# CSE 444: Database Internals

## Section 9:

## Parallel Processing and MapReduce

# Review in this section

- Parallel DBMS
- MapReduce

# Parallel DBMS

R(a,b) is <u>horizontally partitioned</u> 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 <u>block partitioned</u> across machines).

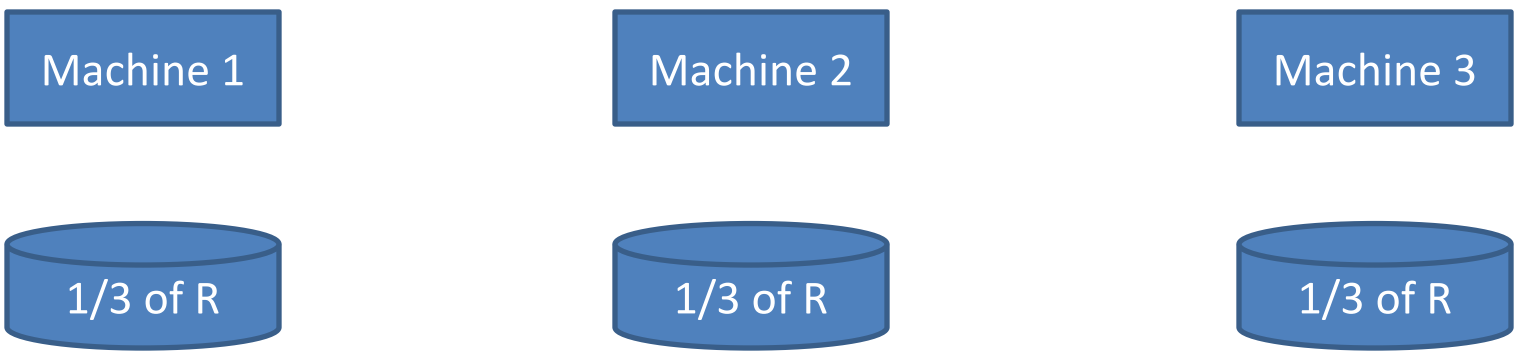
Show a RA plan for this query and how it will be executed across the N = 3 machines.

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)

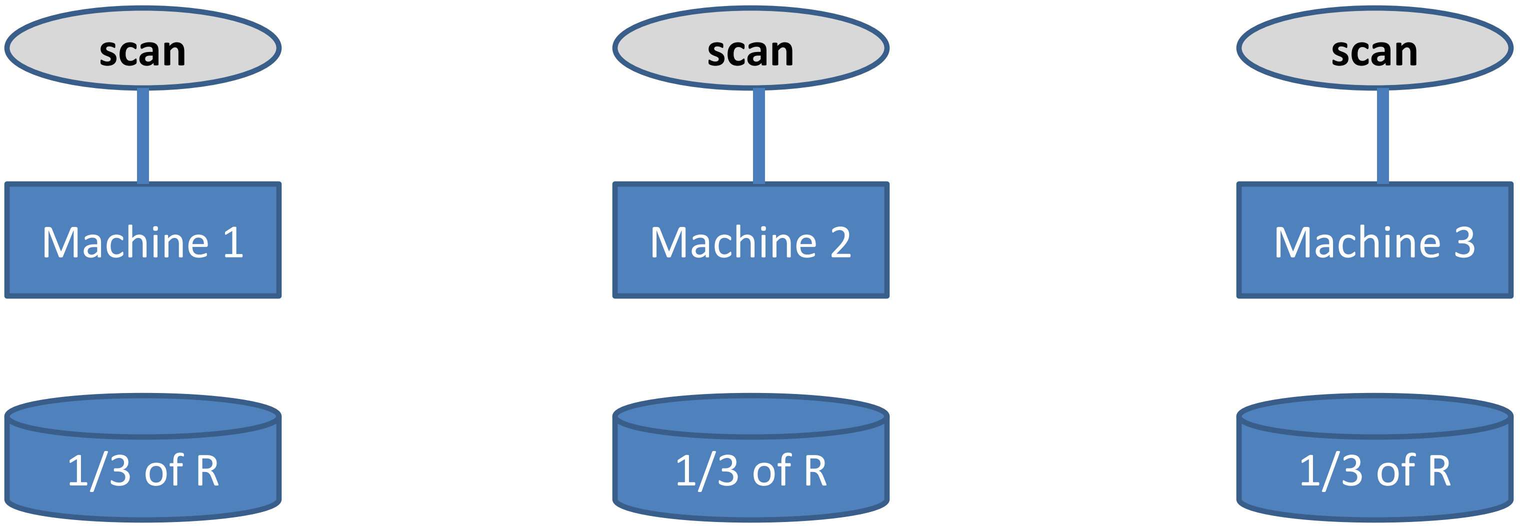
```
SELECT a, max(b) as topb
FROM R
WHERE a > 0
GROUP BY a
```



R(a, b)

