Introduction to Database Systems
CSE 414

Lecture 26:
Parallel Database Queries

HW8

- MapReduce (Hadoop) w/ declarative language (Pig)
- Cluster will run in Amazon's cloud (AWS)
  - Give your credit card (shouldn't get charged unless runaway)
  - Click, click, click… and you have a MapReduce cluster
- We will analyze a real 0.5TB graph
- Processing the entire data takes hours
  - Required problems: queries on a subset only
  - Extra credit problem #4: entire data
- Tomorrow's Quiz Sections
  - Step by step instructions on how to connect to AWS
  - Don't miss!

Amazon Warning

- "We **HIGHLY** recommend you remind students to turn off any instances after each class/session – as this can quickly diminish the credits and start charging the card on file. **You are responsible for the overages."**
- "AWS customers can now use **billing alerts** to help monitor the charges on their AWS bill. You can get started today by visiting your Account Activity page to enable monitoring of your charges. Then, you can set up a billing alert by simply specifying a bill threshold and an e-mail address to be notified as soon as your estimated charges reach the threshold."

Outline

- Today: Query Processing in Parallel DBs
- Then: Parallel Data Processing at Massive Scale (MapReduce)
  - Reading assignment:
    Chapter 2 (Sections 1,2,3 only) of Mining of Massive Datasets, by Rajaraman and Ullman
    http://i.stanford.edu/~ullman/mmds.html

Review

- Why parallel processing?
- What are the possible architectures for a parallel database system?
- What are speedup and scaleup?

Basic Query Processing: Quick Review in Class

Basic query processing on one node.

Given relations R(A,B) and S(B, C), no indexes, how do we compute:

- Selection: $\sigma_{A=123}(R)$
- Group-by: $\gamma_{A,sum(B)}(R)$
- Join: $R \bowtie S$

Basic Query Processing: Quick Review in Class

Basic query processing on one node.

Given relations R(A,B) and S(B, C), no indexes, how do we compute:

- Selection: $\sigma_{A=123}(R)$
  - Scan file R, select records with A=123
- Group-by: $\gamma_{A,sum(B)}(R)$
  - Scan file R, insert into a hash table using attr. A as key
  - When a new key is equal to an existing one, add B to the value
- Join: $R \bowtie S$
  - Scan file S, insert into a hash table using attr. B as key
  - Scan file R, probe the hash table using attr. B

Parallel Query Processing

How do we compute these operations on a shared-nothing parallel db?

- Selection: $\sigma_{A=123}(R)$ (that's easy, won't discuss…)
- Group-by: $\gamma_{A,sum(B)}(R)$
- Join: $R \bowtie S$

Before we answer that: how do we store R (and S) on a shared-nothing parallel db?

