DISTRIBUTED DATABASES

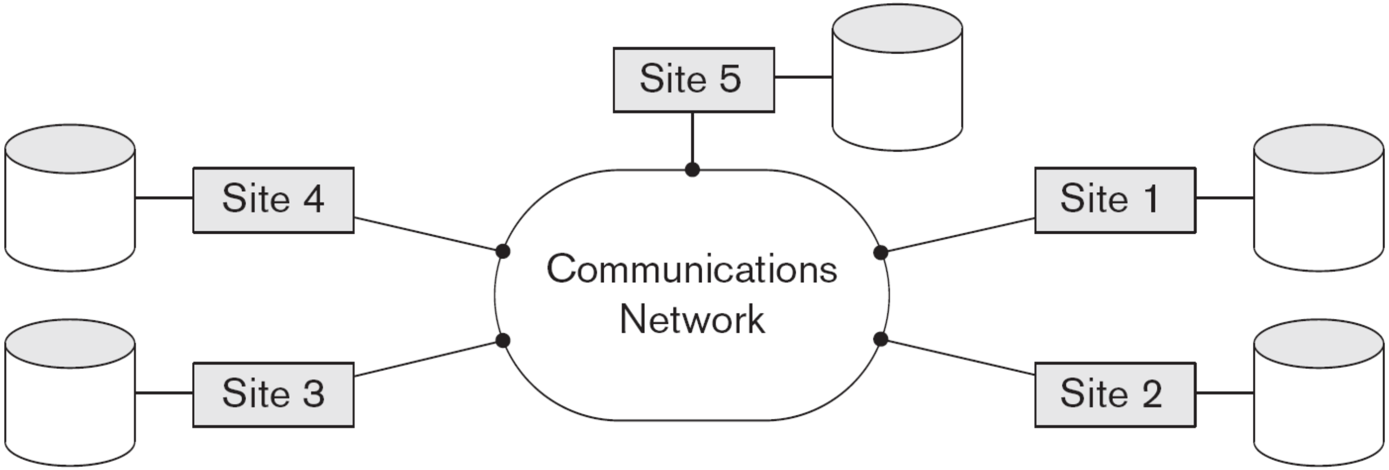
CHAPTER 25

LECTURE OVERVIEW

- What are distributed databases?
- Transparency and autonomy
- Fragmentation, allocation, replication
- Homogeneous vs. heterogeneous DDBMS
- Distributed transaction processing

WHAT ARE DISTRIBUTED DATABASES?

- Distributed Database
  - A logically interrelated collection of shared data (and a description of this data), physically distributed over a computer network
- Distributed DBMS
  - Software system that permits the management of the distributed database and makes the distribution transparent to users
  - Decentralized processing, but (logically) integrated information resources



WHY DDBMSS?

- Advantages
  - Potential for parallel execution
    - More resources available to process queries faster
  - Potential for **replicated** data
    - Processing closer to users' locations
      - Reduced communications time
    - Duplication in case of failures
- Disadvantages
  - Management more complex
  - Higher cost of installation and operation
  - Higher cost of protection (security)
  - Transaction control more difficult

PROPERTIES

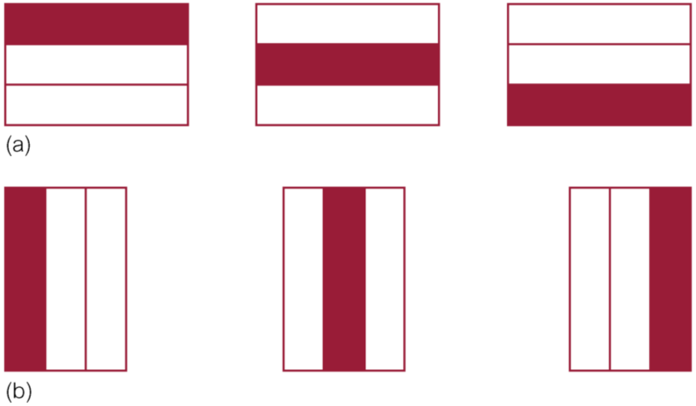
- **Transparency**
  - Hiding distribution details from users
- **Autonomy**
  - Degree to which databases in a connected distributed database can operate independently
    - High autonomy allows flexibility for a participating DBs and DBMSs
    - Can each have its own data model?
    - Can each decide how much and which data to share?
    - Can each decide which transactions to execute and in what order?

