Chapter 2: DDBMS Architecture

- Definition of the DDBMS Architecture
- ANSI/SPARC Standard
- Global, Local, External, and Internal Schemas, Example
- DDBMS Architectures
- Components of the DDBMS

Acknowledgements: I am indebted to Arturas Mazeika for providing me his slides of this course.

Definition

- **Architecture:** The architecture of a system defines its structure:
  - the components of the system are identified;
  - the function of each component is specified;
  - the interrelationships and interactions among the components are defined.
- Applies both for computer systems as well as for software systems, e.g,
  - division into modules, description of modules, etc.
  - architecture of a computer
- There is a close relationship between the architecture of a system, standardisation efforts, and a reference model.

Motivation for Standardization of DDBMS Architecture

- DDBMS might be implemented as homogeneous or heterogeneous DDBMS
- **Homogeneous** DDBMS
  - All sites use same DBMS product
  - It is much easier to design and manage
  - The approach provides incremental growth and allows increased performance
- **Heterogeneous** DDBMS
  - Sites may run different DBMS products, with possibly different underlying data models
  - This occurs when sites have implemented their own databases first, and integration is considered later
  - Translations are required to allow for different hardware and/or different DBMS products
  - Typical solution is to use gateways

⇒ A common standard to implement DDBMS is needed!

Standardization

- The standardization efforts in databases developed reference models of DBMS.
- **Reference Model**: A conceptual framework whose purpose is to divide standardization work into manageable pieces and to show at a general level how these pieces are related to each other.
- A reference model can be thought of as an **idealized architectural model** of the system.
- Commercial systems might deviate from reference model, still they are useful for the standardization process
- A reference model can be described according to 3 different approaches:
  - component-based
  - function-based
  - data-based

Standardization . . .

- **Components-based**
  - Components of the system are defined together with the interrelationships between the components
  - Good for design and implementation of the system
  - It might be difficult to determine the functionality of the system from its components

Standardization . . .

- **Function-based**
  - Classes of users are identified together with the functionality that the system will provide for each class
  - Typically a hierarchical system with clearly defined interfaces between different layers
  - The objectives of the system are clearly identified.
  - Not clear how to achieve the objectives
  - Example: ISO/OSI architecture of computer networks

Standardization . . .

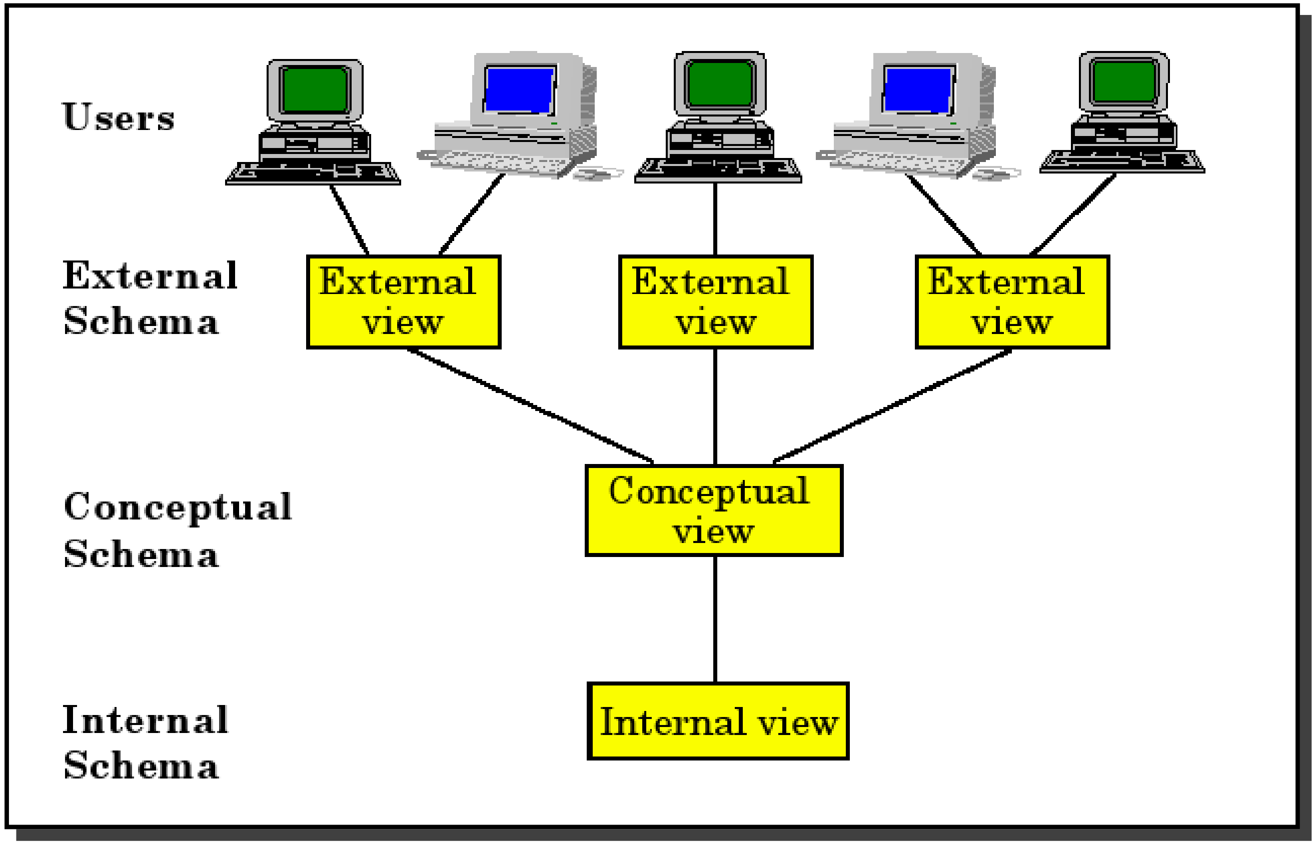
- **Data-based**
  - Identify the different types of the data and specify the functional units that will realize and/or use data according to these views
  - Gives central importance to data (which is also the central resource of any DBMS)
    $\longrightarrow$ Claimed to be the preferable choice for standardization of DBMS
  - The full architecture of the system is not clear without the description of functional modules.
  - Example: ANSI/SPARC architecture of DBMS

Standardization . . .

- The interplay among the 3 approaches is important:
  - Need to be used together to define an architectural model
  - Each brings a different point of view and serves to focus on different aspects of the model

ANSI/SPARC Architecture of DBMS

- ANSI/SPARC architecture is based on data
- 3 views of data: external view, conceptual view, internal view
- Defines a total of 43 interfaces between these views



Example

- Conceptual schema: Provides enterprise view of entire database

```
RELATION EMP [
  KEY = {ENO}
  ATTRIBUTES = {
    ENO  :  CHARACTER(9)
    ENAME:  CHARACTER(15)
    TITLE:  CHARACTER(10)
  }
]

RELATION PAY [
  KEY = {TITLE}
  ATTRIBUTES = {
    TITLE:  CHARACTER(10)
    SAL  :  NUMERIC(6)
  }
]

RELATION PROJ [
  KEY = {PNO}
  ATTRIBUTES = {
    PNO    :  CHARACTER(7)
    PNAME  :  CHARACTER(20)
    BUDGET:  NUMERIC(7)
    LOC    :  CHARACTER(15)
  }
]

RELATION ASG [
  KEY = {ENO,PNO}
  ATTRIBUTES = {
    ENO :  CHARACTER(9)
    PNO :  CHARACTER(7)
    RESP:  CHARACTER(10)
    DUR :  NUMERIC(3)
  }
]
```

Example . . .