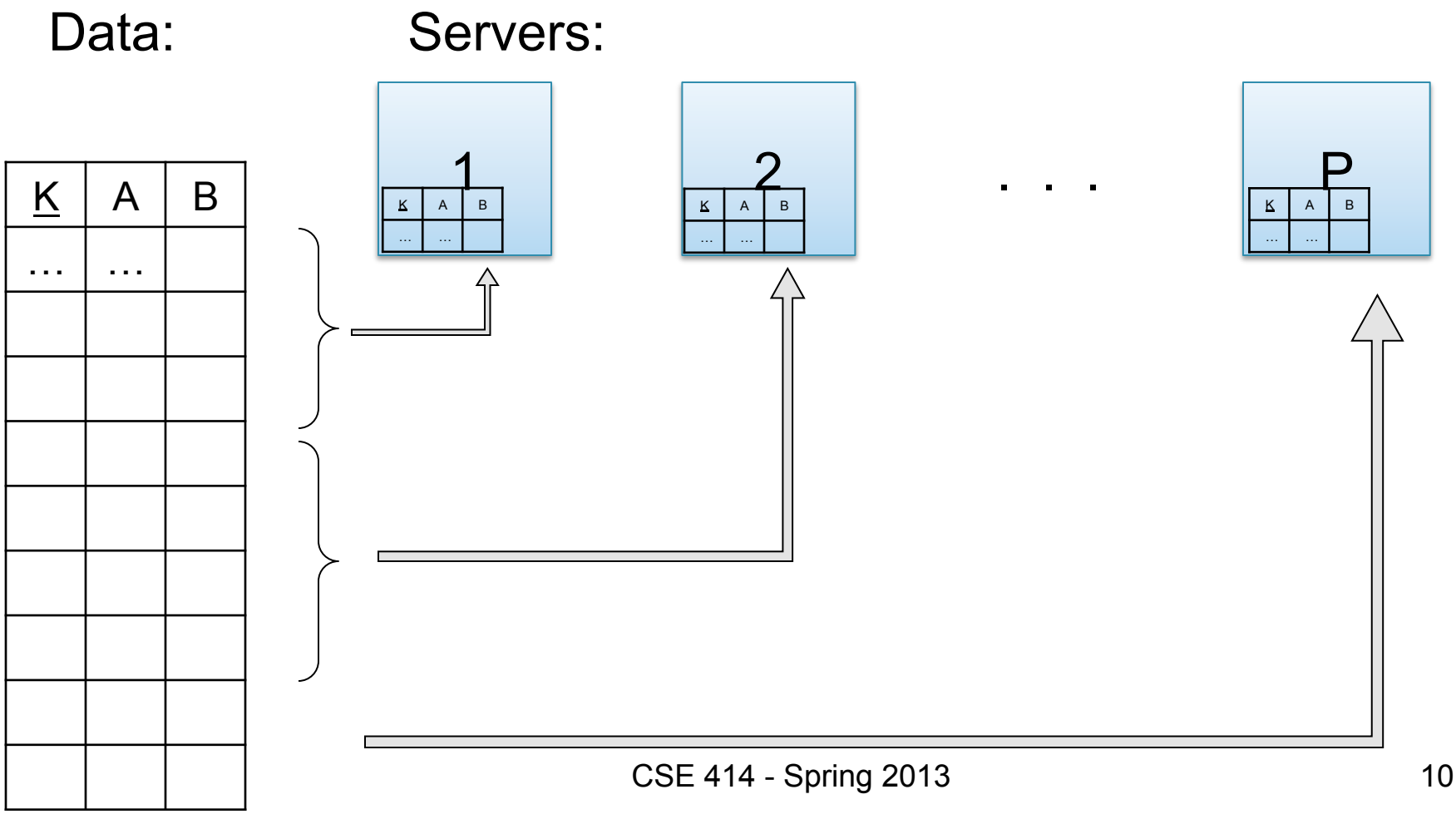
Horizontal Data Partitioning

Data:

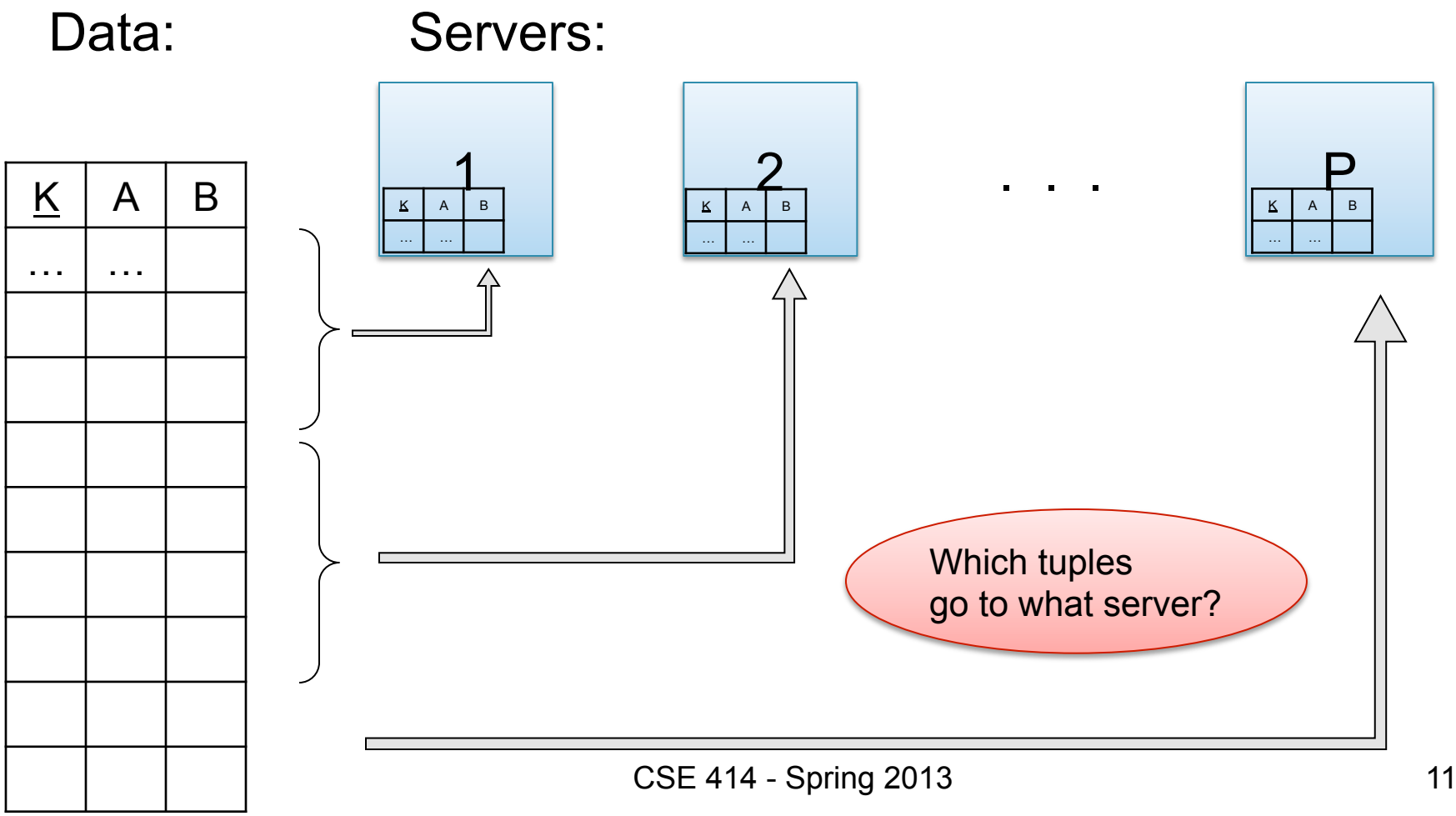
K	A	B
…	…	

Servers:

Horizontal Data Partitioning



Horizontal Data Partitioning



Horizontal Data Partitioning

- Block Partition:
  - Partition tuples arbitrarily s.t. size(R_1)≈ … ≈ size(R_P)
- Hash partitioned on attribute A:
  - Tuple t goes to chunk i, where i = h(t.A) mod P + 1
- Range partitioned on attribute A:
  - Partition the range of A into $-\infty = v_0 < v_1 < \ldots < v_P = \infty$
  - Tuple t goes to chunk i, if $v_{i-1} < t.A < v_i$

Parallel GroupBy

Data: R(K,A,B,C)

Query: $\gamma_{A,sum(C)}(R)$

Discuss in class how to compute in each case:

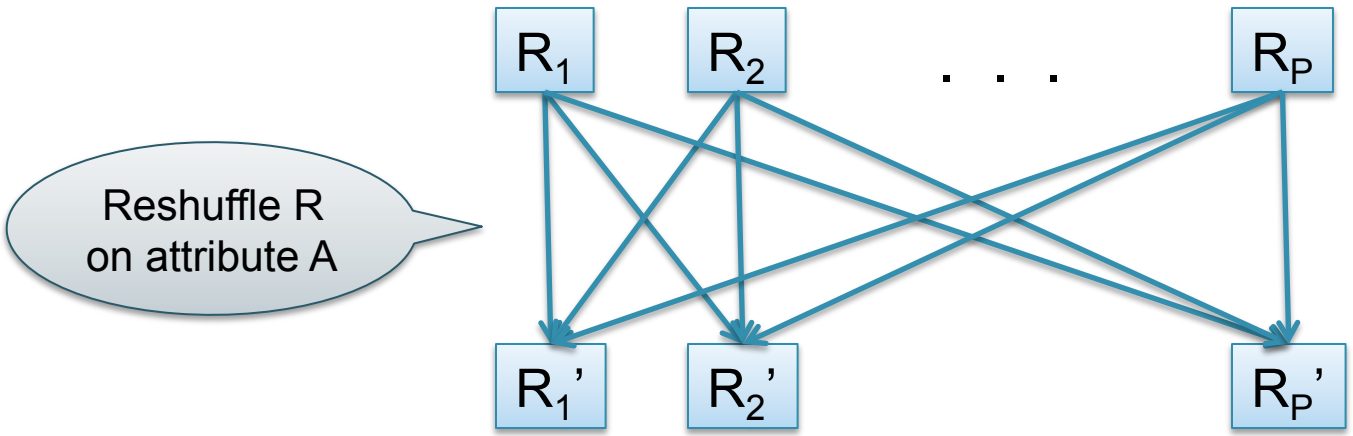
- R is hash-partitioned on A
- R is block-partitioned
- R is hash-partitioned on K

Parallel GroupBy

Data: R(K,A,B,C)

