Topic 2: Software Design

❖Design Process

- Transforming the customer requirements as described in the SRS documents into a form implementable using a programming language.
- Iterative process through which requirements are translated into "blueprint" for constructing the software.
- The software design process can be divided into the following three levels or phases of design:

1.Interface Design

2.Architectural Design

3.Detailed Design

❑Interface Design

- Specification of the interaction between a system and its environment.
- Proceeds at a high level of abstraction with respect to the inner workings of the system.
- for eg: During interface design, the internal of the systems are completely ignored, and the system is treated as a black box.
- Attention is focused on the dialogue between the target system and the users, devices, and other systems with which it interacts.
- The design problem statement produced during the problem analysis step should identify the people, other systems, and devices which are collectively called agents.

- Interface design should include the following details:

1. Precise description of events in the environment, or messages from agents to which the system must respond.
2. Precise description of the events or messages that the system must produce.
3. Specification of the data, and the formats of the data coming into and going out of the system.
4. Specification of the ordering and timing relationships between incoming events or messages, and outgoing events or outputs.

❑Architectural Design

- Architectural design is the specification of the major components of a system, their responsibilities, properties, interfaces, and the relationships and interactions between them.
- The overall structure of the system is chosen, but the internal details of major components are ignored.
- Issues in architectural design includes:

1.Gross decomposition of the systems into major components.

2.Allocation of functional responsibilities to components.

3.Component Interfaces.

4.Component scaling and performance properties, resource consumption properties, reliability properties.

5.Communication and interaction between components.

- The architectural design adds important details ignored during the interface design. Design of the internals of the major components is ignored until the last phase of the design.

❑Detailed Design

- Detailed design is the specification of the internal elements of all major system components, their properties, relationships, processing, and often their algorithms and the data structures.
- The detailed design may include:

1. Decomposition of major system components into program units.
2. Allocation of functional responsibilities to units.
3. User interfaces.
4. Unit states and state changes.
5. Data and control interaction between units.
6. Data packaging and implementation, including issues of scope and visibility of program elements.
7. Algorithms and data structures.

❖ Design concepts

- Design concepts provides the software designer with a foundation from which more sophisticated design methods can be applied and helps the software engineer to answer the questions like:

- What criteria can be used to partition software into individual components?
- How is function or data structure detail separated from a conceptual representation of the software?
- What uniform criteria define the technical quality of a software design?
- Fundamental software design concepts provide the necessary framework for "getting it right."

➢ **Abstraction** :Data, Procedure and Control
➢ **Architecture** :The overall structure of the software
➢ **Patterns** :Coveys the essence of the proven design solution

- **Separation of Concerns** :Complex problem can be easily handled if it subdivided into smaller parts.
- **Modularity** :Compartmentalization of data and functions.
- **Information Hiding** :Controlled interfaces.
- **Functional Independence** :Single minded function and low coupling.
- **Refinement** :Elaboration of detail for all abstraction.
- **Aspects** :Mechanism for understanding how global requirement affect the design.
- **Refactoring** :A reorganization techniques that simplifies the design.
- **Object-Oriented Design Concepts**
- **Design Classes**: Provide design detail that will enable analysis class to be enabled.

❖ Design Modes

- Design modes or design patterns are standard solutions to common problems in software design. They provide templates for how to solve a problem that can be used in many different situations. Some well-known design patterns include:

1. **Creational Patterns:** Deal with object creation mechanisms, aiming to create objects in a manner suitable for the situation.
    - **Singleton:** Ensures a class has only one instance and provides a global point of access to it.
    - **Factory Method:** Defines an interface for creating an object but lets subclasses alter the type of objects that will be created.

2. Behavioral Patterns: Deal with communication between objects, making the flow of control more manageable.

- **Observer:** Defines a one-to-many dependency between objects so that when one object changes state, all its dependents are notified.
- **Strategy:** Defines a family of algorithms, encapsulates each one, and makes them interchangeable.

3. Structural Patterns: Deal with object composition or structure, simplifying the design by identifying a simple way to realize relationships between entities.

- **Adapter:** Allows incompatible interfaces to work together.
- **Composite:** Composes objects into tree structures to represent part-whole hierarchies.

