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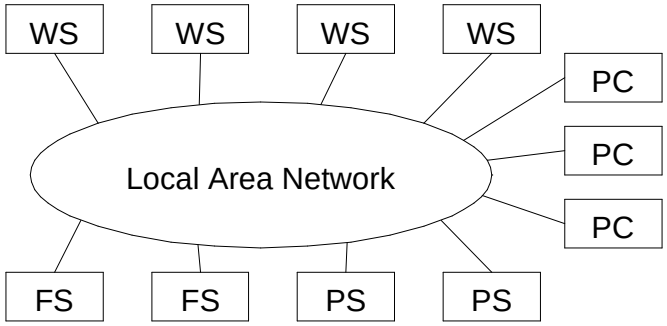
Background

What is a Distributed System?

A Distributed System is a number of autonomous computers communicating over a network with software for integrated tasks.

Examples of Distributed Systems:

- SUN's Network File System (NFS), distributed file system



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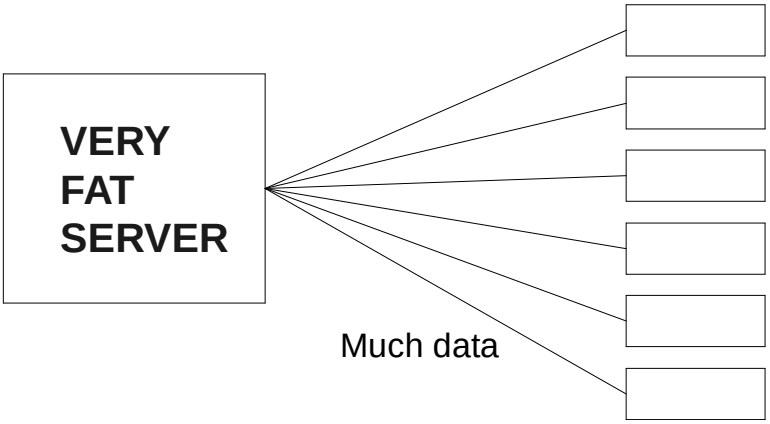
Centralized Database Server



Many clients

- Stream (row-by-row) based client-server interfaces
- DBMS specific interfaces
- Compiler integrated interfaces (embedded SQL)
- ODBC: SQL-based standardized subroutine call library (MicroSoft)
- JDBC: ODBC for Java (not MicroSoft)

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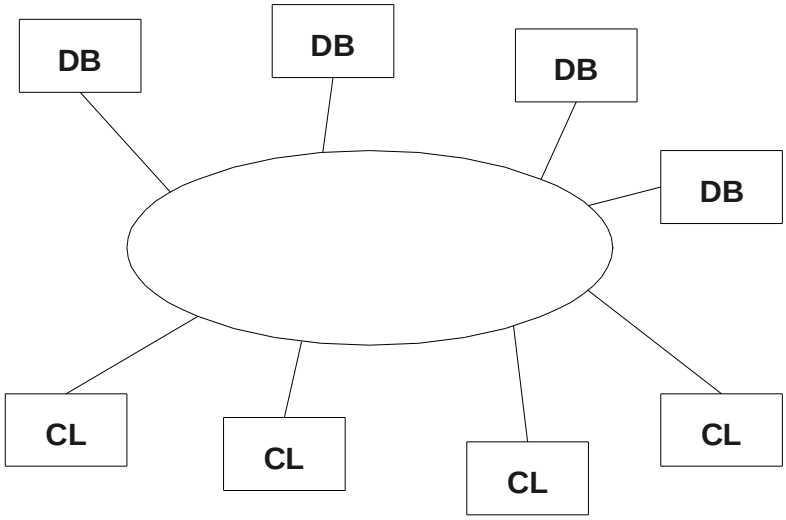
Distributed Databases



- Database seen as one unit; queries and updates to ONE database.
- Data in database *transparently* distributed over many DB nodes.
- Manual partitioning or *fragmentation* of data tables.
- DBMS automatically optimizes queries and updates to distributed database.

