QUESTION ONE

a) Distributed computing systems can be classified into four groups: clusters, peer-to-peer networks, grids, and clouds. Describe each class with the aid of examples. (8marks)

1. Clusters: A cluster is a group of computers that work together to perform a common task. They are usually located in the same physical location and are connected by a high-speed network. Clusters are used in scientific research, weather forecasting, and financial modeling. Examples of clusters include Beowulf clusters, Hadoop clusters, and Apache Spark clusters 1.

2. Peer-to-peer networks: In a peer-to-peer network, all computers are equal and can act as both clients and servers. They are used for file sharing, distributed storage, and communication. Examples of peer-to-peer networks include BitTorrent, Gnutella, and Freenet 1.

3. Grids: A grid is a collection of computers that are geographically distributed but work together to perform a common task. They are used for scientific research, data analysis, and simulations. Examples of grids include the World Community Grid, the European Grid Infrastructure, and the Open Science Grid 1.

4. Clouds: A cloud is a collection of computers that are accessed over the internet. They are used for data storage, software development, and web hosting. Examples of clouds include Amazon Web Services, Microsoft Azure, and Google Cloud Platform 1

b) Define the term scalability as applied to cloud computing systems, and name any two types of scaling techniques that are possible for use in cloud systems.

Scalability in cloud computing refers to the ability of a system to handle an increasing amount of work by adding resources to the existing infrastructure 1. It is a crucial feature of cloud computing systems as it allows businesses to accommodate growth and handle increased demand without compromising performance.

There are two types of scaling techniques that are possible for use in cloud systems:

1. Vertical scaling: Also known as "scaling up," this technique involves adding more power to an existing server to increase its computing power or storage capacity. This technique is useful when a business needs to handle a sudden increase in demand for a specific application or service. Examples of vertical scaling include upgrading memory (RAM), storage, or processing power (CPU) 12.

2. Horizontal scaling: Also known as "scaling out," this technique involves adding more servers to distribute the workload. This technique is useful when a business needs to handle a large number of requests simultaneously. Examples of horizontal scaling include adding more web servers to handle web traffic or more database servers to handle database queries 12.

c) Discuss some advantages of Clouds over Traditional Distributed Systems.

1. Scalability: Cloud computing systems can scale up or down to meet changing demands. This means that businesses can easily accommodate growth and handle increased demand without compromising performance 1.

2. Cost-effectiveness: Cloud computing eliminates the need for businesses to invest in expensive hardware and software. Instead, they can pay for the services they use on a subscription basis, which can be more cost-effective in the long run 2.

3. Flexibility: Cloud computing systems are highly flexible and can be customized to meet the specific needs of a business. This means that businesses can choose the services they need and only pay for what they use 2.

4. Reliability: Cloud computing systems are designed to be highly reliable and available. They use redundant hardware and software to ensure that services are always available to users 2.

5. Security: Cloud computing systems are designed with security in mind. They use advanced security measures to protect data and applications from unauthorized access 1.

6. Performance: Cloud computing systems are designed to deliver high performance. They use advanced hardware and software to ensure that services are delivered quickly and efficiently 1.

7. Ease of use: Cloud computing systems are easy to use and require minimal technical expertise. This means that businesses can focus on their core competencies instead of worrying about managing their IT infrastructure 2.

d) Briefly explain the design issues needed to be considered when developing a distributed system.

1. Flexibility: The system should be designed to be easily adaptable and changeable.

2. Reliability: The system should be able to maintain availability even in the face of hardware, software, and network failures.

3. Performance: The system should be able to handle varying loads and be reconfigurable to improve performance.

4. Heterogeneity: The system should be able to accommodate and handle the differences in networks, computer hardware, operating systems, programming languages, and implementations.

5. Openness: The system should have well-defined interfaces and be open to extensions and improvements.

6. Security: The system should ensure the security and privacy of data and provide authentication for remote users or agents.

7. Scalability: The system should be able to accommodate more users and respond faster without requiring major changes to its components.

8. Failure Handling: The system should have mechanisms for recovery and redundancy to maintain availability even in the presence of failures.

9. Concurrency: The system should be able to handle concurrent processes and ensure that shared information objects can be accessed without interference.