- Internal schema: Describes the storage details of the relations.
  - Relation EMP is stored on an indexed file
  - Index is defined on the key attribute ENO and is called EMINX
  - A HEADER field is used that might contain flags (delete, update, etc.)

```
INTERNAL_REL EMPL [
  INDEX ON E#  CALL EMINX
  FIELD =
    HEADER:  BYTE(1)
    E#    :  BYTE(9)
    ENAME :  BYTE(15)
    TIT   :  BYTE(10)

]
```

Conceptual schema:

```
RELATION EMP [
  KEY = {ENO}
  ATTRIBUTES = {
    ENO  : CHARACTER(9)
    ENAME: CHARACTER(15)
    TITLE: CHARACTER(10)
  }
]
```

Example . . .

- External view: Specifies the view of different users/applications
  - Application 1: Calculates the payroll payments for engineers

```
CREATE VIEW PAYROLL (ENO, ENAME, SAL) AS
SELECT EMP.ENO,EMP.ENAME,PAY.SAL
FROM   EMP, PAY
WHERE  EMP.TITLE = PAY.TITLE
```

  - Application 2: Produces a report on the budget of each project

```
CREATE VIEW BUDGET(PNAME, BUD) AS
SELECT PNAME, BUDGET
FROM PROJ
```

Architectural Models for DDBMSs

- Architectural Models for DDBMSs (or more generally for multiple DBMSs) can be classified along three dimensions:
  - Autonomy
  - Distribution
  - Heterogeneity

Architectural Models for DDBMSs ...

- **Autonomy**: Refers to the distribution of control (not of data) and indicates the degree to which individual DBMSs can operate independently.
  - *Tight integration*: a single-image of the entire database is available to any user who wants to share the information (which may reside in multiple DBs); realized such that one data manager is in control of the processing of each user request.
  - *Semiautonomous* systems: individual DBMSs can operate independently, but have decided to participate in a federation to make some of their local data sharable.
  - *Total isolation*: the individual systems are stand-alone DBMSs, which know neither of the existence of other DBMSs nor how to comunicate with them; there is no global control.
- Autonomy has different dimensions
  - *Design autonomy*: each individual DBMS is free to use the data models and transaction management techniques that it prefers.
  - *Communication autonomy*: each individual DBMS is free to decide what information to provide to the other DBMSs
  - *Execution autonomy*: each individual DBMS can execture the transactions that are submitted to it in any way that it wants to.

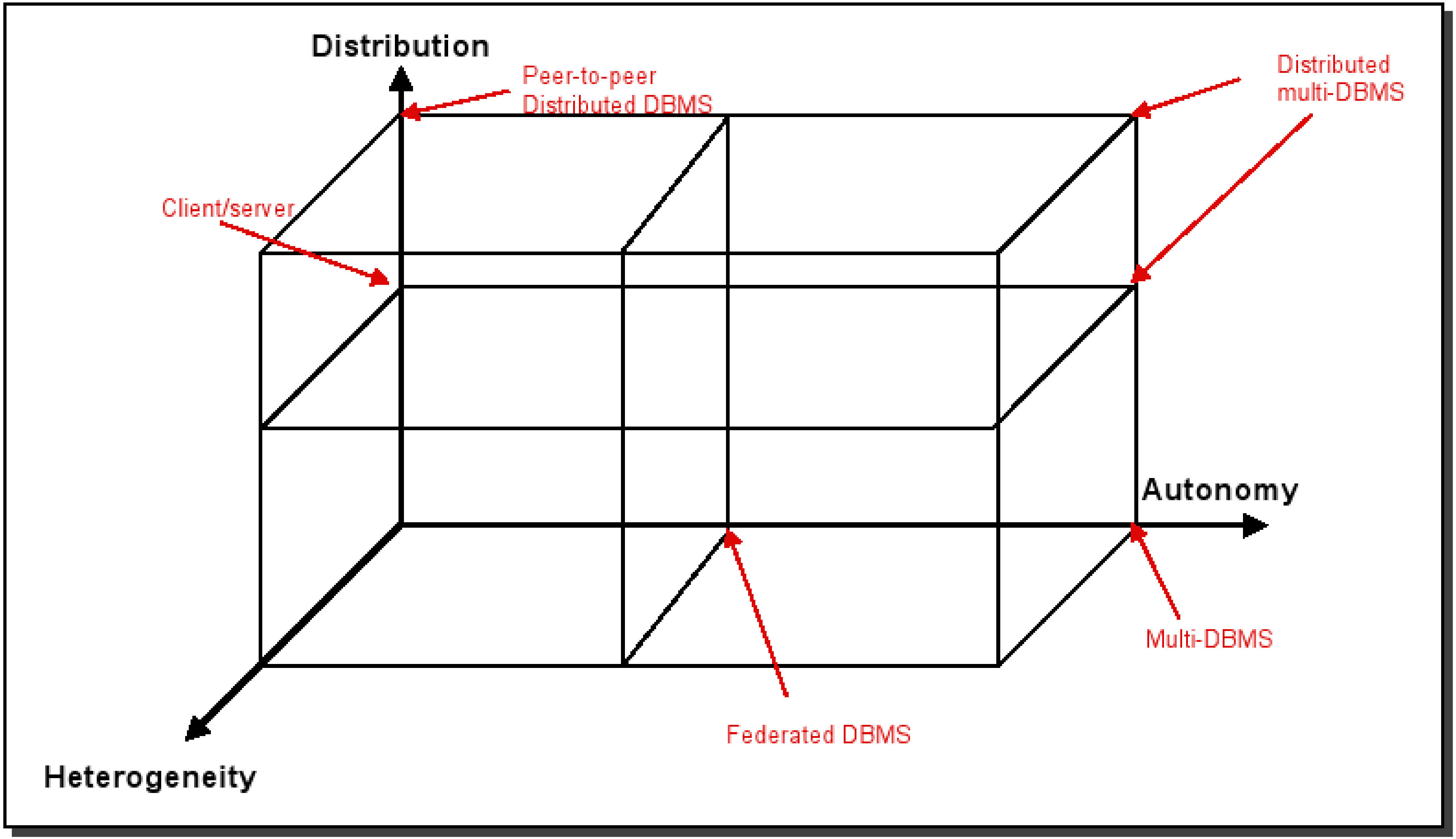
Architectual Models for DDBMSs . . .