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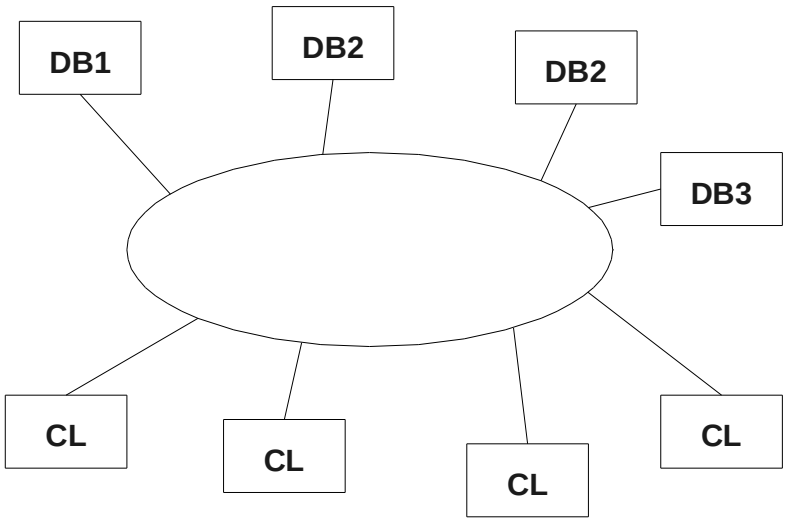
Multi Databases



- Database seen as several heterogeneous units
- Multi-database query language needed to combine data from the databases.
- Primitives needed to integrate (combine, fuse) data from the databases.
- Special query optimization techniques to deal with heterogneity and dynamism.

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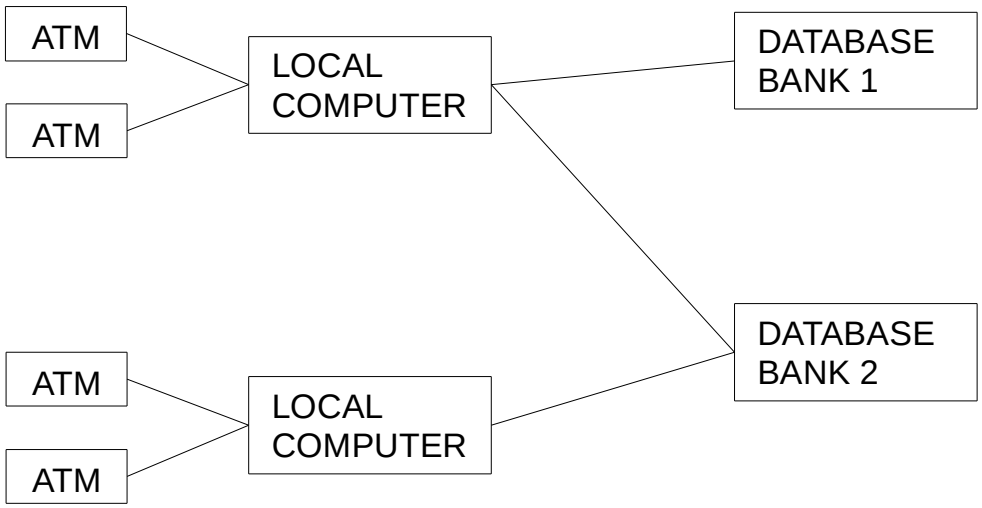
Example of Multi-Database