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

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



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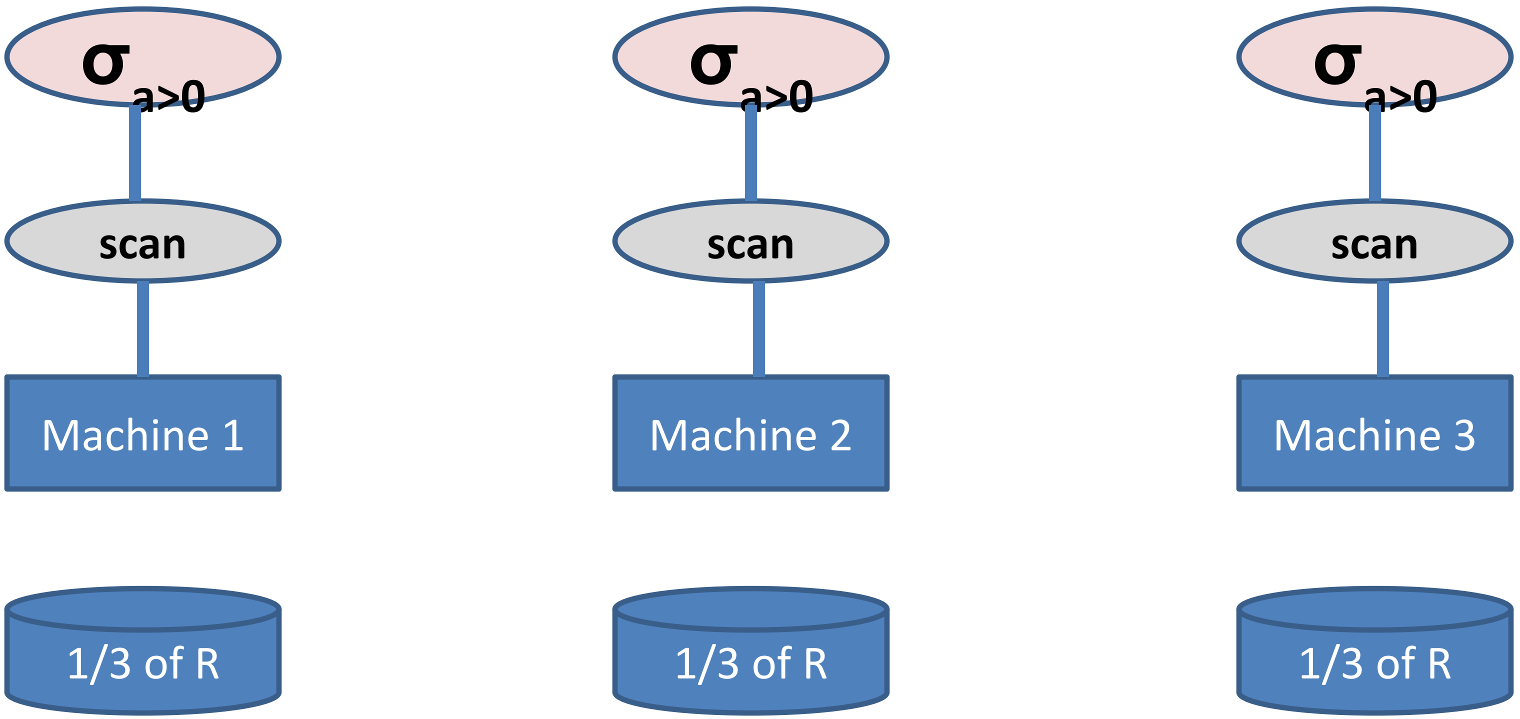

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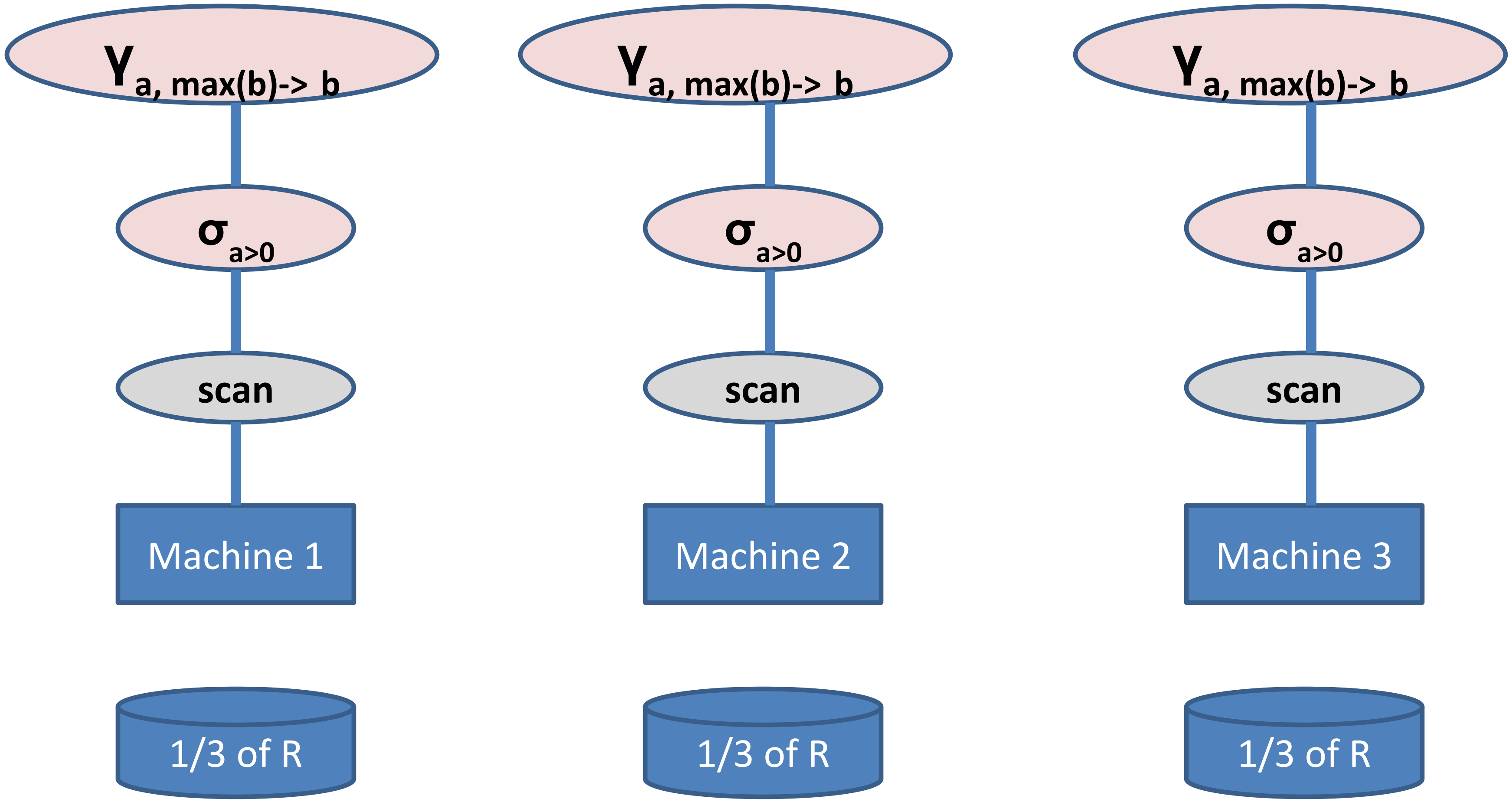

