CSE 444: Database Internals

Section 10:

Parallel Processing and MapReduce

Review in this section

- Parallel DBMS
- MapReduce

Parallel DBMS

R(a,b) is horizontally partitioned across N = 3 machines.

Each machine locally stores approximately 1/N of the tuples in R.

The tuples are randomly organized across machines (i.e., R is block partitioned across machines).

Show a RA plan for this query and how it will be executed across the N = 3 machines.

Pick an efficient plan that leverages the parallelism as much as possible.

SELECT a, max(b) as topb
FROM R
WHERE a > 0
GROUP BY a

R(a, b)

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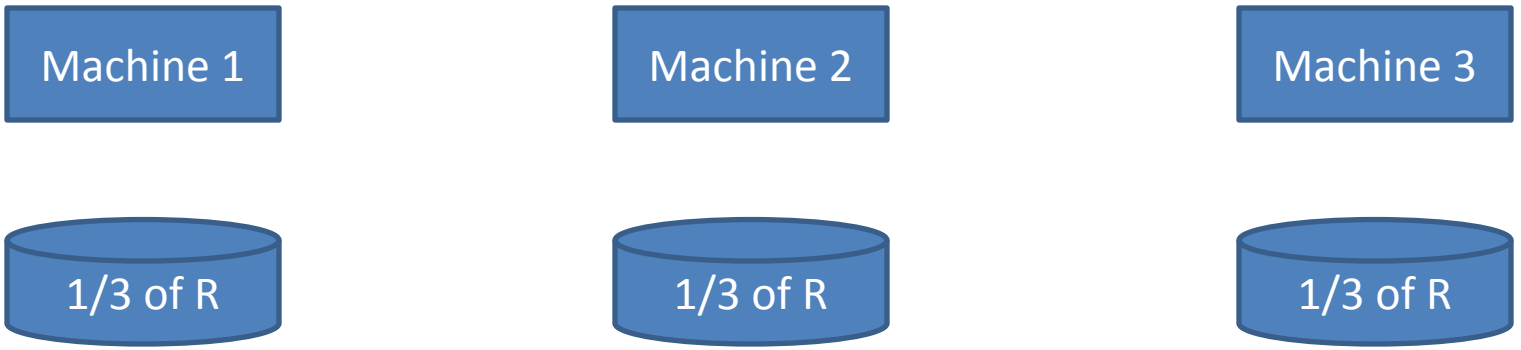

R(a, b)

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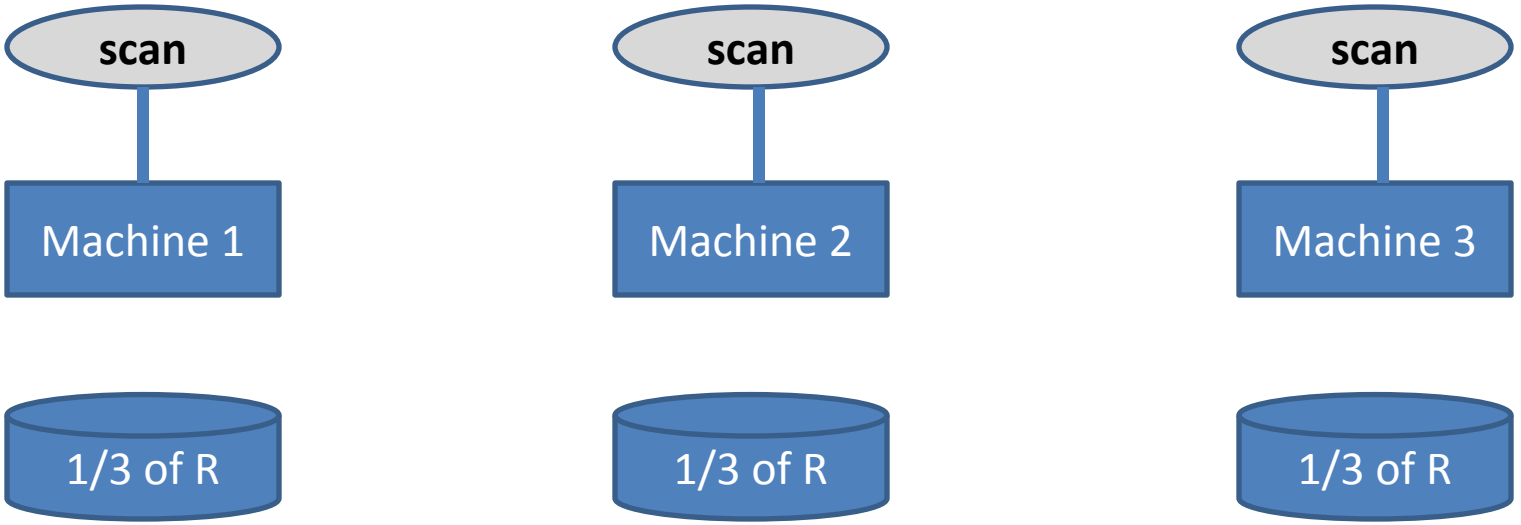
If more than one relation on a machine, then “scan S”, “scan R” etc



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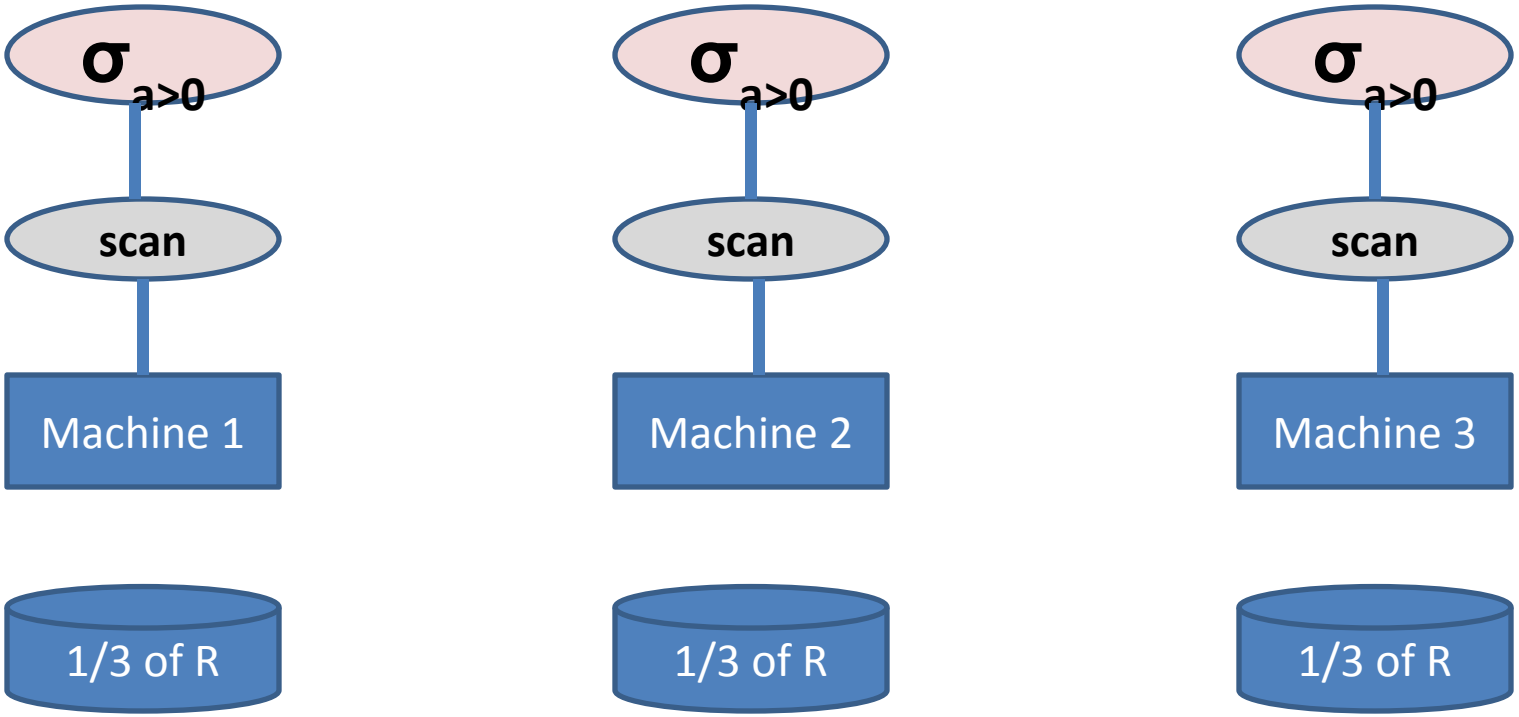