Automatic Teller Machines, ATMs



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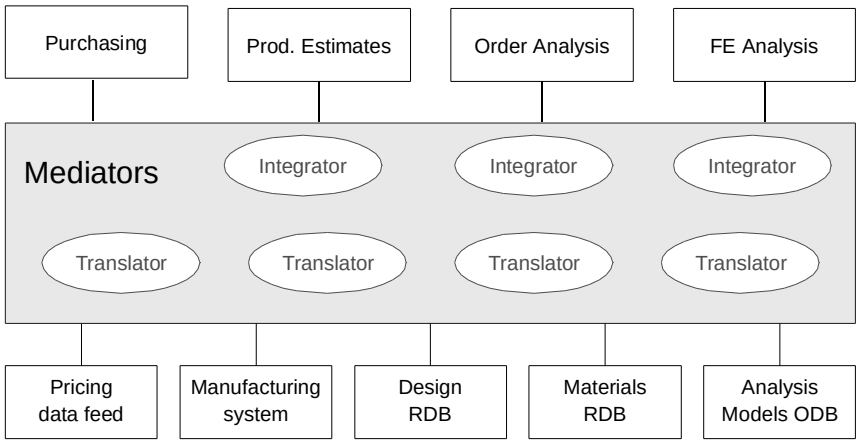
Amos2 meditator system

- Purpose: Software to facilitate queries to databases and other data sources.



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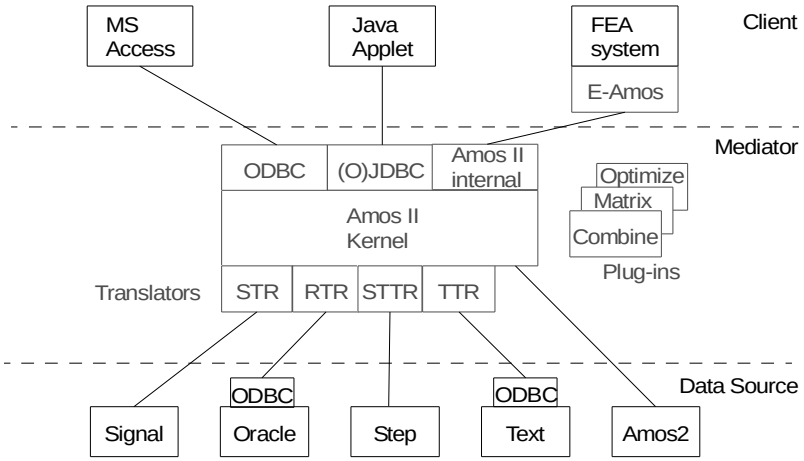
Amos2 Architecture

- 3-level multi-database architecture.



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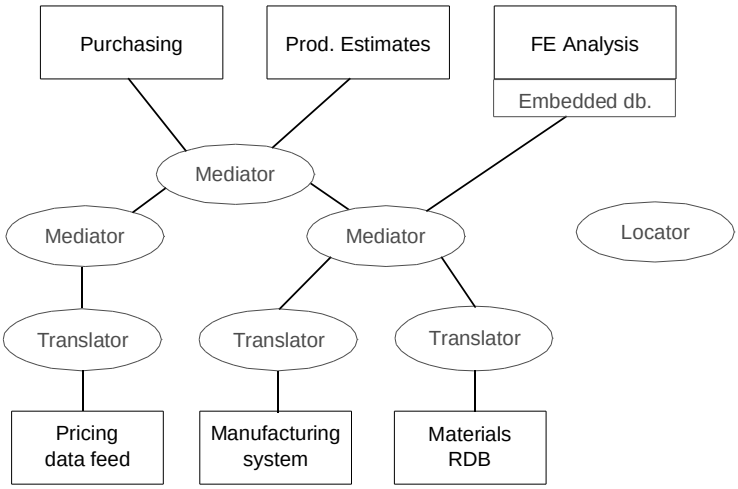
Amos II Distribution Architecture

- Amos II is a distributed system:
  Mediator data server may access other mediator data servers.

  => many layers of mediator servers possible.



=> Special optimizations to push computations close to sources when needed.

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What is a Distributed Database?

