Chapter 4:
Security Part II:
Auditing Database Systems

IT Auditing, Hall, 4e

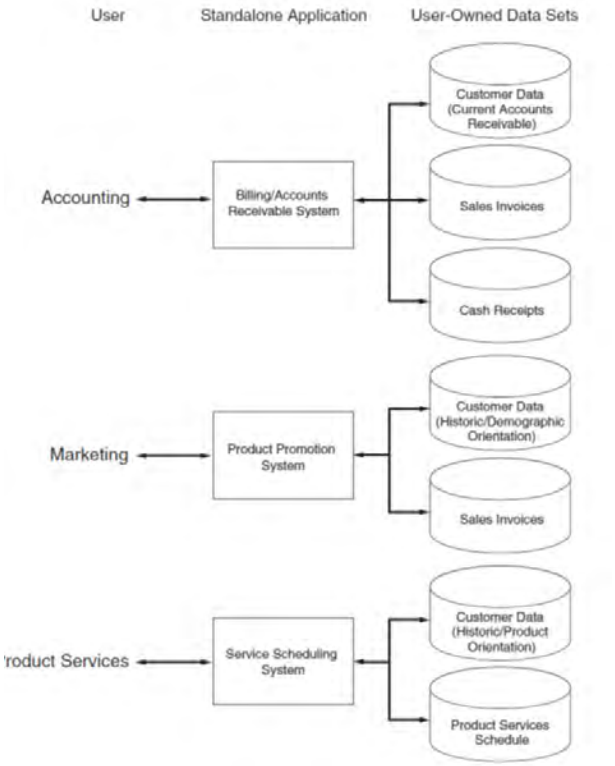
Learning Objectives

- Understand the operational problems inherent in the flat-file approach to data management that gave rise to the database approach.
- Understand the relationships among the fundamental component's of the database concept.
- Recognize the defining characteristics of three database models: hierarchical, network, and relational.
- Understand the operational features and associated risks of deploying centralized, partitioned, and replicated database models in the DDP environment.
- Be familiar with the audit objectives and procedures used to test data management controls.

Flat-File Approach

- Associated with large, older **legacy systems** still in use today.
- Promotes a single-user view approach where end users own rather than share data files.
- Separate data sets for each user leads to **data redundancy** which causes problems with:
  - **Data storage**: Commonly used data duplicated multiple times within the organization.
  - **Data updating**: Changes must be made separately for each user. If updating fails problem of **currency of information** with users having outdated information.
  - **Task-data dependency**: Users cannot obtain additional information as needs change.