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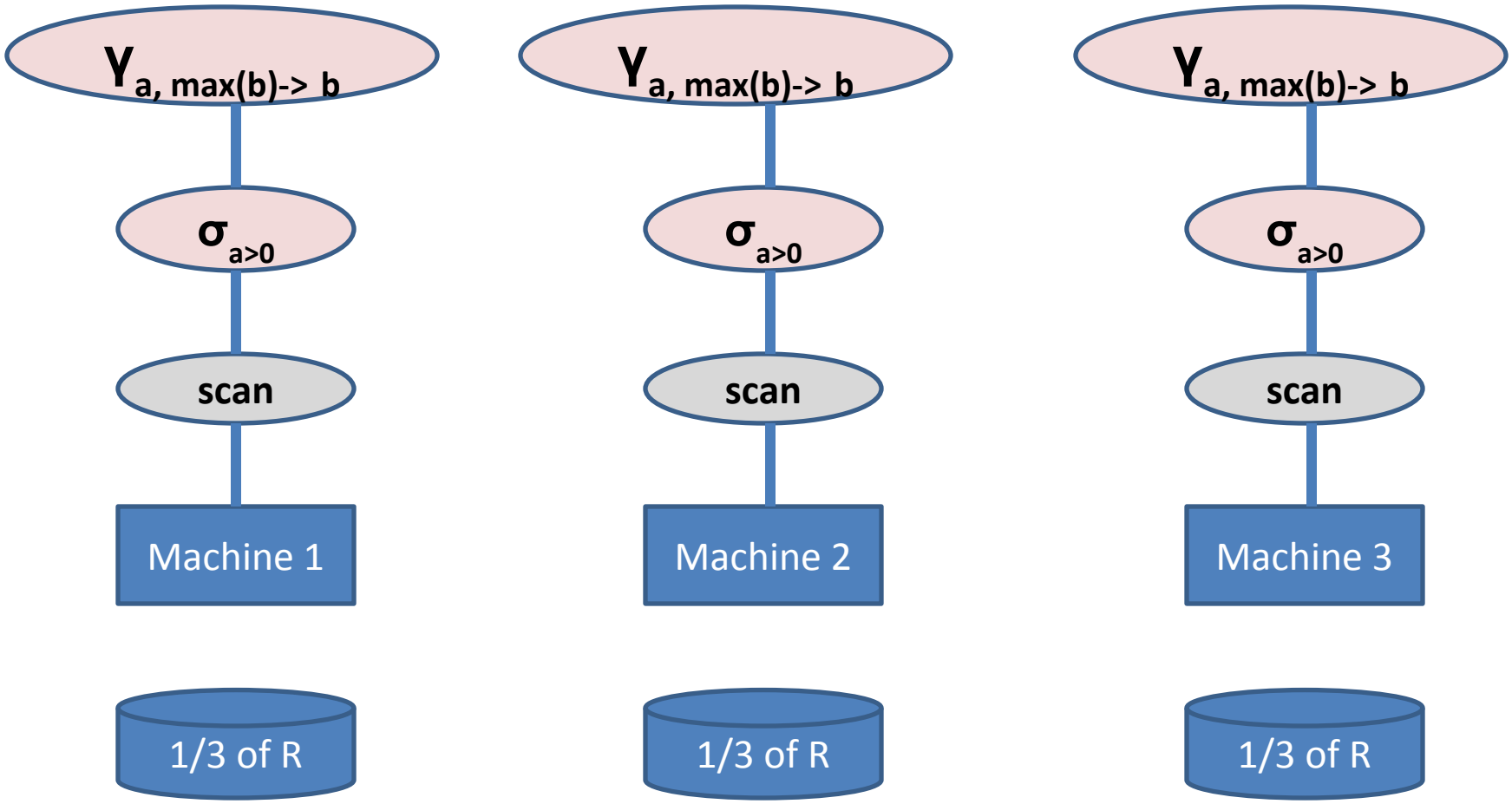

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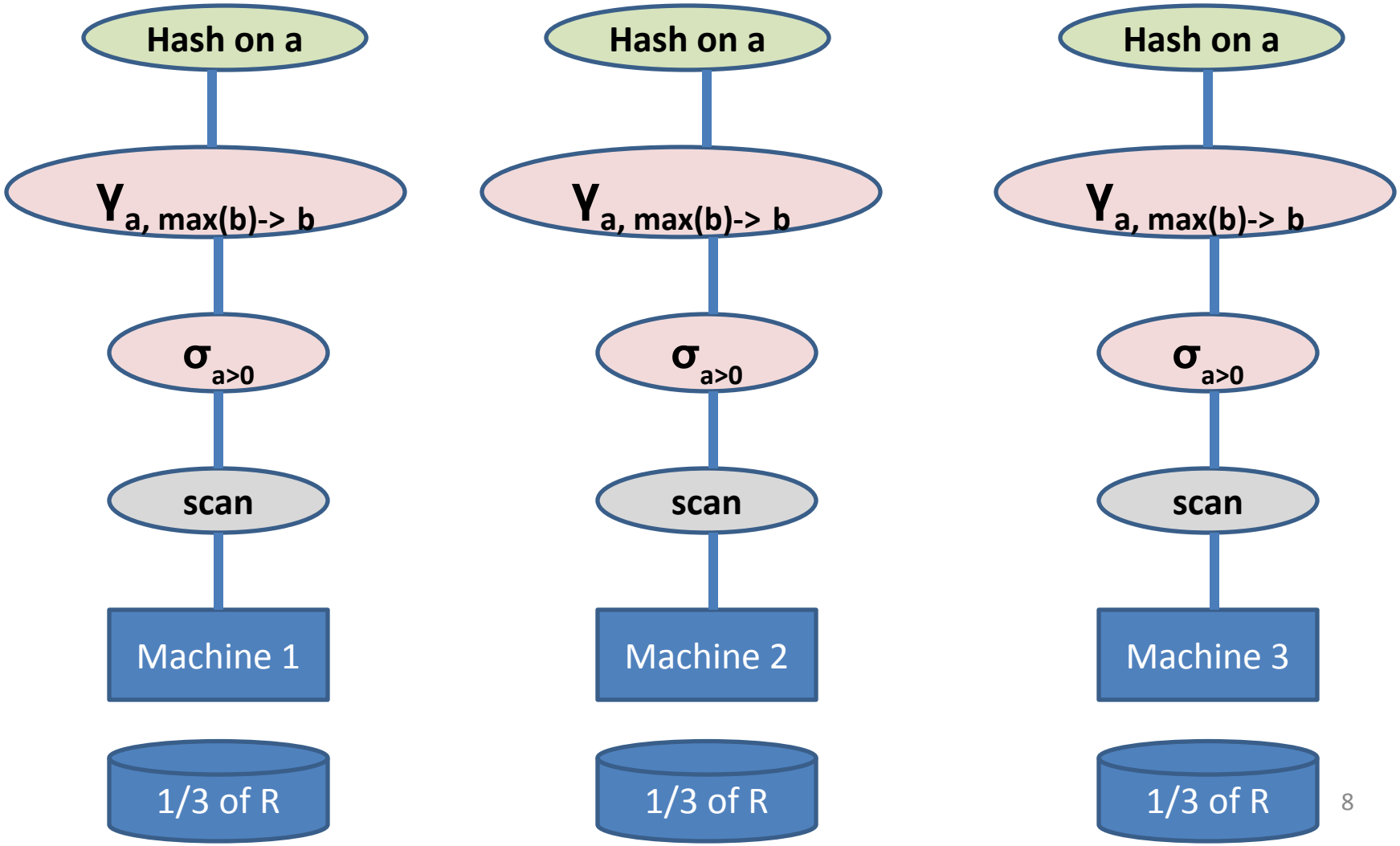