"A distributed database (DDB) is a collection of multiple, *logically interrelated* databases *distributed over a computer network*. A DDBMS is the software system that permits the management of DDBs and makes the distribution transparent to the user."

- A DDB is NOT:
  - A collection of files (need structure and DB manager)
  - A client-server interface to a database

    Data on one node, clients on other nodes in network

    (Almost) every centralized DBMS has client-server interface

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Example of DDB

- Multi-national company with distributed departments
- Distributed data management:
  - Each location keep local records of local employees
  - R & D keeps track of what is going on at its facility.
  - Manufacturing plants keep data related to their engineering operations and access to R & D
  - Manufacturing keeps track of local inventory. Access to warehouse also possible.
  - Warehouses keeps local inventory. Manufacturing can access inventory levels.
  - Headquarters keep marketing and sales records per region. Share with other headquarters and can access inventory data at plants and warehouses.

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Advantages with DDBs

- Local autonomy
  - Local control
  - Local policies
- Improved performance
  - Avoid data shipping
- Improved Reliability
  - Crashes less severe (if appl. no dep. on non-local data)
- Expandability
  - Easy to add new nodes (not always linear scale-up because of central directory)
- Sharability
  - Uniform interface and sharing through DDBMS

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Replication and fragmentation

- Data replication
  Same data on several nodes
  - For reliability and access performance
  - Not necessary to replicate all tables
    Fully replicated vs *partially replicated*
    Full replication often not realistic!
  - Updates must be propagated to each replica!
  - Special procedures after failures to restore consistency
  - More problematic transaction synchronization!
- Data Fragmentation (= data partitioning)
  Tables transparently split over several nodes
  - For access performance
  - Good when nodes far apart

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Problems with DDBs

- Complexity
  Database administration may be complex
  E.g. recovery after crashes complex
- Distribution of Control
  More meetings
- Security
- Networking a known problem

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Problems with DDBs

- Distributed schema management
  Schema is accessed whenever SQL query issued!
  - Global directory => Central Database becomes *hot spot*
  - Local directories => Data replication
  => Since schema is not updated often but need to be accessed very often it is normally *fully replicated* by the DDBMS.
- Distributed concurrency control
- Reliability of DDBMS
  - Consistency of replicas
  - Bring up (fragmented) database at failed sites
- OS Support
  - Multiple layers of network software

Transparency

- Replication Transparency
  - User unaware of data replicas
  - Automatic replica propagation at update
  - Special problems when nodes are down
- Fragmentation Transparency
  - E.g. a logical relation is horizontally fragmented into local physical tables
  - Translation from *global queries* to *fragmented queries*
- Network Transparency
  - Protect user from operational details of network
  - Hide existence of network
  - No machine names in database table references
    - Location transparency
    - Naming transparency

Distributed database design

- Where to put data and applications?
- Partitioned data:
  - Split data into distributed partitions
- Replicated data:
  - Several sites have data copies
- Goal: Minimize combined cost of storing data, communication, transactions.
- NP complete optimization problem.

- Distributed Query Processing
  - Automatically done by distributed query processor of DDBMS
  - Analyze query --> distributed execution plan
  - Factors:
    - Data replication
    - Data availability
    - Communication costs

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Parallel Databases

Parallel data servers

- Use parallel processing in cluster of computer nodes for data servers
- Automatic *fragmentation and replication* of data over the different nodes by the Parallel DBMS (PDBMS)

  To achieve maximal throughput and availablility
- Utilization of modern hardware
  - Multiple independent hardware components interconnected through fast communication medium (e.g. a bus)
  - Modern multi-processor architectures natural to support interquery, intraquery, and intraoperation parallelism
  - Connect disk per processor unit

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DDBMS Reliability

Two-Phase Commit Protocol (2PC)

- The most well known protocol to ensure atomic commitment of distributed transactions.
- Extend local site commit protocols by ‘contract’ (synchronization) that they all agree on committing (or aborting) in a distributed transaction.

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