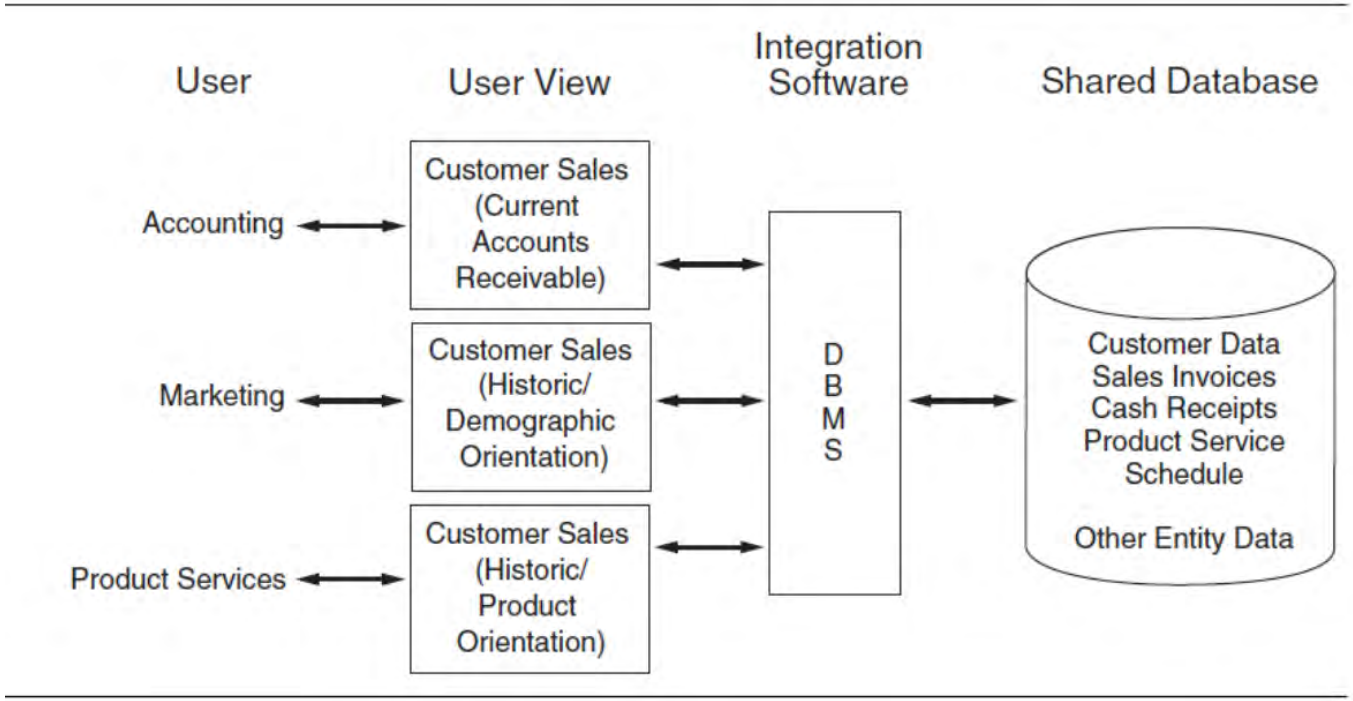
Flat-File Model



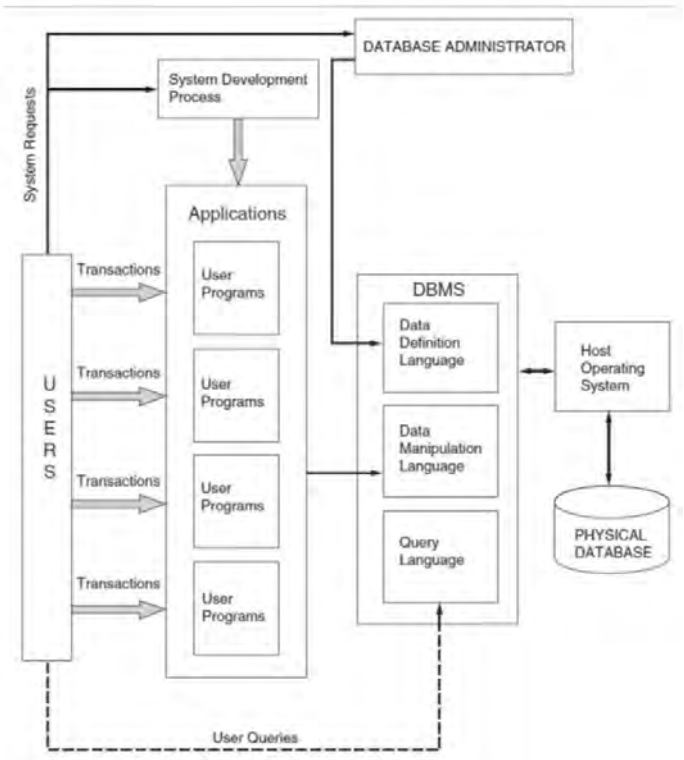
Database Approach

- Access to the data resource is controlled by a **database management system (DBMS).**
- Centralizes organization's data into a common database shared by the user community.
- All users have access to data they need which may overcome flat-file problems.
  - **Elimination of data storage problem**: No data redundancy.
  - **Elimination of data updating problem**: Single update procedure eliminates currency of information problem.
  - **Elimination of task-data dependency problem**: Users only constrained by legitimacy of access needs.

Database Model



Elements of the Database Concept



DBMS Features and Data Definition Language

- **Program Development** – Applications may be created by programmers and end users.
- **Backup and Recovery** - Copies made during processing.
- **Database Usage Reporting** - Captures statistics on database usage (who, when, etc.).
- **Database Access** - Authorizes access to sections of the database.
- **Data definition language** used to define the database to the DBMS on three levels (views).