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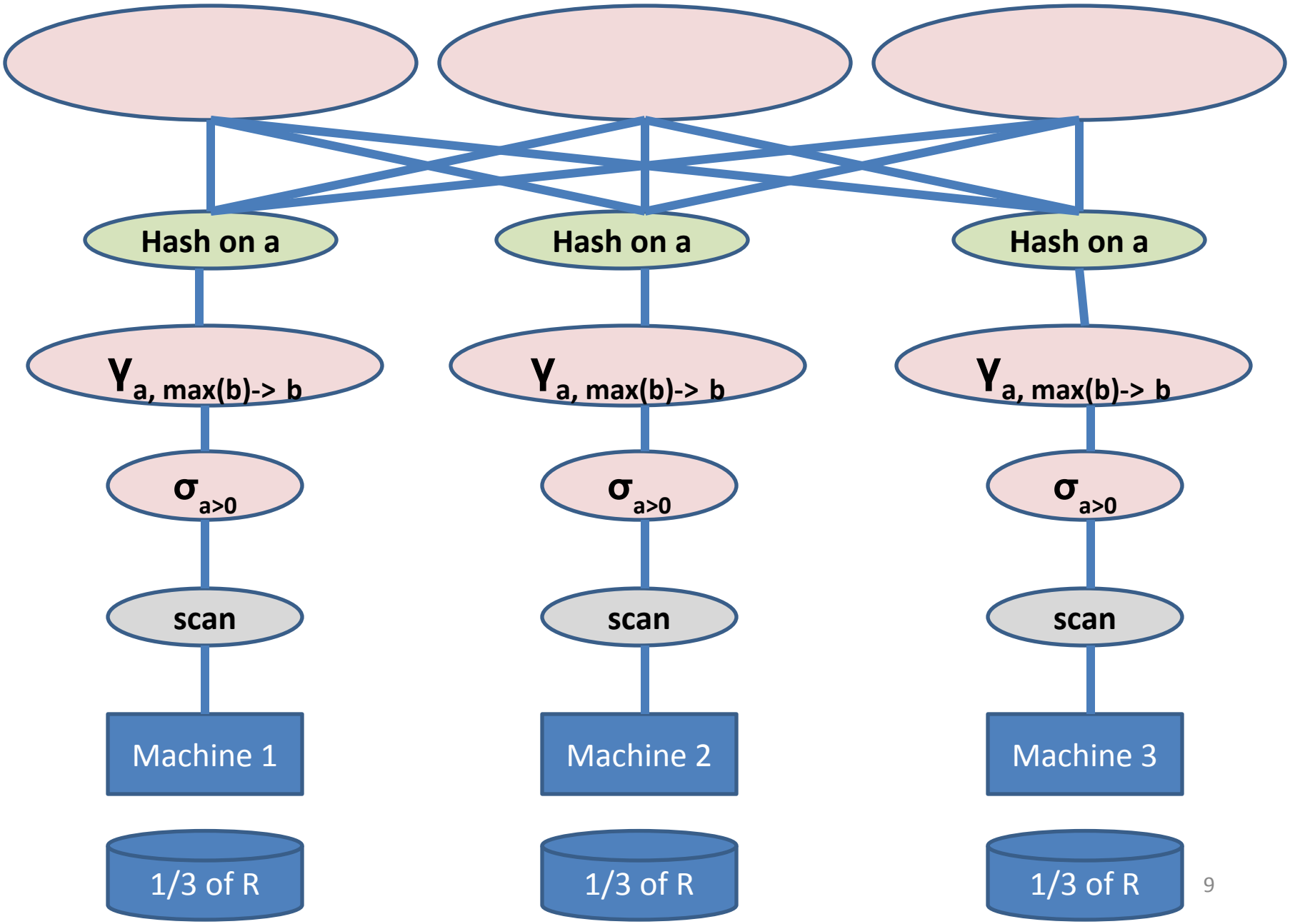

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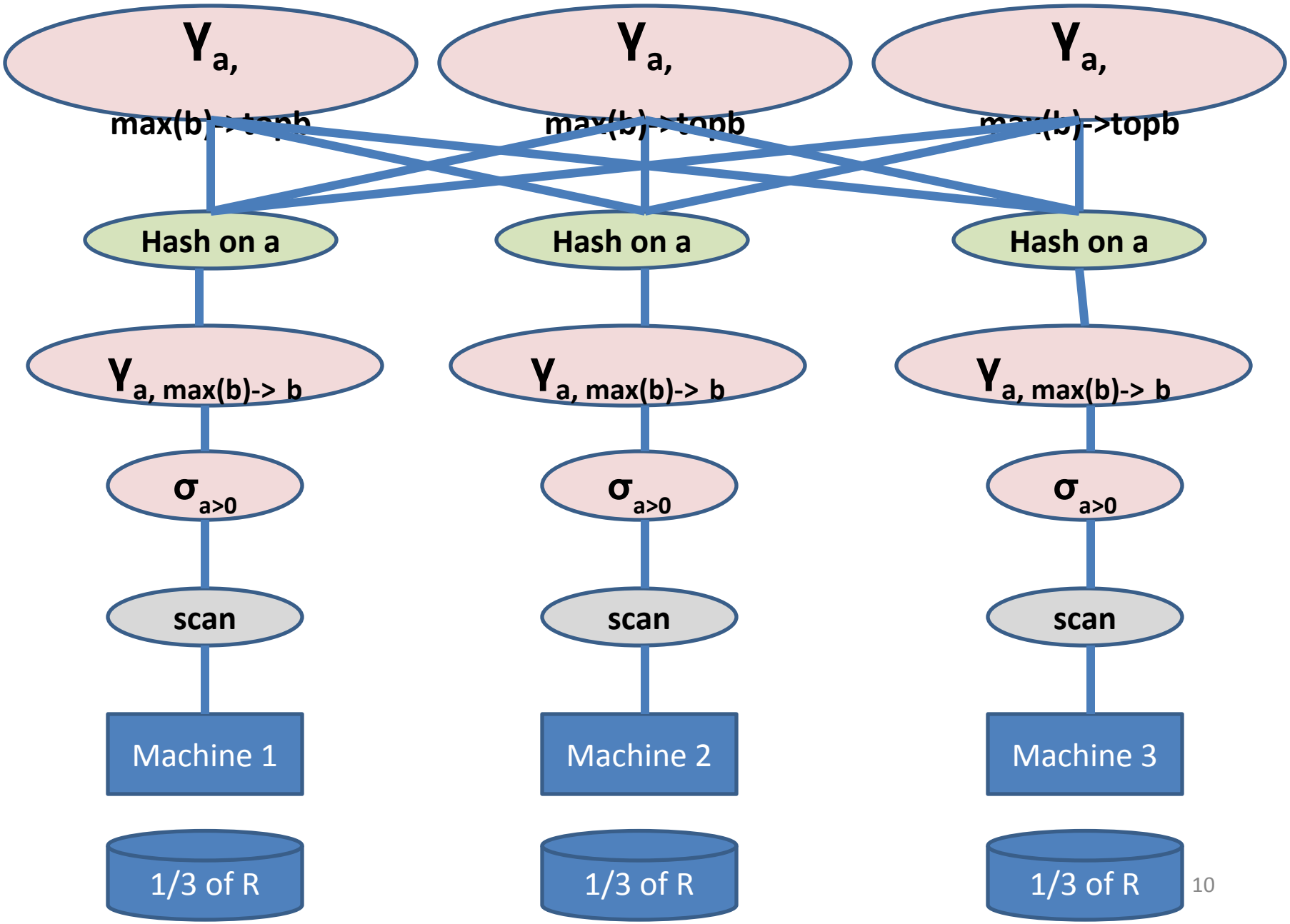