- **Distribution**: Refers to the physical distribution of data over multiple sites.
  - *No distribution*: No distribution of data at all
  - *Client/Server distribution*:
    - Data are concentrated on the server, while clients provide application environment/user interface
    - First attempt to distribution
  - *Peer-to-peer distribution* (also called *full distribution*):
    - No distinction between client and server machine
    - Each machine has full DBMS functionality

Architectural Models for DDBMSs . . .

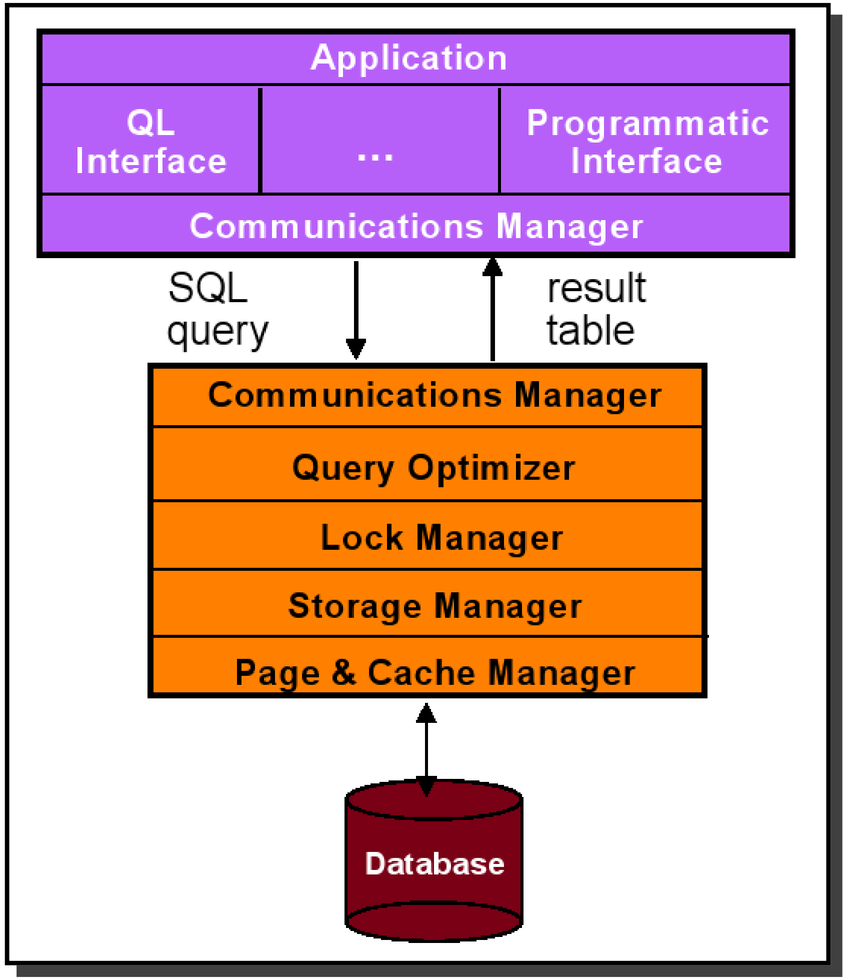
- **Heterogeneity**: Refers to heterogeneity of the components at various levels
  - hardware
  - communications
  - operating system
  - DB components (e.g., data model, query language, transaction management algorithms)

Architectural Models for DDBMSs . . .



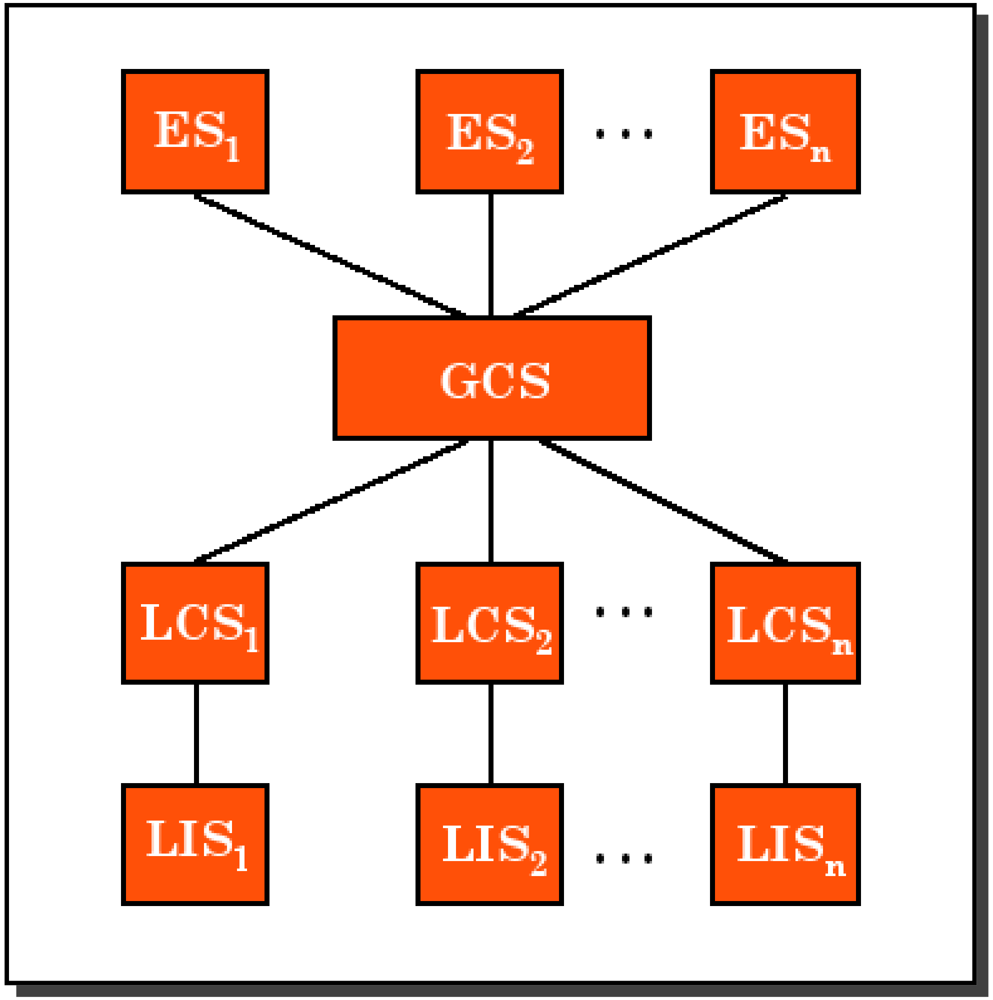
Client-Server Architecture for DDBMS (Data-based)

- General idea: Divide the functionality into two classes:
  - server functions
    - ∗ mainly data management, including query processing, optimization, transaction management, etc.
  - client functions
    - ∗ might also include some data management functions (consistency checking, transaction management, etc.) not just user interface
- Provides a two-level architecture
- More efficient division of work
- Different types of client/server architecture
  - Multiple client/single server
  - Multiple client/multiple server



Peer-to-Peer Architecture for DDBMS (Data-based)

