CSE 444: Database Internals

Lecture 23
Distributed Query Processing
and Optimization

Readings

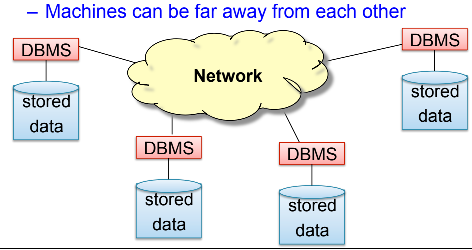
- Main textbook: Sections 20.3 and 20.4
- Other textbook:
  Database management systems.
  Ramakrishnan and Gehrke.
  Third Ed. Chapter 22

Outline

- Distributed DBMS motivation
- Distributed query optimization/processing
- Distributed DBMS limitations and challenges

Distributed DBMS

- Important: many forms and definitions
- Our definition: shared nothing infrastructure
  – Multiple machines connected with a network
  – Machines can be far away from each other



Reasons for a Distributed DBMS

- Scalability (ex: Amazon, eBay, Google)
  – Many small servers cheaper than one big server
  – Need to scale incrementally
  – This is the focus of ***parallel*** DBMSs
- Inherent distribution
  – Large organizations have data at multiple locations (different offices) -> original motivation
  – Different types of data in different DBMSs
  – Web-based and Internet-based applications
  – This is the focus of ***distributed*** DBMSs

Distributed vs Parallel DBMS

- Parallel DBMS
  – Goal: improve performance through parallelization
  – Data distribution is governed solely by performance
  – Typically all machines are on the same cluster
- Distributed DBMS
  – Goal: manage data stored across several sites
  – Each site is administered autonomously
  – Each site capable of running independently of others

Distributed Databases: Principles

- Distributed data independence:
  - Users should be able to write queries without specifying where the relations, or fragments of relations are stored
  - Generalizes physical data independence
- Distributed transaction atomicity:
  - Users should be able to write transactions that access and update data at several sites, as if they were stored on at a single site

Distributed DBMS Architectures

- Client-server
  - Client talks to different DBMSs separately
  - Back-end DBMSs do not know about each other
- Collaborating server
  - DBMS servers are inter-connected with each other
  - Servers know how to send parts of queries to others
- Middleware system
  - Only one DBMS server needs to know about all others and how to split queries among them

Vertical Fragmentation

Students

StudentID	Name	Address	GPA	Status
234234	Mary	Houston	3.5	Scholarship
345345	Sue	Seattle	2.9	Fellowship
345343	Joan	Seattle	3.2	Veteran
234234	Ann	Portland	3.9	None

Registrar

StudentID	Name	Address	GPA
234234	Mary	Houston	3.5
345345	Sue	Seattle	2.9
…	…	…	…

Bursar

SID	Status
234234	Scholarship
345345	Fellowship

Horizontal Fragmentation

Customers

SSN	Name	City	Country
234234	Mary	Houston	USA
345345	Sue	Seattle	USA
345343	Joan	Seattle	USA
234234	Ann	Portland	USA
--	Frank	Calgary	Canada
--	Jean	Montreal	Canada

CustomersInHouston

SSN	Name	City	Country
234234	Mary	Houston	USA

CustomersInSeattle

SSN	Name	City	Country
345345	Sue	Seattle	USA
345343	Joan	Seattle	USA

CustomersInCanada

SSN	Name	City	Country
--	Frank	Calgary	Canada
--	Jean	Montreal	Canada

Goals of a Distributed DBMS

- Shield users from distribution details
- Distribution transparency
  - Naming transparency
  - Location transparency
  - Fragmentation transparency
  - Performance transparency
    - Distributed query optimizer ensures similar performance no matter where query is submitted
  - Schema change and transaction transparency
- Replication transparency

Distributed DBMS Features

- 70's and 80's, three main prototypes:
  - SDD-1, distributed INGRES, and R*
- Main components of a distributed DBMS
  - Defining data placement and fragmentation
  - Distributed catalog
  - Distributed query optimization (today)
  - Distributed transactions (next lecture)
  - Managing replicas (lecture after that)

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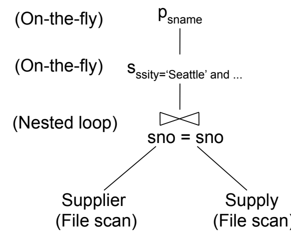
Review: Query Evaluation

