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CS 764: Topics in Database Management Systems
Lecture 7: Distribution Query Optimization

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Today's Paper: Query Optimization

DISTRIBUTED QUERY PROCESSING IN A
RELATIONAL DATA BASE SYSTEM

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ABSTRACT: In this paper we present a new algorithm for retrieving and updating data from a distributed relational data base. Within such a data base, any number of relations can be distributed over any number of sites. Moreover, a user supplied distribution criteria can optionally be used to specify what site a tuple belongs to.

The algorithm is an efficient way to process any query by "breaking" the qualification into separate "pieces" using a few simple heuristics. The cost criteria considered are minimum response time and minimum communications traffic. In addition, the algorithm can optimize separately for two models of a communication network representing respectively ARPANET and ETHERNET like networks. This algorithm is being implemented as part of the INGRES data base system.

KEYWORDS AND PHRASES: Distributed databases, relational model, distributed decomposition, communication networks, distribution criteria.

I Introduction

In this paper we are concerned with algorithms for processing data base commands that involve data from multiple machines in a distributed data base environment. These algorithms are being implemented as part of our work in extending INGRES [HELD75, STON76] to manage a distributed data base. As such, we are concerned with processing interactions in the data sublanguage, QUEL. The specific data model that we use is discussed in Section II. Some of our initial thoughts on these subjects have been presented elsewhere [STON77, WONG77].

We are not concerned here with control of concurrent updates or multiple copies [THOM75, LAMP76, ROTH77, CHU76]. Rather we assume that these are handled by a separate mechanism or can be integrated into our algorithms.

This paper is organized as follows: In section II we formalize the problem by indicating our view of a distributed data base and the interactions to be solved. Then, in section III we discuss our model for the computer network. In section IV a detailed algorithm is presented for handling the decomposition of queries in a distributed environment. There are a few complications concerning updates and aggregates in a distributed data base which are covered in sections V and VI. Lastly, in section VII we draw some conclusions.

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SIGMOD 1978

Agenda

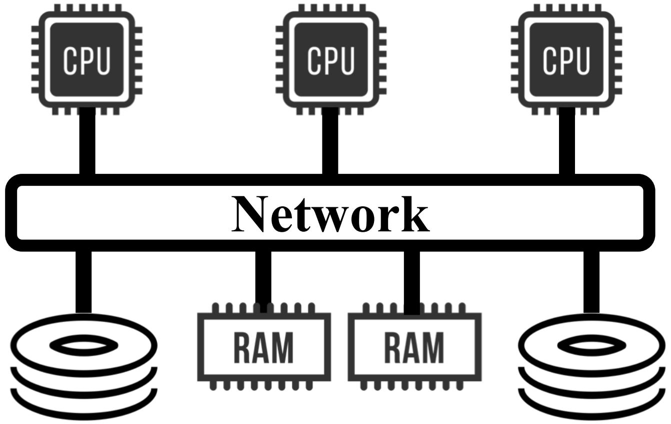
Distributed database architecture

Data partitioning

Parallel operators

Distributed query optimization

Distributed Database Architecture

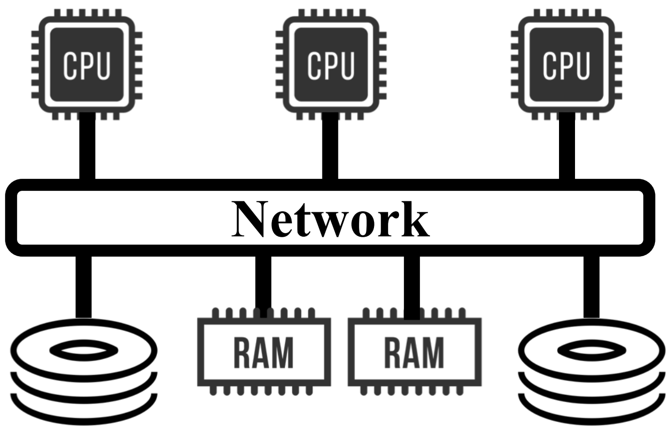


Shared Memory

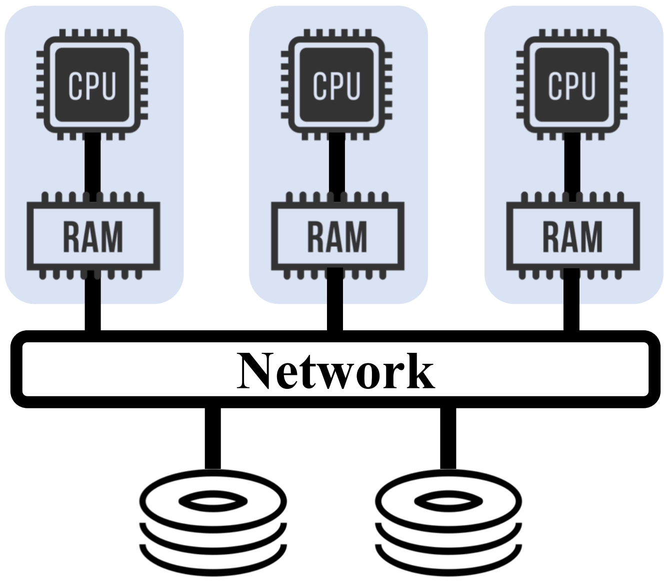
Example: Multicore shared-memory machine

Scale: Single machine

Distributed Database Architecture



Shared Memory

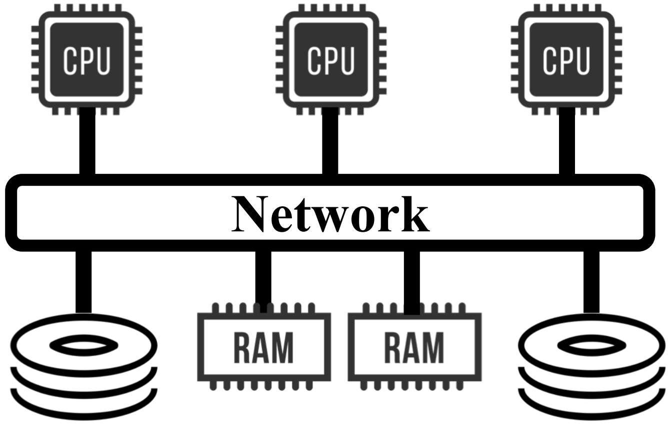


Shared Disk

Example: Network attached storage (NAS) and storage area network (SAN), some Oracle and IBM database systems