❖ Design Heuristics

- Design heuristics are rules of thumb or guidelines that help designers make decisions during the design process. They are less formal than design patterns and are used to improve the quality of the design.
- These heuristics and design patterns are tools that can help software developers create systems that are robust, maintainable, and scalable. Some common are

1. **Encapsulation:** Hide implementation details and expose only what is necessary. This reduces complexity and increases modularity.
2. **Separation of Concerns:** Divide the system into distinct sections, each addressing a separate concern. This makes the system easier to understand, develop, and maintain.
3. **DRY (Don't Repeat Yourself):** Avoid duplication of code. Each piece of knowledge must have a single, unambiguous representation in the system.

4. KISS (Keep It Simple, Stupid): Simplicity should be a key goal in design and unnecessary complexity should be avoided.

5. YAGNI (You Aren't Gonna Need It): Don't add functionality until it is necessary. This prevents overengineering and reduces the potential for bugs.

6.Open/Closed Principle: Software entities should be open for extension but closed for modification. This means you should be able to extend the behavior of a system without altering its existing code.

7. Single Responsibility Principle: A class should have only one reason to change means it should have only one job or responsibility.

8. Liskov Substitution Principle: Objects of a superclass should be replaceable with objects of a subclass without affecting the correctness of the program.

9. Interface Segregation Principle: No client should be forced to depend on methods it does not use. This means providing small, specific interfaces rather than a large, general-purpose one.

❖ Architectural design Decision

- Concerned with understanding how a system should be organized and designing the overall structure of that system.
- Architectural design is the first stage in the software design process.
- Identifies the main structural components in a system and the relationships between them.
- Architectural model that describes how the system is organized as a set of communicating components.

Architectural design decisions:

- Creative process where you design a system organization that will satisfy the functional and non-functional requirements of a system.

- The activities within the process depend on the type of system being developed, the background and experience of the system architect and the specific requirements for the system. It is therefore useful to think of architectural design as a series of decisions to be made rather than a sequence of activities.
- The system architects have to consider the following fundamental questions about the system:

➢ Is there generic application architecture that can act as a template for the system that is being designed?

➢ What strategy will be used to control the operation of the components in the system?

➢ What architectural organization is best for delivering the non-functional requirement of the system?

➢ How will the architectural design be evaluated?

➢ How should the architecture of the system be documented?

- The close relationship between nonfunctional requirements and software architecture, the particular architectural style and structure that choose for a system depend on the nonfunctional system requirements:

1. Performance: The architecture should be designed to localize critical operations within a small number of components, with these components all deployed on the same computer rather than distributed across the network.

2. Security: A layered structure for the architecture should be used, with the most critical assets protected in the innermost layers with a high level of security validation applied to these layers.

3. Safety: The architecture should be designed so that safety related operations are all located in either a single component or in a small number of components.

4. Availability: The architecture should be designed to include redundant components so that it is possible to replace and update components without stopping the system.

5. Maintainability: The system architecture should be designed using fine-grain, self-contained components that may readily be changed. Producers of data should be separated from consumers and shared data structures should be avoided.

❖System organization

- Reflects the basic strategy that is used to structure a system.
- Three organizational styles are widely used:

1. Shared Data Repository Style:

➢Multiple systems or components share a common data repository.

➢All components interact with the same dataset, which acts as a central point of data management.

➢This approach ensures consistency and reduces data redundancy but may create a bottleneck if the repository becomes a single point of failure or a performance constraint.

➢Common in database-centric applications and environments where data integrity and consistency are paramount.

2.Shared Services and Servers Style:

- This style involves sharing common services or servers among different components or systems.
- Services can include authentication, logging, data processing, etc., and servers can be web servers, application servers, etc.
- Promotes reusability and modularity, as components can leverage existing services without duplicating functionality.
- Often used in microservices architectures and environments with a Service-Oriented Architecture (SOA).

3.Abstract Machine or Layered Style:

- In this style, the system is organized into layers, each providing a set of services to the layer above and using services from the layer below.
- This abstraction helps in managing complexity by separating concerns and promoting a clear structure of responsibilities.
- Each layer operates as an abstract machine, hiding the details of lower-level operations and exposing a simpler interface to the upper layers.
- Commonly seen in operating system design, network protocol stacks, and software frameworks.

❖Modular decomposition styles:

- Styles of decomposing sub-systems into modules.
- No rigid distinction between system organization and modular decomposition.

Sub-systems and modules

- A sub-system is a system whose operation is independent of the services provided by other sub-systems.
- A module is a system component that provides services to other components but would not normally be considered as a separate system.

