Outline

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- Distributed Query Processing
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- Distributed Transaction Management
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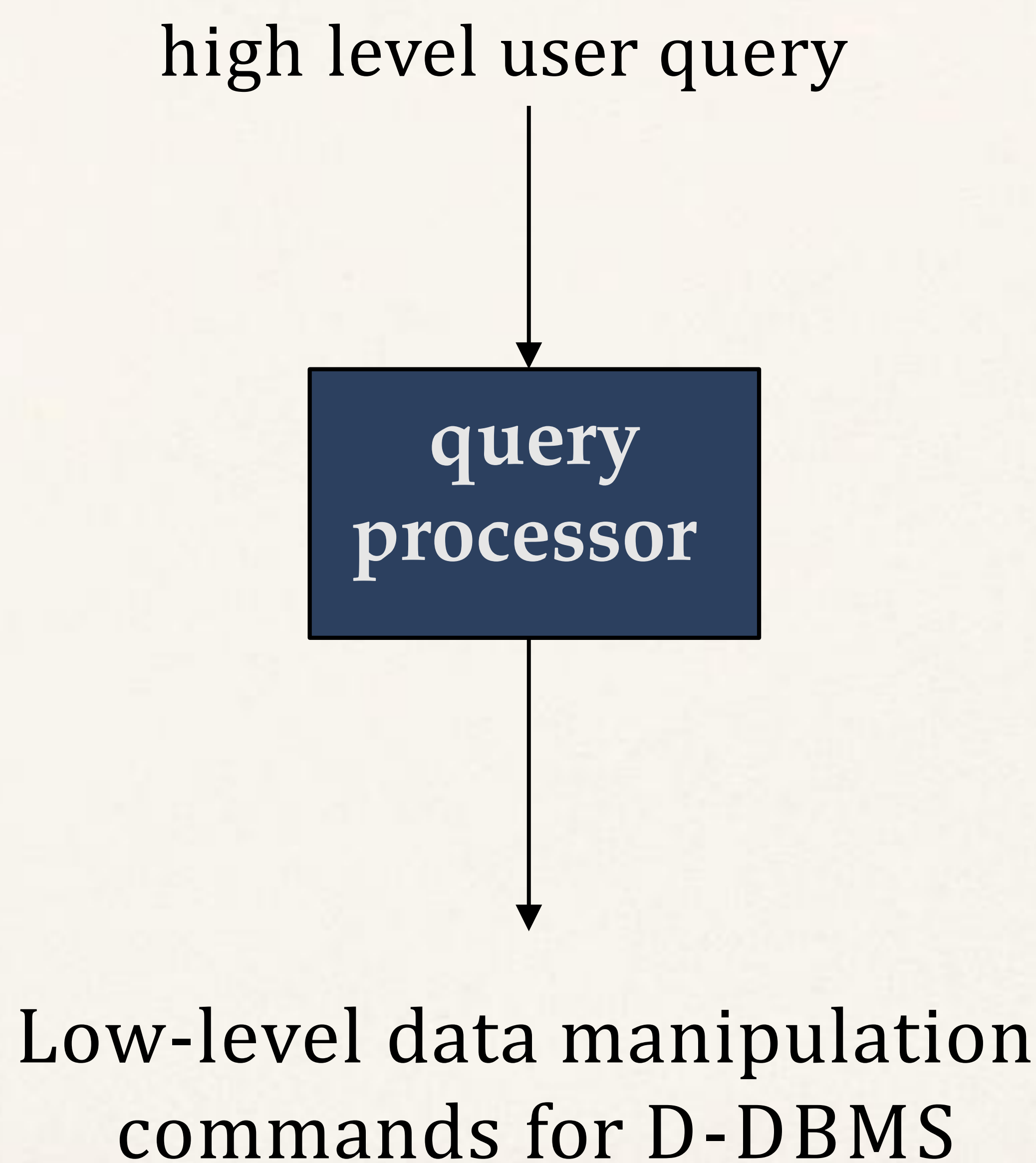
- Distributed Object DBMS
- Peer-to-Peer Data Management
- Web Data Management
- Current Issues