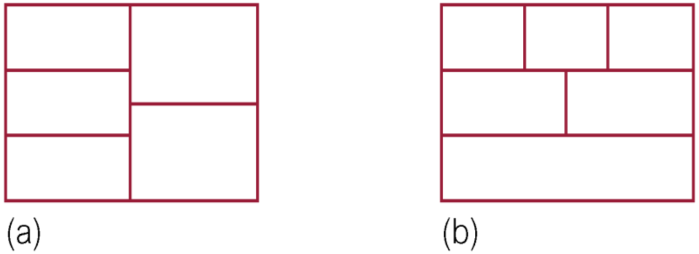
DATA ALLOCATION

- Assume users are geographically distributed.
- Alternative strategies for placing data
  - **Centralized**
    - Single database stored at one site
    - DBMS functionality might be partially distributed
  - **Partitioned**
    - Database partitioned into disjoint fragments
    - Each fragment assigned to one site
  - **(Complete) Replication**
    - Complete copy of database at each site
  - **Selective Replication**
    - Combination of partitioning, replication, and centralization.

FRAGMENTATION

- Splitting data among sites
  - **Horizontal fragmentation**: distributing rows of tables
  - **Vertical fragmentation**: distributing (columns of) tables

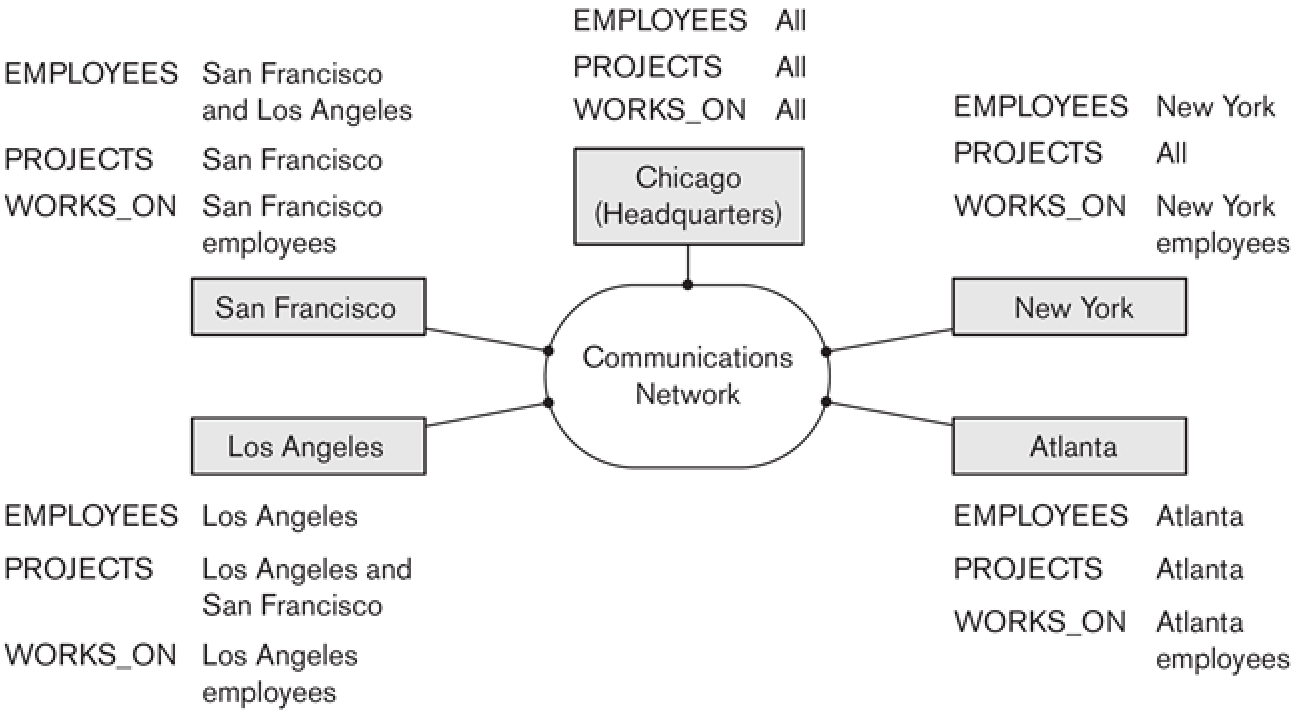




Mixed fragmentation

  - With or without replication
- Usage
  - Applications work with views rather than entire relations.