Modular decomposition

- Another structural level where sub-systems are decomposed into modules.
- Two modular decomposition models covered
  - An object model where the system is decomposed into interacting objects,
  - A pipeline or data-flow model where the systems is decomposed into functional modules which transform inputs to outputs.
- If possible, decisions about concurrency should be delayed until modules are implemented.

❖ Control styles

- Are concerned with the control flow between sub-systems. Distinct from the system decomposition model.

1. Centralized control

➢ One sub-system has overall responsibility for control and starts and stops other sub-systems.

Types

✓**Call-return model**

- Top-down subroutine model where control starts at the top of a subroutine hierarchy and moves downwards. Applicable to sequential systems.

✓**Manager model**

- Applicable to concurrent systems. One system component controls the stopping, starting and coordination of other system processes. Can be implemented in sequential systems as a case statement.

2. Event-based control

- Each sub-system can respond to externally generated events from other sub-systems or the system's environment.

Types

- ✓ **Broadcast models**

- An event is broadcast to all sub-systems. Any subsystem which can handle the event may do so.

- ✓ **Interrupt- driven models**

- Used in real-time systems where interrupts are detected by an interrupt handler and passed to some other component for processing.

❖ Reference Architecture

- Reference architecture captures important features of system architectures in a domain.
- Purpose of reference architectures is to evaluate and compare design proposal and educate people about architectural characteristics in that domain.
- Architectural models may be applicable to some application domain:

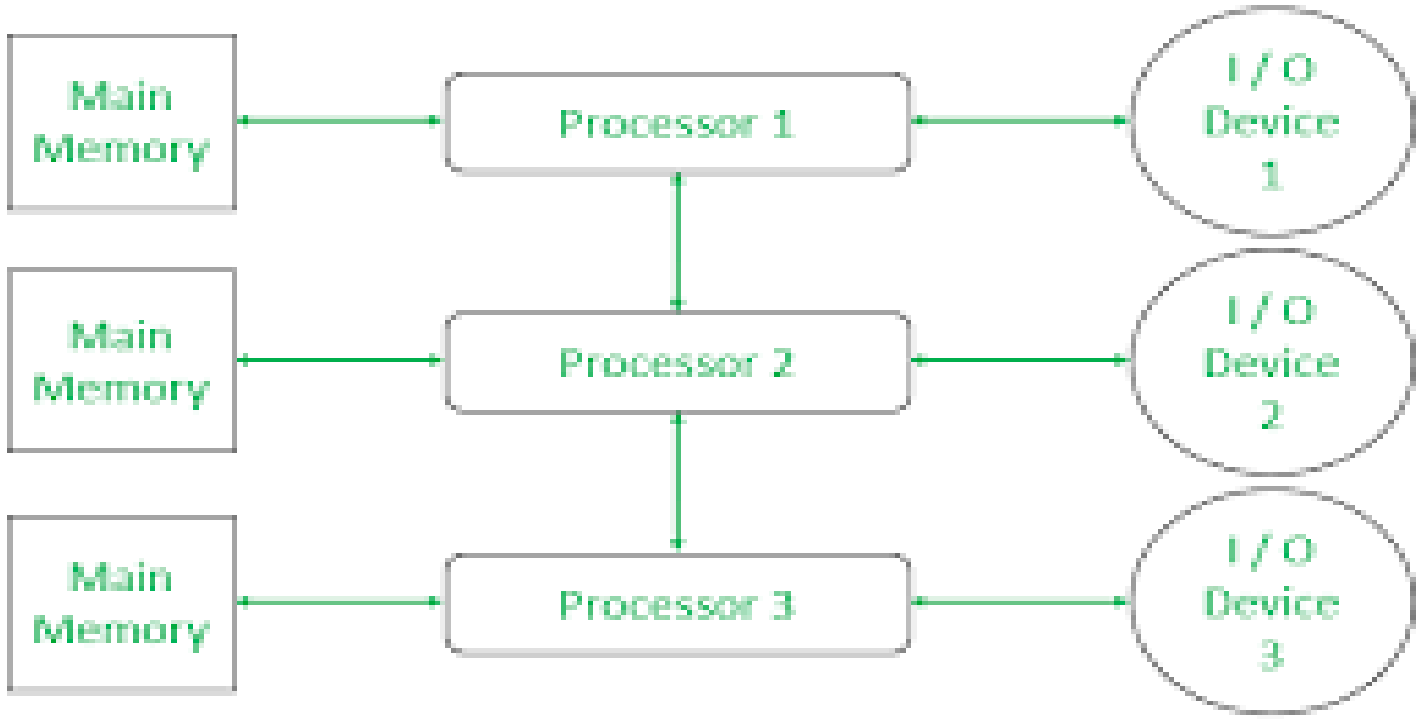
1. Generic model: bottom-top model

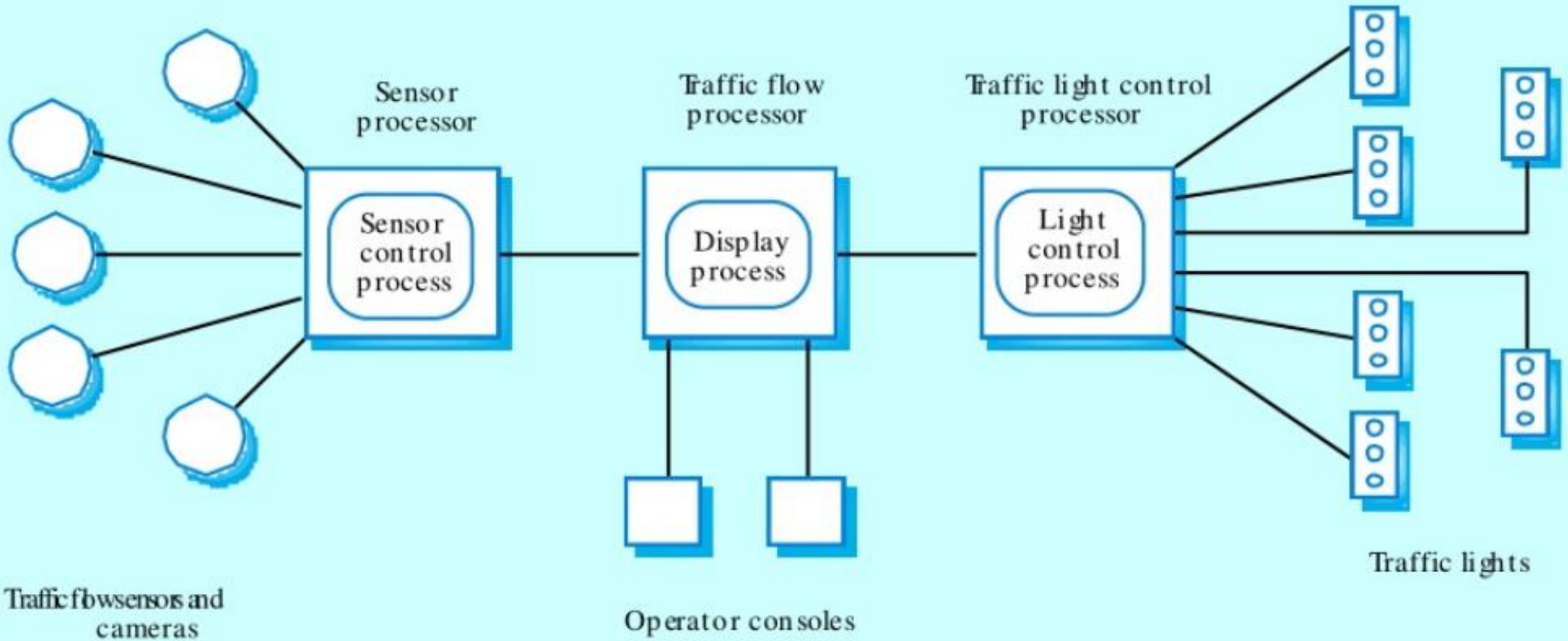
2. Reference model: top-down approach

- Reference models are derived from study of application domain rather than from existing system- maybe used as a basic system implementation or to compare different system.
- It acts as a standard against which system can be evaluated.
- OSI reference model is a layered model of communication system

