

# NATIONAL INSTITUTE OF TRANSPORT



## DEPARTMENT OF COMPUTING AND COMMUNICATION TECHNOLOGY

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- A. Your institution plans to implement a **smart campus** with Wi-Fi everywhere, smart attendance systems, CCTV streaming, and IoT sensors for energy management.

**Questions:**

1. Explain how *pervasive networking* would support continuous connectivity for students and staff across the campus.

**Answer:**

**Pervasive networking** refers to a computing environment where network connectivity is available everywhere, at all times, and across multiple devices. In a smart campus environment, pervasive networking enables students and staff to remain continuously connected regardless of their location.

**Wi-Fi access points** are strategically deployed across lecture halls, libraries, hostels, offices, and outdoor spaces to provide seamless wireless coverage. Network handover mechanisms allow users to move from one access point to another without losing connection. Authentication systems such as Single Sign-On (SSO) ensure users connect securely using one campus identity.

This **continuous connectivity supports smart attendance systems** (via mobile apps or RFID), live CCTV streaming, and real-time data collection from IoT sensors. As a result, learning, security, and campus services become more efficient and responsive.

2. The management wants online learning materials that include video lectures, animations, and real-time quizzes. Describe how a *distributed multimedia system* would handle the storage, streaming, and synchronization of these contents.

**Answer:**

A distributed multimedia system manages multimedia content such as video lectures, animations, and real-time quizzes across multiple servers and locations.

**Storage:**

Content is stored in distributed servers or cloud storage to ensure availability and fault tolerance. Large video files are broken into chunks and replicated across servers to reduce access delays.

**Streaming:**

Content Delivery Networks (CDNs) stream videos to students from the nearest server, minimizing buffering and latency. Adaptive streaming adjusts video quality based on network conditions.

**Synchronization:**

Real-time quizzes and live lectures require synchronization mechanisms such as timestamps and event coordination services to ensure all users receive the same content simultaneously.

This approach **improves scalability, reliability, and user experience** for online learning platforms.

3. Discuss how the *modern Internet* enables students to access campus systems remotely and securely.

**Answer:**

The modern Internet enables secure remote access to campus systems **through technologies such as Virtual Private Networks (VPNs), HTTPS, and cloud platforms**. Students and staff can access learning management systems, digital libraries, and administrative services from anywhere.

Authentication protocols and encryption protect data during transmission. Cloud computing ensures systems are available 24/7, while firewalls and intrusion detection systems prevent unauthorized access. This allows the **campus to extend its services beyond physical boundaries securely**.

- B. A university research lab needs a **high-performance computing cluster** to run simulation programs for engineering and medical research.

**Questions:**

1. Describe how you would design a computing cluster using networked computers to increase processing power.

**Answer:**

A **computing cluster** consists of multiple interconnected computers (nodes) working together as a single system. To increase processing power, **tasks are divided into smaller subtasks** and distributed among nodes.

A master node coordinates task allocation, while worker nodes execute computations. Parallel processing libraries such as MPI (**Message Passing Interface**) are used to manage communication between nodes. This design enables faster execution of complex simulations in engineering and medical research.

2. If each computer node must communicate using Gigabit Ethernet, explain the network architecture you would use and justify why.

**Answer:**

A **star topology** using high-speed switches is ideal for a Gigabit Ethernet cluster. Each node connects **directly to a central switch**, ensuring high bandwidth and low latency communication.

This architecture is **easy to manage, scalable, and reduces network congestion**. Using managed switches allows monitoring and prioritization of critical data traffic, which is essential for performance-intensive applications.

3. The researchers want the cluster to still operate even if one node fails. What cluster design principles would you apply to ensure reliability?

**Answer:**

**To ensure the cluster operates even if one node fails, the following principles are applied:**

**Redundancy:** Multiple nodes perform similar tasks so that failure of one does not halt operations.

**Failover mechanisms:** Tasks assigned to a failed node are automatically reassigned.

**Checkpointing:** Intermediate results are saved periodically to allow recovery.

**Monitoring systems:** Detect failures and trigger corrective actions.

- C. An online retail company processes thousands of customer orders every minute. They want to build a **parallel order-processing system** that uses *message queues* rather than direct communication between services.

**Questions:**

1. Explain how *indirect communication* (e.g., message queues, shared memory, mailboxes) can improve scalability of the order-processing system.

**Answer:**

**Indirect communication** uses message queues, mailboxes, or shared memory instead of direct service-to-service communication. This improves scalability by **decoupling services, allowing them to operate independently**.

**Message queues buffer** requests during peak loads, prevent system overload, and enable asynchronous processing. Services can scale horizontally by adding more consumers without affecting producers.

2. Design a simple parallel programming model where several worker processes pull tasks from a queue. Describe how this avoids bottlenecks.

**Answer:**

In parallel programming model, incoming orders are placed into a central message queue. Multiple worker processes pull tasks from the queue and process them in parallel.

**This avoids bottlenecks because:**

- i. No single service handles all requests.
  - ii. Load is evenly distributed.
  - iii. Workers can be added dynamically based on demand.
3. Discuss what could happen if the message queue becomes overloaded and propose strategies to mitigate the issue.

**Answer:**

**If the message queue becomes overloaded,** delays may occur, and system performance may degrade. This can lead to lost messages or service timeouts.

**Mitigation strategies include:**

- i. Auto-scaling worker services.
  - ii. Rate limiting incoming requests.
  - iii. Queue partitioning to distribute load.
  - iv. Back-pressure mechanisms to slow producers when queues are full.
- D. A bank wants to connect its **loan service, customer records, and ATM network** using distributed objects so that each component can request services from others remotely.

**Questions:**

1. Explain how *remote invocation* (e.g., RMI, gRPC, SOAP, REST) would allow these distributed components to communicate.

**Answer:**

Remote invocation **allows a program to call methods on objects located on remote systems as if they were local.** Technologies such as RMI, gRPC, SOAP, and REST enable this communication.

Each service exposes an interface, and communication **occurs over a network using standardized protocols.** This allows the bank's loan service, customer records, and ATM systems to interact seamlessly.

2. Describe the steps needed for a customer record service to access the loan-approval service remotely.

**Answer:**

**The customer record service sends a request to the loan-approval service endpoint.**

- i. The request is serialized into a network-friendly format (JSON or XML).

- ii. The loan service processes the request and applies approval rules.
  - iii. A response is returned with the approval decision.
  - iv. The customer record service updates the customer profile accordingly.
  - v. This process occurs transparently through remote invocation mechanisms.
3. The bank is concerned about security when invoking services remotely. Identify the risks and propose solutions to secure remote object communication.

**Answer:**

**Risks:**

- i. Unauthorized access.
- ii. Data interception.
- iii. Replay attacks.
- iv. Service impersonation.

**Solutions:**

- i. Encryption using SSL/TLS.
- ii. Strong authentication and authorization (OAuth, API keys).
- iii. Firewalls and network segmentation.
- iv. Logging and monitoring service calls.

**These measures ensure secure communication between distributed banking services.**

**Conclusion**

**Distributed systems** play a critical role in modern computing environments such as **smart campuses, research laboratories, e-commerce platforms, and banking systems**. By applying concepts such as pervasive networking, distributed multimedia systems, computing clusters, indirect communication, and remote invocation, organizations can achieve scalability, reliability, performance, and security.