Scale: Cluster with tens of machines

Distributed Database Architecture



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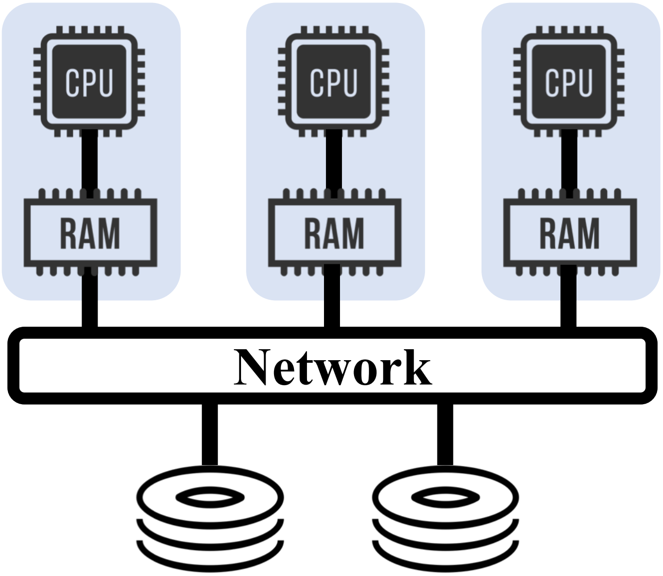

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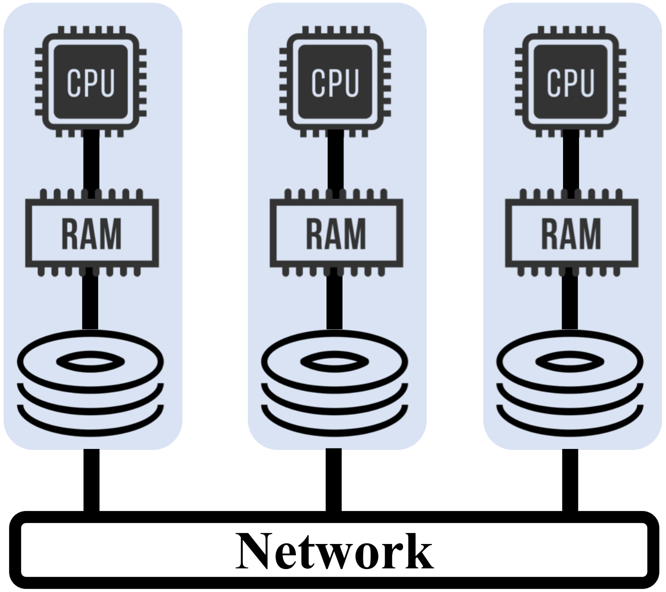
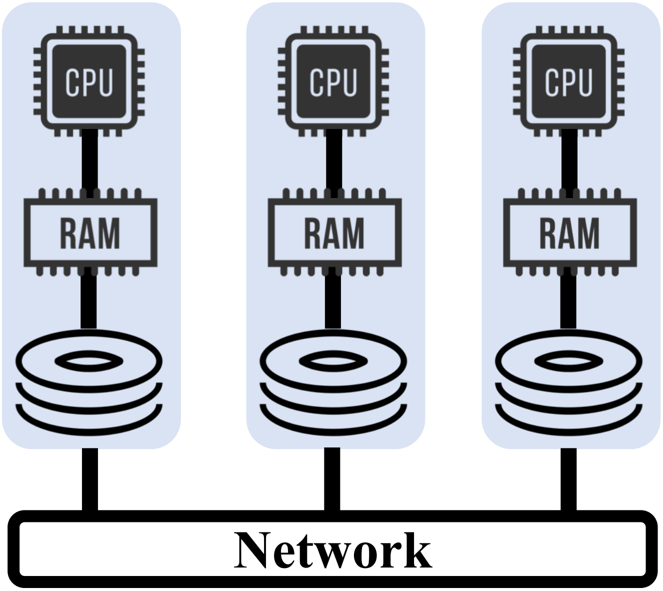


Shared Nothing

Example: Modern massively parallel databases including Google Spanner, Redshift, CosmosDB, etc.

Scale: Any number of machines

Shared-Nothing Architecture



Shared Nothing

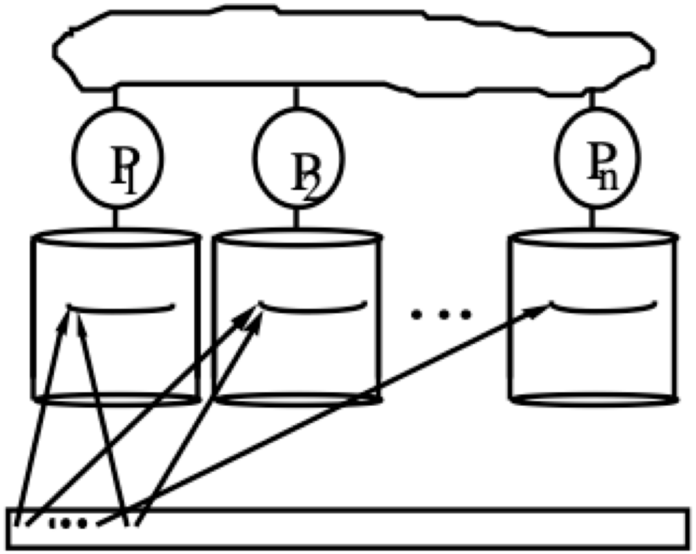
Advantages:

- High scalability
- High availability
- Good data locality

Challenges:

- Must partition data
- Network overhead

Data Partitioning

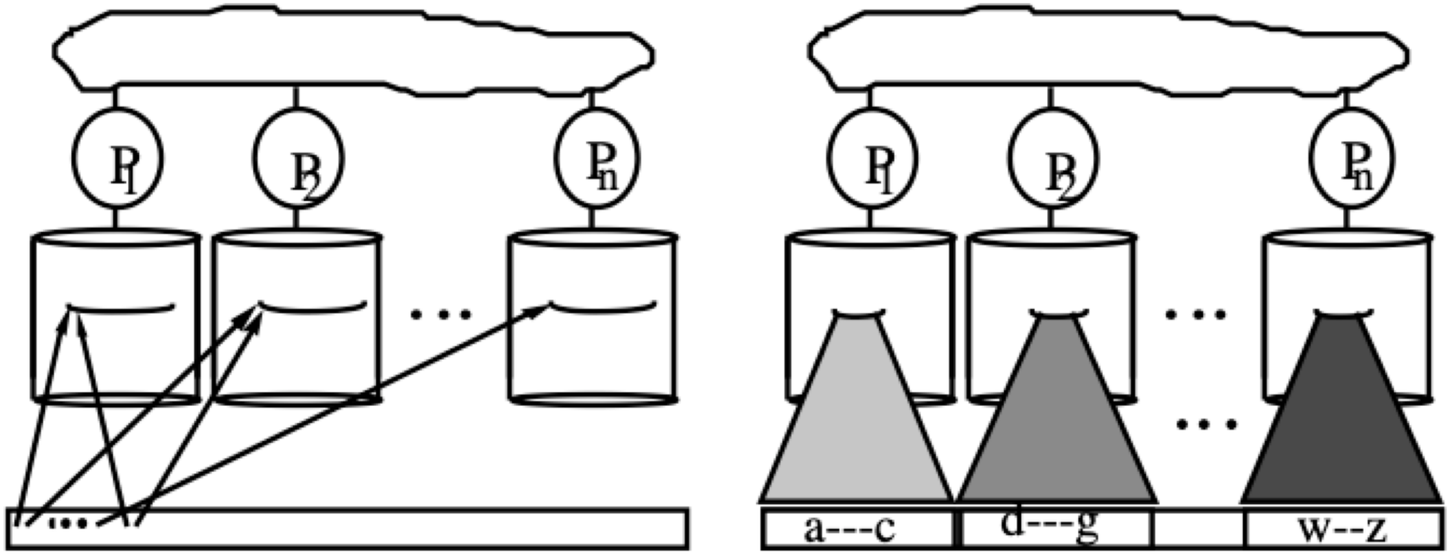


Round robin

Map tuple *i* to disk (*i mode n*)

