Chapter 1: Introduction

Database Applications Examples

- Enterprise Information
  - Sales: customers, products, purchases
  - Accounting: payments, receipts, assets
  - Human Resources: Information about employees, salaries, payroll taxes.
- Manufacturing: management of production, inventory, orders, supply chain.
- Banking and finance
  - customer information, accounts, loans, and banking transactions.
  - Credit card transactions
  - Finance: sales and purchases of financial instruments (e.g., stocks and bonds; storing real-time market data
- Universities: registration, grades

Purpose of Database Systems

In the early days, database applications were built directly on top of file systems, which leads to:

- Data redundancy and inconsistency: data is stored in multiple file formats resulting induplication of information in different files
- Difficulty in accessing data
  - Need to write a new program to carry out each new task
- Data isolation
  - Multiple files and formats
- Integrity problems
  - Integrity constraints (e.g., account balance > 0) become "buried" in program code rather than being stated explicitly
  - Hard to add new constraints or change existing ones

Purpose of Database Systems (Cont.)

- Atomicity of updates
  - Failures may leave database in an inconsistent state with partial updates carried out
  - Example: Transfer of funds from one account to another should either complete or not happen at all
- Concurrent access by multiple users
  - Concurrent access needed for performance
  - Uncontrolled concurrent accesses can lead to inconsistencies
    - Ex: Two people reading a balance (say 100) and updating it by withdrawing money (say 50 each) at the same time
- Security problems
  - Hard to provide user access to some, but not all, data

Database systems offer solutions to all the above problems

Advantages of DBMS

- Control redundancy
- Consistency
- Integrity
- Security
- Concurrency control
- Backup & recovery
- Data standard
- More information
- Data sharing & conflict control
- Productivity & accessibility
- Economy of scale
- Maintenance

Limitations of DBMS

- Complexity
- Size
- Cost
  - Software
  - Hardware
  - Conversion
- Performance
- Vulnerability

Data Models

- A collection of tools for describing
  - Data
  - Data relationships
  - Data semantics
  - Data constraints
- Other older models:
  - Network model
  - Hierarchical model
- Relational model
- Entity-Relationship data model (mainly for database design)
- Object-based data models (Object-oriented and Object-relational)
- Semi-structured data model (XML)

DBMS Database Models

A Database model defines the logical design and structure of a database and defines how data will be stored, accessed and updated in a database management system. While the Relational Model is the most widely used database model, there are other models too:

- Hierarchical Model
- Network Model
- Entity-relationship Model
- Relational Model

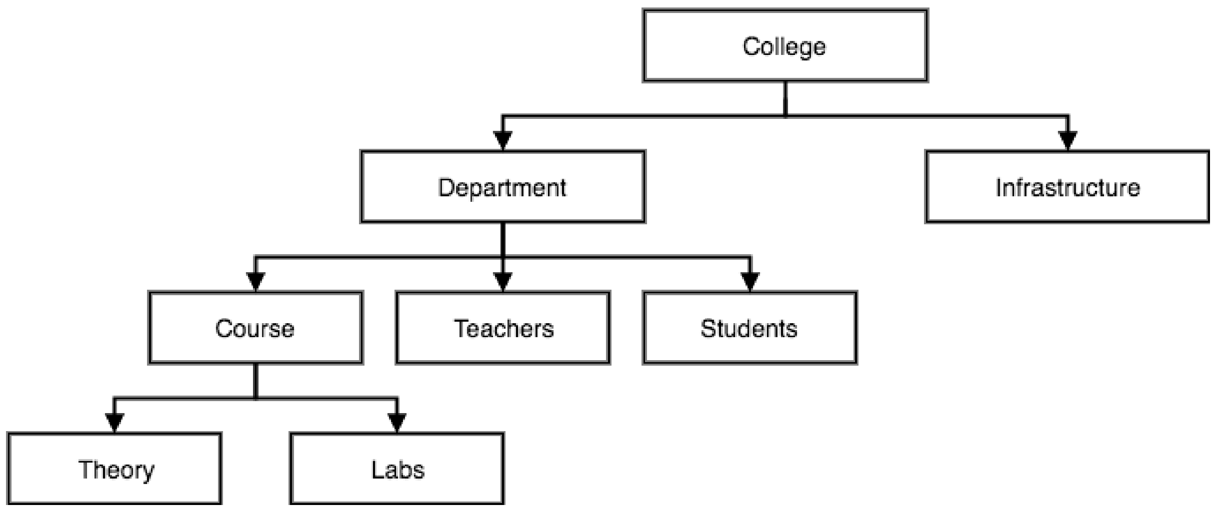
DBMS Database Models

Hierarchical Model:

- This database model organises data into a tree-like-structure, with a single root, to which all the other data is linked. The hierarchy starts from the **Root** data, and expands like a tree, adding child nodes to the parent nodes.
- In this model, a child node will only have a single parent node.
- This model efficiently describes many real-world relationships like index of a book, recipes etc.
- In hierarchical model, data is organised into tree-like structure with one one-to-many relationship between two different types of data, for example, one department can have many courses, many professors and of-course many students.

DBMS Database Models

Hierarchical Model:



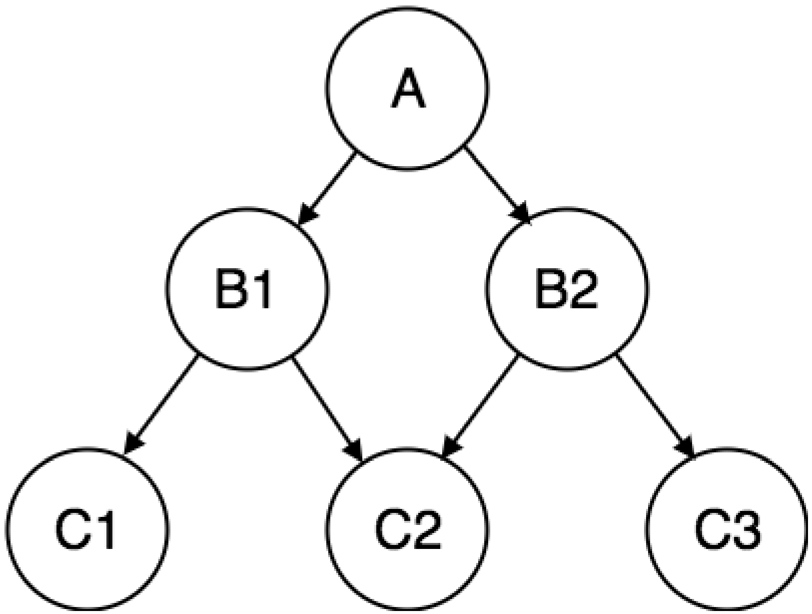
DBMS Database Models

Network Model:

- This is an extension of the Hierarchical model. In this model data is organised more like a graph, and are allowed to have more than one parent node.
- In this database model data is more related as more relationships are established in this database model. Also, as the data is more related, hence accessing the data is also easier and fast. This database model was used to map many-to-many data relationships.
- This was the most widely used database model, before Relational Model was introduced.

DBMS Database Models

Network Model:



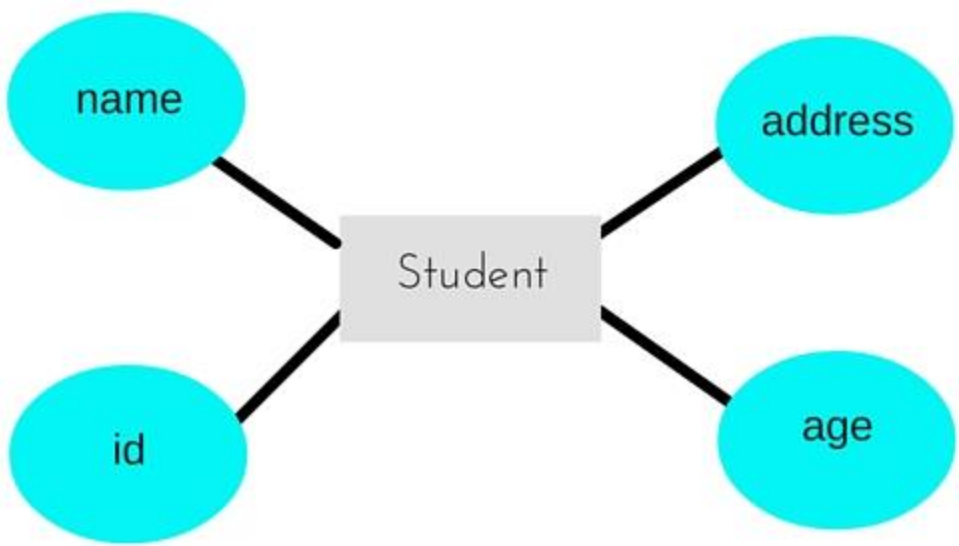
DBMS Database Models

Entity-relationship Model:

- In this database model, relationships are created by dividing object of interest into entity and its characteristics into attributes.
- Different entities are related using relationships.
- E-R Models are defined to represent the relationships into pictorial form to make it easier for different stakeholders to understand.
- This model is good to design a database, which can then be turned into tables in relational model(explained below).
- Let's take an example, If we have to design a School Database, then **Student** will be an **entity** with **attributes** name, age, address etc. As **Address** is generally complex, it can be another **entity** with **attributes** street name, pin code, city etc, and there will be a relationship between them.

DBMS Database Models

Entity-relationship Model:



DBMS Database Models

Relational Model:

- In this model, data is organised in two-dimensional **tables** and the relationship is maintained by storing a common field.
- This model was introduced by E.F Codd in 1970, and since then it has been the most widely used database model, infact, we can say the only database model used around the world.
- The basic structure of data in the relational model is tables. All the information related to a particular type is stored in rows of that table.
- Hence, tables are also known as **relations** in relational model.

DBMS Database Models

Relational Model:

student_id	name	age
1	Akon	17
2	Bkon	18
3	Ckon	17
4	Dkon	18

subject_id	name	teacher
1	Java	Mr. J
2	C++	Miss C
3	C#	Mr. C Hash
4	Php	Mr. P H P

student_id	subject_id	marks
1	1	98
1	2	78
2	1	76
3	2	88

Relational Model

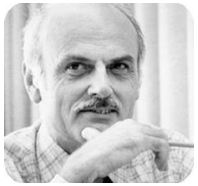
- All the data is stored in various tables.
- Example of tabular data in the relational model

Columns

Rows

ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

(a) The *instructor* table



Ted Codd
Turing Award 1981

A Sample Relational Database

ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
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76543	Singh	Finance	80000

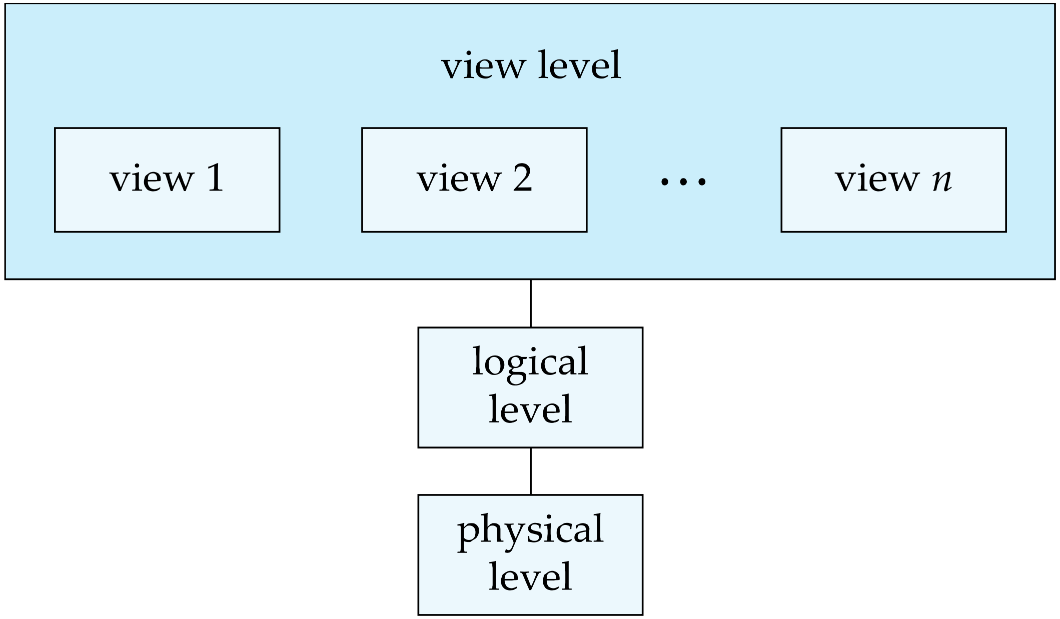
(a) The *instructor* table

dept_name	*building*	*budget*
Comp. Sci.	Taylor	100000
Biology	Watson	90000
Elec. Eng.	Taylor	85000
Music	Packard	80000
Finance	Painter	120000
History	Painter	50000
Physics	Watson	70000