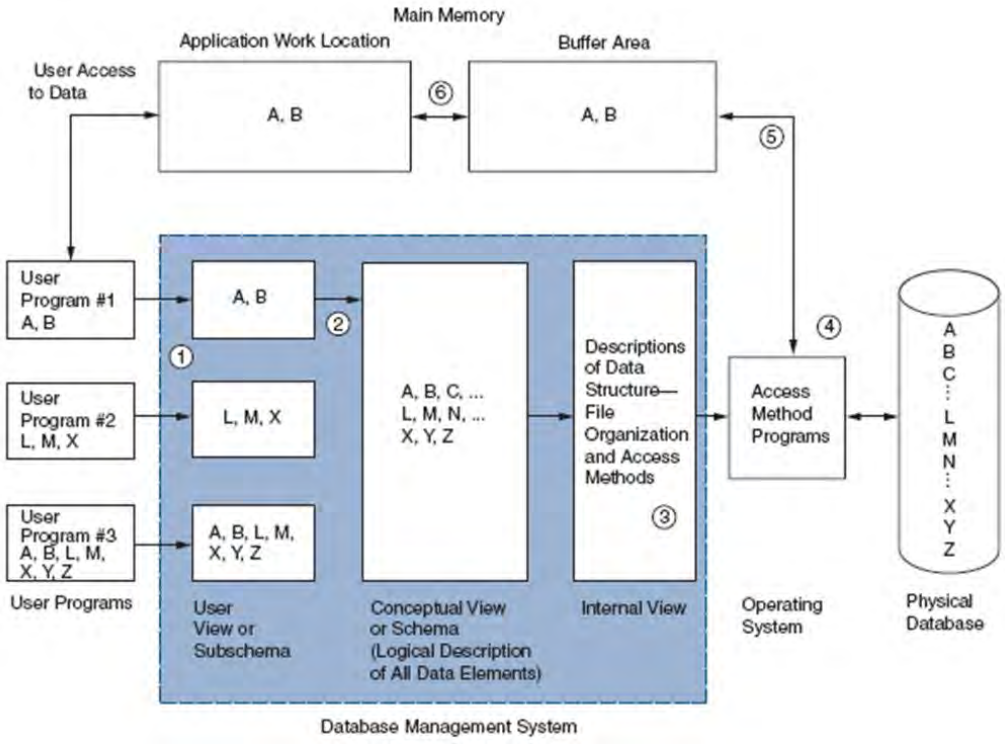
Database Views

- **Internal view/ Physical view**: Physical arrangement of records in the database.
  - Describes structures of data records, linkage between files and physical arrangement and sequence of records in a file. Only one internal view.
- **Conceptual view/ Logical view (schema):** Describes the entire database logically and abstractly rather than physically. Only one conceptual view.
- **External view/ User view (subschema):** Portion of database each user views. May be many distinct users.

Data Manipulation Language (DML)

- DML is the proprietary programming language that a particular DBMS uses to retrieve, process, and store data to / from the database.
- Entire user programs may be written in the DML, or selected DML commands can be inserted into universal programs, such as COBOL and FORTRAN.
- Can be used to 'patch' third party applications to the DBMS

Overview of DBMS Operation



Informal Access: Query Language

- Query is an ad hoc access methodology for extracting information from a database.
  - Users can access data via direct query which requires no formal application programs.
- IBM's **Structured Query Language (SQL)** has emerged as the standard query language.
- Query feature enhances ability to deal with problems that pop-up but poses an important control issue.
  - Must ensure it is not used for unauthorized database access.

Functions of the Database Administrator (DBA)

Database Planning:

Develop organization's database strategy
Define database environment
Define data requirements
Develop data dictionary

Design:

Logical database (schema)
External users' views (subschemas)
Internal view of database
Database controls

Implementation:

Determine access policy
Implement security controls
Specify test procedures
Establish programming standards

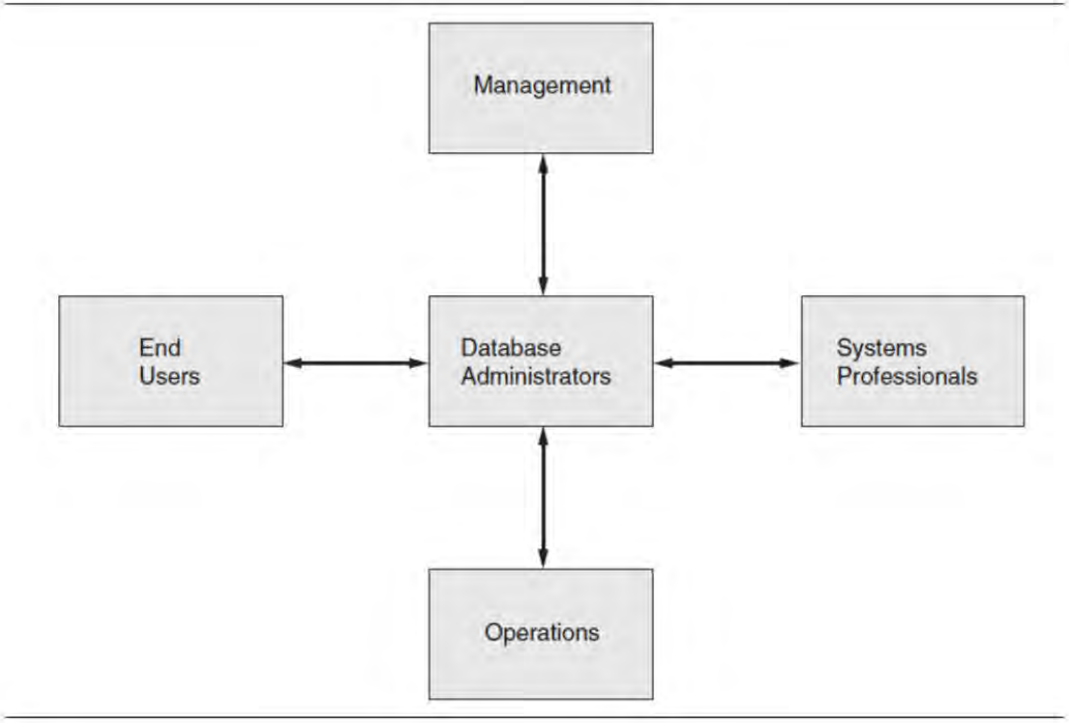
Operation and Maintenance:

Evaluate database performance
Reorganize database as user needs demand
Review standards and procedures

Change and Growth:

Plan for change and growth
Evaluate new technology

Organizational Interaction of the DBA



The Physical Database

- Lowest level and only one in physical form.
- Magnetic sports on metallic coated disks that create a logical collection of files and records.
- **Data structures** are bricks and mortar of database.
  - Allows records to be located, stored, and retrieved.
  - Two components: organization and access methods.
- The **organization** of a file refers to way records are physically arranged on the storage device - either sequential or random.
- **Access methods** are programs used to locate records and to navigate through the database.