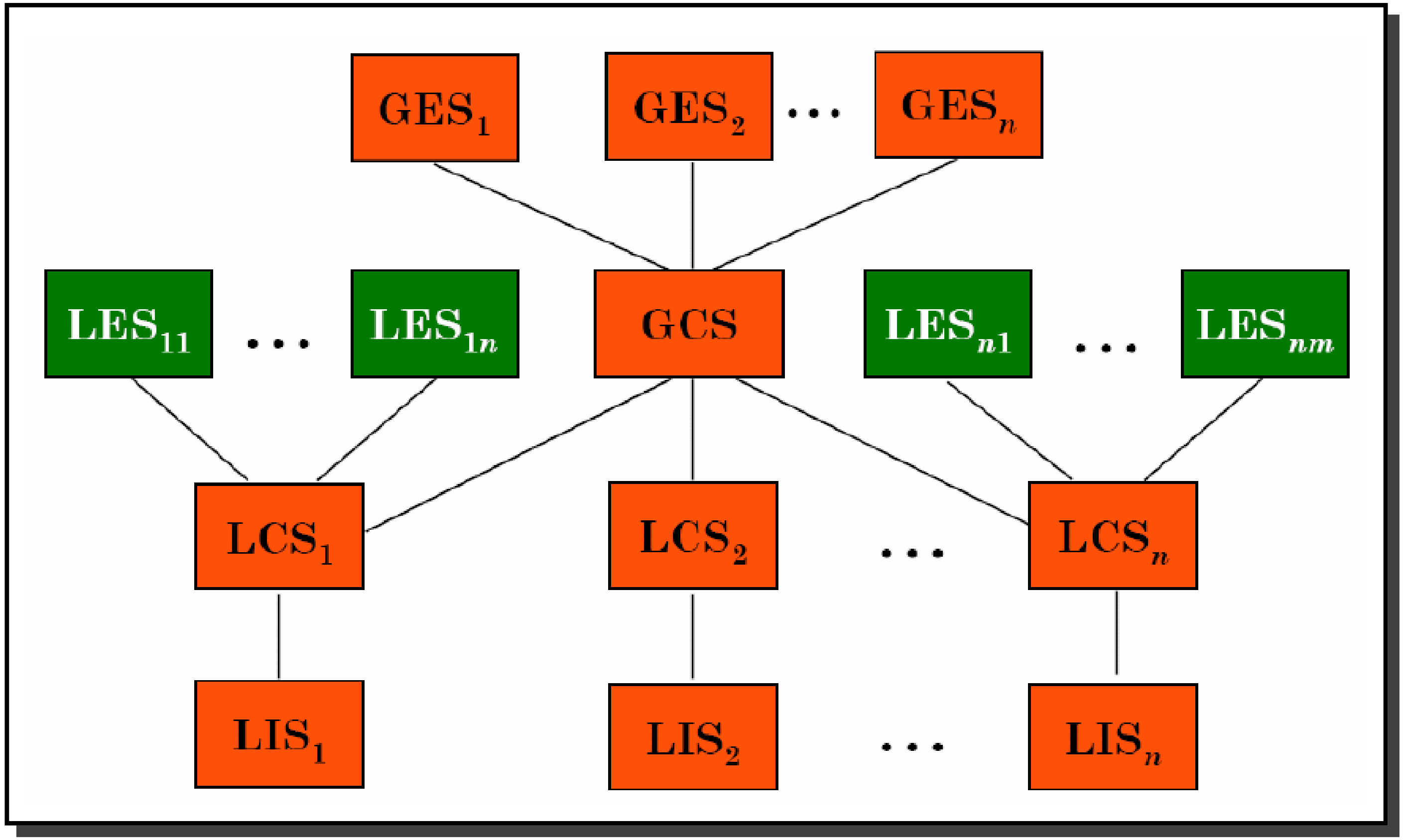
- *Local internal schema* (LIS)
  - Describes the local physical data organization (which might be different on each machine)
- *Local conceptual schema* (LCS)
  - Describes logical data organization at each site
  - Required since the data are fragmented and replicated
- Global conceptual schema (GCS)
  - Describes the global logical view of the data
  - Union of the LCSs
- *External schema* (ES)
  - Describes the user/application view on the data



Multi-DBMS Architecture (Data-based)

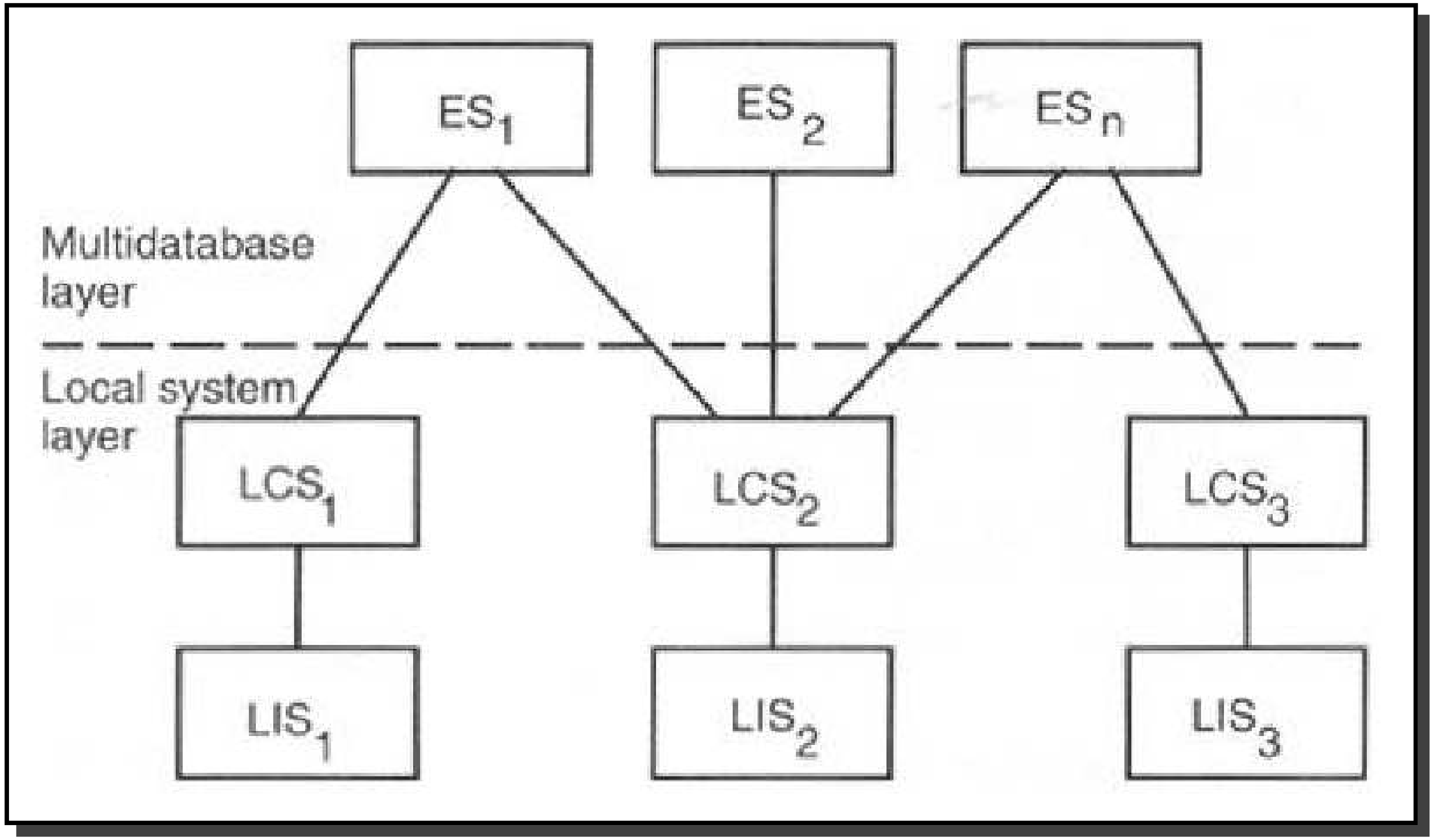
- Fundamental difference to peer-to-peer DBMS is in the definition of the global conceptual schema (GCS)
  - In a MDBMS the GCS represents only the collection of *some* of the local databases that each local DBMS want to share.
- This leads to the question, whether the GCS should even exist in a MDBMS?
- Two different architecutre models:
  - Models with a GCS
  - Models without GCS