Query: $\gamma_{A,sum(C)}(R)$

- R is block-partitioned or hash-partitioned on K



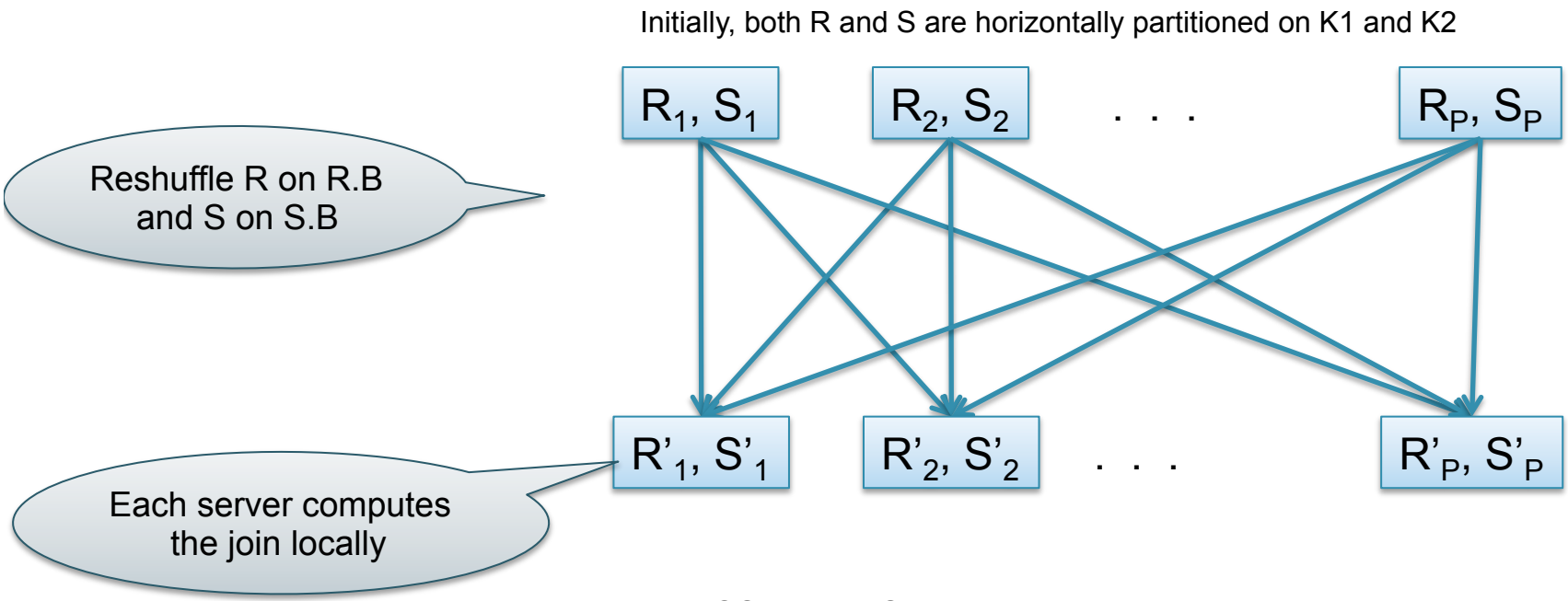
Parallel Join

- Data: R(K1,A, B), S(K2, B, C)
- Query: R(K1,A,B) ⋈ S(K2,B,C)

Initially, both R and S are horizontally partitioned on K1 and K2

Parallel Join

- Data: R(K1,A, B), S(K2, B, C)
- Query: R(K1,A,B) ⋈ S(K2,B,C)



Speedup and Scaleup

- Consider:
  - Query: $\gamma_{A,sum(C)}(R)$
  - Runtime: dominated by reading chunks from disk
- If we double the number of nodes P, what is the new running time?

- If we double both P and the size of R, what is the new running time?

Speedup and Scaleup

- Consider:
  - Query: $\gamma_{A,sum(C)}(R)$
  - Runtime: dominated by reading chunks from disk
- If we double the number of nodes P, what is the new running time?
  - Half (each server holds ½ as many chunks)
- If we double both P and the size of R, what is the new running time?
  - Same (each server holds the same # of chunks)

Uniform Data v.s. Skewed Data

- Let R(K,A,B,C); which of the following partition methods may result in skewed partitions?