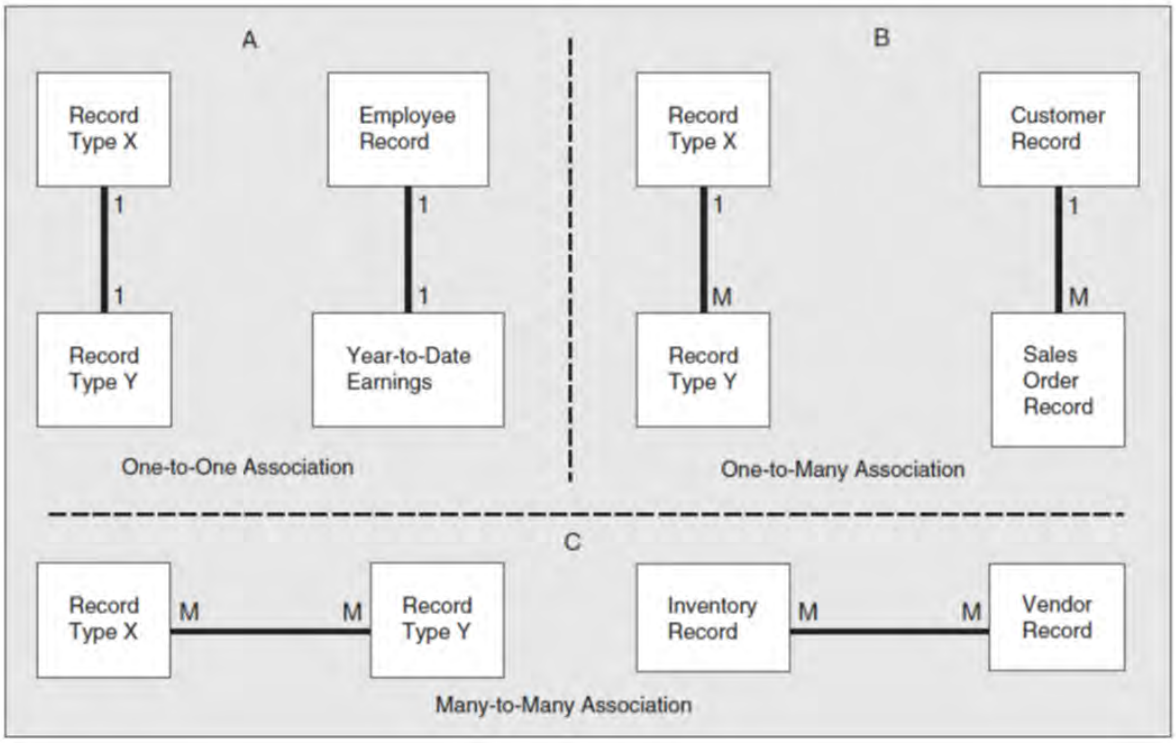
Database Terminology

- **Entity**: Anything organization wants to capture data about.
- **Record Type**: Physical database representation of an entity.
- **Occurrence**: Related to the number of records of represented by a particular record type.
- **Attributes**: Defines entities with values that vary (i.e. each employee has a different name).
- **Database**: Set of record types that an organization needs to support its business processes.

Associations

- Record types that constitute a database exist in relation to other record types. Three basic record association:
  - **One-to-one**: For every occurrence of Record Type X there is one (or zero) of Record Type Y.
  - **One-to-many**: For every occurrence of Record Type X, there are zero, one or many occurrences of Record Type Y.
  - **Many-to-many**: For every occurrence of Record Types X and Y, there are zero, one or many occurrences of Record Types Y and X, respectively.