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Benefit of hash-partitioning

- **For parallel DBMS**
  - It would avoid the data re-shuffling phase
  - It would compute the aggregates locally

Hash-partition on a for R(a, b)

SELECT a, max(b) as topb FROM R
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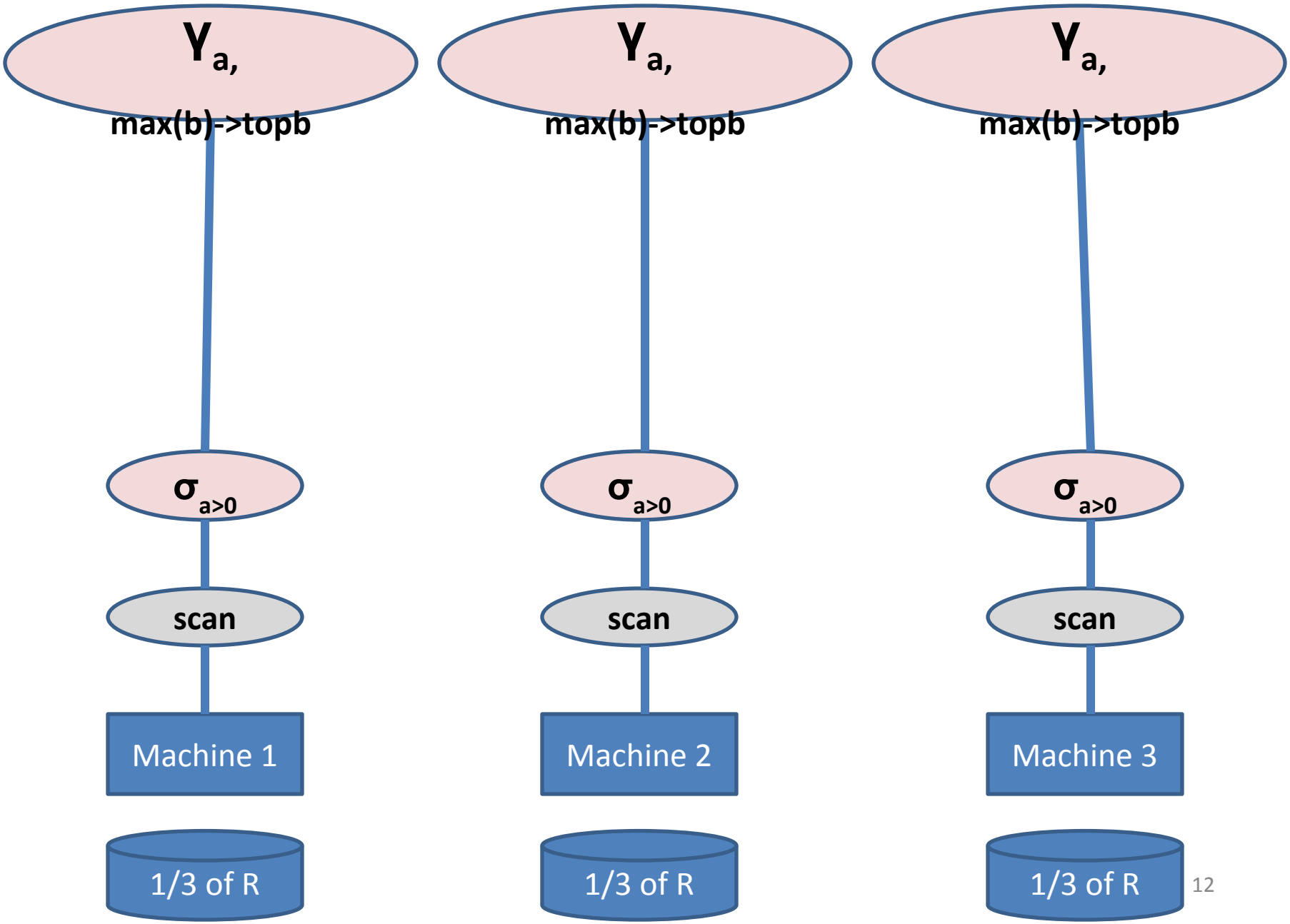

Problem 1)

Consider relations R(a,b), S(c,d), and T(e,f). All three are horizontally partitioned across N = 3 machines.

The tuples are randomly organized across machines.

Show a relational algebra plan for the following query and how it will be executed across the N = 3 machines:

```
SELECT *
FROM R, S, T
WHERE R.b = S.c
    AND S.d = T.e
    AND (R.a - T.f) > 100
```

Problem 1)

R(a,b)
S(c,d)
T(e,f)

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SELECT *
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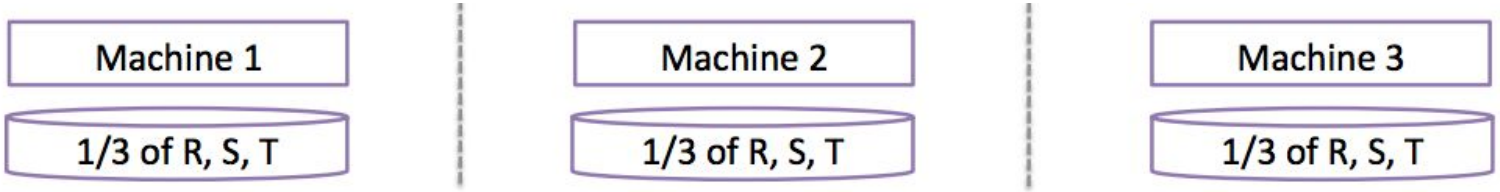

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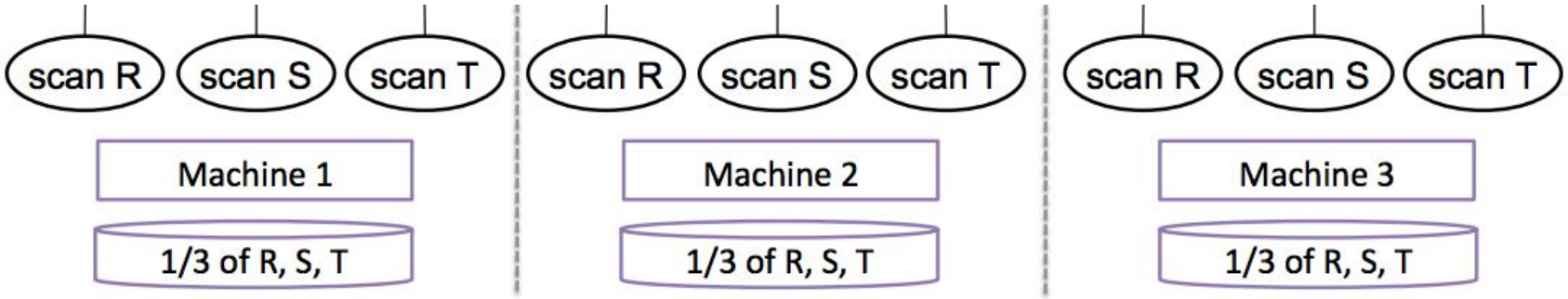