10. Transparency: The system should provide access transparency, location transparency, concurrency transparency, replication transparency, failure transparency, mobility transparency, performance transparency, and scaling transparency.

e) Describe how concurrency transaction problems are addressed in distributed system.

Recovery involves implementing mechanisms to handle failures and ensure the availability of the system even in the presence of hardware, software, or network failures. This can include techniques like checkpointing, where the system periodically saves its state to allow for recovery in case of failure.

Redundancy is another approach to address concurrency transaction problems. It involves replicating data or processes across multiple nodes in the distributed system. By having redundant copies, the system can continue to operate even if some nodes fail. Redundancy can be achieved through techniques like data replication, where multiple copies of data are stored on different nodes, or process replication, where multiple instances of a process are running on different nodes.

QUESTION TWO

a) Explain the important roles played by Virtualization in cloud computing.

1. Resource Sharing: Virtualization allows for the sharing of physical resources, such as CPU, memory, and storage, among multiple virtual machines (VMs). This helps in optimizing resource utilization and reducing costs.
2. Isolation: Virtual machines are isolated from each other, providing a level of security and privacy. Each VM operates as if it is running on a separate physical machine, ensuring that one VM cannot access or interfere with the resources of another VM.
3. Encapsulation: Virtual machines encapsulate a complete computing environment, including the guest operating system and applications. This encapsulation makes it easier to deploy and manage VMs, as they can be treated as self-contained units.
4. Hardware Independence: Virtual machines are independent of the underlying hardware. This means that VMs can be migrated between different hosts without

requiring any modifications. It provides flexibility and scalability in cloud environments.

5. Portability: Virtual machines can be easily migrated between different hosts within a cloud infrastructure. This allows for workload balancing, disaster recovery, and efficient resource allocation.

b) Describe the role of the following in the cloud infrastructure anatomy:

1. Virtual Machine Manager: A virtual machine manager, also known as a hypervisor, is a software program that allows multiple operating systems to run on a single physical server. It enables cloud providers to serve users with their existing physical computer hardware. This maximizes the use of available resources and ensures that the investment the company makes on its physical server is returned with the highest level of performance 1.

2. Network Manager: A network manager is responsible for managing the network infrastructure of a cloud computing system. It ensures that the network is reliable, secure, and scalable. It also provides network services such as routing, switching, and load balancing. Examples of network managers include Cisco Network Manager, SolarWinds Network Performance Monitor, and Nagios Network Analyzer 2.

3. Image Manager: An image manager is responsible for managing the images used in a cloud computing system. It enables cloud users to purchase only the computing resources they need when they need it, and to scale those resources cost-effectively as their workloads grow. Examples of image managers include Azure VM Image Builder, VMware vSphere, and OpenStack Glance 34.

4. Federation Manager: A federation manager is responsible for managing the federation of multiple cloud computing systems. It enables businesses to create, configure, scale, and retire cloud infrastructure as needed. Examples of federation managers include VMware Cloud Foundation, OpenStack Keystone, and Microsoft Active Directory Federation Services 5.

c) As a key component in a modern datacenter, the cloud operating system is responsible for different functions. Name and explain two of these functions.

A cloud operating system is an operating system designed to operate within cloud computing and virtualization environments. It manages the operation, execution, and processes of virtual machines, virtual servers, and virtual infrastructure, as well as the back-end hardware and software resources 1. Here are two functions of a cloud operating system:

1. Resource management: A cloud operating system is responsible for managing the resources of a cloud computing system. It ensures that the resources are allocated efficiently and that the system is running at optimal performance. It also provides resource monitoring and reporting capabilities to help administrators manage the system effectively 2.

2. Security management: A cloud operating system is responsible for managing the security of a cloud computing system. It ensures that the system is secure and that data is protected from unauthorized access. It also provides security monitoring and reporting capabilities to help administrators manage the system effectively 2.

QUESTION THREE

a) Define what is meant by a Cloud Service Broker.

A Cloud Service Broker is an entity that manages the use, performance and delivery of cloud services, and negotiates relationships between cloud providers and cloud consumers 1. As cloud computing evolves, the integration of cloud services may be too complex for cloud consumers to manage alone.

b) Name and briefly describe the services that a Cloud Service Broker is capable of performing.