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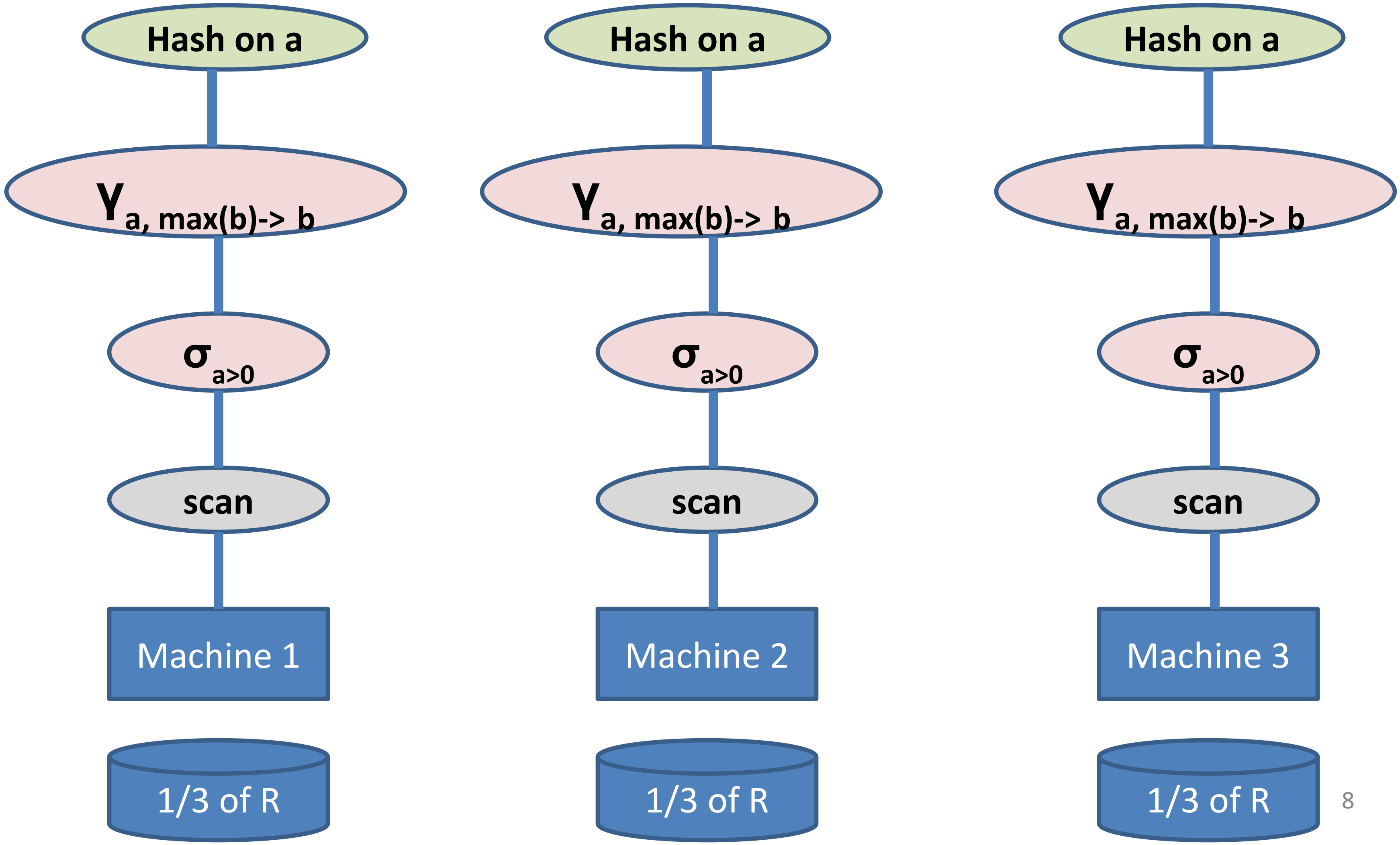

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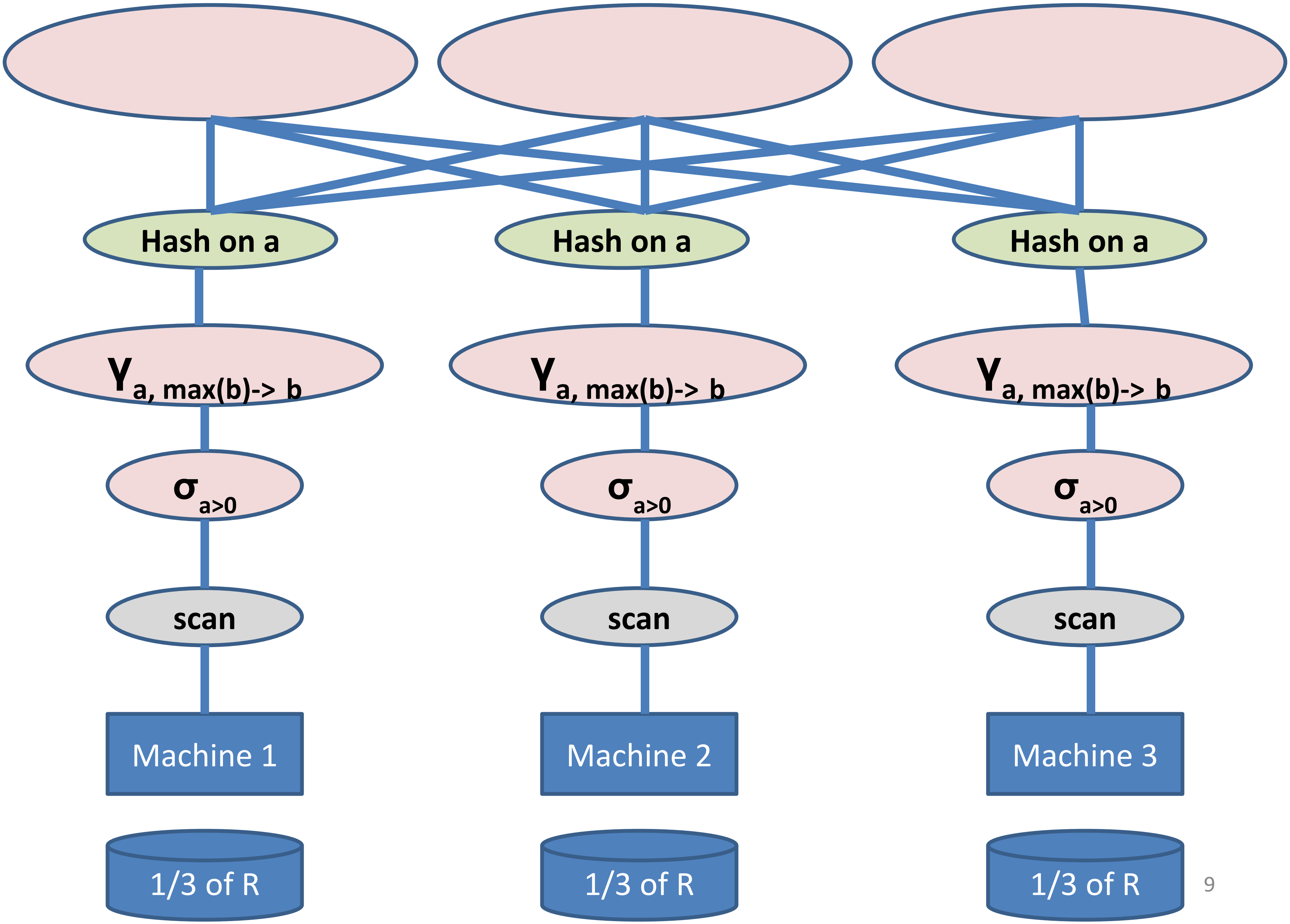