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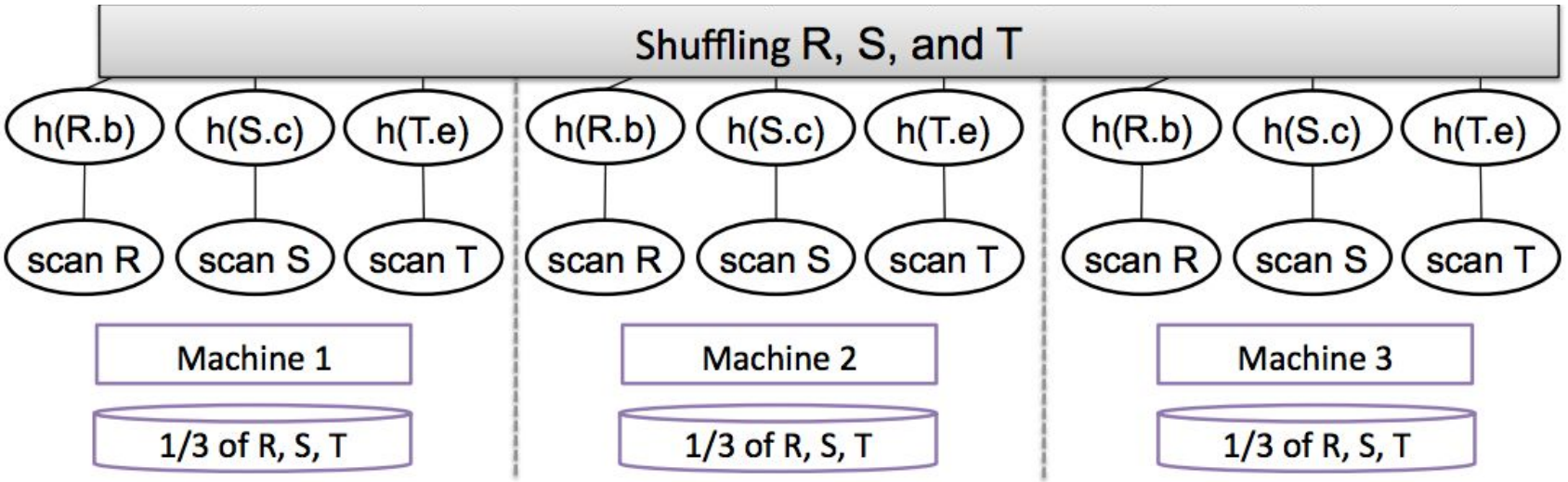

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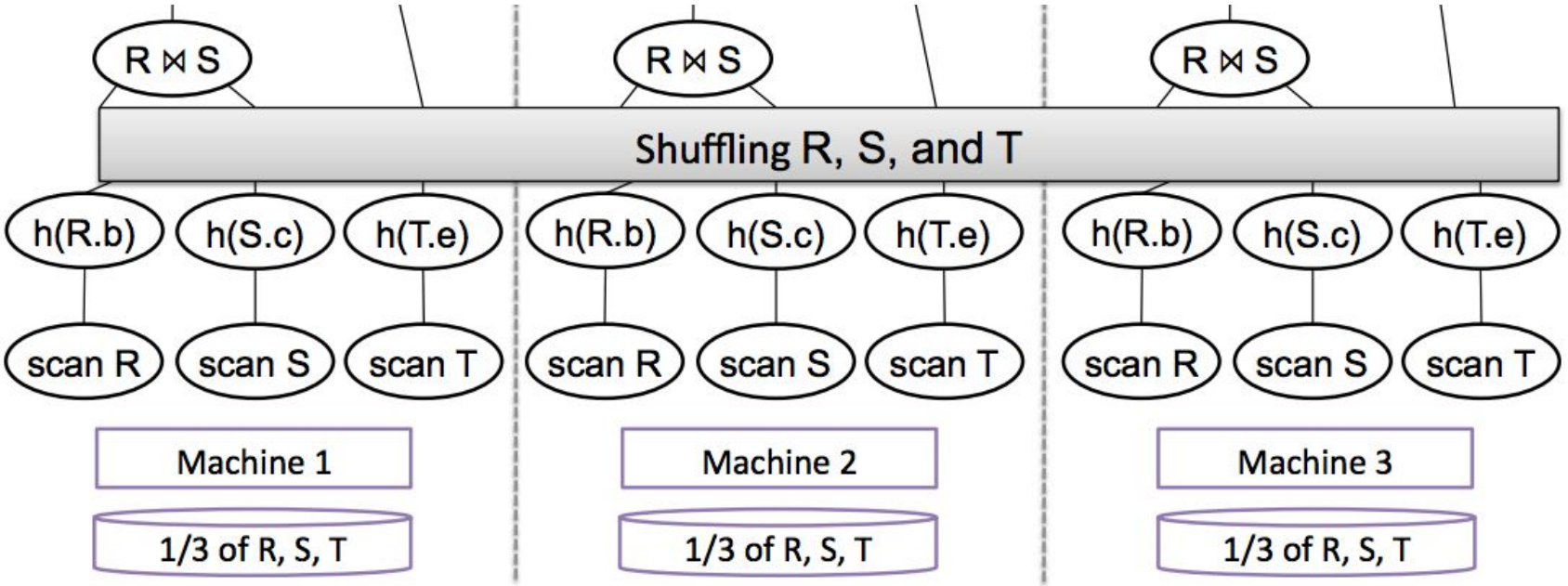

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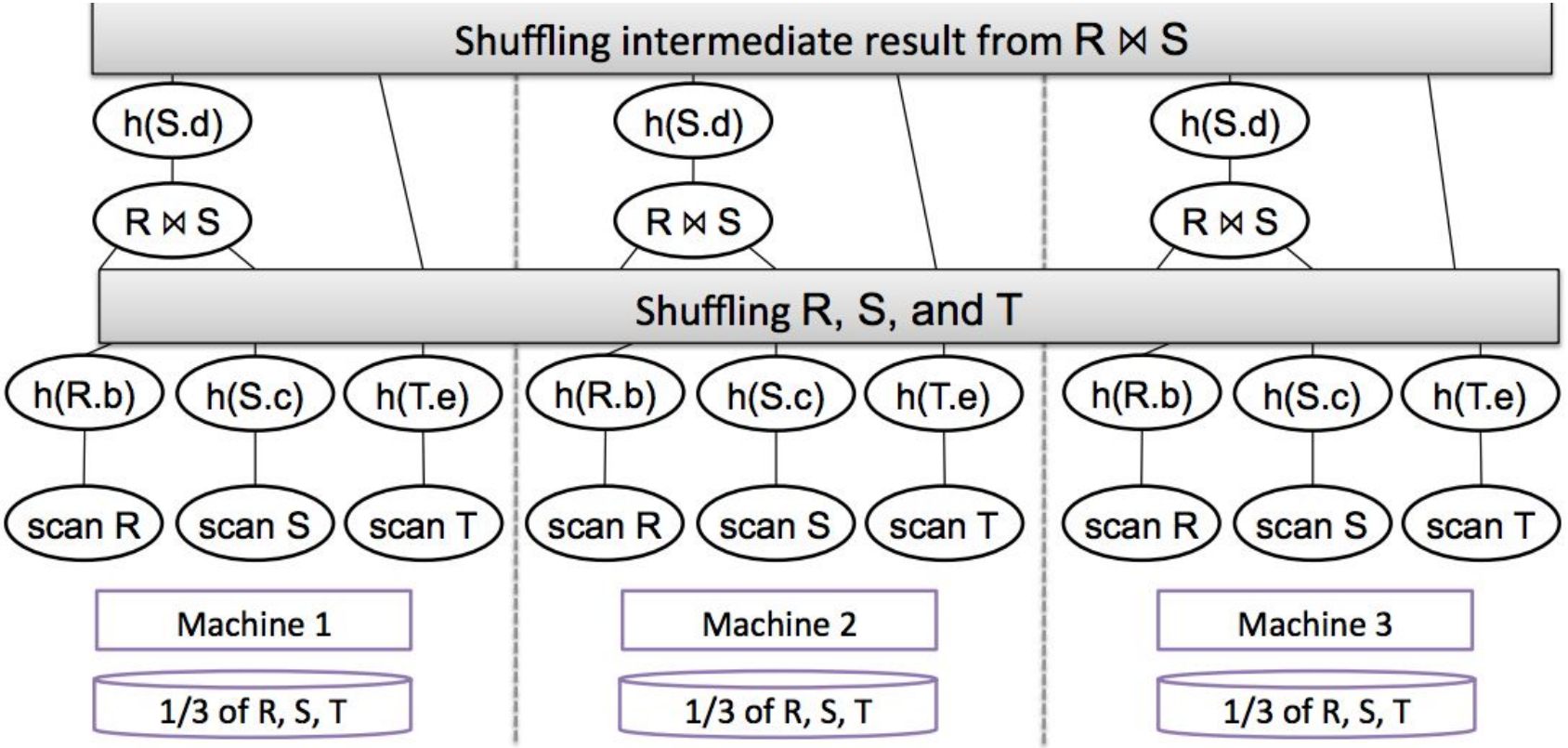