❖ Multiprocessor Architecture

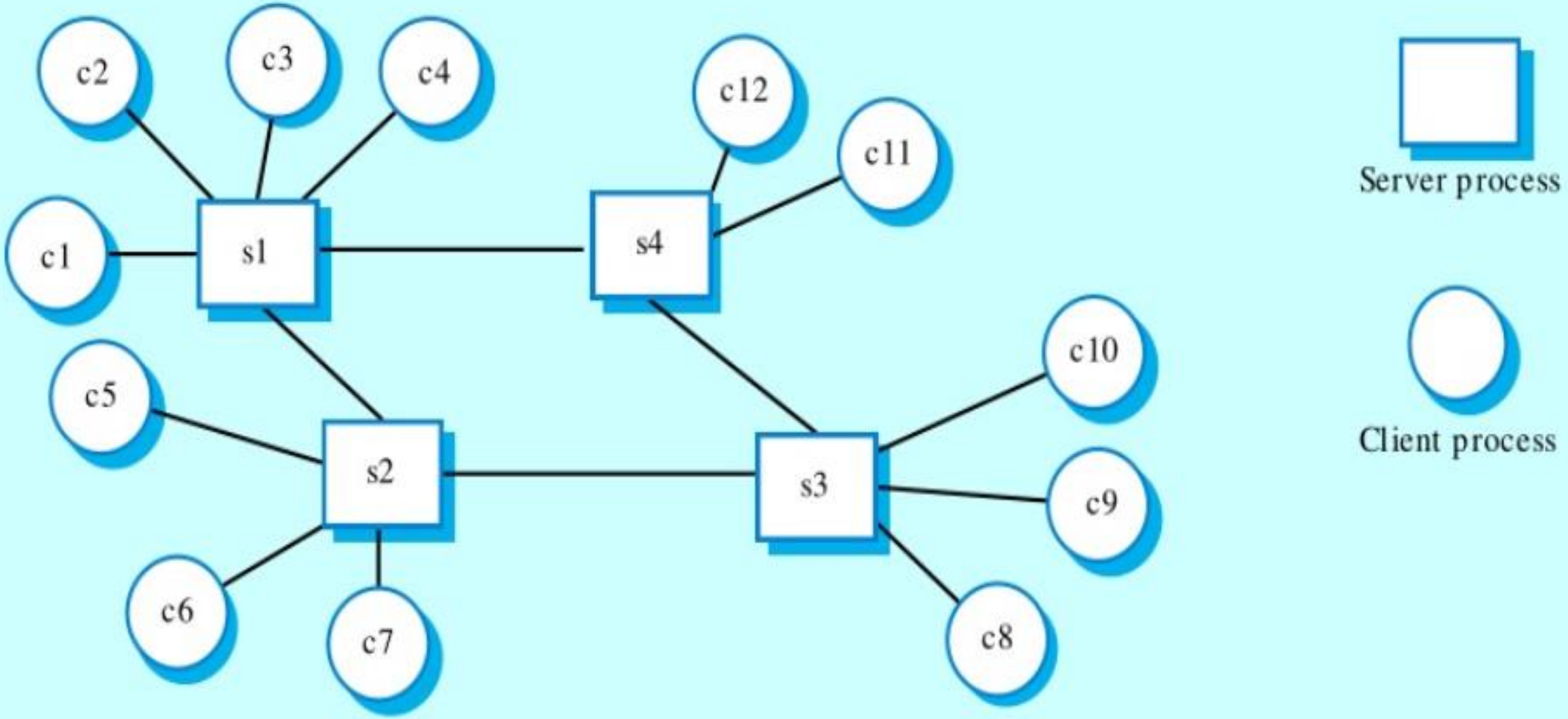
- It is the simplest distributed system model. The system is composed of multiple processor processes which may execute on different processor.
- It is Architectural model of many large real time systems. In this architecture, distribution of process to processor may be preordered or may be under the control of the dispatcher.




Sensor processor
Traffic flow processor
Traffic light control processor
Sensor control process
Display process
Light control process
Traffic flow sensors and cameras
Operator consoles
Traffic lights

❖ Client server Architecture

- This architectural model is used for the set of services that are provided by server and a set of clients that use this service.
- Client should know about the server, but the server need not know about clients in client-server architecture.
- Mapping of processor to process is not necessarily 1:1 in case of client server architecture.
- Client and server are logical processors in client-server architecture.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c3
c4
c12
c11
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s1
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c10
c5
s2
s3
c9
c6
c7
c8
Server process
Client process

1. Two-Tier Architecture

➢Characteristics:

- **Client**: Directly interacts with the server.
- **Server**: Provides resources or services to the client.
- **Communication**: Typically uses protocols like HTTP, TCP/IP, or UDP.