(b) The *department* table

View of Data

An architecture for a database system



Instances and Schemas

- Similar to types and variables in programming languages
- **Logical Schema** – the overall logical structure of the database
  - Example: The database consists of information about a set of customers and accounts in a bank and the relationship between them
    - Analogous to type information of a variable in a program
- **Physical schema** – the overall physical structure of the database
- **Instance** – the actual content of the database at a particular point in time
  - Analogous to the value of a variable

Physical Data Independence

- **Physical Data Independence** – the ability to modify the physical schema without changing the logical schema
  - Applications depend on the logical schema
  - In general, the interfaces between the various levels and components should be well defined so that changes in some parts do not seriously influence others.

Data Definition Language (DDL)

- Specification notation for defining the database schema

  Example: **create table** *instructor* (
  ID **char**(5),
  name **varchar**(20)**,**
  dept_name **varchar**(20),
  salary **numeric**(8,2))

- DDL compiler generates a set of table templates stored in a ***data dictionary***
- Data dictionary contains metadata (i.e., data about data)
  - Database schema
  - Integrity constraints
    - Primary key (ID uniquely identifies instructors)
  - Authorization
    - Who can access what

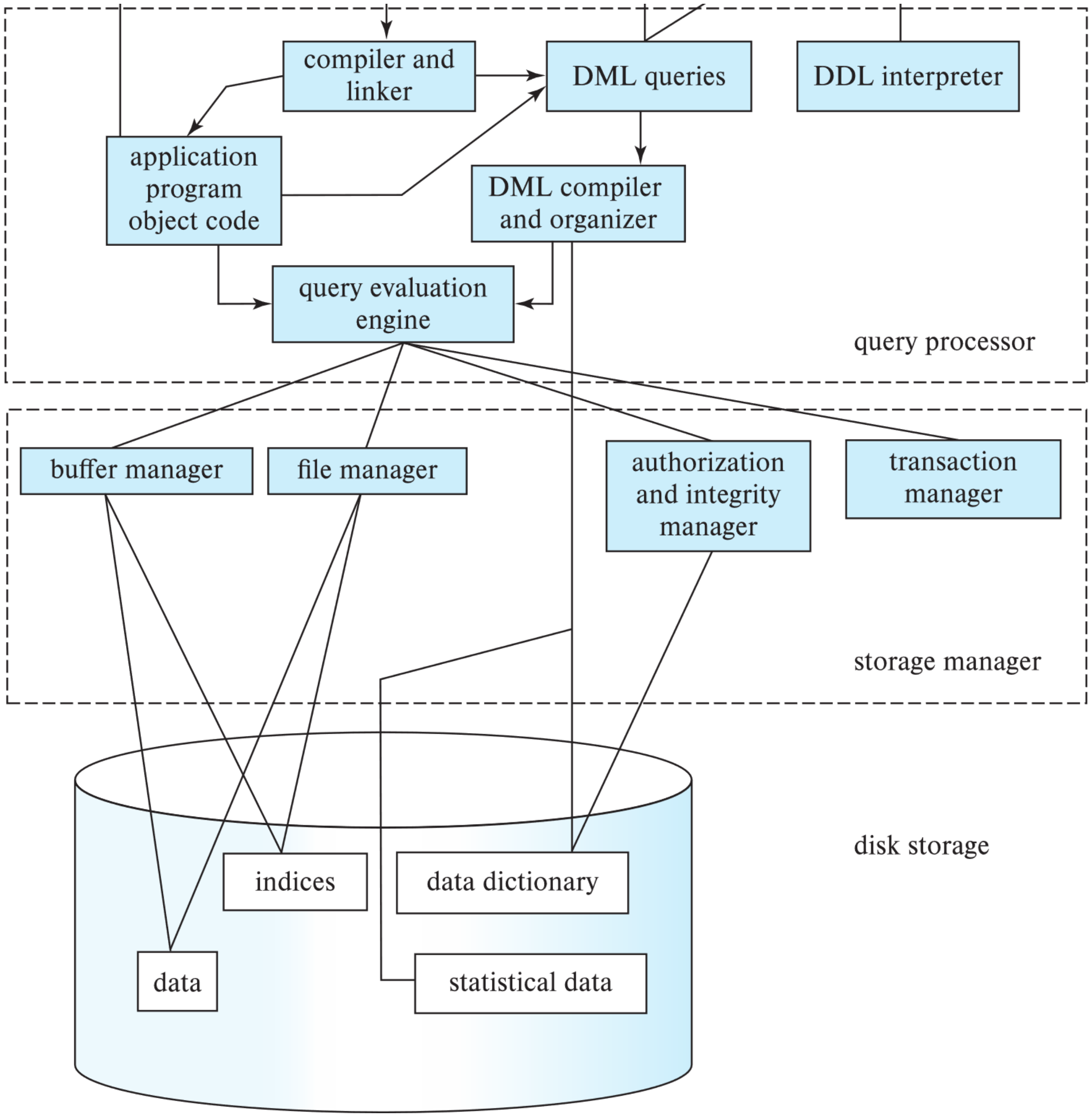
Data Manipulation Language (DML)