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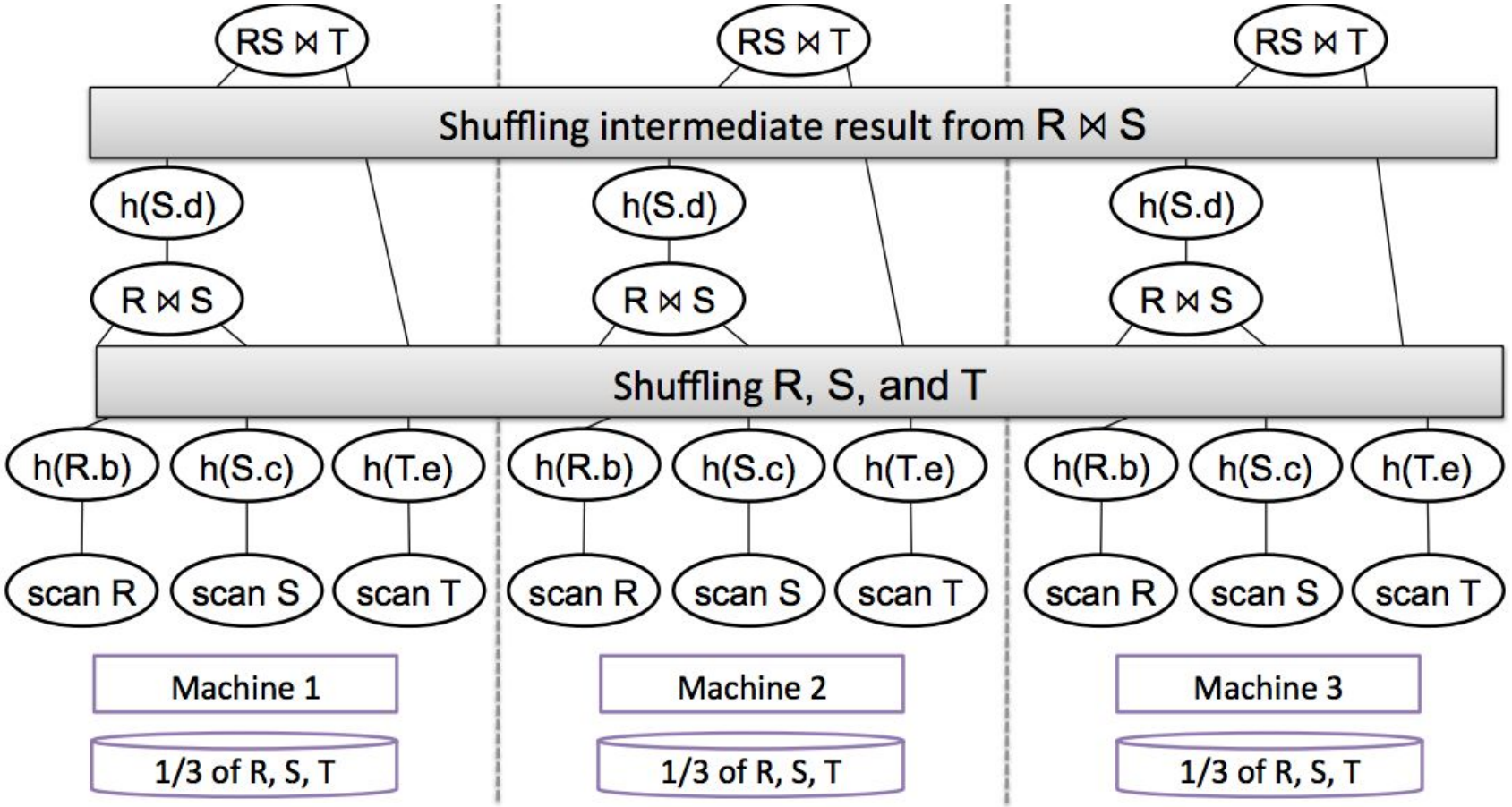

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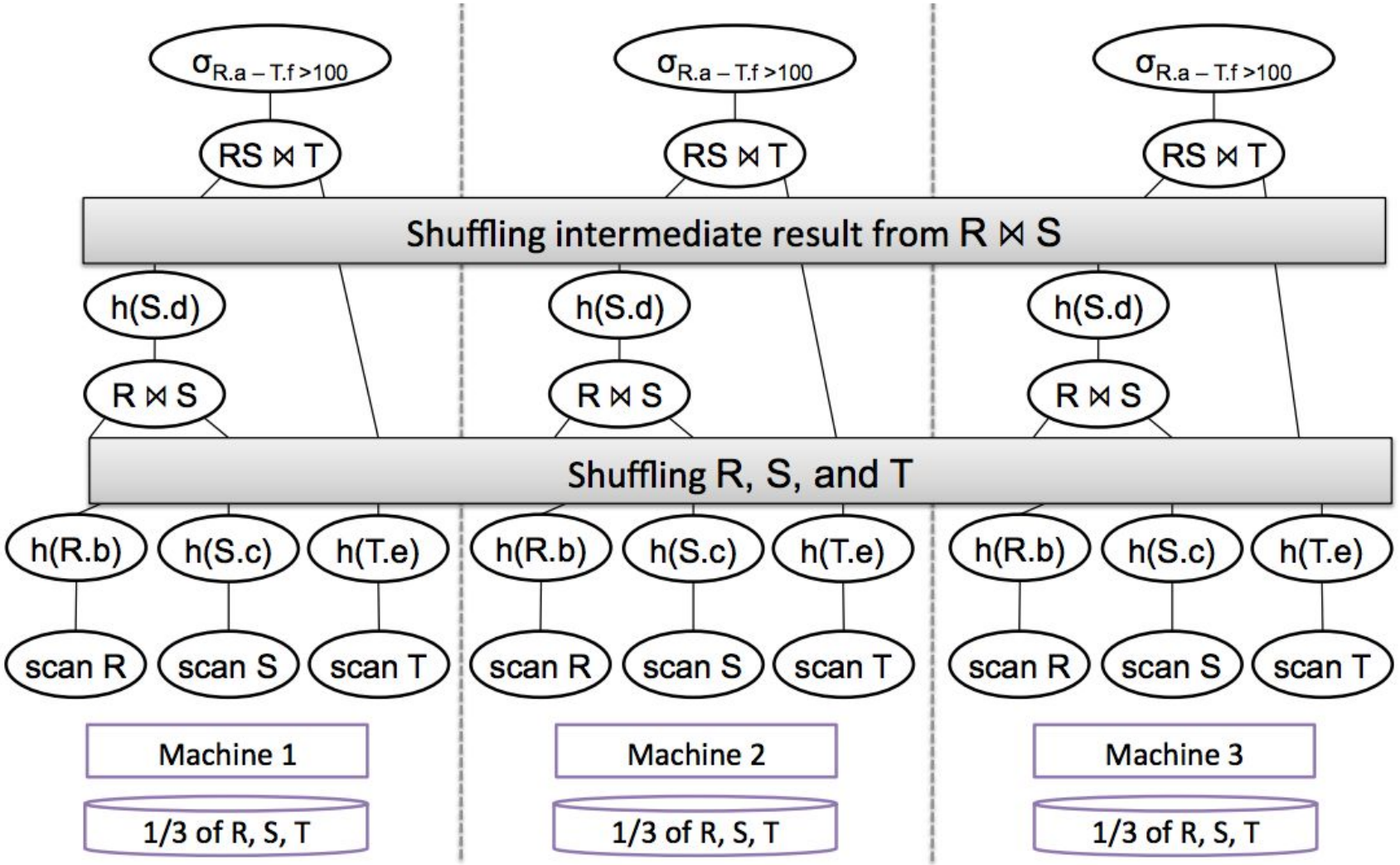