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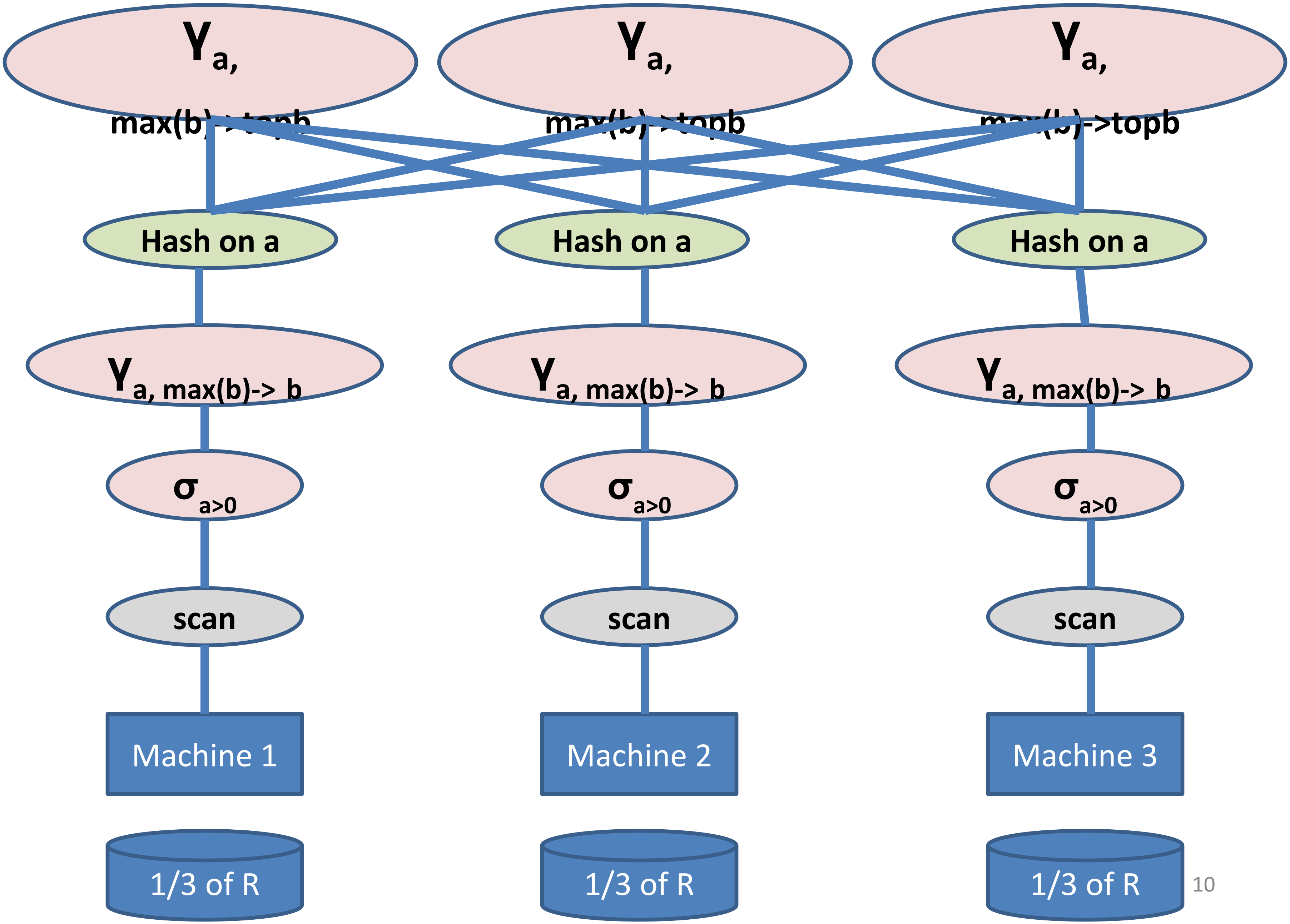