Query Processing in a DDBMS



Query Processing Components

- Query language that is used
  - ➡ SQL: "intergalactic dataspeak"
- Query execution methodology
  - ➡ The steps that one goes through in executing high-level (declarative) user queries.
- Query optimization
  - ➡ How do we determine the "best" execution plan?
- We assume a homogeneous D-DBMS

Selecting Alternatives

```
SELECT   ENAME
FROM     EMP,ASG
WHERE    EMP.ENO = ASG.ENO
AND      RESP = "Manager"
```

Strategy 1

$$\Pi_{ENAME}(\sigma_{RESP=\text{“Manager”} \wedge EMP.ENO=ASG.ENO}(EMP \times ASG))$$

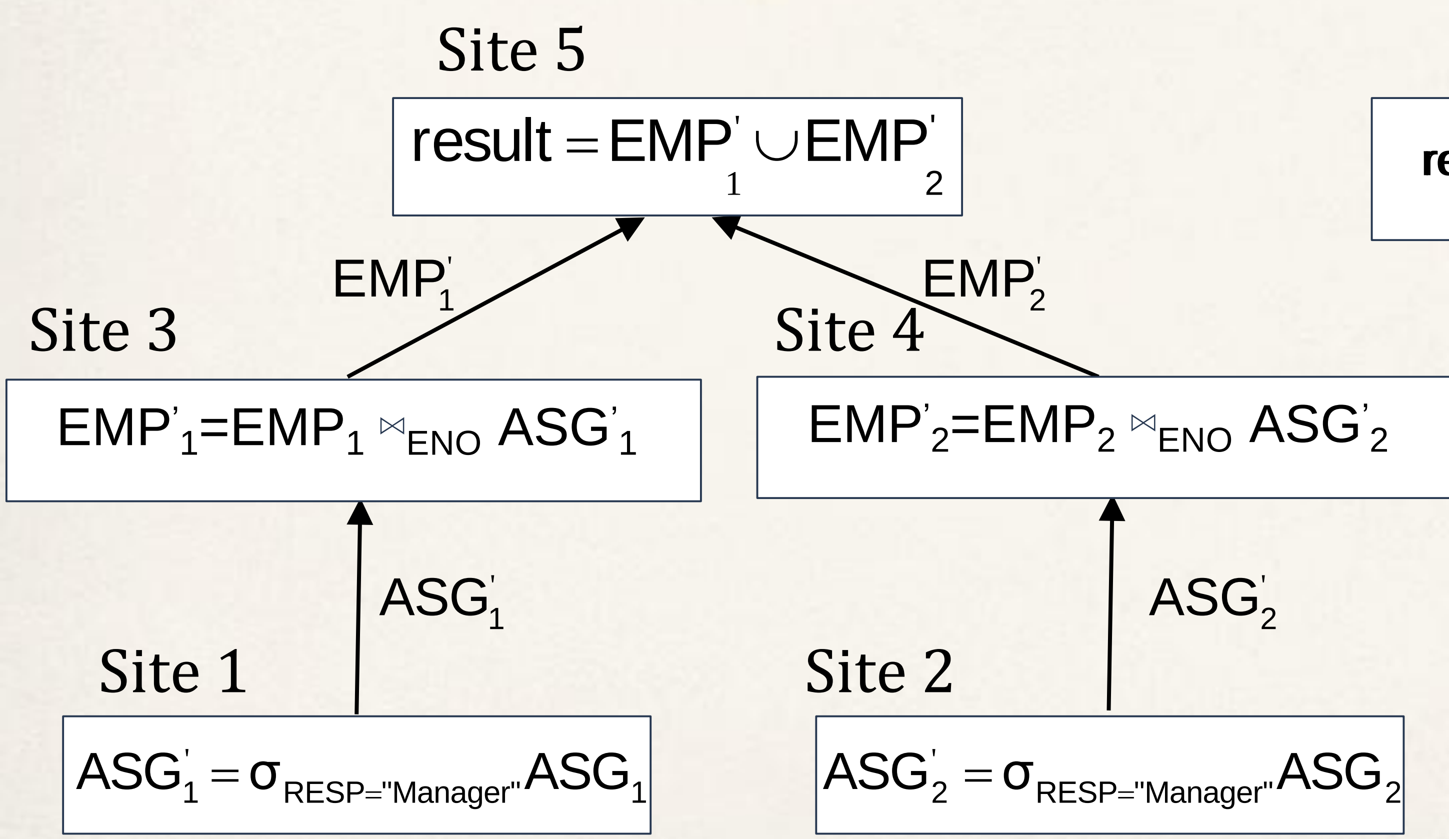
Strategy 2

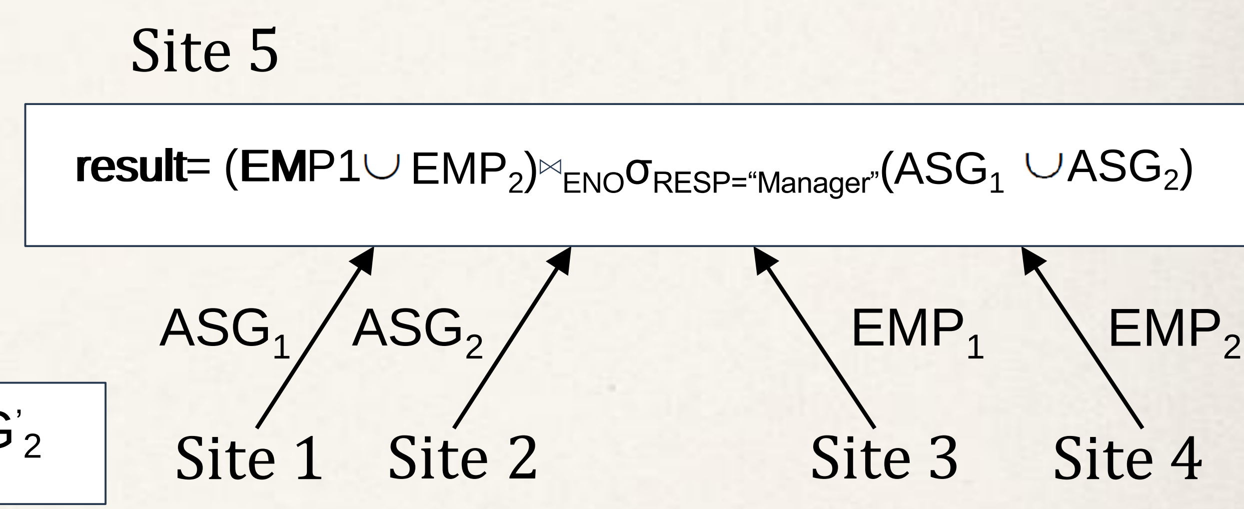
$$\Pi_{ENAME}(EMP \bowtie_{ENO} (\sigma_{RESP=\text{“Manager”}}(ASG))$$

Strategy 2 avoids Cartesian product, so may be “better”

What is the Problem?