- Block partition

- Hash-partition
  - On the key K
  - On the attribute A

Uniform Data v.s. Skewed Data

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- Block partition

- Hash-partition
  - On the key K
  - On the attribute A

Assuming good hash function

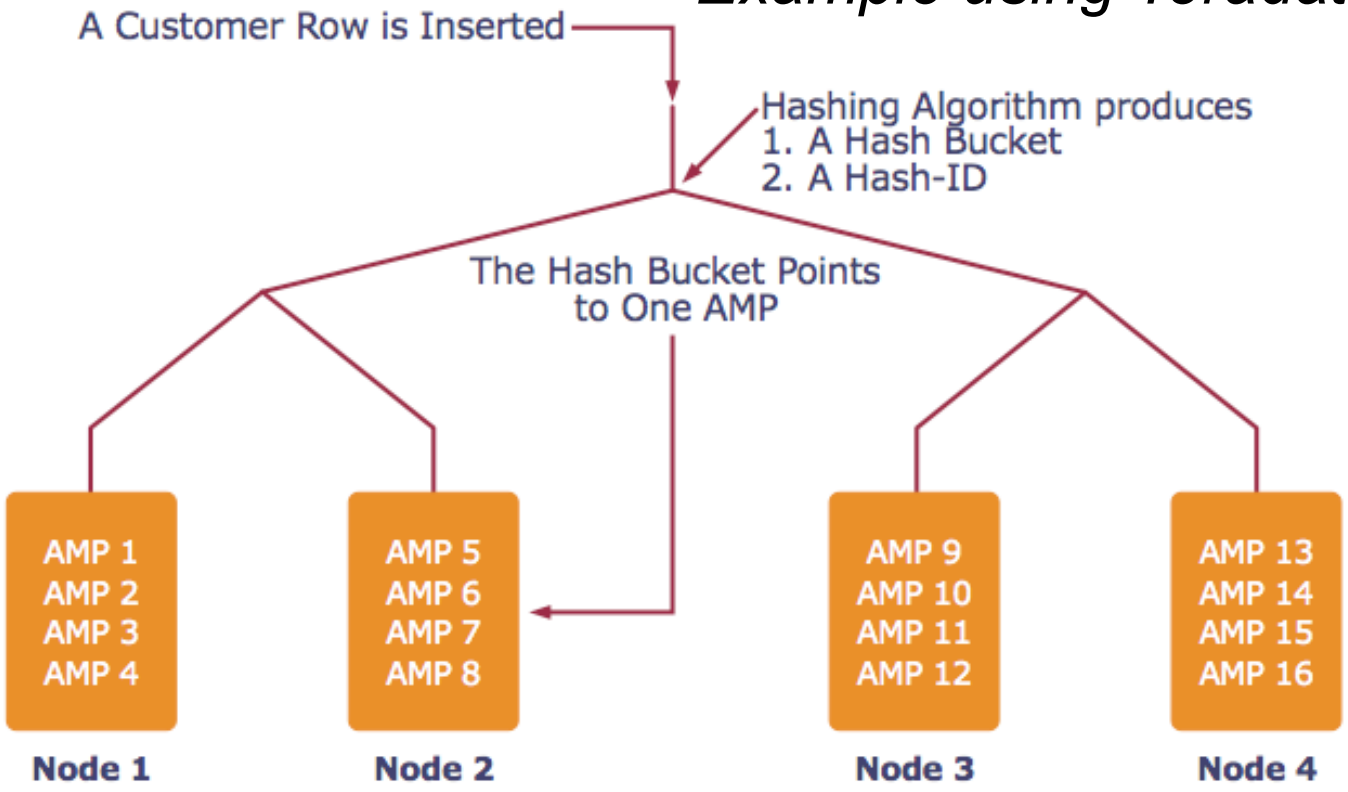
E.g. when all records have the same value of the attribute A, then all records end up in the same partition

Parallel DBMS

- Parallel query plan: tree of parallel operators
  Intra-operator parallelism
  - Data streams from one operator to the next
  - Typically all cluster nodes process all operators
- Can run multiple queries at the same time
  Inter-query parallelism
  - Queries will share the nodes in the cluster
- Notice that user does not need to know how his/her SQL query was processed

Loading Data into a Parallel DBMS

Example using Teradata System



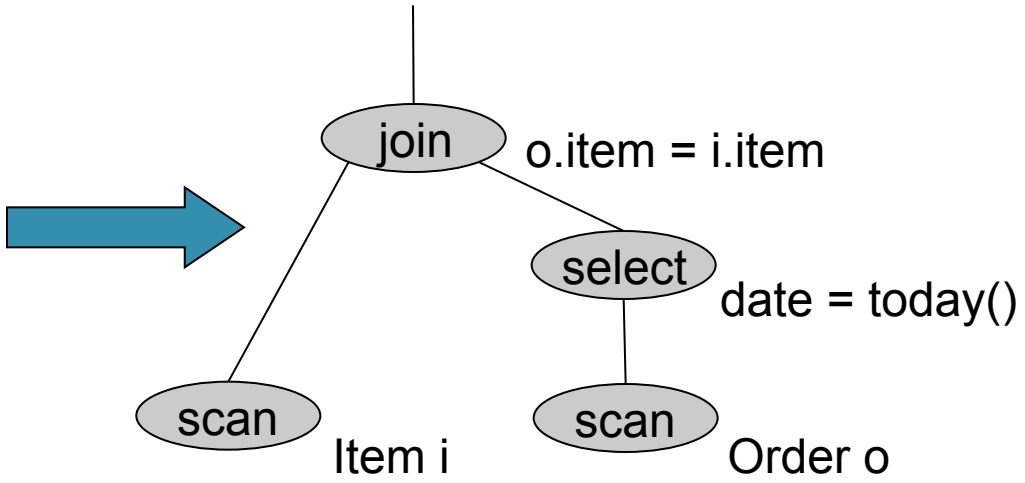
AMP = "Access Module Processor" = unit of parallelism