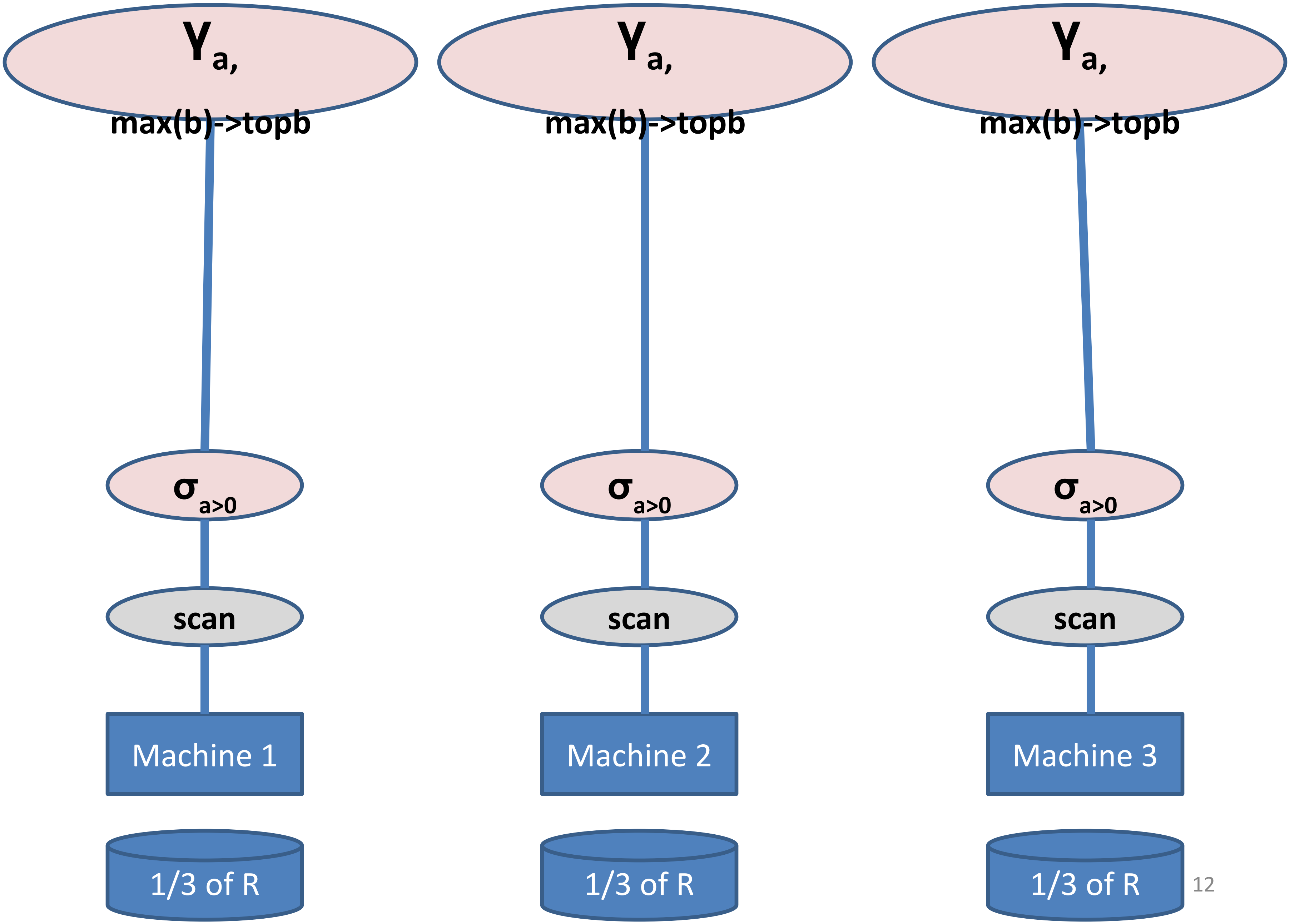
```
SELECT a, max(b) as topb
FROM R
WHERE a > 0
GROUP BY a
```

# 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
WHERE a > 0 GROUP BY a



# 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 *
FROM R, S, T
WHERE R.b = S.c
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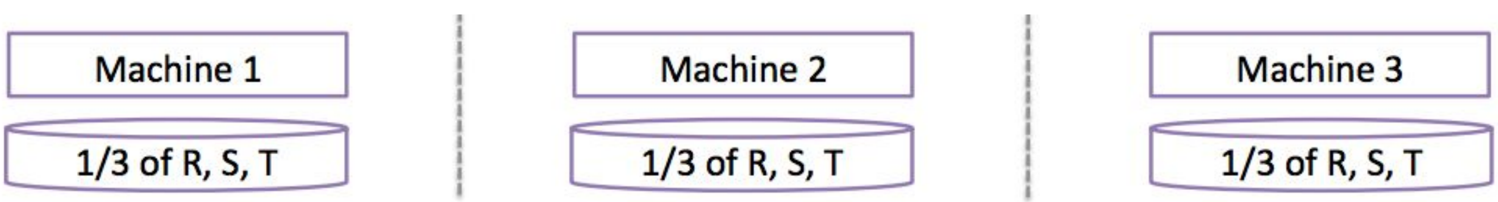

# Problem 1)

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

**SELECT** *
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**WHERE** R.b = S.c
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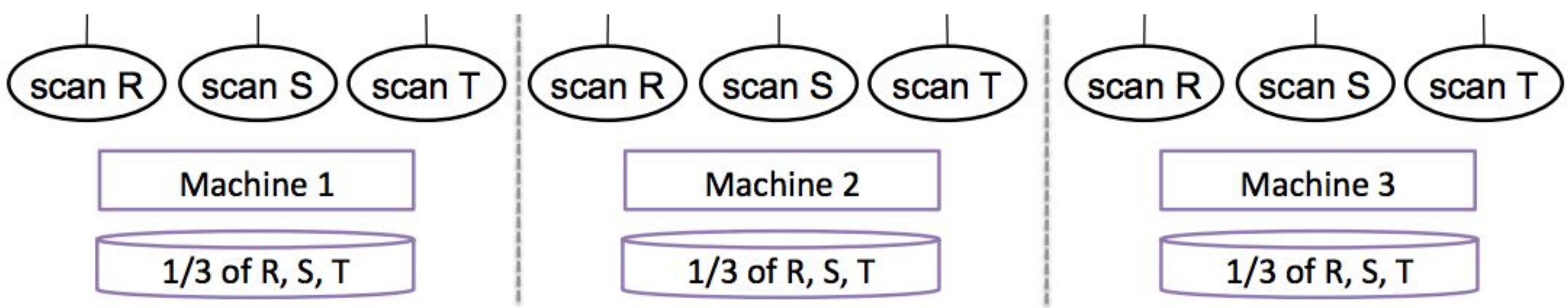