Site 1	Site 2	Site 3	Site 4	Site 5
$ASG_1=\sigma_{ENO \leq \text{"E3"}}(ASG)$	$ASG_2=\sigma_{ENO > \text{"E3"}}(ASG)$	$EMP_1=\sigma_{ENO \leq \text{"E3"}}(EMP)$	$EMP_2=\sigma_{ENO > \text{"E3"}}(EMP)$	Result





Cost of Alternatives

- Assume
  - → *size*(EMP) = 400, *size*(ASG) = 1000
  - → tuple access cost = 1 unit; tuple transfer cost = 10 units
- Left:

→ produce ASG': (10+10) ∗ tuple access cost	20
→ transfer ASG' to the sites of EMP: (10+10) ∗ tuple transfer cost	200
→ produce EMP': (10+10) ∗ tuple access cost ∗ 2	40
→ transfer EMP' to result site: (10+10) ∗ tuple transfer cost	200
Total Cost	460

- Right:

→ transfer EMP to site 5: 400 ∗ tuple transfer cost	4,000
→ transfer ASG to site 5: 1000 ∗ tuple transfer cost	10,000
→ produce ASG': 1000 ∗ tuple access cost	1,000
→ join EMP and ASG': 400 ∗ 20 ∗ tuple access cost	8,000
Total Cost	23,000

Query Optimization Objectives

- Minimize a cost function

    I/O cost + CPU cost + communication cost

These might have different weights in different distributed environments

- Wide area networks
    - → communication cost may dominate or vary much
        - ◆ bandwidth
        - ◆ speed
        - ◆ high protocol overhead
- Local area networks
    - → communication cost not that dominant
    - → total cost function should be considered
- Can also minimize the response time

Complexity of Relational Operations

- Assume
  - relations of cardinality n
  - sequential scan

Operation	Complexity
Select Project (without duplicate elimination)	$O(n)$
Project (with duplicate elimination) Group	$O(n * \log n)$
Join Semi-join Division Set Operators	$O(n * \log n)$
Cartesian Product	$O(n^2)$

Query Optimization Issues – Types Of Optimizers

- Exhaustive search
  - Cost-based
  - Optimal
  - Combinatorial complexity in the number of relations
- Heuristics
  - Not optimal
  - Regroup common sub-expressions
  - Perform selection, projection first
  - Replace a join by a series of semijoins
  - Reorder operations to reduce intermediate relation size
  - Optimize individual operations

Query Optimization Issues – Optimization Granularity

- Single query at a time
    - ➡ Cannot use common intermediate results
- Multiple queries at a time
    - ➡ Efficient if many similar queries
    - ➡ Decision space is much larger

Query Optimization Issues – Optimization Timing

- Static
  - Compilation ➔ optimize prior to the execution
  - Difficult to estimate the size of the intermediate results⇒error propagation
  - Can amortize over many executions
- Dynamic
  - Run time optimization
  - Exact information on the intermediate relation sizes
  - Have to reoptimize for multiple executions
- Hybrid
  - Compile using a static algorithm
  - If the error in estimate sizes > threshold, reoptimize at run time

Query Optimization Issues – Statistics

- Relation
  - → Cardinality
  - → Size of a tuple
  - → Fraction of tuples participating in a join with another relation
- Attribute
  - → Cardinality of domain
  - → Actual number of distinct values
- Common assumptions
  - → Independence between different attribute values
  - → Uniform distribution of attribute values within their domain

Query Optimization Issues – Decision Sites

- Centralized
  - → Single site determines the "best" schedule
  - → Simple
  - → Need knowledge about the entire distributed database
- Distributed
  - → Cooperation among sites to determine the schedule
  - → Need only local information
  - → Cost of cooperation
- Hybrid
  - → One site determines the global schedule
  - → Each site optimizes the local subqueries

Query Optimization Issues – Network Topology

- Wide area networks (WAN) – point-to-point
  - Characteristics
    - Low bandwidth
    - Low speed
    - High protocol overhead
  - Communication cost will dominate; ignore all other cost factors
  - Global schedule to minimize communication cost
  - Local schedules according to centralized query optimization
- Local area networks (LAN)
  - Communication cost not that dominant
  - Total cost function should be considered
  - Broadcasting can be exploited (joins)
  - Special algorithms exist for star networks

Distributed Query Processing Methodology