Order(oid, item, date), Line(item, …)

Example Parallel Query Execution

Find all orders from today, along with the items ordered

```
SELECT *
  FROM Order o, Line i
 WHERE o.item = i.item
   AND o.date = today()
```



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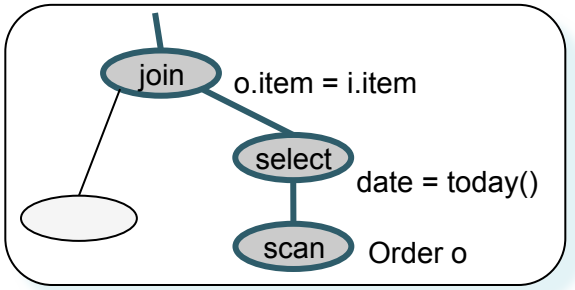
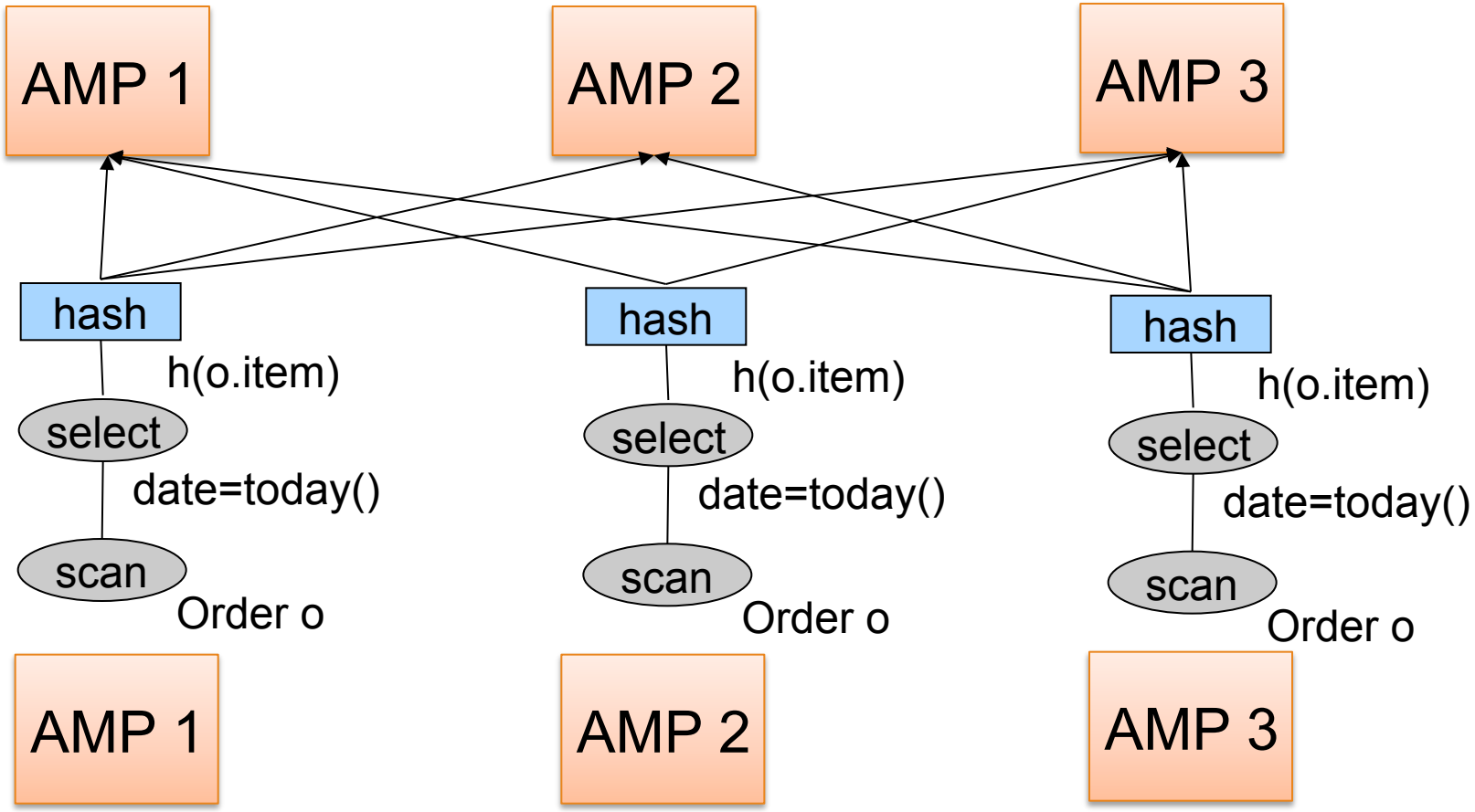
Example Parallel Query Execution