1. Aggregation: A cloud broker combines and integrates multiple services into one or more new services. The broker provides data integration and ensures the security of data in transition between the cloud consumer and multiple cloud providers.

2. Arbitrage: Service arbitrage is similar to service aggregation, except that the services being aggregated are not fixed. Service arbitrage means a broker has the flexibility to choose services from multiple providers, depending upon the characteristics of the data or the context of the service.

3. Intermediation: A cloud broker enhances a given service by improving some specific capability and providing value-added services to cloud consumers. The improvement can be managing access to cloud services, identity management, performance reporting, enhanced security, etc.

c) Define what is meant by cloud federation and clearly explain some of the benefits to cloud computing

Cloud federation refers to the collaboration and integration of multiple cloud computing environments to create a unified and scalable infrastructure. It allows organizations to combine resources and services from different cloud providers to meet their specific needs.

Some benefits of cloud federation in cloud computing include:

1. Increased scalability: Cloud federation enables organizations to scale their resources and services by seamlessly integrating with additional cloud providers. This allows for greater flexibility and the ability to handle increased workloads.
2. Improved reliability and availability: By federating multiple cloud environments, organizations can distribute their resources across different providers, reducing the risk of single points of failure. This enhances the reliability and availability of their applications and services.
3. Cost optimization: Cloud federation allows organizations to choose the most cost-effective cloud providers for their specific requirements. They can leverage competitive pricing and take advantage of different pricing models offered by different providers, resulting in cost savings.
4. Enhanced performance: By federating multiple cloud environments, organizations can leverage the resources and capabilities of different providers to improve the performance of their applications and services. This can include accessing specialized hardware or utilizing geographically distributed data centers for reduced latency.
5. Data sovereignty and compliance: Cloud federation enables organizations to store and process their data in specific geographic regions or comply with data protection regulations. They can choose cloud providers that offer data centers in desired locations, ensuring compliance with local laws and regulations.

d) Define Interoperability as used in cloud computing and clearly explain three perspectives on interoperability (6marks)

Interoperability in cloud computing refers to the ability of different cloud systems and services to work together and exchange information seamlessly. It ensures that various components of the cloud infrastructure can communicate and interact effectively.

1. Technical perspective: From a technical perspective, interoperability refers to the ability of different cloud systems to communicate with each other using standard protocols and data formats. This ensures that data can be exchanged between systems without any loss of information or functionality 1.

2. Business perspective: From a business perspective, interoperability refers to the ability of different cloud systems to work together to achieve common business goals. This includes the ability to share data, collaborate on projects, and integrate business processes across different systems 1.

3. Legal perspective: From a legal perspective, interoperability refers to the ability of different cloud systems to comply with legal and regulatory requirements. This includes the ability to protect data privacy, ensure data security, and comply with data protection laws and regulations 1.

QUESTION FOUR

a) State what the acronym "Eucalyptus" and clearly explain its use in cloud computing.

The acronym "Eucalyptus" stands for "Elastic Utility Computing Architecture for Linking Your Programs to Useful Systems." Eucalyptus is an open-source software platform that allows organizations to create their own private cloud infrastructure. It provides an interface compatible with Amazon Web Services (AWS), allowing users to build and manage their own cloud environment using their own hardware resources.

b) Discus Eucalyptus key benefits.

1. Compatibility: Eucalyptus is compatible with Amazon Web Services (AWS), allowing users to build hybrid clouds that seamlessly integrate with AWS services.

2. Flexibility: Eucalyptus provides a flexible and scalable infrastructure, allowing users to easily provision and manage virtual machines, storage, and networking resources.

3. Cost Savings: By using Eucalyptus, organizations can leverage their existing infrastructure and resources, reducing the need for additional hardware and software investments.

4. Security: Eucalyptus offers robust security features, including user authentication, access control, and data encryption, ensuring the protection of sensitive data in the cloud.

5. Control: Eucalyptus gives users full control over their cloud environment, allowing them to customize and configure the infrastructure according to their specific requirements.