- **Advantage**: Simplicity, good load balancing
- **Disadvantage**: Hard to identify the partition of a particular record

Data Partitioning

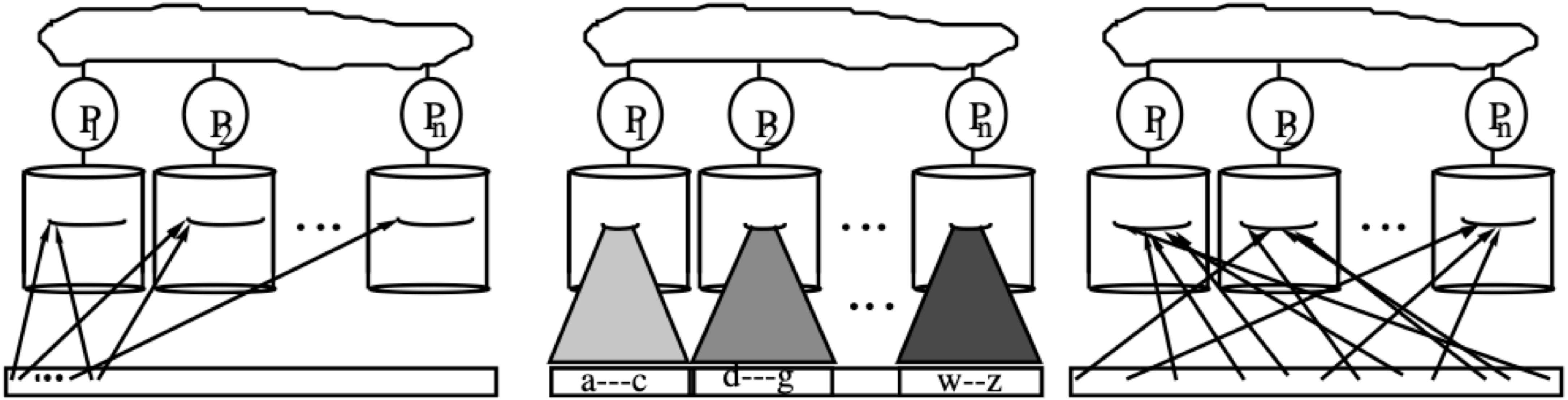


Round robin Range Partitioning

Map contiguous attribute ranges to partitions

- **Advantage**: Good locality due to clustering
- **Disadvantage**: May suffer from skewness

Data Partitioning



Round robin Range Partitioning Hash Partitioning

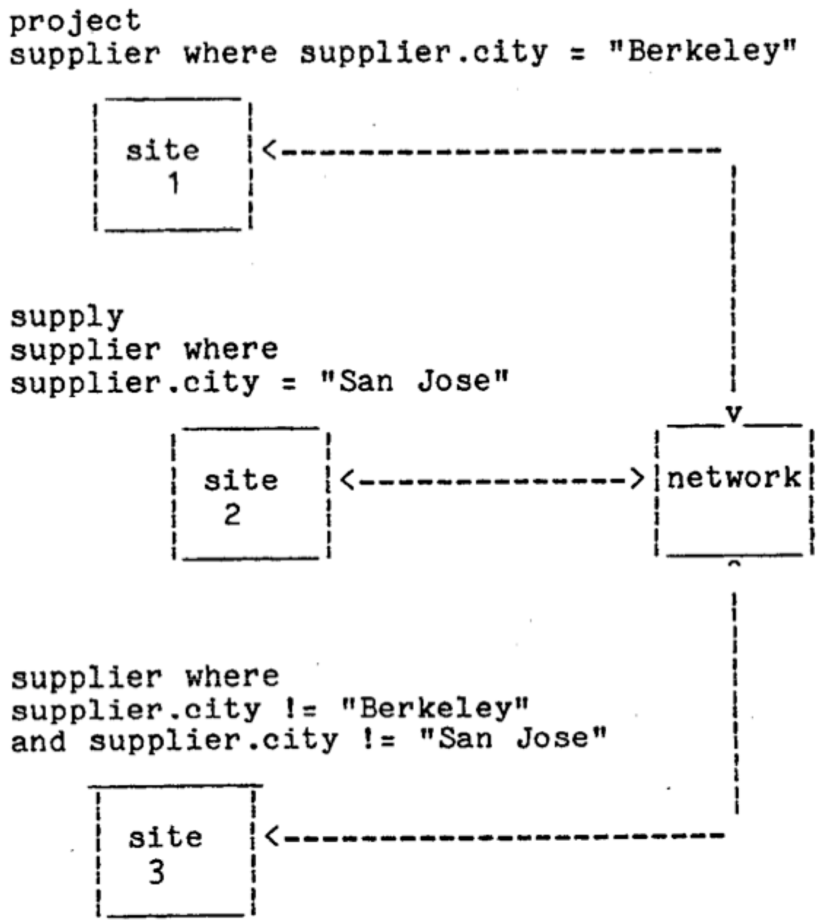
Map based on the hash value of tuple attributes

– **Advantage**: Good load balance, low skewness
– **Disadvantage**: Bad locality

Data Partitioning

Generally, the **partitioning function (distribution criteria)** can be any function that maps tuples to partition ID

For example:



Algorithm Flowchart

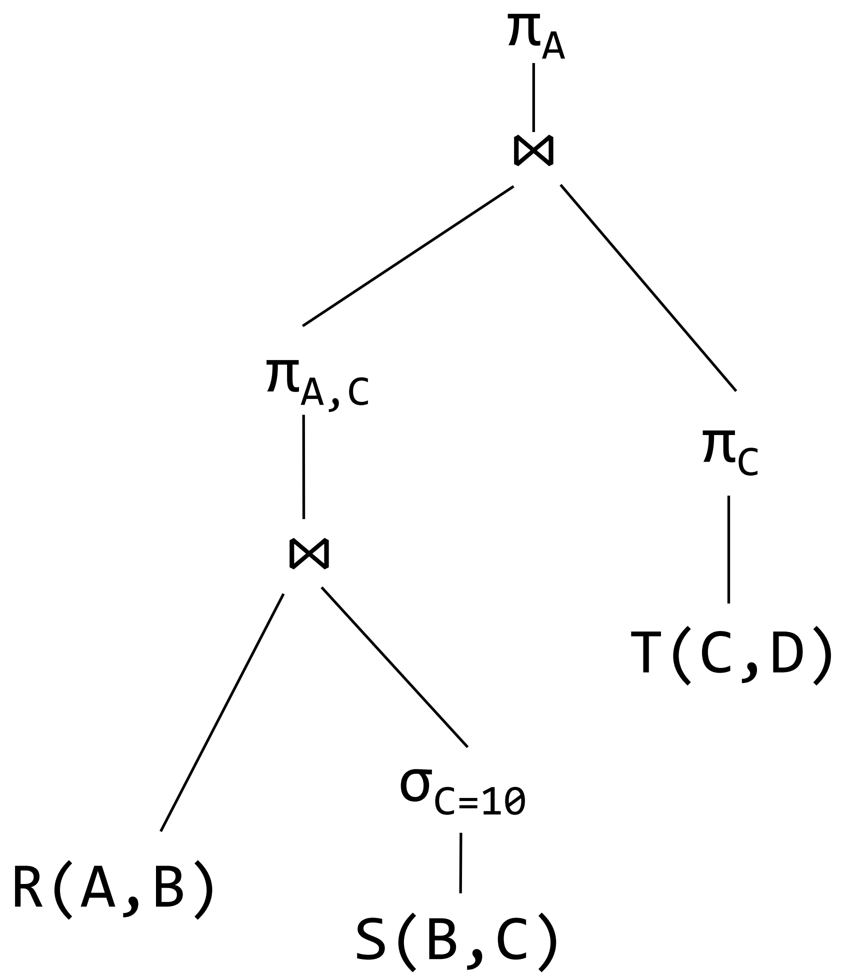
Perform all single-table operations

While (exists next piece of query) {

    Select processing sites and transmit data

    Run query on each site

}



Algorithm Flowchart

Perform all single-table operations

While (exists next piece of query) {

  Select processing sites and transmit data

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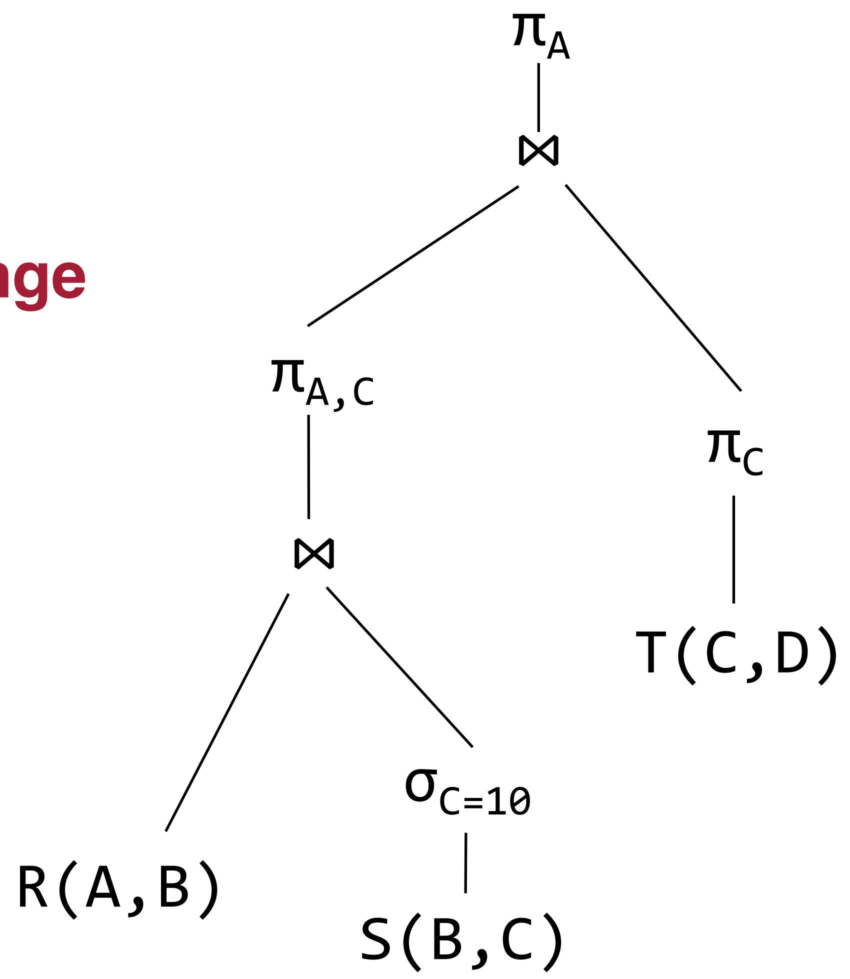
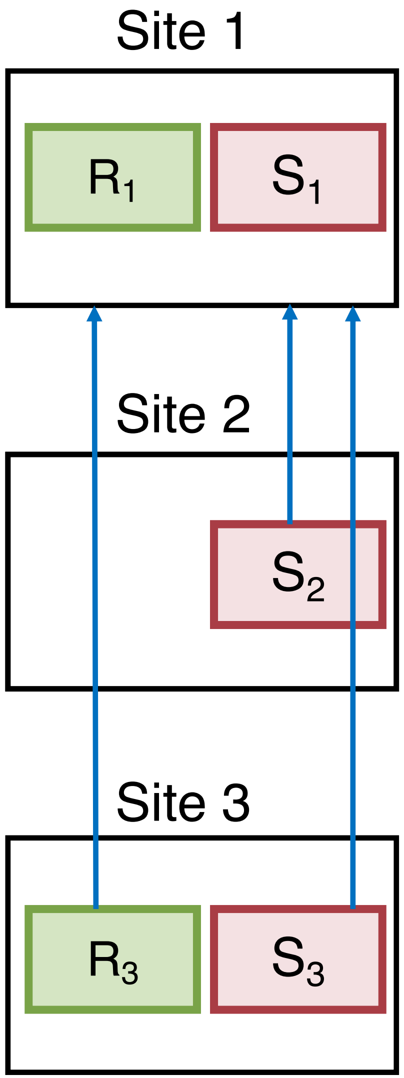
}