- Model with a GCS
  - GCS is the union of parts of the LCSs
  - Local DBMS define their own views on the local DB

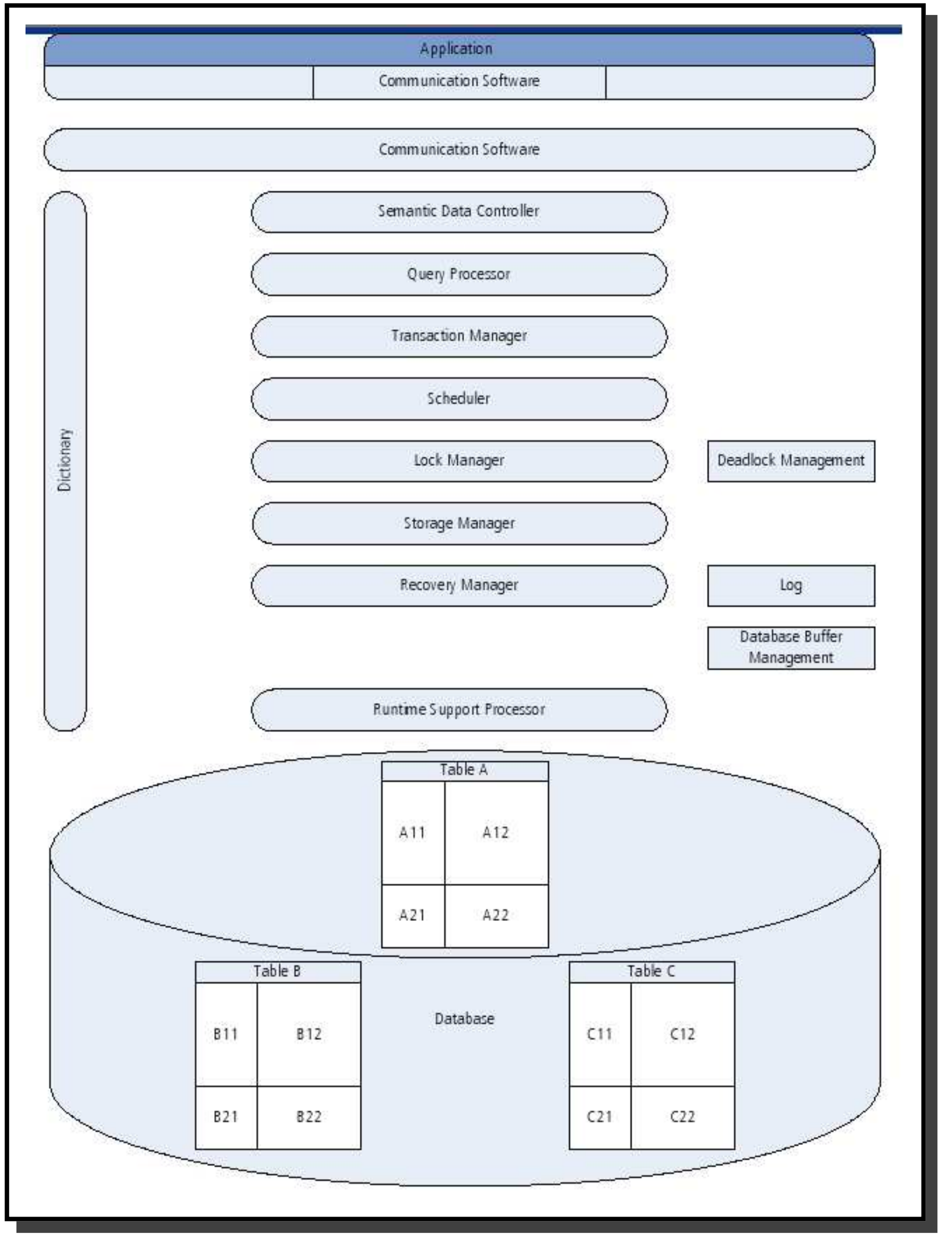


Multi-DBMS Architecture (Data-based) . . .