# Problem 1)

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

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SELECT *
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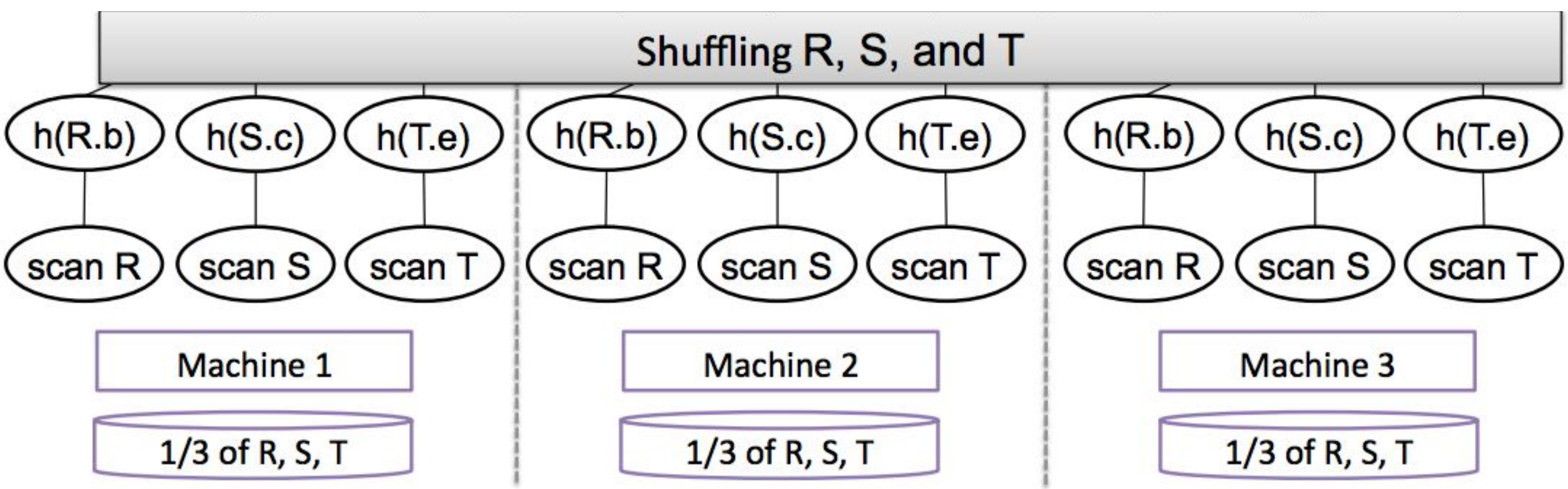

# Problem 1)

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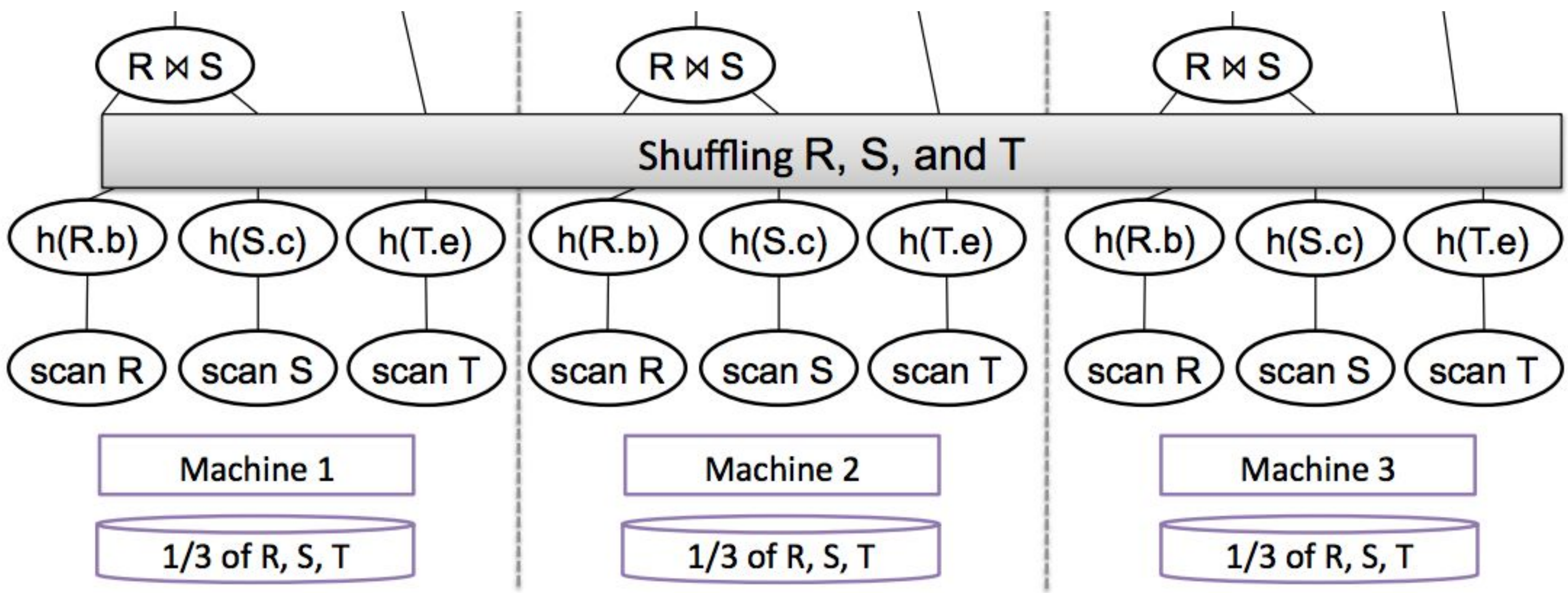