- Language for accessing and updating the data organized by the appropriate data model
  - DML also known as query language
- There are basically two types of data-manipulation language
  - **Procedural DML** -- require a user to specify what data are needed and how to get those data.
  - **Declarative DML** -- require a user to specify what data are needed without specifying how to get those data.
- Declarative DMLs are usually easier to learn and use than are procedural DMLs.
- Declarative DMLs are also referred to as non-procedural DMLs
- The portion of a DML that involves information retrieval is called a **query** language.

Database Architecture

- Centralized databases
  - One to a few cores, shared memory
- Client-server,
  - One server machine executes work on behalf of multiple client machines.
- Parallel databases
  - Many core shared memory
  - Shared disk
  - Shared nothing
- Distributed databases
  - Geographical distribution
  - Schema/data heterogeneity

Database Architecture (Centralized/Shared-Memory)

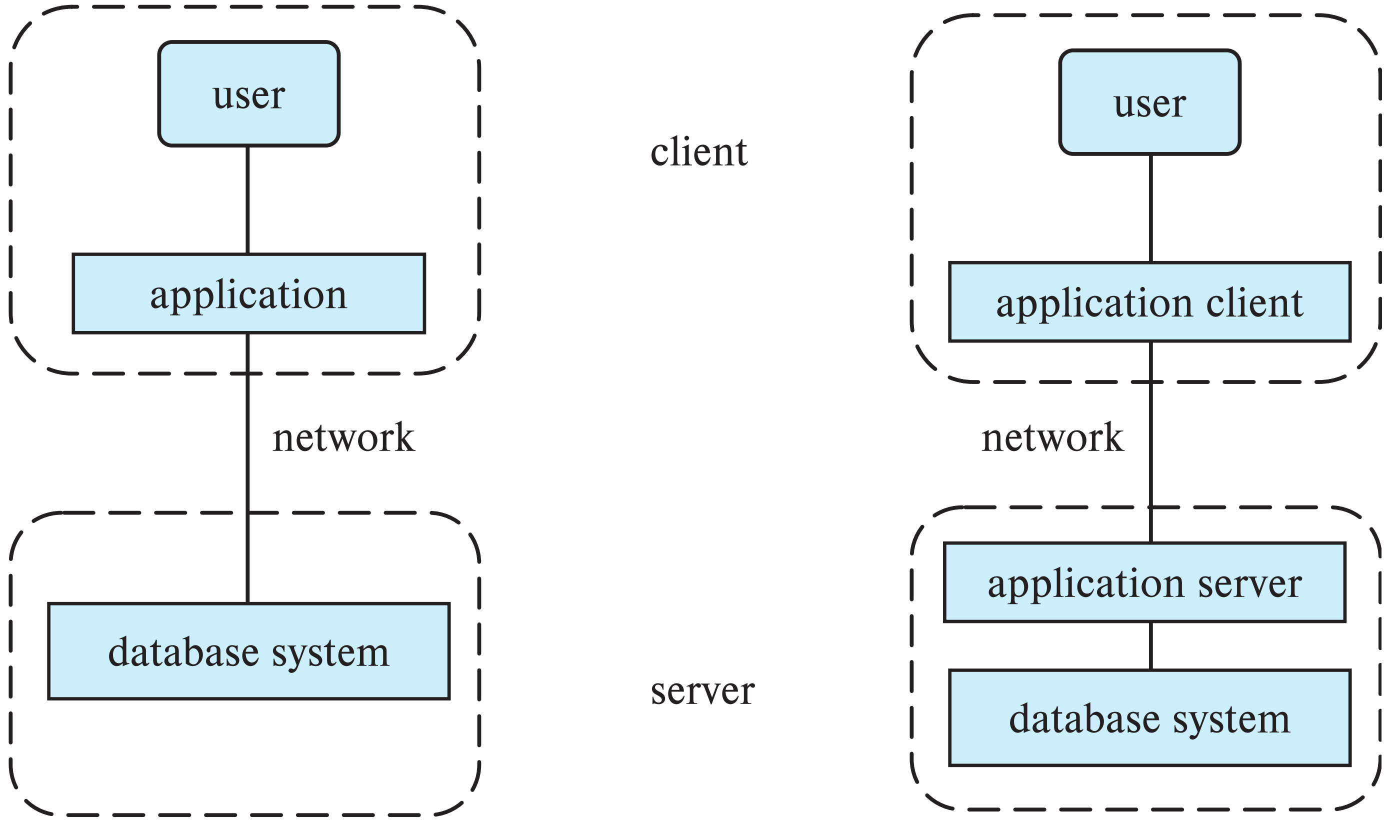


Database Applications

Database applications are usually partitioned into two or three parts

- Two-tier architecture -- the application resides at the client machine, where it invokes database system functionality at the server machine
- Three-tier architecture -- the client machine acts as a front end and does not contain any direct database calls.
  - The client end communicates with an application server, usually through a forms interface.
  - The application server in turn communicates with a database system to access data.