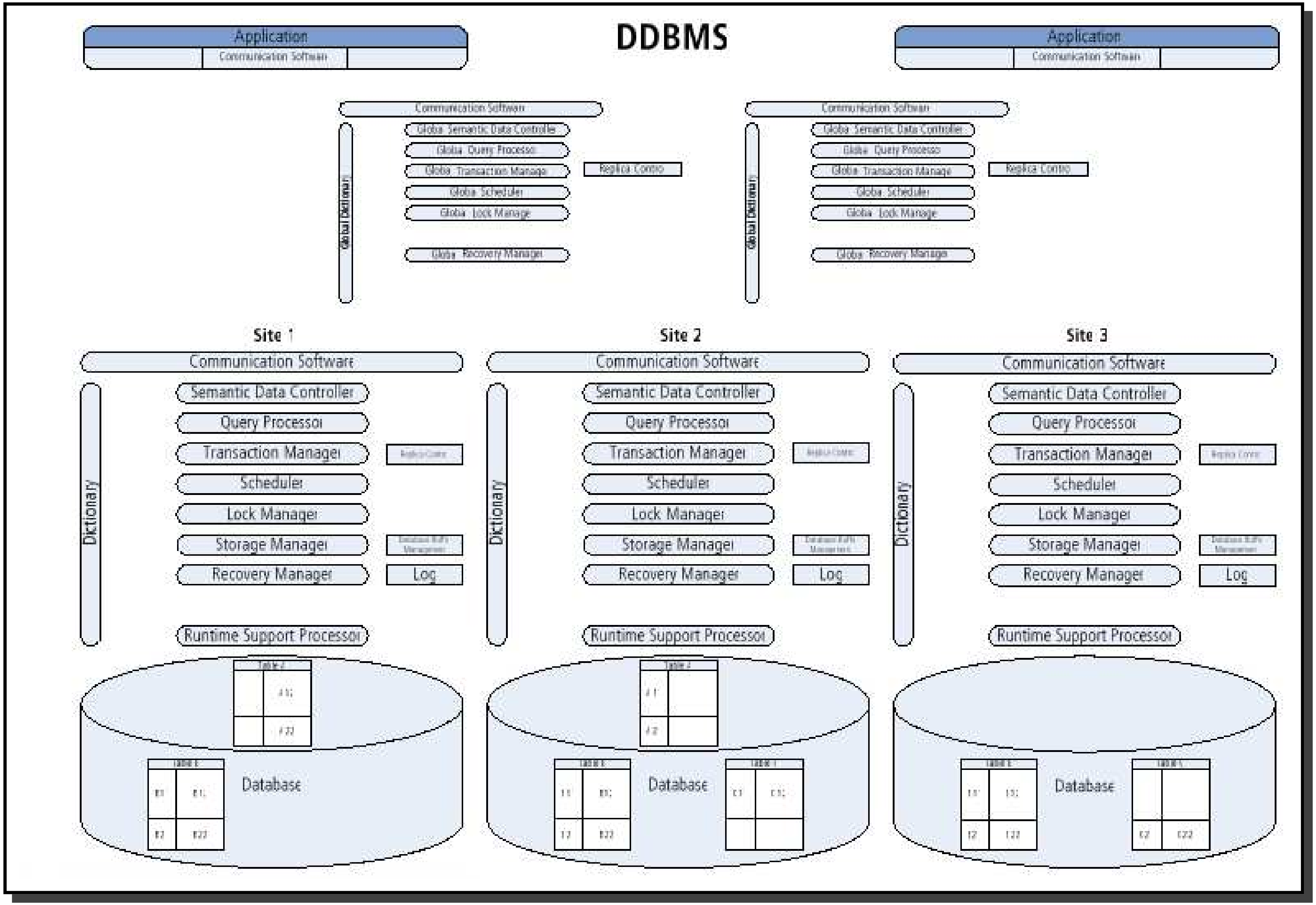
- Model without a GCS
  - The local DBMSs present to the multi-database layer the part of their local DB they are willing to share.
  - External views are defined on top of LCSs



Regular DBMS (Component-based)

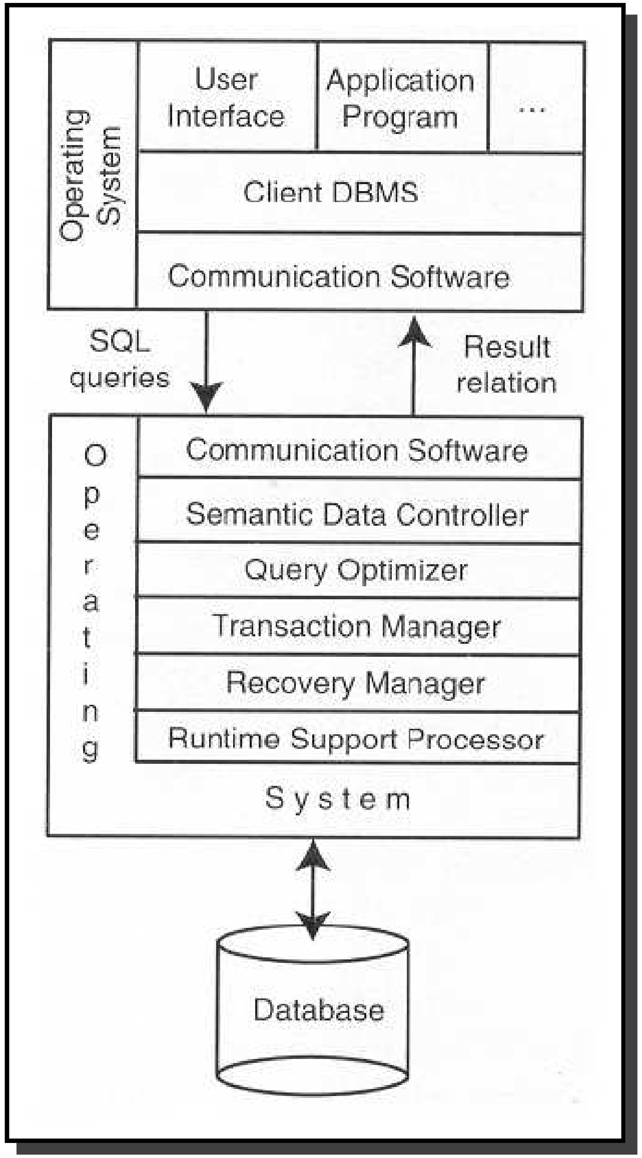


General DDBMS (Component-based)



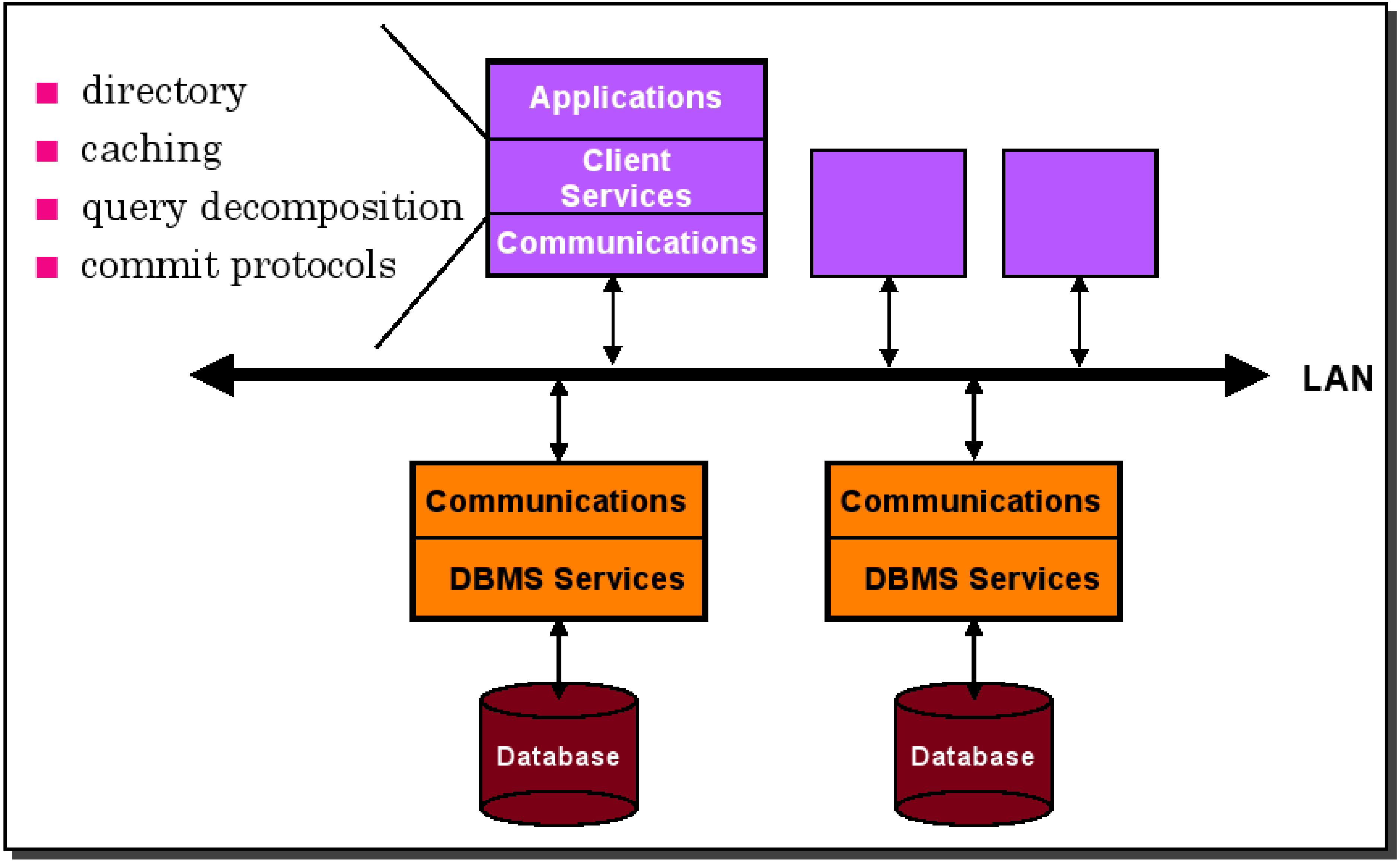
Client-Server Architecture (Component-based)