Map Reduce

Explain how the query will be executed in MapReduce

SELECT a, max(b) as topb
FROM R
WHERE a > 0
GROUP BY a

Specify the computation performed in the map and the reduce functions

R(a, b)

```
SELECT a, max(b) as topb
FROM R
WHERE a > 0
GROUP BY a
```

Map

- Each **map** task
  - Scans a block of R
  - Calls the map function for each tuple
  - The map function applies the selection predicate to the tuple
  - For each tuple satisfying the selection, it outputs a record with key = a and value = b

Note: When each map task scans multiple relations, it needs to output something like **key = a and value = ('R', b)** which has the relation name 'R'

R(a, b)

SELECT a, max(b) as topb
FROM R
WHERE a > 0
GROUP BY a

Shuffle

- The MapReduce engine reshuffles the output of the map phase and groups it on the intermediate key, i.e. the attribute a

Note: the programmer has to write only the map and reduce functions, the shuffle phase is done by the MapReduce engine (although the programmer can rewrite the partition function).

R(a, b)

SELECT a, max(b) as topb
FROM R
WHERE a > 0
GROUP BY a

Reduce

- Each reduce task
  - computes the aggregate value **max(b) = topb** for each group (i.e. ***a***) assigned to it (by calling the reduce function)
  - outputs the final results: **(a, topb)**

Note: A local combiner can be used to compute local max before data gets reshuffled (in the map tasks)

R(a, b)

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SELECT a, max(b) as topb
FROM R
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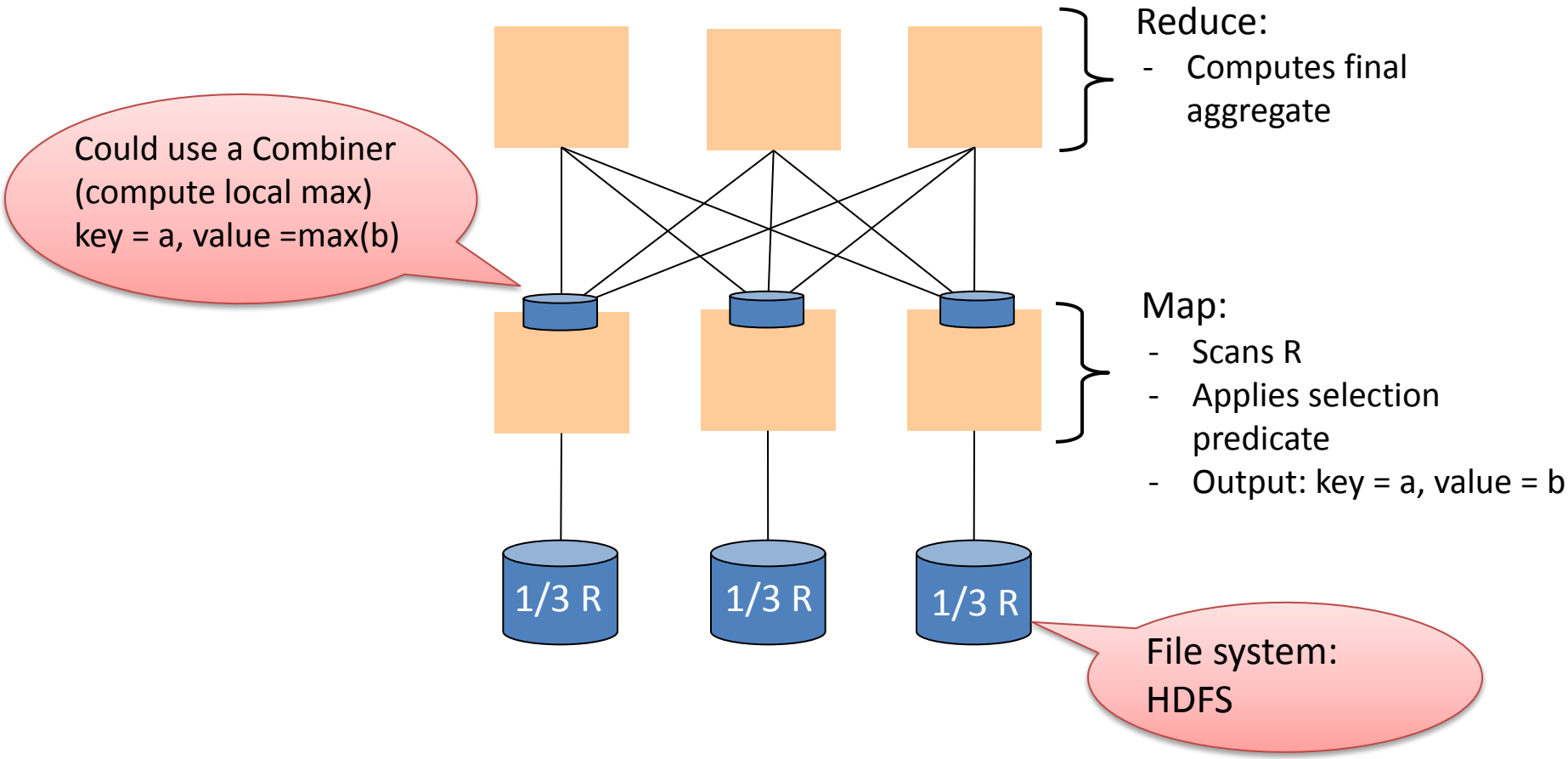
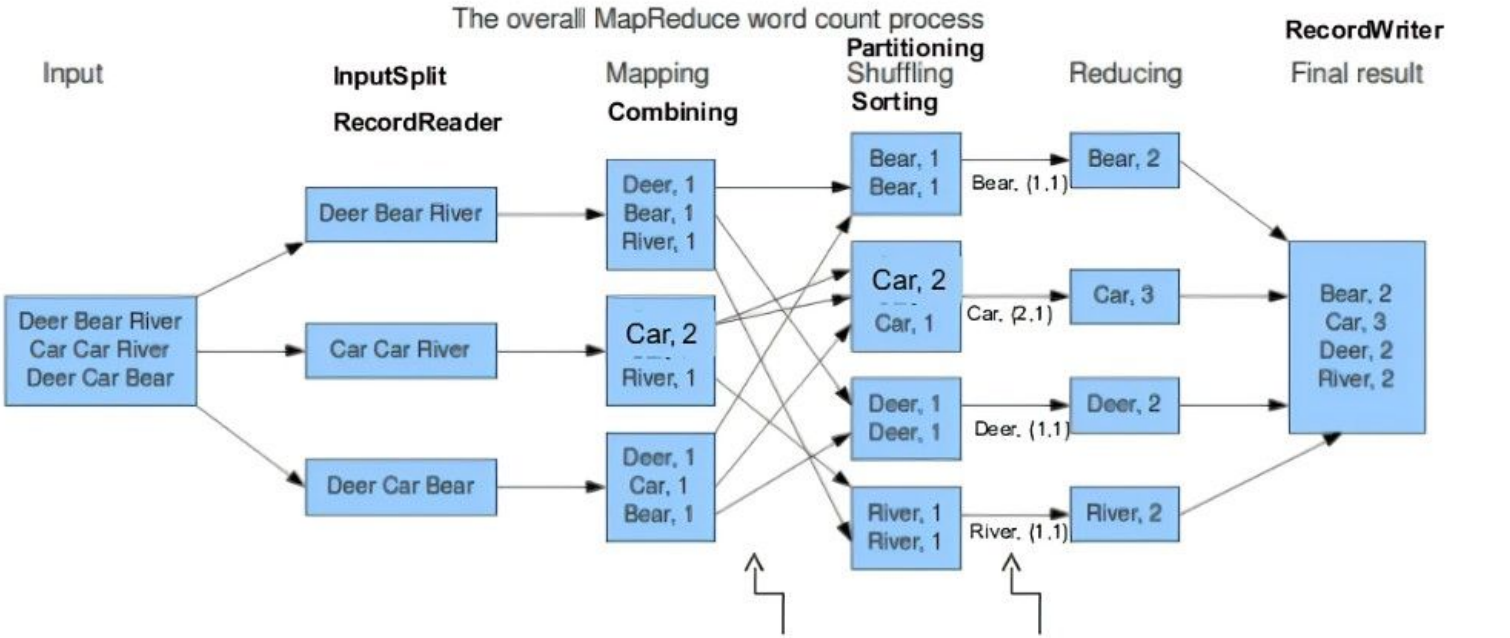