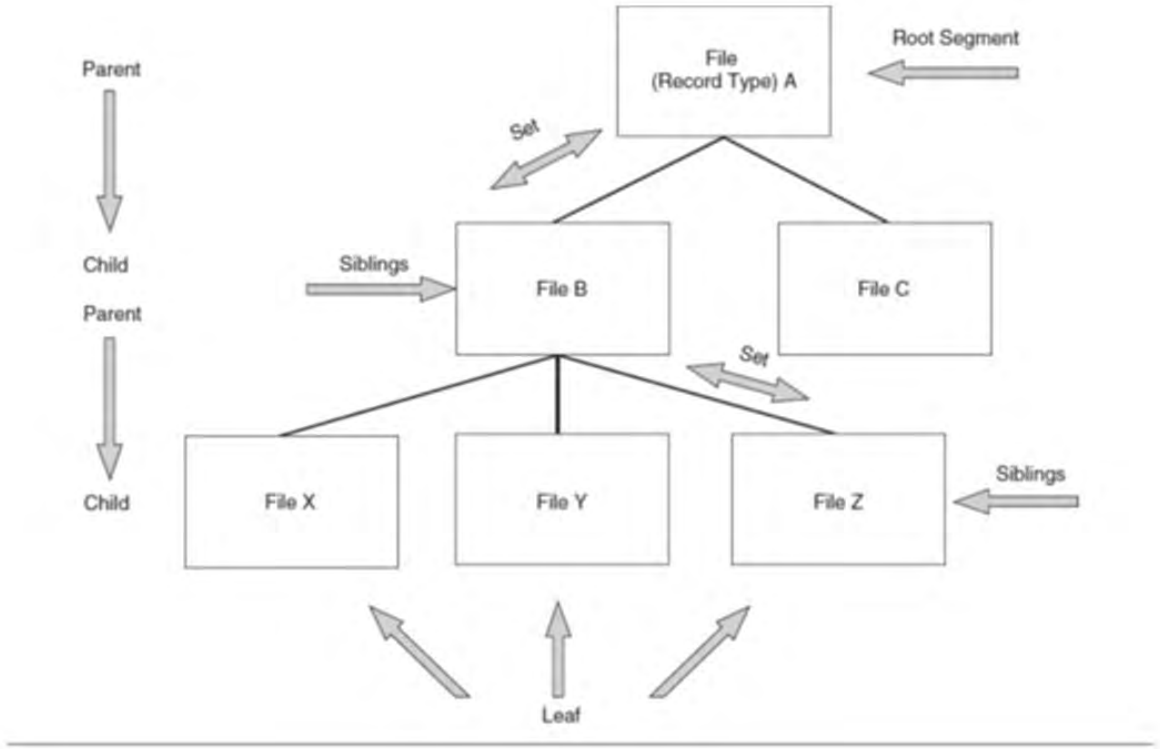
Record Associations



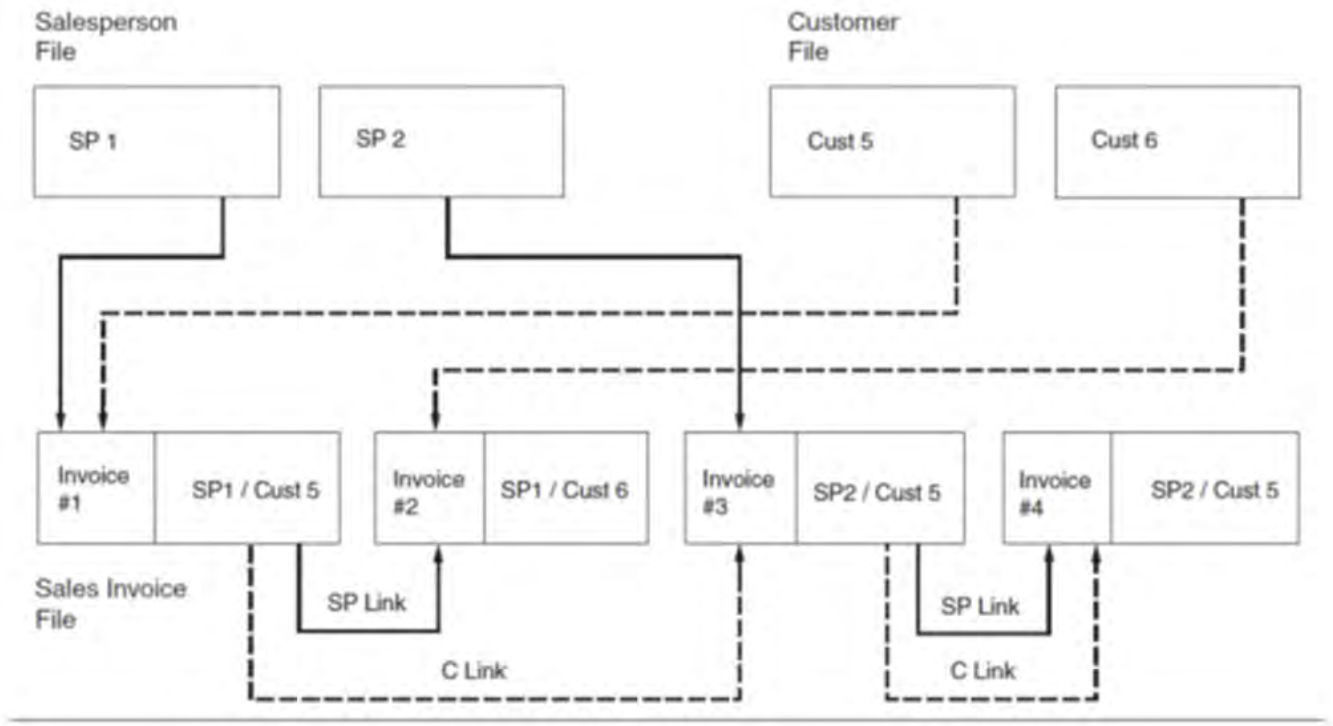
The Hierarchical Model

- Basis of earliest DBAs and still in use today.
- Sets that describe relationship between two linked files.
  - Each set contains a *parent* and a *child*.
  - Files at the same level with the same parent are *siblings*.
  - *Tree structure* with the highest level in the tree being the *root* segment and the lowest file in a branch the *leaf.*
- Also called a *navigational database.*
- Usefulness of model is limited because no child record can have more than one parent which leads to data redundancy.