- One server, many clients



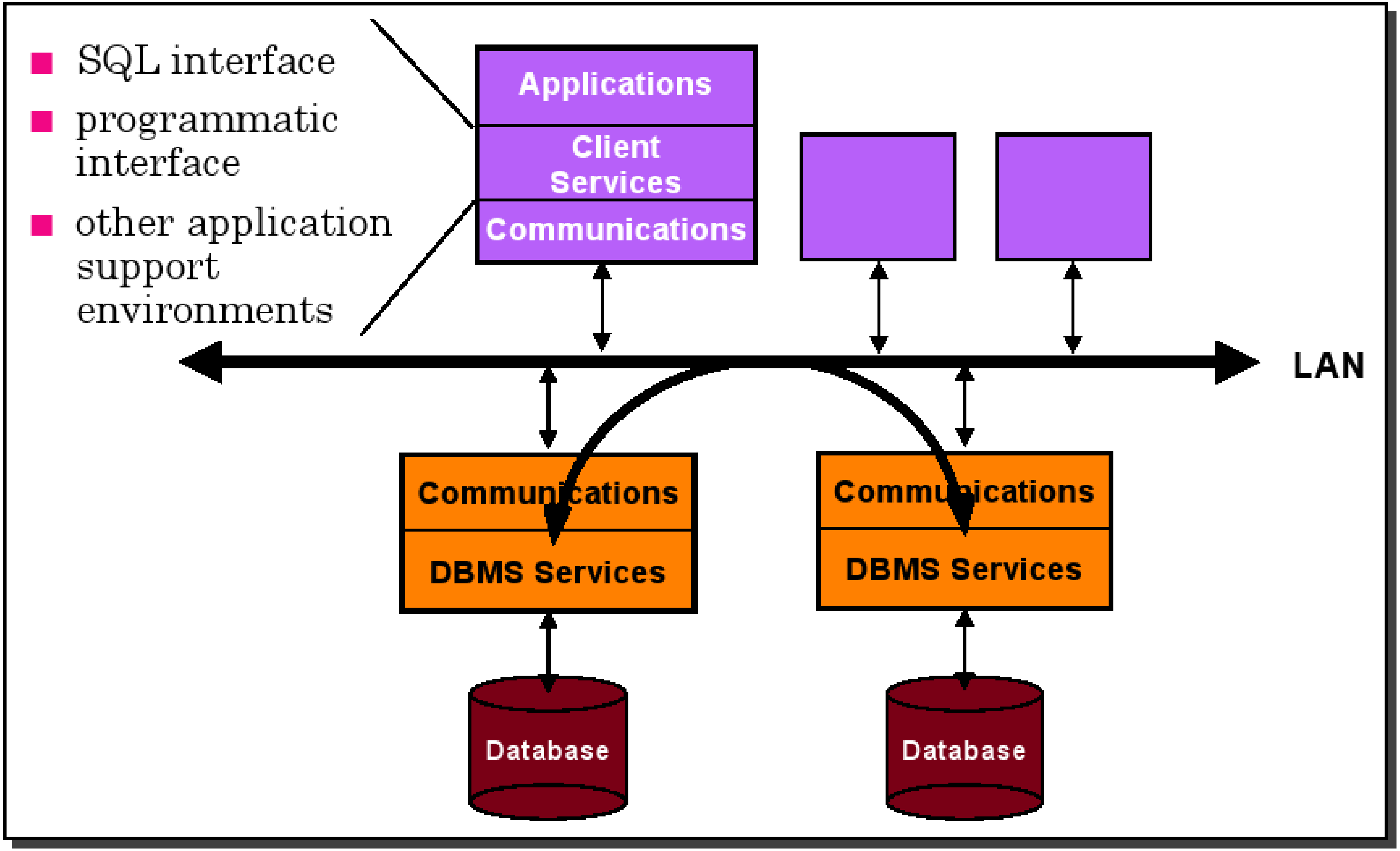
Components of Client-Server Architecture (Component-based)