How does the MapReduce work?



SELECT a, max(b) as topb
FROM R
WHERE a > 0
GROUP BY a

Benefit of hash-partitioning

- **For MapReduce**
  - Logically, MR won't know that the data is hash-partitioned
  - MR treats map and reduce functions as black-boxes and does not perform any optimizations on them

- But, if a local combiner is used
  - Saves communication cost:
    - fewer tuples will be emitted by the map tasks
  - Saves computation cost in the reducers:
    - the reducers would not have to do as much work

Problem 2)

Consider two relations R(a, b) and S(b, c).

```
SELECT R.b, max(S.c) as cmax
FROM R, S
WHERE R.b = S.b
      AND R.a <= 100
GROUP BY R.b
```

For the **Map** function, what are the computations performed, and what will be its outputs? Assume that the Map function reads a block of R or S relation as input.

For the **Reduce** function, what will be its inputs, what are the computations performed, and what will be its outputs?

Problem 2)

SELECT R.b, max(S.c) as cmax
FROM R, S
WHERE R.b = S.b
AND R.a <= 100
GROUP BY R.b

R(a, b)
S(b, c)

Note: In some cases, you may need to perform more than one MapReduce job to get the final result

Map Function:

- If the map function processes a block of the **R** relation, it applies the selection predicate to each R tuple in that block (R.a <= 100), and if the tuple passes the selection, it outputs a record with key= R.b and value= ('R' , R.a).
- If the map function processes a block of the **S** relation, it outputs a record with key = S.b and value = ('S', S.c).

Reduce Function:

- Input to the reducer: The same b as the key and a list of R or S tuples ('R' , R.a) or ('S', S.c). In other words, we have … (b, *(value from R, value from S, value from S, etc* ….))
- Computation: The reducer performs the local join of R and S and finds the max(S.c) value.

Comparing between Parallel DBMSs and MapReduce Systems

Parallel DBMS:

- Offers updates, transactions, indexing
- Pipelined parallelism

MapReduce:

- Fault-tolerance
- Can handle stragglers
- Easy to scale

2PC Crash/Recovery Scenarios

Recovery Process

- At each active site a recovery process (RP) exists
  - It processes messages from RPs at other sites, and
  - handles all the transactions that were executing 2PC at the time of the last failure of the site.
- At recovery from a crash, the RP at the recovering site
  - reads the log on stable storage, and
  - accumulates in virtual storage information relating to transactions executing 2PC at the time of the crash.
- This information in virtual storage is used to
  - answer queries from other sites about transactions that had their coordinators at this site, and
  - to send unsolicited information to other ‘subordinate sites’ for transactions at this ‘coordinator site’

2PC Recovery Scenarios

1. **If the recovery process finds that**
   - **a transaction was executing at the time of the crash,**
   - **And that no commit/prepare protocol log record had been written**

- Then the recovery process neither knows nor cares whether it is dealing with a subordinate or the coordinator of the transaction.
- It aborts that transaction by
  - "undoing" its actions, if any, using the UNDO log records,
  - writing an abort record,
  - and "forgetting" it.

2PC Recovery Scenarios

2. If the recovery process at a coordinator finds a transaction in the committing (resp. aborting) state

- It periodically tries to send the COMMIT (ABORT) to all the subordinates that have not acknowledged and awaits their ACKs.
- Once all the ACKs are received, the recovery process writes the end record and “forgets” the transaction.

2PC Recovery Scenarios

3. If the coordinator process notices the failure of a subordinate while waiting for the latter to send its vote

- then the former aborts the transaction (and follows the necessary steps).

4. If the failure occurs when the coordinator is waiting to get an ACK

- then the coordinator hands the transaction over to the recovery process.
- (commit/abort state must be maintained)

2PC Recovery Scenarios

5. **If a subordinate notices the failure of the coordinator before the former sent a YES VOTE and moved into the prepared state**
   - then it aborts the transaction (unilateral abort)

6. **If the failure (of the coordinator) occurs after the subordinate is in prepared state**
   - then the subordinate hands the transaction over to the recovery process.

2PC Recovery Scenarios

7. When a recovery process receives an inquiry message from a prepared subordinate site

- it looks at its information in virtual storage.
- If it has information that says the transaction is in the aborting or committing state, then it sends the appropriate response.

- **What if no information is found?**

2PC Recovery Scenarios

7 contd.

- **How can such a situation arise when no info is found**

- Both COMMITS and ABORTS are being acknowledged
- Inquiry is being made means that the inquirer had not received and processed a COMMIT/ABORT before the inquiree "forgot" the transaction.
- Such a situation comes about when
  - (1) the inquiree sends out PREPARES,
  - (2) it crashes before receiving all the votes and deciding to commit/abort, and
  - (3) on restart, it aborts the transaction and does not inform any of the subordinates.

2PC Recovery Scenarios

7 contd.

- **What to do?**

- On restart, the recipient of an inquiry cannot tell whether it is a coordinator or subordinate, if no commit protocol log records exist for the transaction.
- Given this fact, the correct response to an inquiry in the no information case is an ABORT.

2PC Recovery Scenarios

8. **When the recovery process finds that it (the subordinate) is in the prepared state for a particular transaction**

- It cannot take a unilateral decision
- The rest you have to figure out ☺️
- Write in HW6 what happens from receiving the PREPARE message at this subordinate
- Note that we assumed that a site will recover at some point after a crash.