6. Ease of Use: Eucalyptus provides a user-friendly interface and management tools, making it easy for users to deploy and manage their cloud resources.

c) Describe the following as applied in the eucalyptus open-source private cloud:

1. Cluster Controller: The cluster controller is responsible for managing the overall operation of the cloud infrastructure. It handles the coordination and scheduling of resources, such as virtual machines, across the nodes in the cloud. The cluster controller also manages the storage and networking components of the cloud.

2. Node Controller: The node controller is responsible for managing the individual nodes in the cloud infrastructure. It handles the provisioning and management of virtual machines on each node. The node controller communicates with the cluster controller to receive instructions on resource allocation and to report the status of the node.

d) Elements that Drive Cloud Efficiency and Economics are given as virtualization of hardware, utilization of infrastructure, Self service and standardization of workloads. Explain how-the named elements are utilized for cloud economy.

1. Virtualization of hardware: Virtualization allows one computer to host multiple virtual machines (VMs) that share the physical hardware resources. This enables better utilization of hardware resources by maximizing their usage and reducing the need for dedicated servers. By virtualizing hardware, cloud providers can optimize resource allocation and achieve cost savings.

2. Utilization of infrastructure: Cloud computing leverages large resource pools to provide cloud services. These resource pools consist of infrastructure components such as servers, storage, and networking equipment. By efficiently utilizing this infrastructure, cloud providers can achieve economies of scale and offer cost-effective cloud resources to users.

3. Self-service: Cloud computing enables self-service provisioning, where users can access and manage cloud resources on-demand without requiring manual intervention from the cloud provider. This self-service capability allows users to quickly scale their resources up or down based on their needs, leading to improved efficiency and cost savings.

4. Standardization of workloads: Cloud computing promotes the standardization of workloads by providing a consistent and uniform environment for running applications. This standardization simplifies the management and deployment of workloads, reduces compatibility issues, and enables seamless migration of workloads between different cloud environments. Standardization also contributes to cost savings by streamlining operations and reducing complexity.

(6marks)

QUESTION FIVE

a) Explain the meaning of the term distributed system.
Is a collection of independent computers, interconnected via a network capable of collaborating in a task

b) Explain briefly why distributed are gaining popularity nowadays.

   a. Economics: Distributed systems offer a better price/performance ratio compared to centralized systems. They allow for the use of a collection of microprocessors, which are more cost-effective than mainframes.

b. Speed: Distributed systems can have more total computing power than a single mainframe. By distributing the workload across multiple machines, they can enhance performance through load distribution.

c. Inherent distribution: Some applications are inherently distributed, such as a supermarket chain. Distributed systems provide a natural way to handle the distributed nature of these applications.

d. Reliability: Distributed systems are more reliable than centralized systems. If one machine crashes, the system as a whole can still survive, ensuring higher availability and improved reliability.

e. Incremental growth: Distributed systems allow for incremental growth in computing power. Additional computing resources can be added in small increments, providing modular expandability.

f. Data and resource sharing: Distributed systems enable data sharing among many users, allowing access to a common database. They also facilitate resource sharing, such as expensive peripherals like color printers.

g. Communication: Distributed systems enhance human-to-human communication through features like email and chat, improving collaboration and information sharing.

h. Flexibility: Distributed systems allow for the distribution of workload over available machines, providing flexibility in resource allocation and utilization.

c) Briefly compare and contrast between the following methods of communication in distributed systems.

1. RPC: RPC allows a client to call a procedure in a remote server. It is a client-server communication model where the client initiates a request and the server provides the requested service. RPC is typically used in systems where the client and server are written in different programming languages.

2. IPC: IPC refers to the exchange of information among independent processes. It provides operations such as send, receive, connect, and disconnect for interprocess communication. IPC can be both synchronous and asynchronous, and it can be implemented using various protocols and APIs depending on the operating system.

3. RMI: RMI allows an object to invoke a method in an object located in a remote process. It is a mechanism used in Java for distributed computing. RMI is based on the concept of remote objects, where objects in different Java Virtual Machines (JVMs) can communicate with each other by invoking methods on remote objects. (d) Briefly explain why few practical distributed systems exist nowadays.