# Problem 1)

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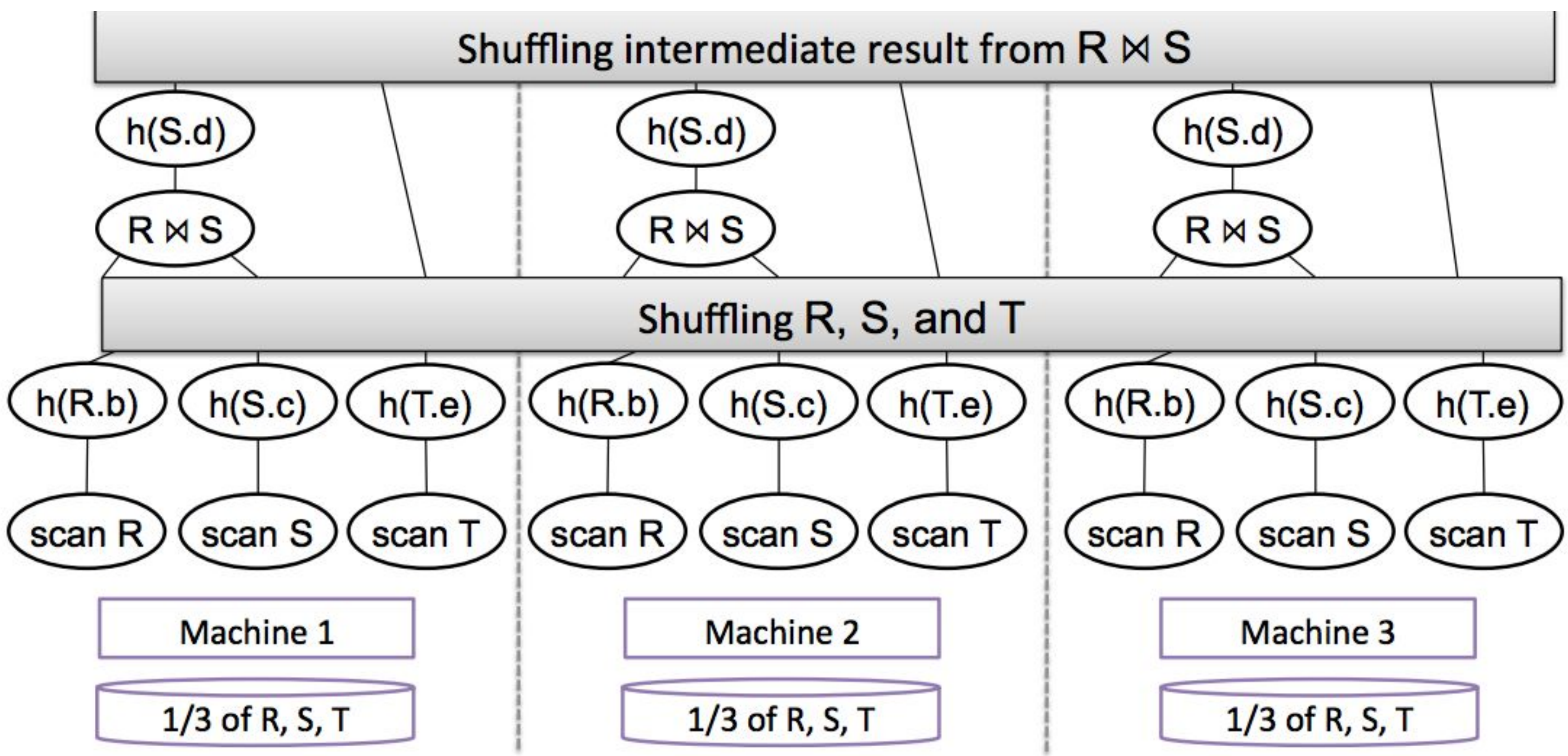

# Problem 1)

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

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SELECT *
FROM R, S, T
WHERE R.b = S.c
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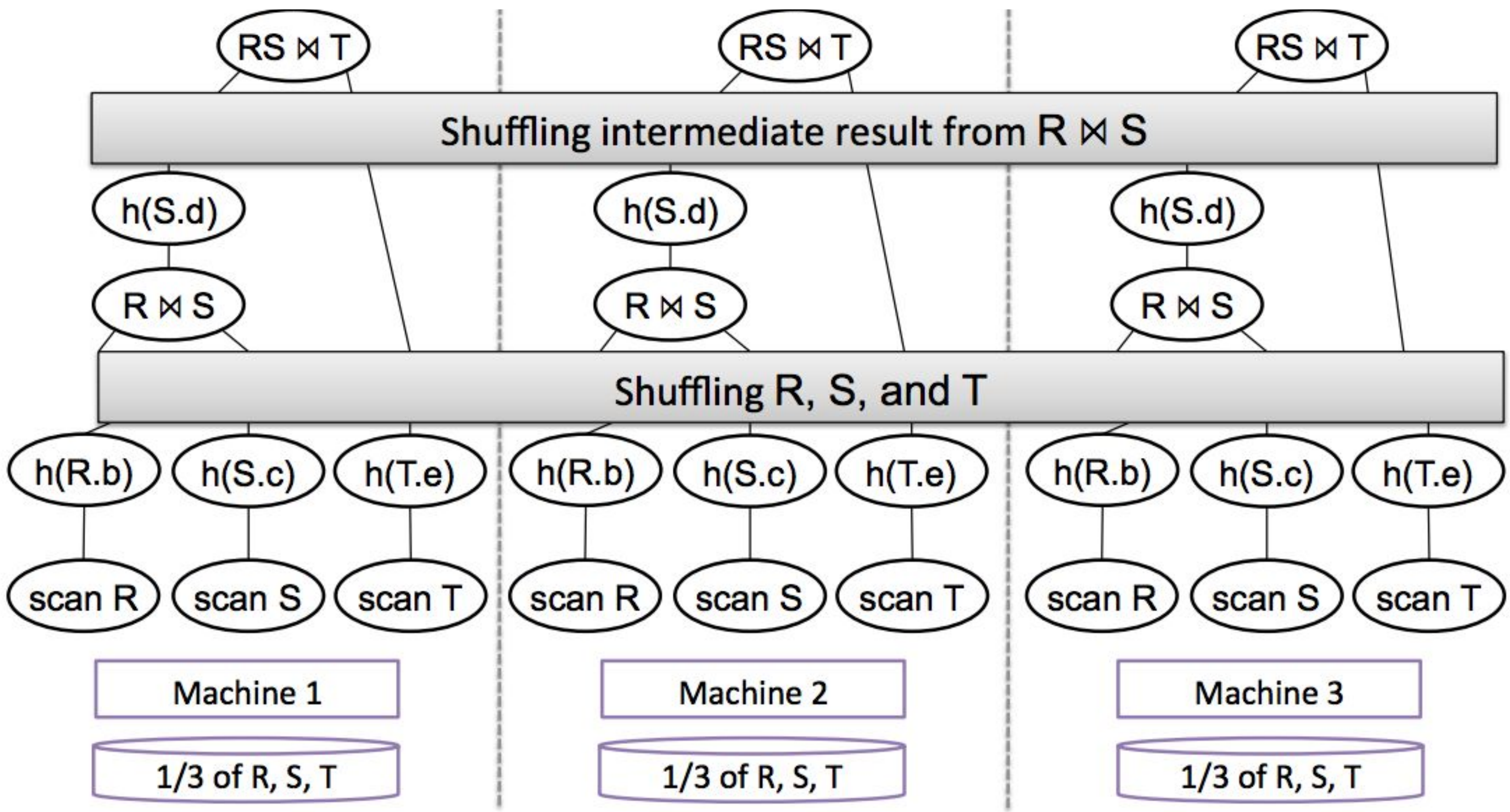

