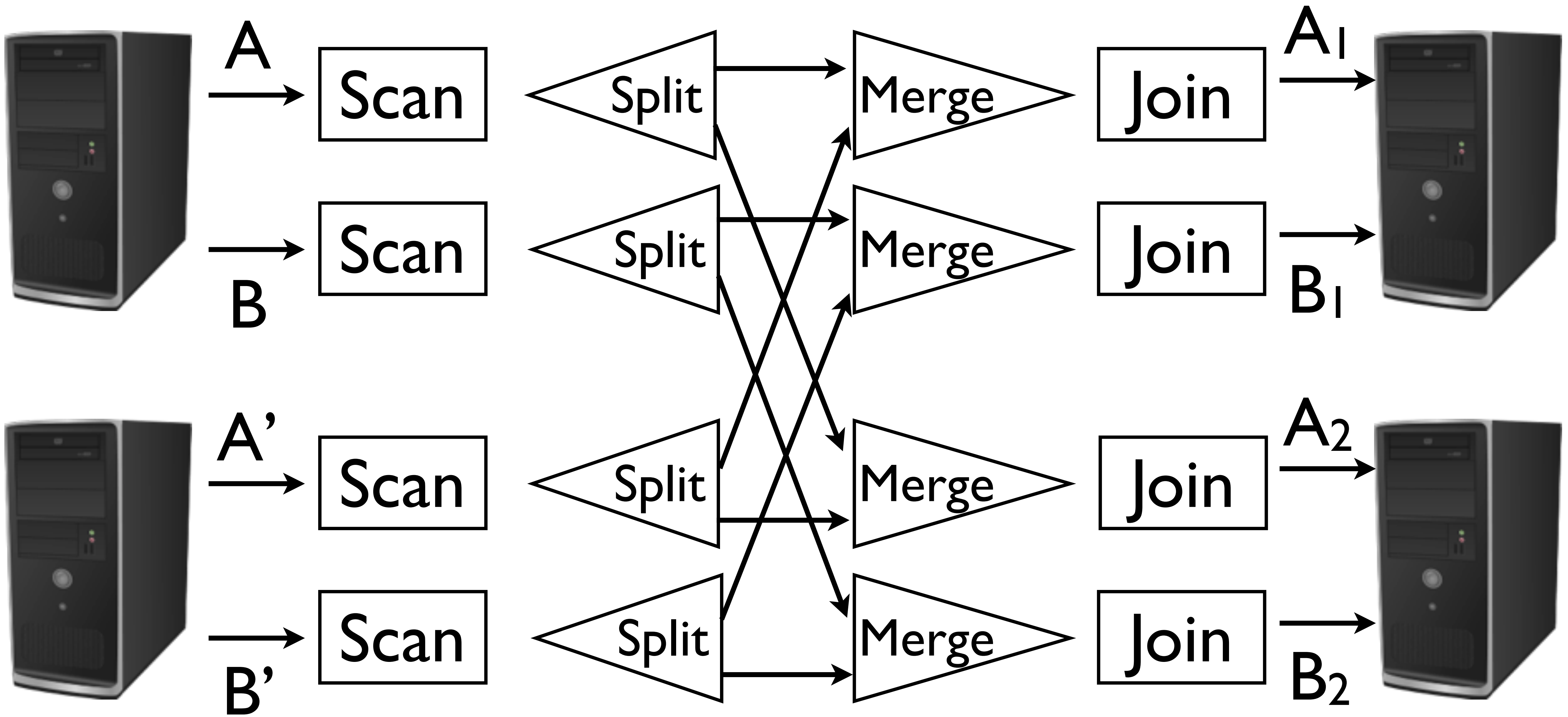
Parallel Joins-Merge Join

- Case 1: Identical Range Partitioning
  - Devolves to Single-Site Sort/Merge
- Case 2: Different Partitioning Schemes
  - Sorting gives range partitions! (what about skew?)
- Case 3: Similar Range Partitioning
  - How would you handle this case?