➢Use Cases:

- Small-scale applications.
- Simple database applications.
- Local area network (LAN) applications.

➢Examples:

- Traditional desktop applications with a database server.
- Simple web applications.

2. Three-Tier Architecture

➢ **Characteristics:**

- **Client**: User interface (UI) tier, which interacts with the user.
- **Application Server**: Middle tier that processes business logic.
- **Database Server**: Data tier where data is stored and managed.

➢ **Use Cases:**

- Enterprise applications.
- Web applications requiring separation of concerns.
- Scalable and maintainable systems.

➢ **Examples:**

- Web applications using a web server, an application server, and a database server.
- E-commerce applications.

3. N-Tier Architecture (Multitier Architecture)

- **Characteristics:**

. Extends the three-tier architecture to more tiers.

. Allows for greater separation of concerns and more scalability.

. Additional tiers might include additional business logic layers, data processing layers, etc.

- **Use Cases:**

. Large-scale enterprise applications.

. Complex web services.

. Systems requiring high scalability and flexibility.

- **Examples:**

. Applications using microservices architecture.

4. Peer-to-Peer (P2P) Architecture

- **Characteristics:**

. Each node (peer) can act as both client and server.

. Peers share resources directly with each other without a centralized server.

. Often used for file sharing and distributed computing.

- **Use Cases:**

. File-sharing applications.

. Distributed computing projects.

. Decentralized applications (DApps).