FRAGMENTATION EXAMPLE



Chicago (Headquarters)

EMPLOYEES	All
PROJECTS	All
WORKS_ON	All

San Francisco

EMPLOYEES	San Francisco and Los Angeles
PROJECTS	San Francisco
WORKS_ON	San Francisco employees

New York

EMPLOYEES	New York
PROJECTS	All
WORKS_ON	New York employees

Los Angeles

EMPLOYEES	Los Angeles
PROJECTS	Los Angeles and San Francisco
WORKS_ON	Los Angeles employees

Atlanta

EMPLOYEES	Atlanta
PROJECTS	Atlanta
WORKS_ON	Atlanta employees

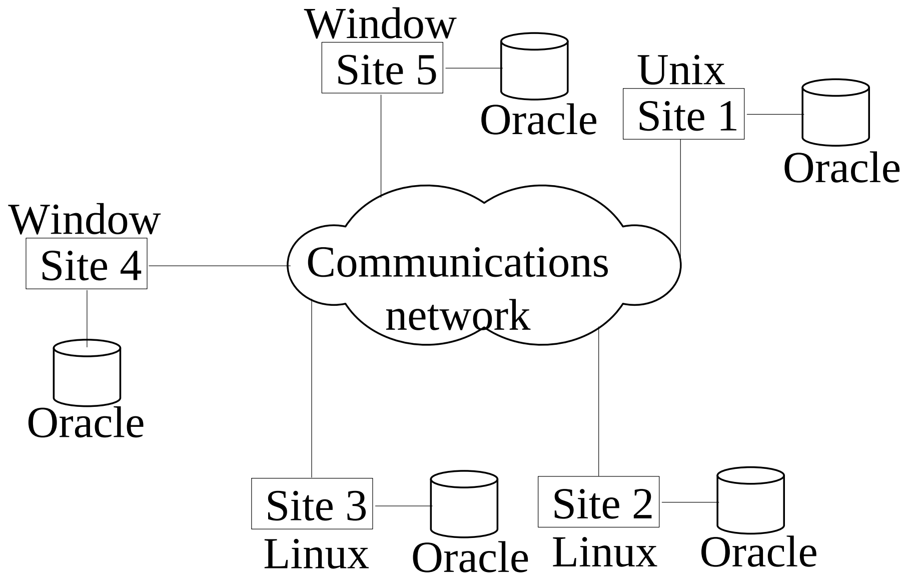
Communications Network

WHY FRAGMENT DATA?

- Advantages
  - Data is stored close to where it is most frequently used.
  - Data not needed by local applications is not stored.
    - Materialized view
  - Transactions can be divided into subqueries that operate on fragments and operate in parallel.
  - Data not required by local applications is not available to unauthorized users.
- Disadvantages
  - May need to access multiple sites to retrieve data
  - Need joins and unions to reconstruct complete relations
  - Difficult to maintain consistency of data across sites