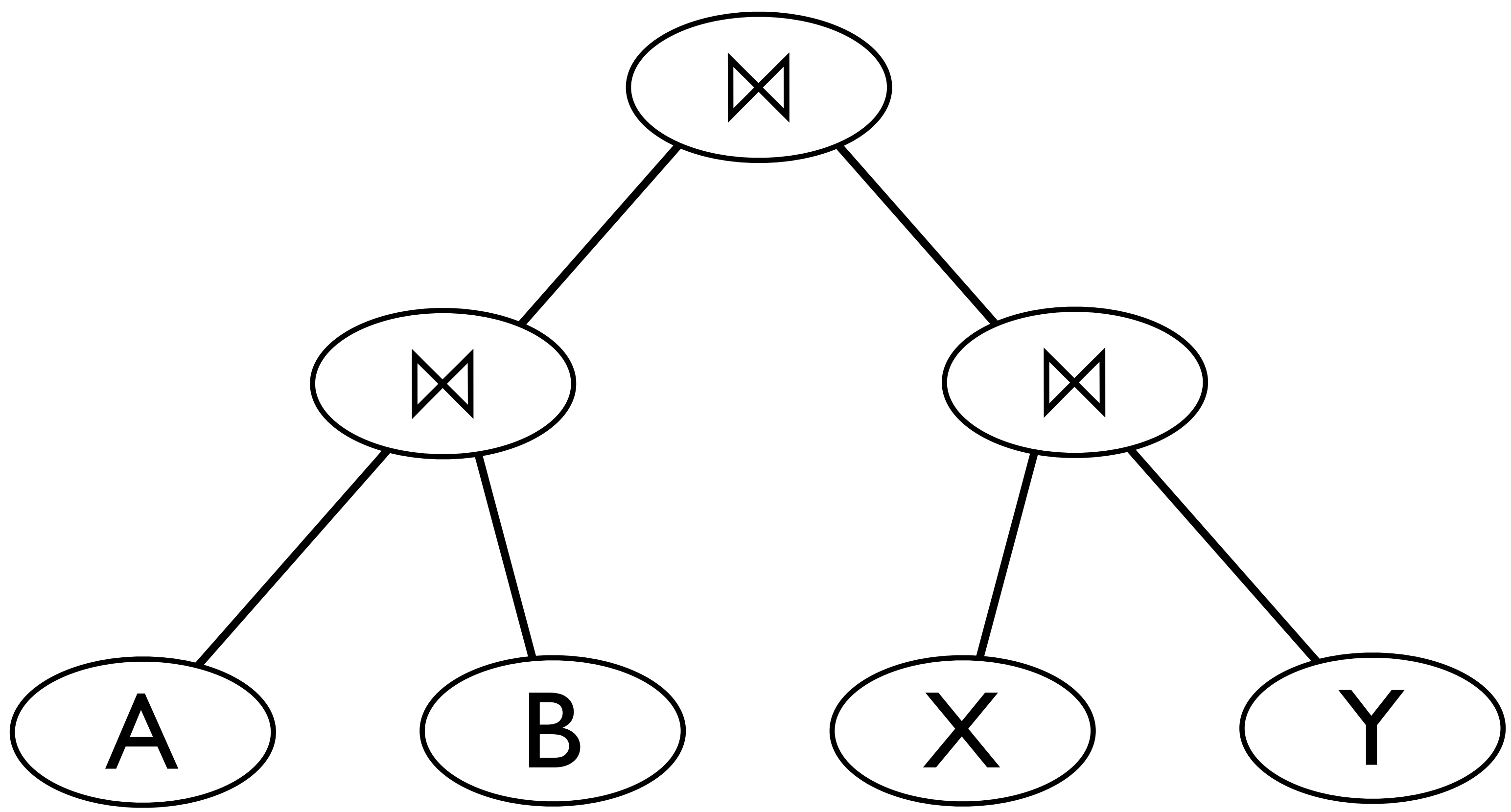
Parallel Joins-Hash

- Phase 1: Partition/Split the data by hash
  - Each partition goes to a different site.
  - (should produce roughly equivalent workloads)
- Phase 2: Join
  - Perform Joins locally
- Almost always the fastest for Equi-Join
  - Common algorithm for equi-joins in Map/Reduce.