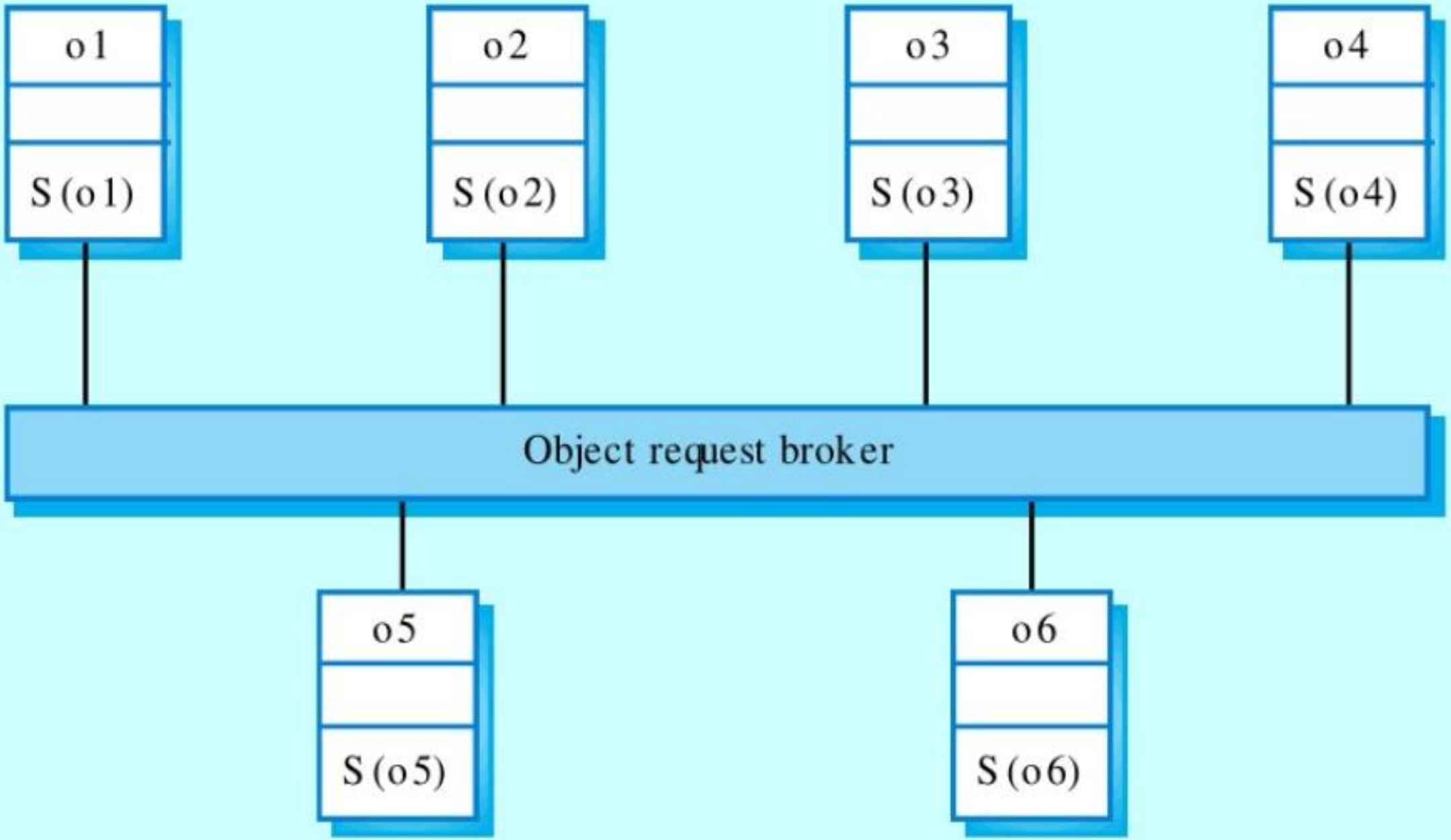
- **Examples:**

. BitTorrent.

. Blockchain networks.

❖ Distributed object Architecture

- No distinction between client and server.
- Each distributed entity is objects that provide service other object and receive from other objects.
- Object communication is through middleware system called an object request booker or software bus.
- However, more complexes to design the client server architecture.
- It allows system designer to delay decision on where and how services should be provided.
- It is very open system architecture that allows to new resources to be as required.
- System is flexible and scalable.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Object request broker
o5
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❖ Inter-organizational distributed computing

- Used for security and interoperability reason.
- Local standards management and operational processes apply for such interorganizational distributed computing.
- Newer model of distributed computing have been designed to support interorganizational
- Computing where different node server are located at different organization.

❖ Real –time software design

- A real-time software system design means that the system is subjected to real-time, i.e., the response should be guaranteed within a specified timing constraint, or the system should meet the specified deadline.
- For eg: flight control systems, real-time monitors, etc.

Types

➢**Hard real-time system:**

- Can never miss its deadline.
- Missing the deadline may have disastrous consequences.
- Example: Flight controller system.

➢**Soft real-time system:**

- This type of system can miss its deadline occasionally with some acceptably low probability.
- Missing the deadline have no disastrous consequences.
- Example: Telephone switches.

➢**Firm Real-Time Systems:**

- Lie between hard and soft real-time systems.
- In firm real-time systems, missing a deadline is tolerable, but the usefulness of the output decreases with time.
- Examples of firm real-time systems include online trading systems, online auction systems, and reservation systems.

❖ Component Based Software Engineering

- Process that focuses on the design and development of computer-based systems with the use of reusable software components.
- It not only identifies candidate components but also qualifies each component's interface, adapts components to remove architectural mismatches, assembles components into a selected architectural style, and updates components as requirements for the system change.
- The process model for component-based software engineering occurs concurrently with *component-based development.*

CBSE framework activities

- **Component Qualification:** This activity ensures that the system architecture defines the requirements of the components for becoming a reusable components.
- **Component Adaptation:** This activity ensures that the architecture defines the design conditions for all components and identifies their modes of connection.
- **Component Composition:** This activity ensures that the Architectural style of the system integrates the software components and forms a working system.
- **Component Update:** This activity ensures update of reusable components.

THANK YOU

MCQ: SOFTWARE DESIGN

1. In Design phase, which is the primary area of concern?
a) Architecture
b) Data
c) Interface
d) All of the mentioned

2. The importance of software design can be summarized in a single word which is:
a) Efficiency
b) Accuracy
c) Quality
d) Complexity

3. Cohesion is a qualitative indication of the degree to which a module
a) can be written more compactly
b) focuses on just one thing
c) is able to complete its function in a timely manner
d) is connected to other modules and the outside world

4. Coupling is a qualitative indication of the degree to which a module
a) can be written more compactly
b) focuses on just one thing
c) is able to complete its function in a timely manner
d) is connected to other modules and the outside world

5. Software Design consists of _____
a) Software Product Design
b) Software Engineering Design
c) Software Product & Engineering Design
d) None of the mentioned

6. Which of these are followed in case of software design process?
a) Analysis occurs at start of product design with a product idea
b) Analysis occurs at the end of engineering design with the SRS
c) Product design resolution produces the design document
d) Engineering design resolution produces the SRS