Hierarchical Data Model



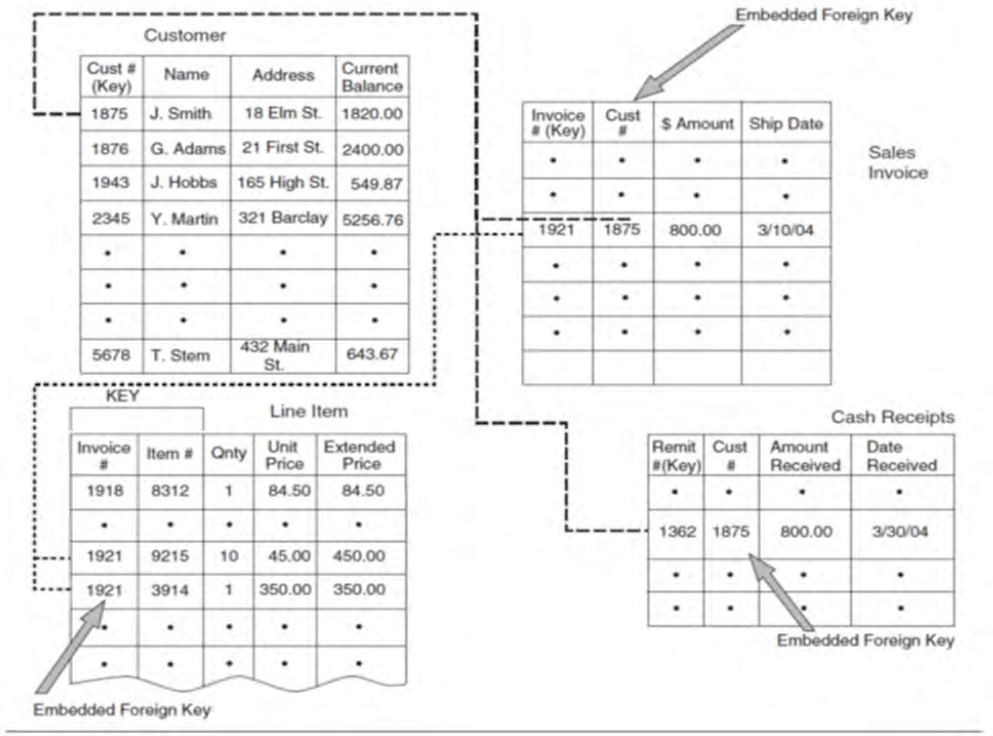
The Network Model



The Relational Model

- Difference between this and navigational models is the way data associations are represented to the user.
  - Relational model portrays data in two-dimensional tables with **attributes** across the top forming columns.
  - Intersecting columns to form rows are **tuples** which are normalized arrays of data similar to records in a flat-file system.
- Relations are formed by an attribute common to both tables in the relation.

Data Integration in the Relational Model



Centralized Databases in a Distributed Environment

- Data retained in a central location.
- Remote IT units send requests to central site which processes requests and transmits data back to the requesting IT units.
  - Actual processing of performed at remote IT unit.
- Objective of database approach it to maintain data currency with can be challenging.
  - During processing, account balances pass through a state of **temporary inconsistency** where values are incorrect.
  - **Database lockout** procedures prevent multiple simultaneous access to data preventing potential corruption.

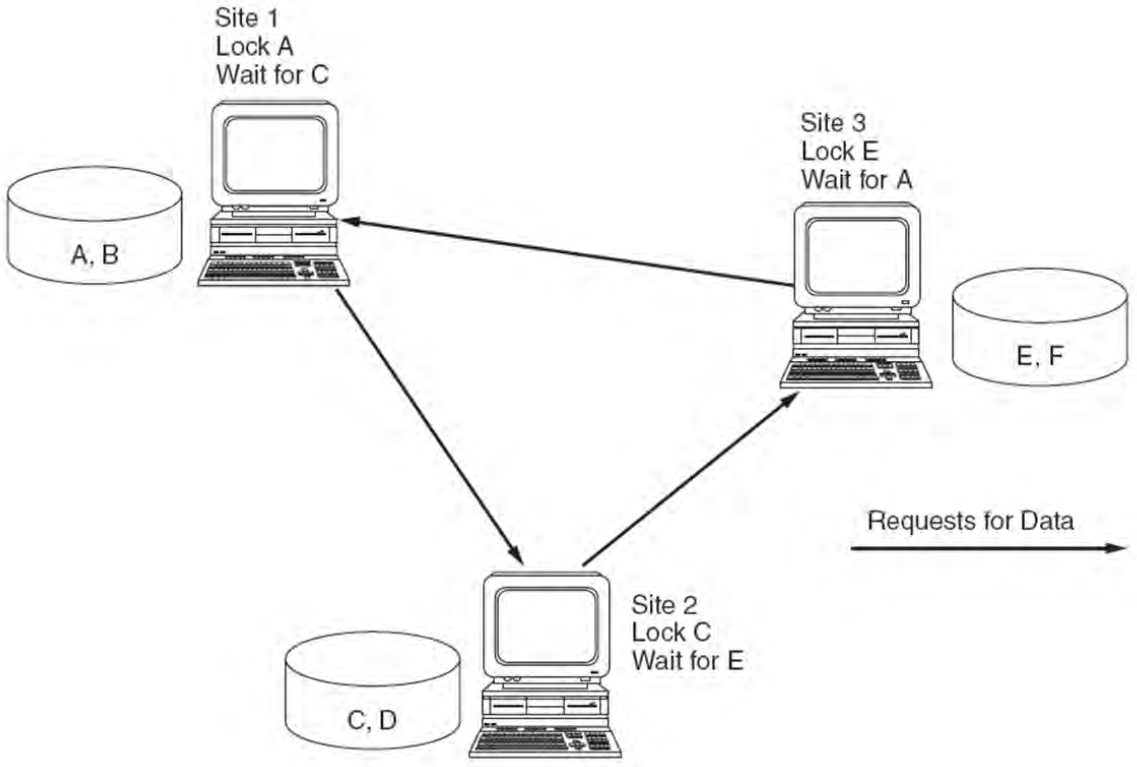
Distributed Databases: Partitioned Databases