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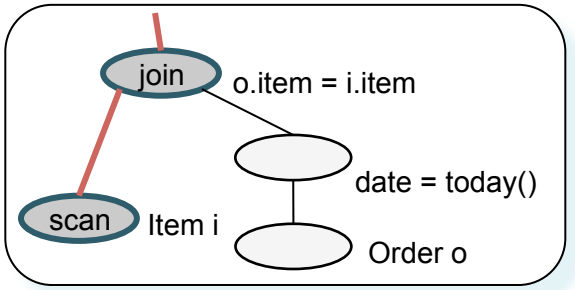

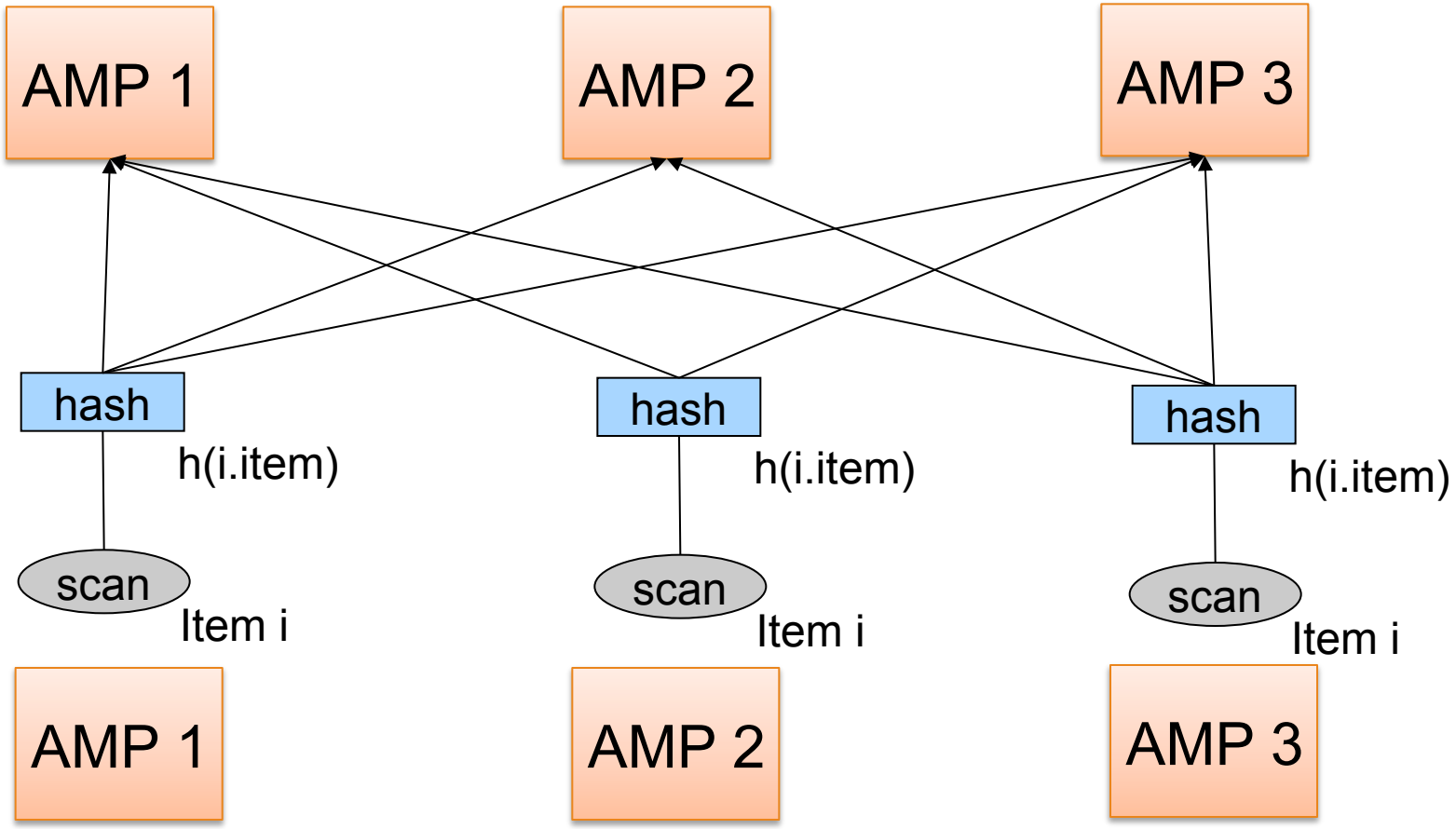

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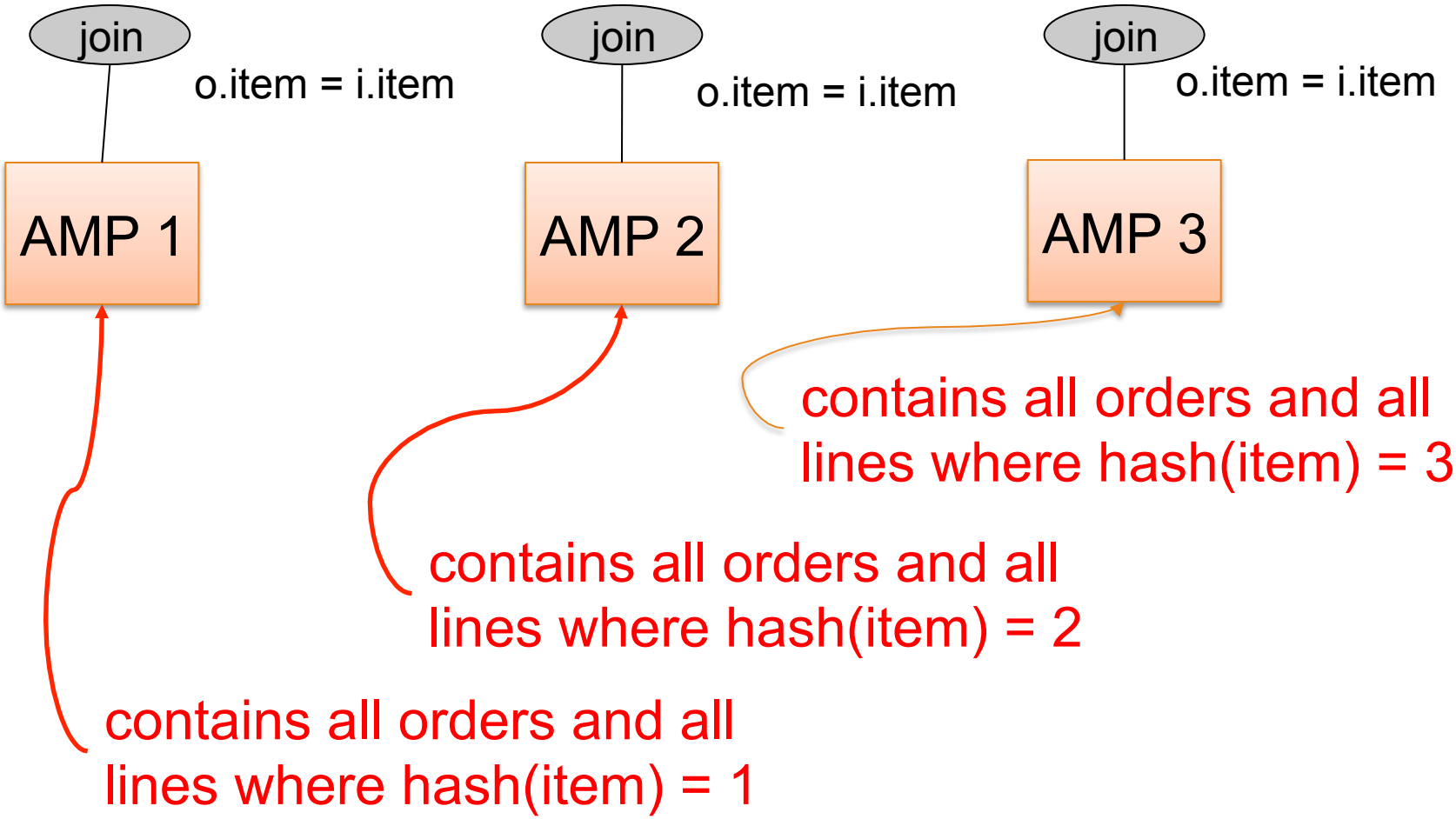

Parallel Dataflow Implementation

- Use relational operators unchanged
- Add a special *shuffle* operator
  - Handle data routing, buffering, and flow control
  - Inserted between consecutive operators in the query plan
  - Two components: ShuffleProducer and ShuffleConsumer
  - Producer pulls data from operator and sends to n consumers
    - Producer acts as driver for operators below it in query plan
  - Consumer buffers input data from n producers and makes it available to operator through getNext interface
- Used extensively in database implementation