Steps of query evaluation

- Query Parser
- Query Rewrite
- Optimizer
- Executor

Query plan



Review: Query Optimization

- Enumerate alternative plans
  - Many possible equivalent trees: e.g., join order
  - Many implementations for each operator
- Compute estimated cost of each plan
  - Compute number of I/Os and CPU utilization
  - Based on statistics
- Choose plan with lowest cost

Distributed Query Optimization

- Search space is larger
  - Must select sites for joining relations
  - Must select method for shipping inner relation: whole or matches
- Minimize resource utilization
  - I/O, CPU, & ***communication costs***
  - Example cost function used in R*
  - $W_{CPU} Nb_{inst} + W_{I/O} Nb_{I/O} + W_{msg} Nb_{msg} + W_{byte} Nb_{bytes}$
- Could also try to minimize response time
  - Least cost plan != Fastest plan

Inner Table Transfer Strategy

- Ship whole
  - Read inner relation at its home site (using index or not)
  - Apply any single-table predicates
  - Project inner relation to remove attributes not needed
  - Ship results to site of outer relation and store in temp file
    - Note: we lose any indexes on the inner relation
- Fetch matches
  - For each tuple of outer, project tuple on join column
  - Send value to site of inner relation
  - Find matching tuples from inner relation
  - Ship projected, matching tuples back

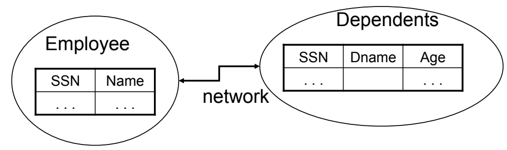
Additional Join Strategies

- Dynamically-created temporary index on inner
  - Ship inner relation, store in temp table, index temp
- Semijoin
  - Project outer relation on join column (eliminate dups)
  - Ship projected column to site with inner relation
  - Compute natural join and ship matching tuples back
  - Join the two relations
- Bloomjoin
  - Same idea as semijoin, but use Bloom filter instead of sending all values in the join column
  - Bloom filter creates some false positives through collisions

Semijoin

- $R \ltimes S = \Pi_{A1,\ldots,An} (R \bowtie S)$
- Where $A_1, \ldots, A_n$ are the attributes in R
- Example:
  - Employee $\ltimes$ Dependents

Semijoins in Distributed Databases



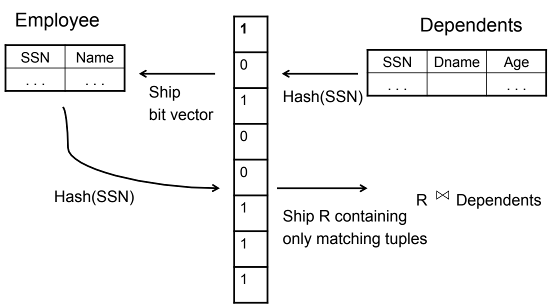
$\text{Employee} \bowtie_{ssn=ssn} (\sigma_{age>71} (\text{Dependents}))$

$T = \Pi_{SSN} (\sigma_{age>71} (\text{Dependents}))$

$R = \text{Employee} \ltimes T$

$\text{Answer} = R \bowtie \text{Dependents}$

Bloomjoin



Distributed vs Local Joins

Why can distributed joins be faster than local ones?

- More resources are available to the join
  - Ex: Distributed query can use twice the buffer pool (useful when accessing relations through unclustered indexes)
- Different parts of the join can proceed in parallel
  - Ex: Join tuples from page 1 while shipping page 2
  - Ex: Can sort the two relations in parallel

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Distributed DBMS Limitations

- Top-down
  - Global, a priori data placement
  - Global query optimization, one query at a time; no notion of load balance
  - Distributed transactions, tight coupling
- Assumes full cooperation of all sites
- Assumes uniform sites
- Assumes short-duration operations
- Limited scalability

Distributed DBMS Challenges

In some distributed databases

- Autonomy: different administrative domains
  - Cannot always assume full cooperation
  - Do not want distributed transactions
- Heterogeneity
  - Different capabilities at different locations
  - Different data types, different semantics -> data integration problem
- Large-scale
  - Internet-scale query processor