Parallel Joins-Hash



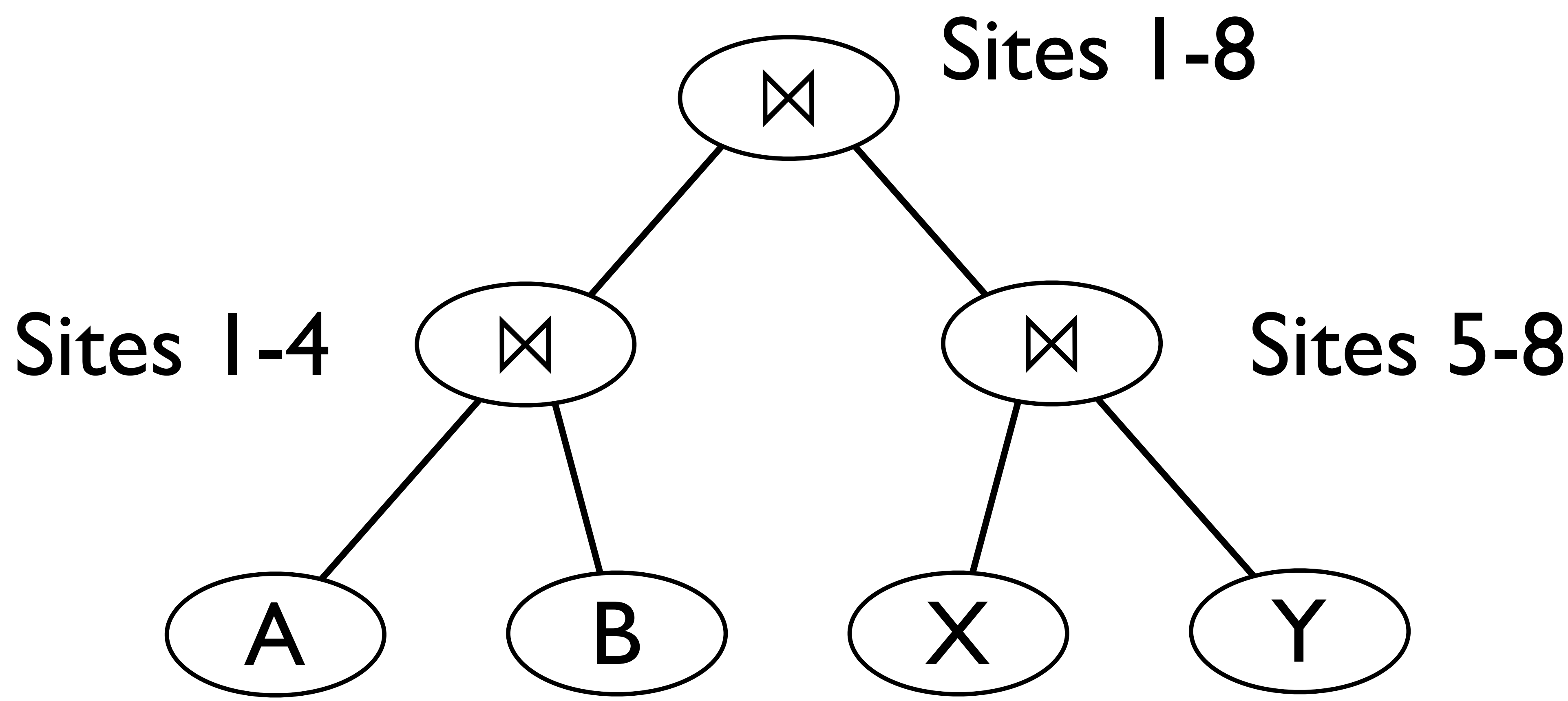
Multi-Stage Query Plans



The Partitioning Phase (Phase 1) of Hash Join is Blocking!

How do we get Operator-Level Parallelism?

Multi-Stage Query Plans



The Partitioning Phase (Phase 1) of Hash Join is Blocking!

How do we get Operator-Level Parallelism?

Optimizing || Query Plans

- Building a fast parallel query execution engine is (relatively) easy.
- Optimizing queries for ||ism is much harder.
  - Even more variables to consider.
  - Optimizer complexity is high!
  - Lots of research being done in this area.

Optimizing || Query Plans

- Common Approach: 2 Phase Optimizer
  - Phase 1: Pick best sequential plan.
  - Phase 2: Assign operators to sites.
    - “Decorate” query tree as above.
- What’s wrong with this?

Example

- SELECT * FROM Officers WHERE Name < “Spock”
- ‘Officers’ partitioned on name with secondary index on name as well.
- Sites 1-5, all < ‘Spock’ : Table Scan Best Access Path
- Site 6: ‘Scott’ through ‘Uhura’ : Index Scan!