Subject Name Solutions

4361602 – Winter 2024

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Define cloud computing and state it's desirable features.

Solution

Cloud Computing is a technology that delivers computing services like servers, storage, databases, and software over the internet, allowing users to access resources on-demand without owning physical infrastructure.
Desirable Features:

Feature	Description
On-demand self-service	Users can access resources instantly without human interaction
Broad network access	Services available over network through standard platforms
Resource pooling	Computing resources are pooled to serve multiple users
Rapid elasticity	Resources can be scaled up or down quickly
Measured service	Usage is monitored and billed automatically

Mnemonic

"On-Demand Broad Resources Rapidly Measured"

Question 1(b) [4 marks]

Draw and explain cloud architecture.

Solution

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Client Layer{br/{}Web Browser, Mobile Apps] {-}{-}{} B[Internet]}
    B {-{-}{} C[Cloud Service Provider]}
    C {-{-}{} D[Frontend Platform{}br/{}User Interface]}
    D {-{-}{} E[Backend Platform]}
    E {-{-}{} F[IaaS {-} Infrastructure]}
    E {-{-}{} G[PaaS {-} Platform]}
    E {-{-}{} H[SaaS {-} Software]}
    F {-{-}{} I[Physical Infrastructure{}br/{}Servers, Storage, Network]}
{Highlighting}
{Shaded}
```

Cloud Architecture Components:

- **Client Layer**: End-user devices accessing cloud services
- **Internet**: Network connection medium
- **Frontend**: User interface and service management
- **Backend**: Core processing and resource management
- **Service Models**: IaaS, PaaS, SaaS layers
- **Physical Infrastructure**: Hardware resources in data centers

Mnemonic

"Clients Connect Through Frontend Backend Services Infrastructure"

Question 1(c) [7 marks]

Explain the cloud service models in detail.

Solution

Service Model	Description	Examples	User Control
IaaS	Infrastructure as a Service - Virtual machines, storage, networks	AWS EC2, Google Compute Engine	High - OS, Runtime, Apps
PaaS	Platform as a Service - Development platform with tools	Google App Engine, Heroku	Medium - Apps and Data
SaaS	Software as a Service - Ready-to-use applications	Gmail, Office 365, Salesforce	Low - Only Data

Detailed Explanation:

- **IaaS (Infrastructure as a Service)**: Provides virtualized computing resources including virtual machines, storage, and networking. Users have complete control over operating systems and applications.
- **PaaS (Platform as a Service)**: Offers a development platform with programming tools, database management, and middleware. Developers focus on application logic without infrastructure management.
- **SaaS (Software as a Service)**: Delivers complete applications over the internet. Users simply access the software through web browsers without installation or maintenance.

Mnemonic

"Infrastructure Platforms Software - Increasing Abstraction"

Question 1(c OR) [7 marks]

Explain service level agreement (SLA) in cloud computing with example.

Solution

Service Level Agreement (SLA) is a contract between cloud service provider and customer that defines the expected level of service, performance metrics, and penalties for non-compliance.
Key Components:

Component	Description	Example
Availability	Uptime guarantee	99.9% uptime
Performance	Response time metrics	<200ms response time
Security	Data protection standards	ISO 27001 compliance
Support	Help desk response time	24/7 support, 4-hour response
Penalties	Compensation for failures	Service credits for downtime

Example - AWS SLA:
- **EC2 SLA**: 99.99% monthly uptime
- **S3 SLA**: 99.9% availability, 99.999999999% durability
- **Penalty**: 10% service credit if availability drops below threshold

Benefits:
- **Accountability**: Clear expectations for both parties
- **Quality assurance**: Guaranteed service levels
- **Risk mitigation**: Compensation for service failures

Mnemonic

"Availability Performance Security Support Penalties"

Question 2(a) [3 marks]

Define virtualization. Give characteristics of virtualization.

Solution

Virtualization is a technology that creates virtual versions of computing resources like servers, storage, or networks, allowing multiple virtual instances to run on single physical hardware.

Characteristics:
- **Resource sharing**: Multiple VMs share physical hardware efficiently
- **Isolation**: Virtual machines operate independently without interference
- **Portability**: VMs can be moved between different physical hosts
- **Scalability**: Resources can be allocated dynamically as needed
- **Cost efficiency**: Reduces hardware requirements and operational costs

Mnemonic

"Resources Isolated Portable Scalable Cost-effective"

Question 2(b) [4 marks]

Distinguish between paravirtualization and full virtualization.

Solution

Aspect	Paravirtualization	Full Virtualization
Guest OS Modification	Modified to communicate with hypervisor	No modification needed
Performance	Higher performance	Slightly lower performance
Hardware Support	Doesn't require special hardware	Requires hardware virtualization support
Compatibility	Limited OS compatibility	Supports any OS
Examples	Xen, VMware ESX	VMware Workstation, VirtualBox

Key Differences:
- **Paravirtualization** requires guest OS to be aware of virtualization and cooperate with hypervisor
- **Full Virtualization** completely emulates hardware, making guest OS unaware of virtualization

Mnemonic

"Para Cooperates, Full Emulates"

Question 2(c) [7 marks]

Define hypervisors. Explain Type 1 and Type 2 hypervisors.

Solution

Hypervisor is software that creates and manages virtual machines by abstracting physical hardware and allocating resources to multiple VMs.