- Many servers, many clients

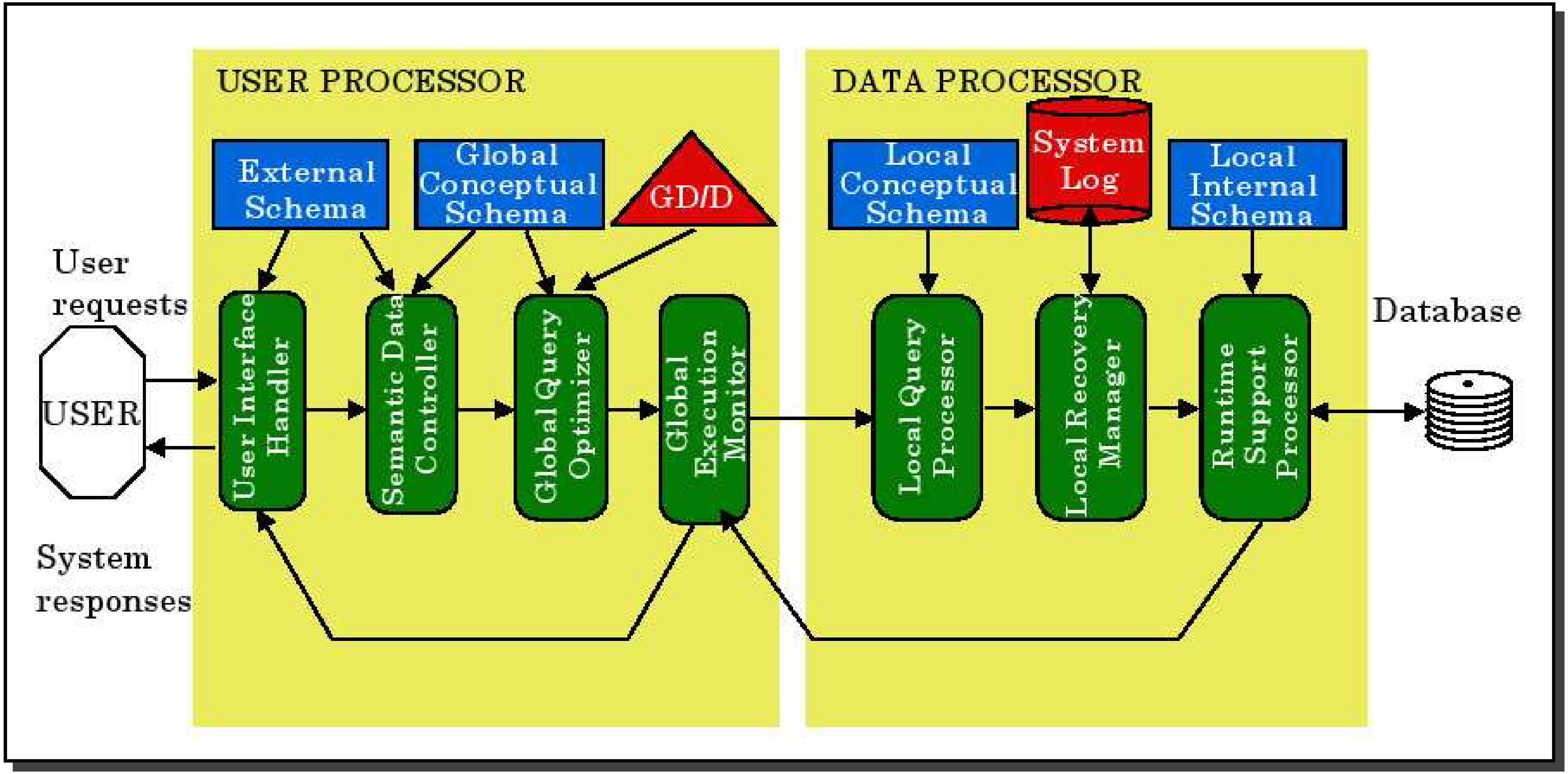


Components of Client-Server Architecture (Component-based) . . .

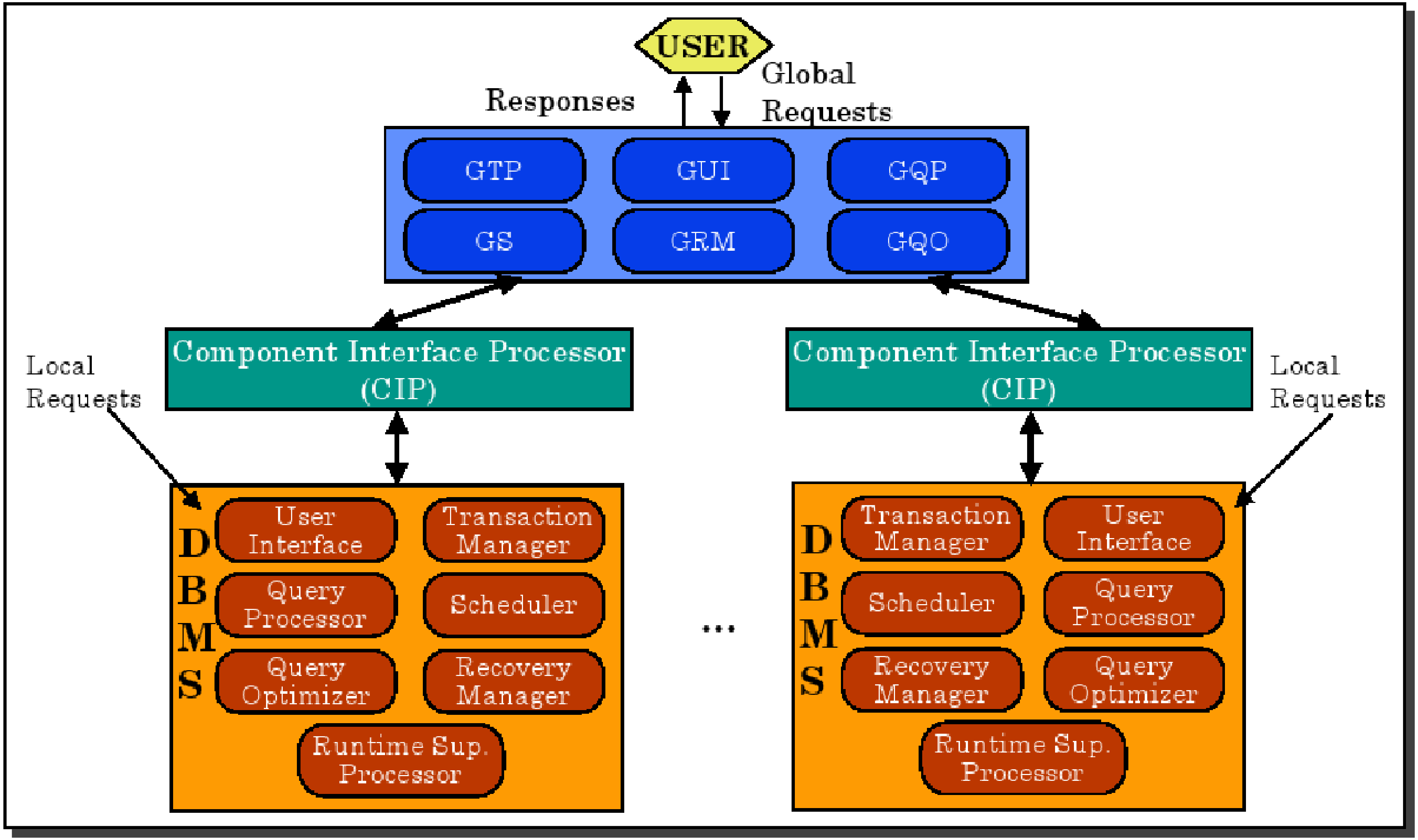
- Many servers, many clients



Components of Peer-to-Peer Architecture (Component-based)



Components of Multi-DBMS Architecture (Component-based)



Conclusion

- Architecture defines the structure of the system. There are three ways to define the architecture: based on components, functions, or data
- DDBMS might be based on identical components (homogeneous systems) or different components (heterogeneous systems)
- ANSI/SPARC architecture defines external, conceptual, and internal schemas
- There are three orthogonal implementation dimensions for DDBMS: level of distribution, autonomity, and heterogeinity
- Different architectures are discussed:
  - Client-Server Systems
  - Peer-to-Peer Systems
  - Multi-DBMS