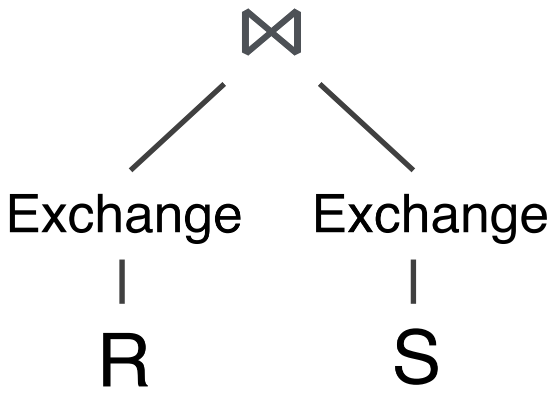
Key Challenge



Join – Single-Site



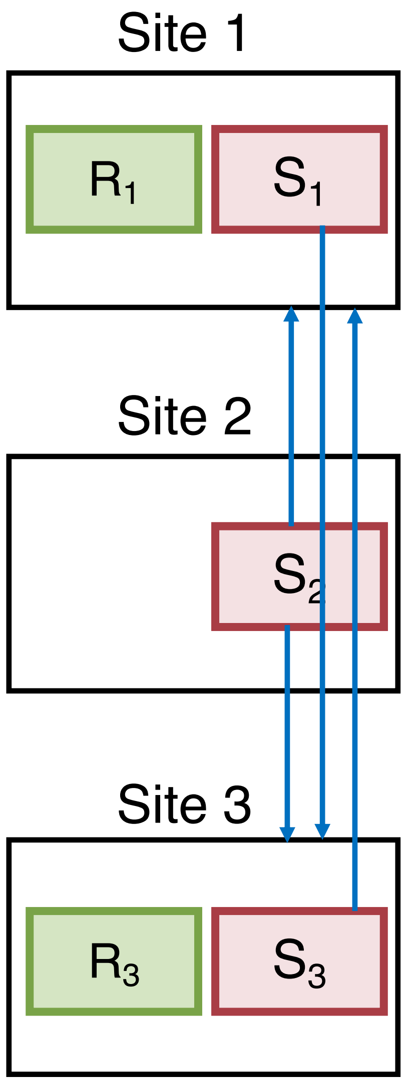
Query plan

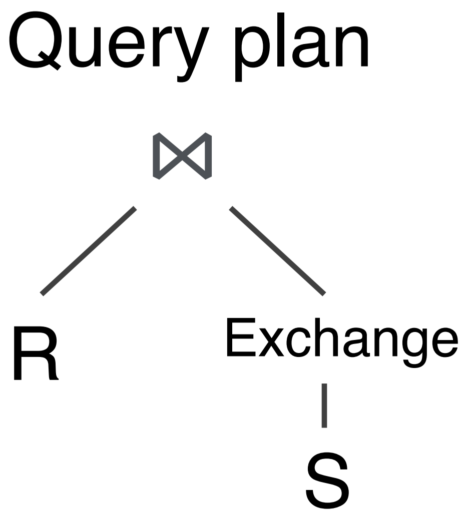


Solution 1: send all the involved tables to a single site

- **Advantage**: Single-site query execution is a solved problem
- **Disadvantage**: (1) Single site execution can be slow (2) Data may not fit in single site's memory or disk

Join – Broadcast

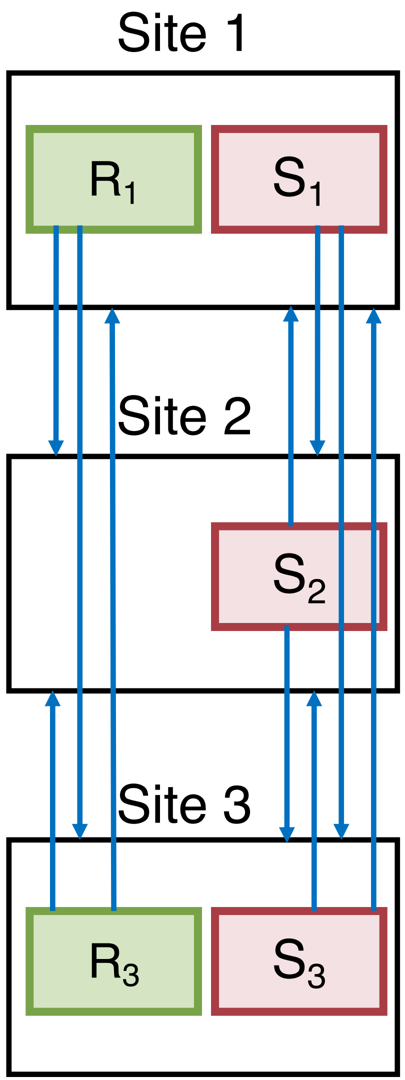




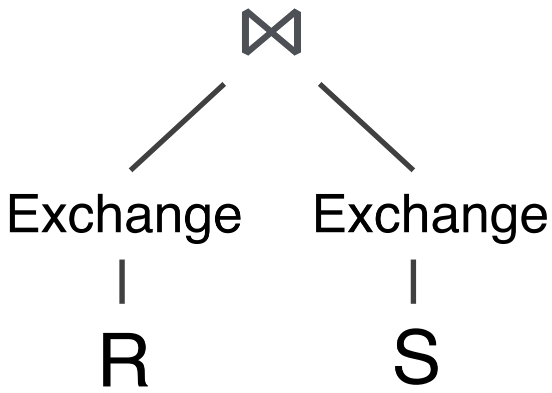
Solution 2: Keep one relation partitioned and broadcast the other relation to all sites

- **Advantage**: One relation does not need to move
- **Disadvantage**: Still need to broadcast the other relation to all sites

Join – Co-partition



Query plan



Solution 3: Partition both relations using the join key

- **Advantage**: Each site has less data to process
- **Disadvantage**: Both relations are shuffled (if not already partitioned based on join key)