# Problem 1)

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

**SELECT** *
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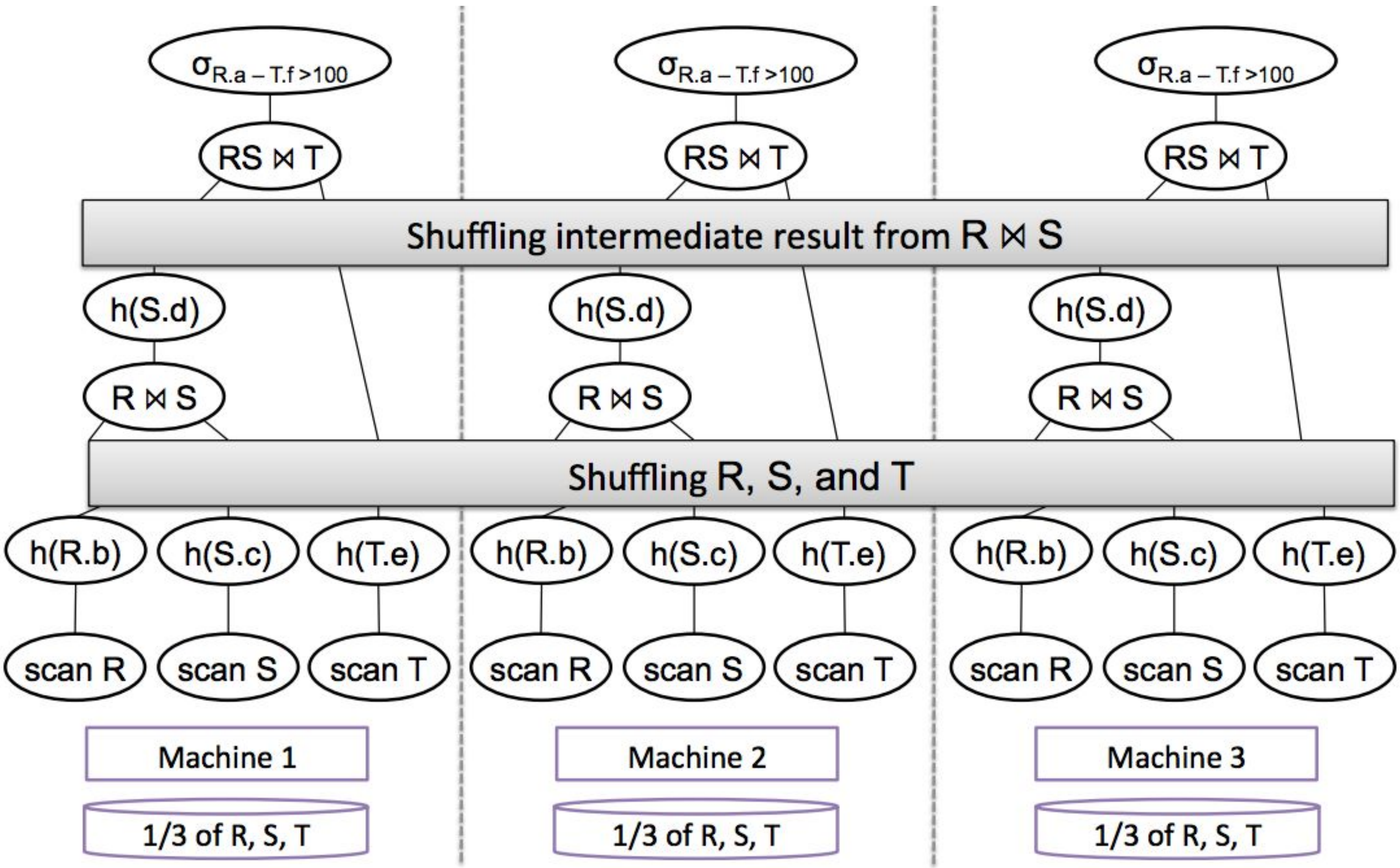


# Map Reduce

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)

# Map

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

- 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), but you should still mention this in HW6 answers.

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)**

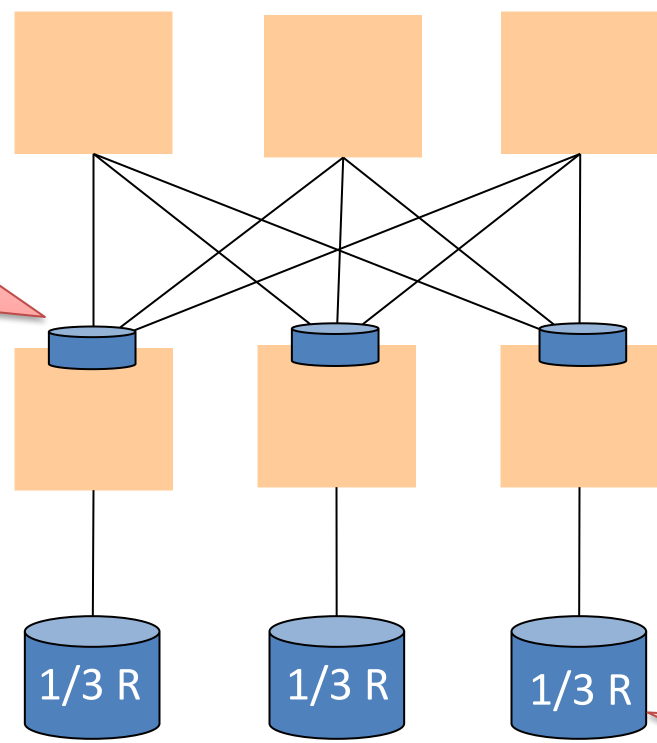
***Note:*** A local combiner can be used to compute local max before data gets reshuffled (in the map tasks)

R(a, b)

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

Reduce:
- Computes final aggregate

Could use a Combiner (compute local max)
key = a, value =max(b)




Map:
- Scans R
- Applies selection predicate
- Output: key = a, value = b

File system: HDFS

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