- Splits central database into segments distributed to their primary users.
- Advantages:
  - Users' control increased by having data stored at local sites.
  - Improved transaction processing response time.
  - Volume of transmitted data between IT units is reduced.
  - Reduces potential data loss from a disaster.
- Works best for organizations that require minimal data sharing among units.

The Deadlock Phenomenon

- Occurs when multiple sites lock each other out of the database, preventing each from processing its transactions.
  - Transactions in a “wait” state until locks removed.
  - Can result in transactions being incompletely processed and database being corrupted.
- **Deadlock** is a permanent condition that must be resolved with special software that analyzes and resolve conflicts.
  - Usually involves terminating one or more transactions to complete processing of the other in deadlock.
  - Preempted transactions must be reinitiated.

The Deadlock Condition



Distributed Databases: Replicated Databases

- Effective for situations with a high degree of data sharing, but no primary user.
- Common data replicated at each site, reducing data traffic between sites.
- Primary justification to support read-only queries.
- Problem is maintaining current versions of database at each site.
  - Since each IT unit processes its own transactions, common data replicated at each site affected by different transactions and reflect different values.

Concurrency Control

- Database concurrency is the presence of complete and accurate data at all user sites.
- Designers need to employ methods to ensure transactions processed at each site are accurately reflected in the databases of all the other sites.
- Commonly used method is to serialize transactions which involves labeling each transaction by two criteria:
  - Special software groups transactions into classes to identify potential conflicts.
  - Second part of control is to time-stamp each transaction.

Database Distribution Methods and the Accountant

- Many issues and trade-offs in distributing databases.
- Basic questions to be addressed:
  - Centralized or distributed data?
  - If distributed, replicated or partitioned?
  - If replicated, total or partial replication?
  - If partitioned, what is the allocation of the data segments among the sites?
- Choices impact organization's ability to maintain database integrity, preserve audit trails, and have accurate records.

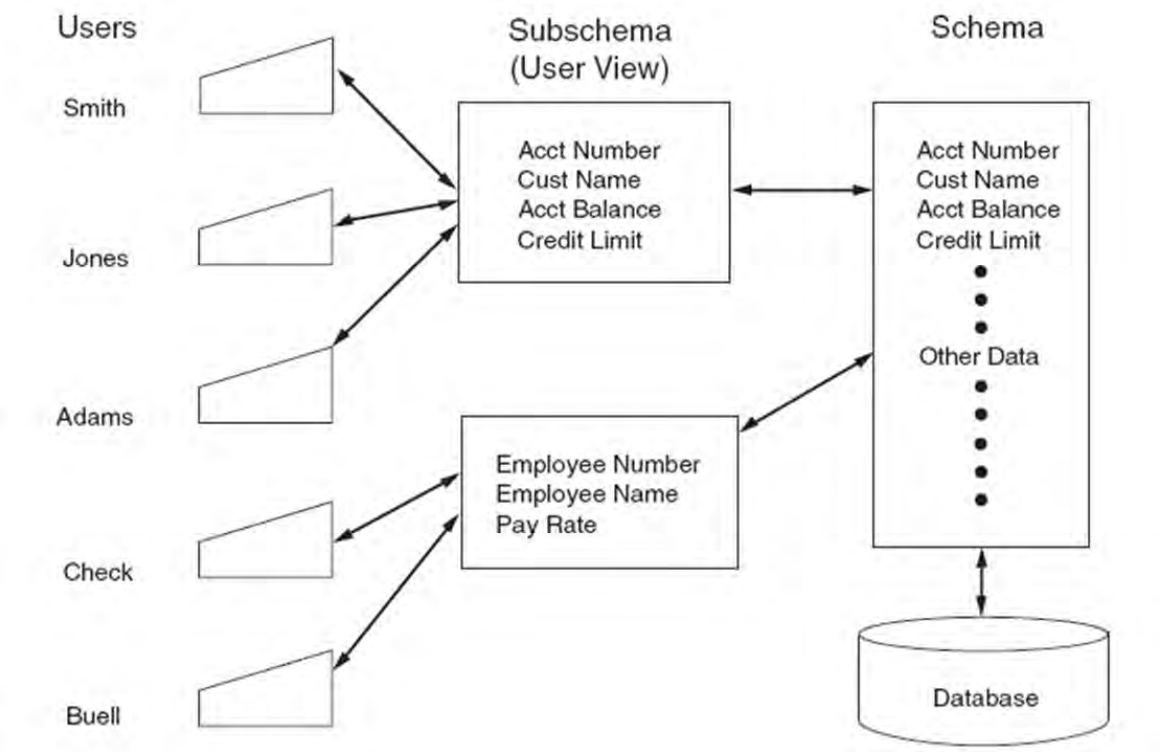
Controlling and Auditing Data Management Systems