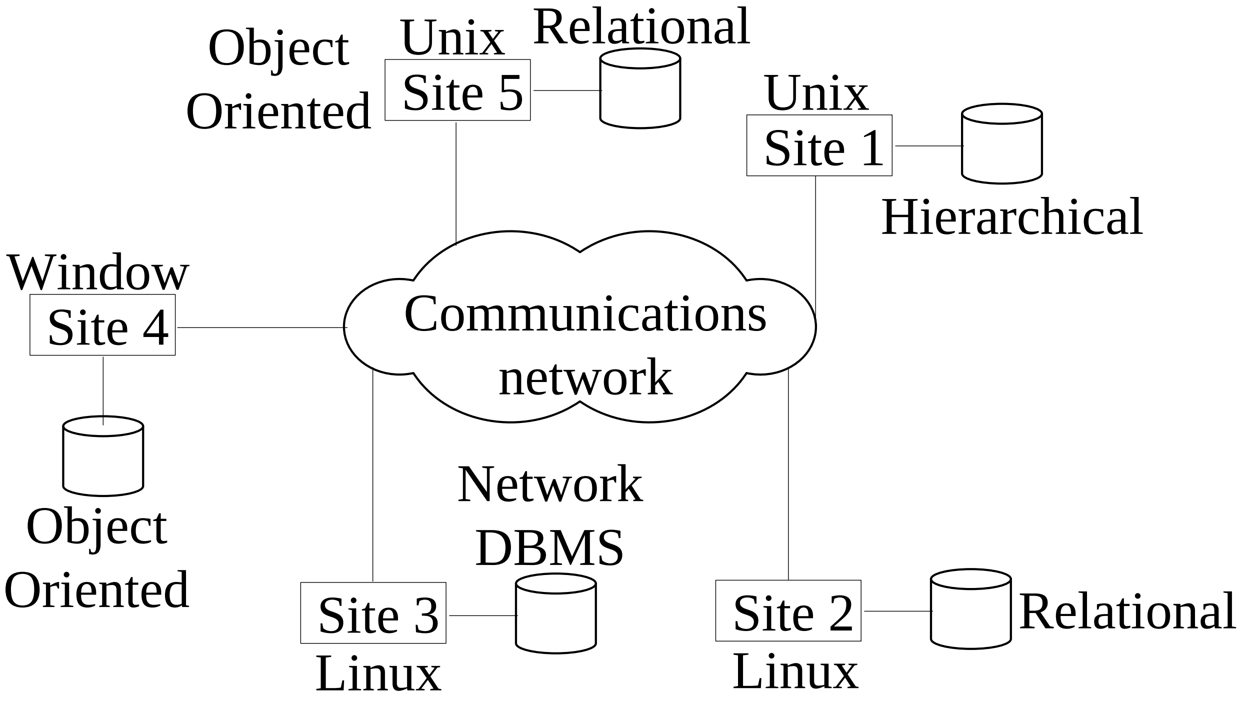
HOMOGENEOUS DDBMS

- All sites use same DBMS product.
  - Much easier to design and manage
  - Note: The deployed operating systems may differ.
- Provides for incremental growth and allows increased performance



HETEROGENEOUS DDBMS

- Sites may run different DBMS products, with possibly different underlying data models.
- **Wrappers**
  - Translations required at interfaces to convert queries and data into common models or dialects.



FEDERATED DATABASE SYSTEMS

- Integration of *autonomous* DBs and DBMSs
- Usually highly heterogeneous
  - Possibly without a common conceptual schema
  - Usually including *semantic heterogeneity*
    - *Meaning* of data varies across systems.
    - Different units of measure (e.g., dollars vs. euros; feet vs. meters)
    - Different attributes (e.g., based on local accounting practices)
    - Different degrees of accuracy (e.g., outdated and missing values)
- **Mediators**
  - Middleware, such as Enterprise Resource Planning (ERP)
    - Manage transport of transactions and queries
    - Integrate data from variety of sites

DDBMS TRANSACTION CONTROL

- Dealing with replicated data
  - Requires global consistency
    - Replicated updates
    - Distributed concurrency control
  - Recovery mechanism must recover all copies
    - Consistent undo/redo across sites
- Dealing with failure of individual sites
  - Global awareness of failed sites
  - Non-disruption of applications that need no data from failed sites
- More complicated management
  - Distributed commit
  - Distributed locking and deadlock detection

LOCK MANAGEMENT

- **Primary site** technique
  - Single site designated as coordinator for transaction management
  - All lock requests go to primary site
    - Might overload site
  - If primary site fails, entire system inaccessible
    - To aid recovery, backup site designated to shadow primary site and replace primary site if needed
- **Primary copy** technique:
  - One replica designated as primary copy for each data item
    - Primary copies distributed at various sites
    - All lock requests for an item go to site holding primary copy of that item
    - Single site not overloaded with transaction management
  - Identification of primary copy (and backup) complex in light of site failures
    - Distributed directory must be maintained, possibly at all sites.
- **Majority vote** technique:
  - Try to lock data item at several sites having copies
  - More than 50% of sites that hold data must grant lock
    - Possible optimizations for improving either readers or writers
  - Complex protocol and deadlock detection in light of site failures

LECTURE SUMMARY

- Overview of distributed database concepts
  - What are the main reasons for and potential advantages of distributed databases?
- Data fragmentation, replication and allocation
  - What is a fragment of a relation? What are the main types of fragments? Where are they stored? Why is fragment a useful concept in distributed database design?
- Peek into distributed transaction management
  - How does the primary site method compare to the primary copy method for distributed concurrency control? When voting, why do we need to obtain so many locks?