7. Which of these is not in sequence for generic problem-solving strategy?
a) Understand the problem
b) Generate candidate solutions
c) Iterate if no solution is adequate
d) None of the mentioned

8. Which of these is not in sequence for generic design process?
a) Analyze the Problem

b) Evaluate candidate solutions
c) Finalize the Design
d) None of the mentioned

9. What is Architecture of a software based on?
a) Design
b) Requirements
c) All of the mentioned
d) None of the mentioned

10. What would happen if different organization were given same set of requirements?
a) It will produce same architecture
b) It will produce different architecture
c) It may or may not produce same architecture
d) None of the mentioned

11. What does Software architecture mean?
a) It is the structure or structure of systems
b) It comprises of software components
c) Relationship among components
d) All of the mentioned

12. The architects are influenced by which of the following factors?
a) Customers and end users
b) Developing organization
c) Background and experience of the architects
d) All of the mentioned

13. What makes a good architecture?
a) The architecture may not be the product of a single architect or a small group
b) The architect should have the technical requirements for the system and an articulated and prioritized list of qualitative properties
c) The architecture may not be well documented
d) All of the mentioned

14. What is architectural style?
a) Architectural style is a description of component types
b) It is a pattern of run-time control
c) It is set of constraints on architecture
d) All of the mentioned

15. What is a Reference Model?
a) It is a division of functionality together with data flow between the pieces
b) It is a description of component types
c) It is standard decomposition of a known problem into parts that cooperatively solve a problem

d) It is a division of functionality together with data flow between the pieces, It is standard decomposition of a known problem into parts that cooperatively solve a problem

16. Which of the following can be considered regarding client and server?
a) Client and server is an architectural style
b) Client and server may be considered as an architectural style
c) Client and server is not an architectural style
d) None of the mentioned

17. Which of the following is incorrect?
a) A reference model divides the functionality
b) A reference architecture is the mapping of that functionality onto system decomposition
c) All of the mentioned
d) None of the mentioned

18. Which of the following is true?
a) Architecture is low level design
b) Architecture is mid-level design
c) Architecture is high level design
d) None of the mentioned

19. Which of the following style's main goal is to achieve modifiability?
a) Independent component architecture
b) Layered Styles
c) Heterogeneous styles
d) None of the mentioned

20. In which of the architecture style main program and subroutine systems are decomposed into parts that live on computers connected via a network?
a) Main program and subroutine Architecture
b) Remote Procedure Call system
c) Object Oriented or abstract data type system
d) All of the mentioned

21. Which of the following are true for pattern?
a) It is a small collection of atomic units
b) They are ubiquitous throughout software development
c) All of the mentioned
d) None of the mentioned

22. Which of the factors make a pattern portable?
a) Creating instances of some appropriate resource at run time
b) Presentation of two different user interface toolkits
c) All of the mentioned
d) None of the mentioned

23. Which design concept focuses on breaking down a system into smaller, independent modules?

a) Coupling
b) Cohesion
c) Modularity
d) Abstraction

24.In architectural design decisions, what does a multiprocessor architecture emphasize?

a) Parallel execution of tasks on multiple processors
b) Centralized processing by a single processor
c) Distributed storage across multiple servers
d) Sequential execution of tasks on multiple processors

25.What does a Client-Server architecture promote?

a) Centralized processing by a single server
b) Decentralized processing by multiple clients
c) Mutual exclusion of clients and servers
d) Shared processing between clients and servers

26.What is a modular decomposition style in software design?

a) A design concept without any practical application
b) A way of breaking down a system into smaller, manageable sub-systems
c) A design heuristic used for user interface development
d) A model used specifically for real-time software design

27.Which architecture emphasizes the division of labor between clients and servers?

a) Multiprocessor architecture
b) Client-server architectures.
c) Distributed object architectures
d) Inter-organizational distributed computing

28.What does Component-based Software Engineering focus on?

a) Designing software systems using reusable components
b) Designing software based on a centralized server
c) Creating software without modular decomposition
d) Using prototypes for system development

1.(d) 11.(d) 21.(d)

2.(c) 12.(d) 22.(c)

3.(b) 13.(b) 23.(c)

4.(d) 14.(d) 24.(a)

5.(c) 15.(d) 25.(d)

6.(a) 16.(a) 26.(b)

7.(c) 17.(d) 27.(b)

8.(b) 18.(c) 28.(a)

9.(b) 19.(a)

10.(b) 20.(b)