- Controls over data management systems fall into two categories.
- **Access controls** are designed to prevent unauthorized individuals from viewing, retrieving, corrupting or destroying data.
- **Backup controls** ensure tat the organization can recover its database in the event of data loss.

Access Controls

- **User views** (subschema) is a subset of the database that defines user's data domain and access.
- **Database authorization table** contains rules that limit user actions.
- **User-defined procedures** allow users to create a personal security program or routine .
- **Data encryption** procedures protect sensitive data.
- **Biometric devices** such as fingerprints or retina prints control access to the database.
- **Inference controls** should prevent users from inferring, through query options, specific data values they are unauthorized to access.

Subschema Restricting Access



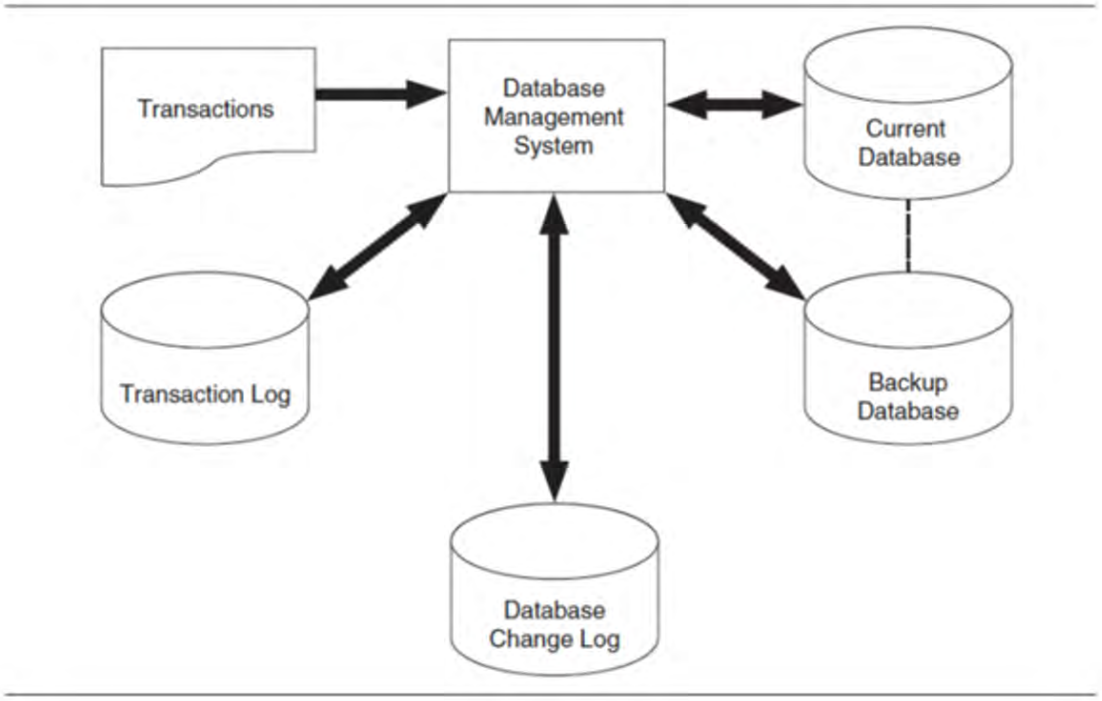
Audit Procedures for Testing Database Access Controls

- Verify DBA personnel retain responsibility for authority tables and designing user views.
- Select a sample of users and verify access privileges are consistent with job description.
- Evaluate cost and benefits of biometric controls.
- Verify database query controls to prevent unauthorized access via inference.
- Verify sensitive data are properly encrypted.

Backup Controls in the Database Environment

- Since data sharing is a fundamental objective of the database approach, environment is vulnerable to damage from individual users.
- Four needed backup and recovery features:
  - **Backup** feature makes a periodic backup of entire database which is stored in a secure, remote location.
  - **Transaction log** provides an audit trail of all processed transactions.
  - **Checkpoint** facility suspends all processing while system reconciles transaction log and database change log against the database.
  - **Recovery module** uses logs and backup files to restart the system after a failure.

Backup of Direct Access Files



Audit Procedures for Testing Database Access Controls

- Verify backups are performed routinely and frequently.
  - Backup policy should balance inconvenience of frequent activity against business disruption caused by system failure.
- Verify that automatic backup procedures are in place and functioning and that copies of the database are stored off-site.