Distributed Join

Single-site

– Preferred when **both relations are small**

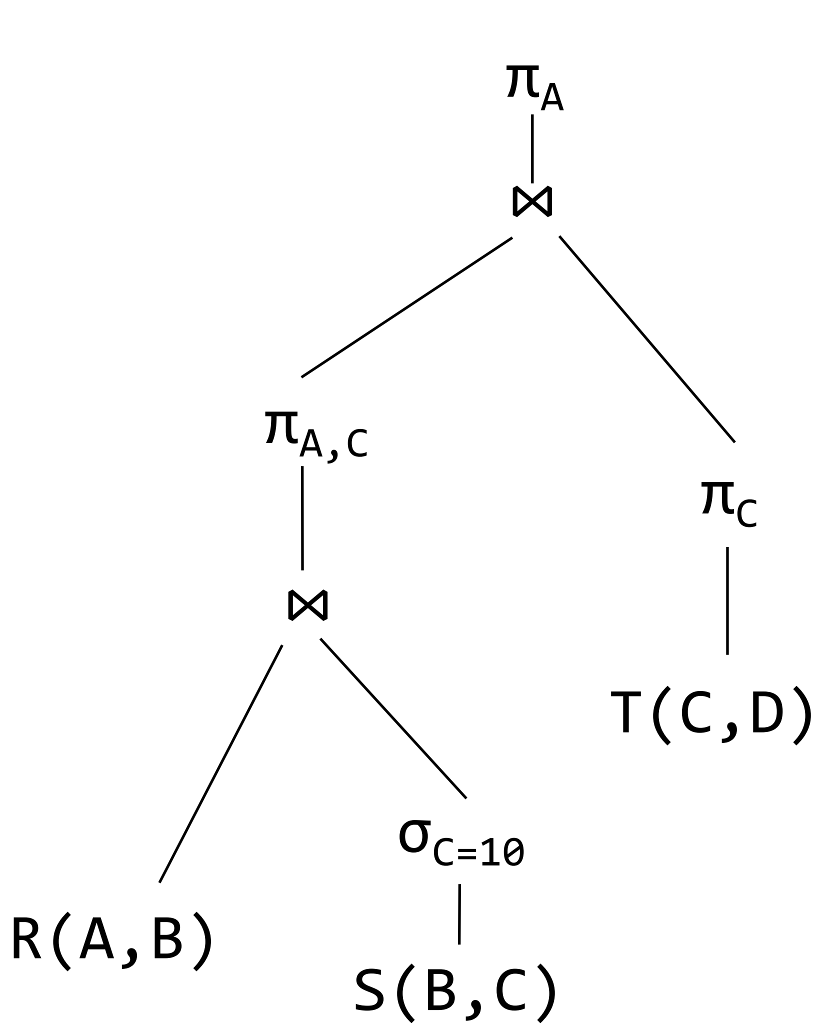
Broadcast

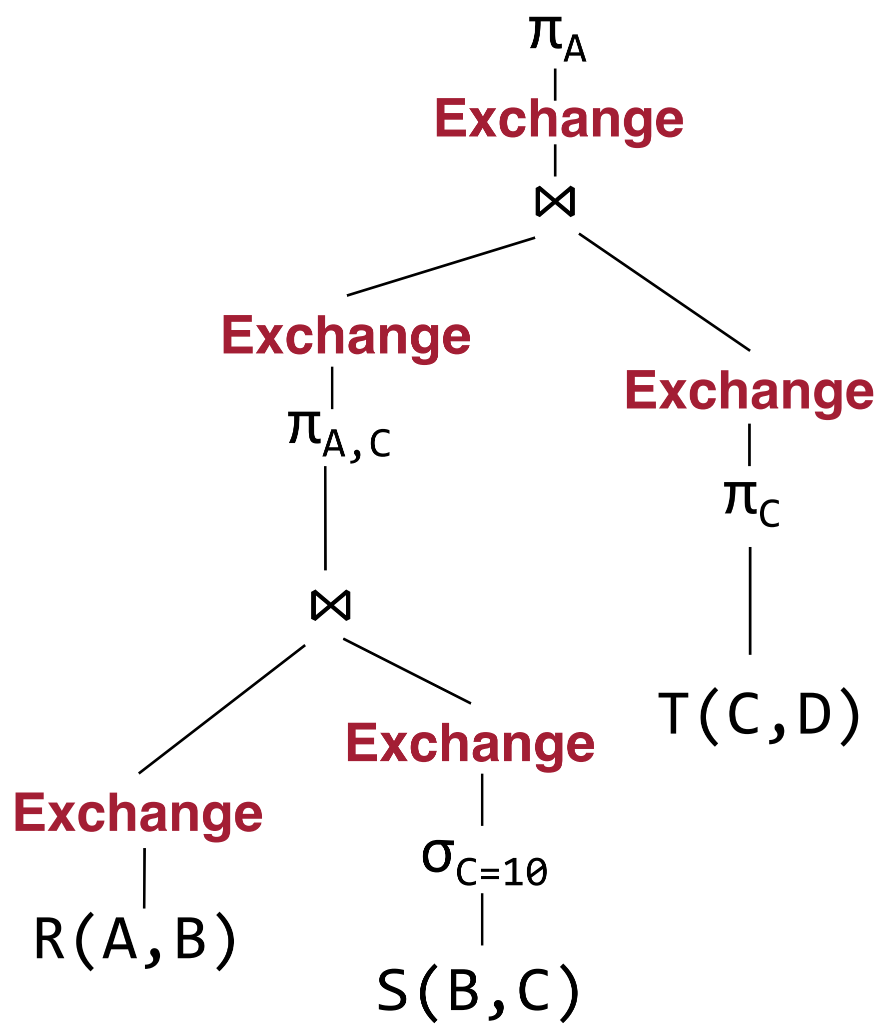
– Preferred when **one relation is small**

Co-partition

– Preferred when **both relations are large**

Distributed Query Optimization

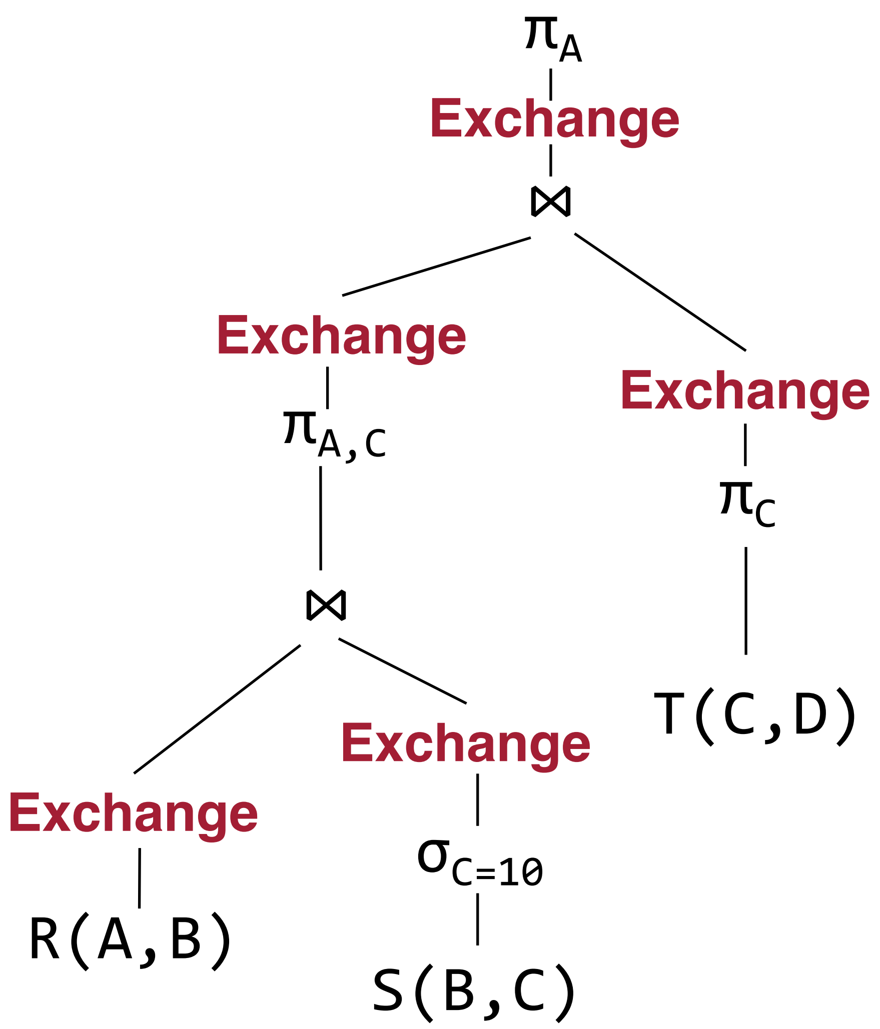




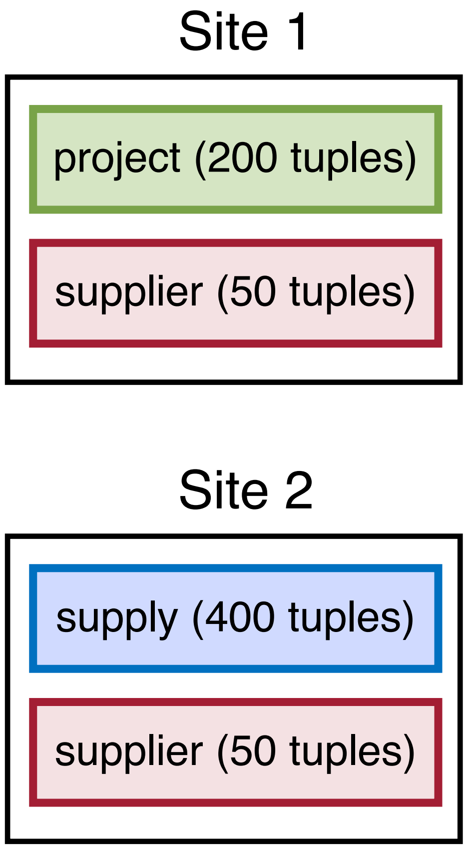
Distributed Query Optimization

Extra design complexity

- Which exchange operator to use?
- Which nodes to use to run the operator?