Two-tier and three-tier architectures



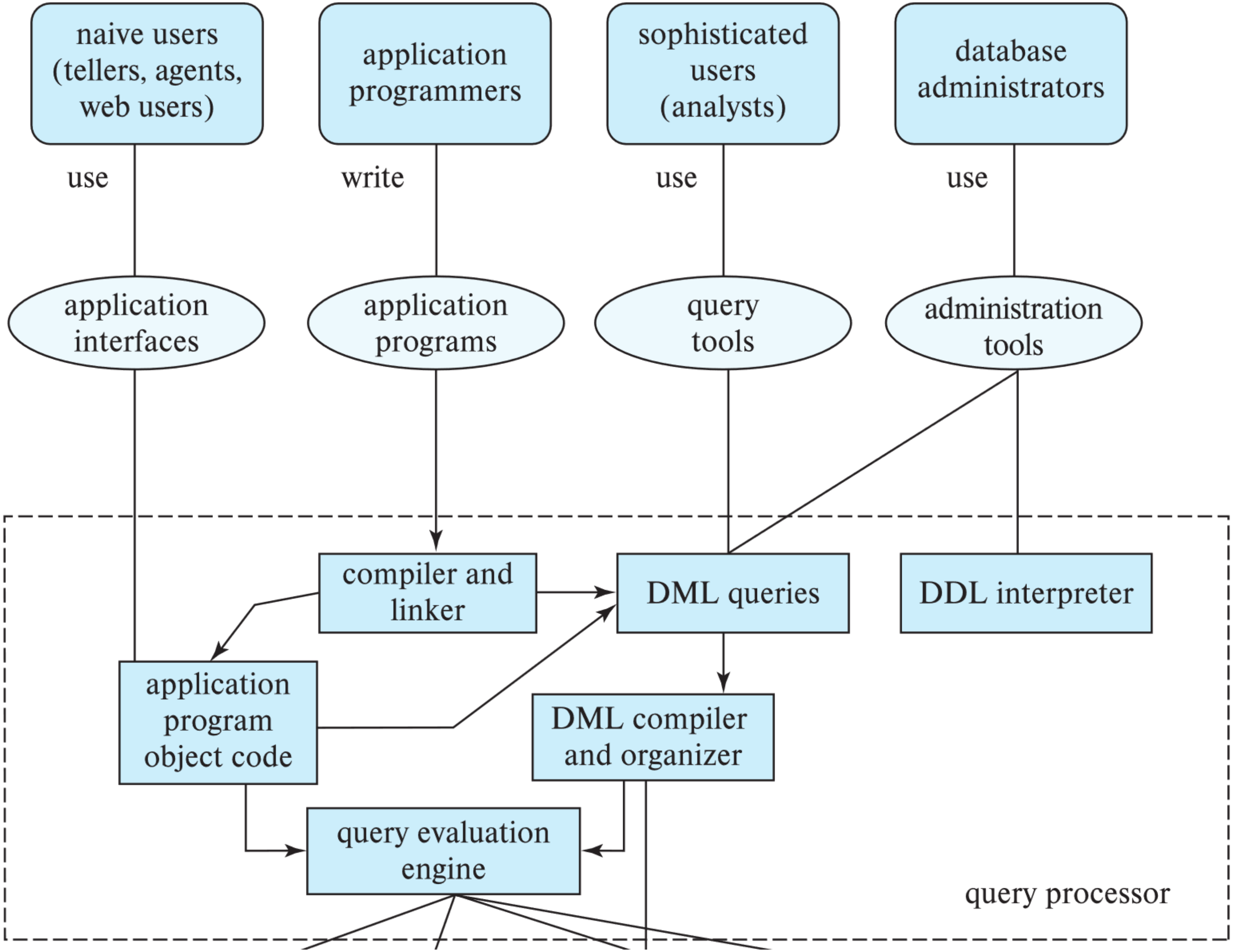
(a) Two-tier architecture

(b) Three-tier architecture

Two-tier and three-tier architectures

- Two-tier architecture -- In two-tier architecture, the Database system is present at the server machine and the DBMS application is present at the client machine, these two machines are connected with each other through a reliable network as shown in the above diagram.
- Whenever client machine makes a request to access the database present at server using a query language like sql, the server perform the request on the database and returns the result back to the client.
- In three-tier architecture, another layer is present between the client machine and server machine.
- In this architecture, the client application doesn’t communicate directly with the database systems present at the server machine, rather the client application communicates with server application and the server application internally communicates with the database system present at the server.

Database Users



Database Administrator

A person who has central control over the system is called a **database administrator (DBA).** Functions of a DBA include:

- Schema definition
- Storage structure and access-method definition
- Schema and physical-organization modification
- Granting of authorization for data access
- Routine maintenance
- Periodically backing up the database