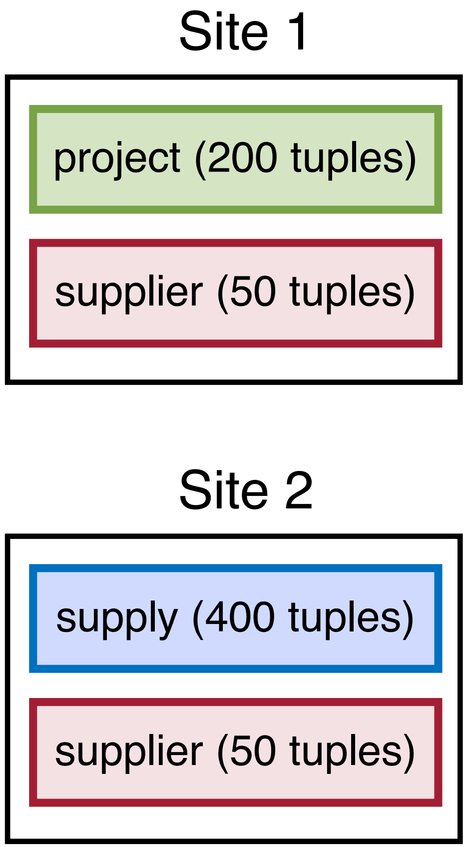
Example



Join order

- (project ⋈ supply) ⋈ supplier
- project ⋈ (supply ⋈ supplier)

Example



Join order

- (project $\bowtie$ supply) $\bowtie$ supplier
- project $\bowtie$ (supply $\bowtie$ supplier)

Plan 1: Send everything to Site 2

- Network traffic 250 tuples

Example

Site 1

project (200 tuples)

supplier (50 tuples)

Site 2

supply (400 tuples)

supplier (50 tuples)

Join order

- (project ⋈ supply) ⋈ supplier
- project ⋈ (supply ⋈ supplier)

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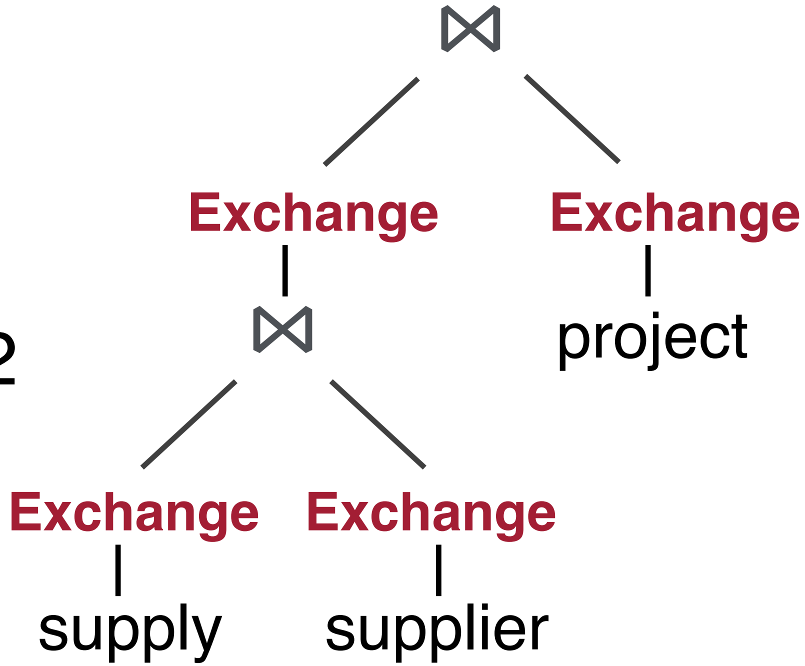
Plan 2:



Example

Site 1

- project (200 tuples)
- supplier (50 tuples)

Site 2

- supply (400 tuples)
- supplier (50 tuples)

Join order

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Plan 1: Send everything to Site 2

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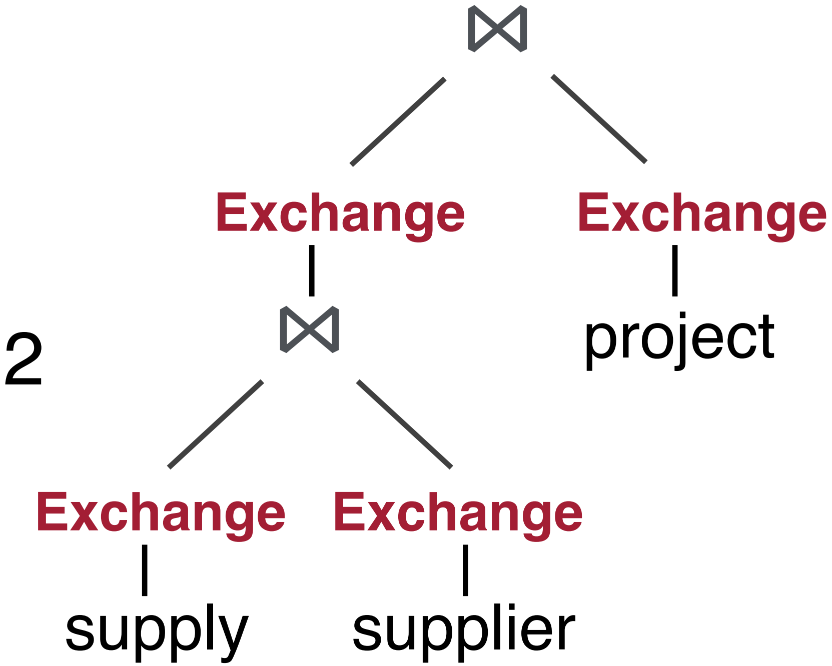


Plan 2:

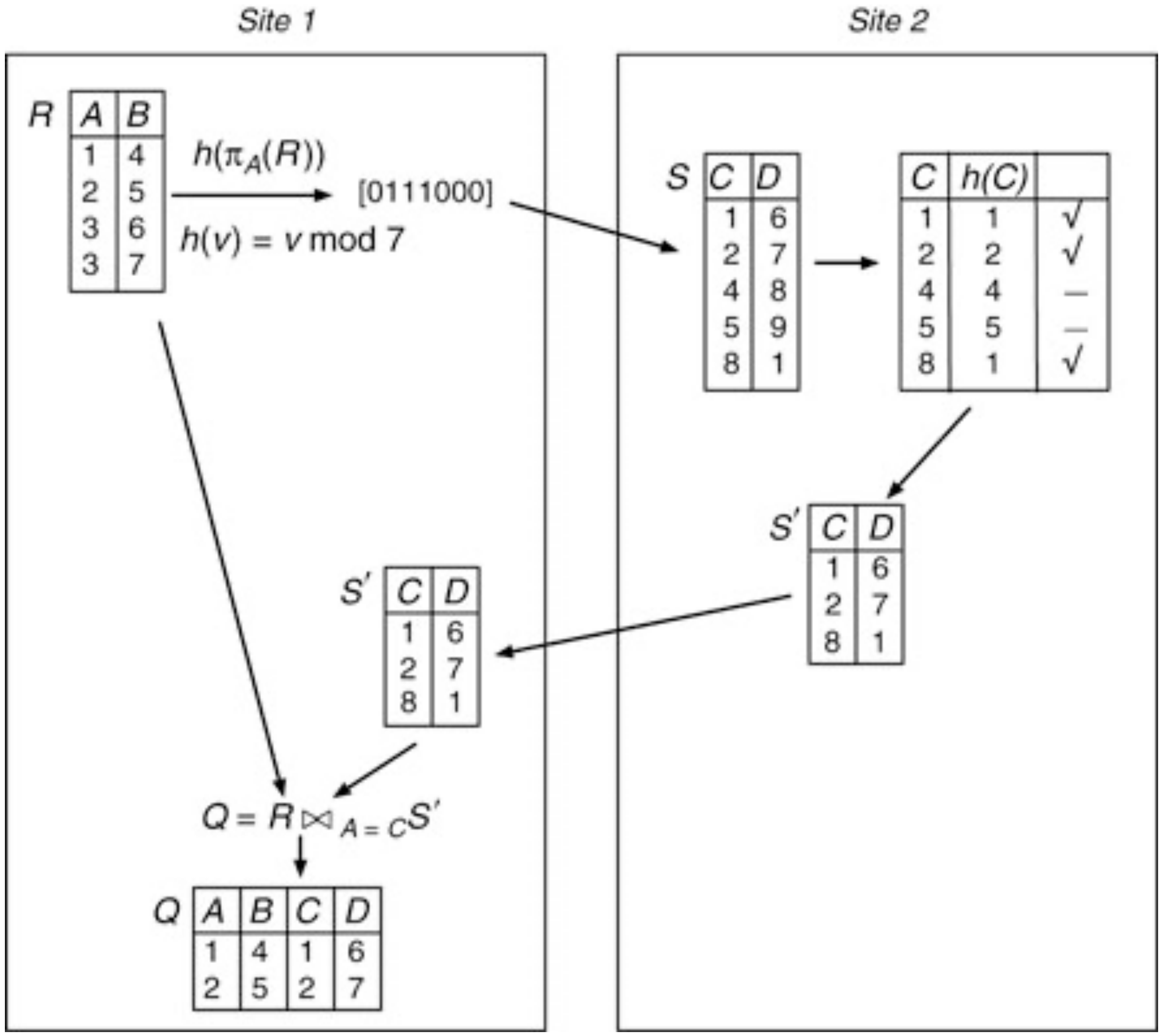
- 1^{st} join: 50 tuples network traffic (on site 2)
- 2^{nd} join: depends result of 1^{st} join

Specialized Parallel Operators

Semi-join

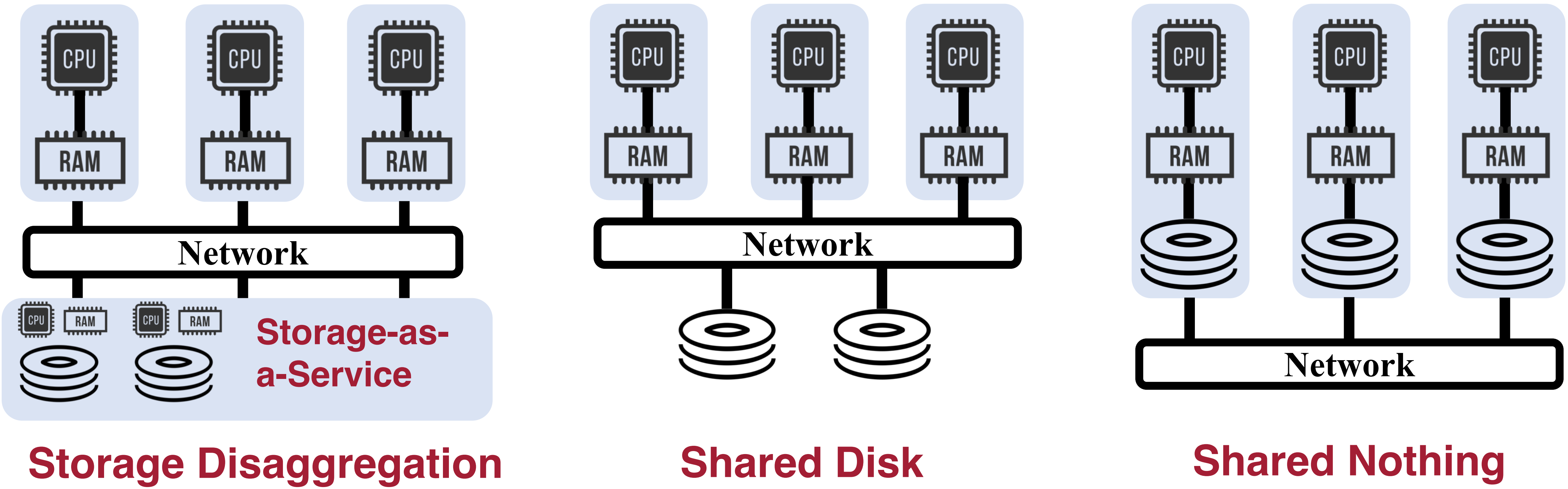
- Example:

```
SELECT *
 FROM T1, T2
 WHERE T1.A = T2.C
```



* Source: Sattler KU. (2009) Semijoin. Encyclopedia of Database Systems.

Distributed Database Architecture



Storage-disaggregation architecture is popular in cloud-native databases

- Features: (1) in-storage computation, (2) high-availability, (3) shared access to storage
- More on this topic in last few lectures

Q/A – Distributed Query Optimization

Details of reduction algorithm?

How is the paper related to modern distributed databases?

How does master-slave failover work?

Fragments being a project of the relation?

Distribute data without distribution logic?

More on updates? (will cover in next few lectures)

Which is the bottleneck, network or compute?

Before Next Lecture

Submit review for

Jim Gray, et al., Granularity of Locks and Degrees of Consistency in a Shared Data Base. Modelling in Data Base Management Systems, 1976