- Ensuring that enough free disk space is available for normal operations, and upgrading disk space as required
- Monitoring jobs running on the database

History of Database Systems

- 1950s and early 1960s:
  - Data processing using magnetic tapes for storage
    - Tapes provided only sequential access
  - Punched cards for input
- Late 1960s and 1970s:
  - Hard disks allowed direct access to data
  - Network and hierarchical data models in widespread use
  - Ted Codd defines the relational data model
    - Would win the ACM Turing Award for this work
    - IBM Research begins System R prototype
    - UC Berkeley (Michael Stonebraker) begins Ingres prototype
    - Oracle releases first commercial relational database
  - High-performance (for the era) transaction processing

History of Database Systems (Cont.)

- 1980s:
  - Research relational prototypes evolve into commercial systems
    - SQL becomes industrial standard
  - Parallel and distributed database systems
    - Wisconsin, IBM, Teradata
  - Object-oriented database systems
- 1990s:
  - Large decision support and data-mining applications
  - Large multi-terabyte data warehouses
  - Emergence of Web commerce

History of Database Systems (Cont.)

- 2000s
  - Big data storage systems
    - Google BigTable, Yahoo PNuts, Amazon,
    - “NoSQL” systems.
  - Big data analysis: beyond SQL
    - Map reduce and friends
- 2010s
  - SQL reloaded
    - SQL front end to Map Reduce systems
    - Massively parallel database systems
    - Multi-core main-memory databases

End of Chapter 1