```
graph TB
    subgraph "Type 1 Hypervisor"
        A1[VM1]
        A2[VM2]
        A3[VM3]
        A4[Type 1 Hypervisor{br/Bare Metal]}
        A5[Physical Hardware]
        A1 {-{-} A4}
        A2 {-{-} A4}
        A3 {-{-} A4}
        A4 {-{-} A5}
    end

    subgraph "Type 2 Hypervisor"
        B1[VM1]
        B2[VM2]
        B3[Type 2 Hypervisor{br/Hosted]}
        B4[Host Operating System]
        B5[Physical Hardware]
        B1 {-{-} B3}
        B2 {-{-} B3}
        B3 {-{-} B4}
        B4 {-{-} B5}
    end
```

Comparison:

Feature	Type 1 (Bare Metal)	Type 2 (Hosted)
Installation	Directly on hardware	On host operating system
Performance	Higher performance	Lower performance
Use Case	Enterprise, data centers	Desktop virtualization, testing
Examples	VMware vSphere, Hyper-V	VMware Workstation, VirtualBox
Resource Overhead	Lower overhead	Higher overhead

Type 1 Advantages: Better performance, direct hardware access, enterprise-grade security **Type 2 Advantages**: Easier setup, runs alongside host OS, good for development

Mnemonic

"Type 1 Bare Metal, Type 2 Hosted"

Question 2(a OR) [3 marks]

List out types of virtualization and explain any one in brief.

Solution

Types of Virtualization:

- Server Virtualization
- Storage Virtualization
- Network Virtualization
- Desktop Virtualization
- Application Virtualization
- Memory Virtualization

Server Virtualization (Detailed): Server virtualization creates multiple virtual servers on single physical server. Each virtual server operates independently with its own operating system and applications.

Benefits:

- **Resource optimization**: Better hardware utilization
- **Cost reduction**: Fewer physical servers needed
- **Flexibility**: Easy VM migration and scaling

Mnemonic

"Server Storage Network Desktop Application Memory"

Question 2(b OR) [4 marks]

Describe hardware and software virtualization.

Solution

Type	Hardware Virtualization	Software Virtualization
Method	Uses CPU virtualization features	Pure software emulation
Performance	Near-native performance	Slower due to emulation
CPU Support	Requires Intel VT-x or AMD-V	Works on any CPU
Guest OS	Unmodified OS can run	May require OS modifications
Examples	VMware vSphere, KVM	QEMU, VMware Workstation (software mode)

Hardware Virtualization: Leverages CPU virtualization extensions to directly execute guest instructions, providing better performance and security isolation.

Software Virtualization: Uses binary translation to convert guest instructions to host-compatible instructions, offering broader compatibility but with performance overhead.

Mnemonic

"Hardware Fast, Software Compatible"

Question 2(c OR) [7 marks]

Explain the process of creating and managing virtual machines.

Solution

VM Creation Process:

```
flowchart TD
    A[Plan VM Requirements] {-{-} B[Select Hypervisor Platform]}
    B {-{-} C[Allocate Resourcesbr/CPU, RAM, Storage]}
    C {-{-} D[Create Virtual Disk]}
```

```
    D {-{-} E[Configure Network Settings]}
    E {-{-} F[Install Guest OS]}
    F {-{-} G[Install VM Tools/Drivers]}
    G {-{-} H[Configure VM Settings]}
    H {-{-} I[Create VM Snapshot]}
```

Detailed Steps:

1. **Planning**: Determine CPU cores, RAM, storage, and network requirements
2. **Resource Allocation**: Assign physical resources to virtual machine
3. **Storage Setup**: Create virtual disks (VMDK, VHD, QCOW2 formats)
4. **Network Configuration**: Set up virtual network adapters and connectivity
5. **OS Installation**: Install operating system using ISO or network boot
6. **Tools Installation**: Install hypervisor-specific tools for better integration
7. **Management Tasks**: Monitor performance, create snapshots, backup VMs

VM Management Operations:

- **Start/Stop/Restart**: Power operations
- **Snapshot Management**: Create, restore, delete snapshots
- **Resource Scaling**: Add/remove CPU, memory, storage
- **Migration**: Move VMs between hosts
- **Backup/Recovery**: Data protection strategies

Mnemonic

"Plan Select Allocate Create Configure Install Manage"

Question 3(a) [3 marks]

Define Data Center. Describe any two types of data centers.

Solution

Data Center is a facility that houses computer systems, networking equipment, and storage systems along with supporting infrastructure like power, cooling, and security systems.

Types of Data Centers:

Type	Description	Characteristics
Enterprise Data Center	Owned and operated by single organization	Private, customized, high security
Colocation Data Center	Shared facility renting space to multiple clients	Shared infrastructure, cost-effective

Enterprise Data Center:

- Built and managed by organization for internal use
- Complete control over infrastructure and security
- Higher initial investment but customized solutions

Colocation Data Center:

- Third-party facility providing space, power, and cooling
- Multiple organizations share common infrastructure
- Lower costs and professional management

Mnemonic

"Enterprise Private, Colocation Shared"

Question 3(b) [4 marks]

Differentiate between scalability and elasticity in cloud data center.

Solution

Aspect	Scalability	Elasticity
Definition	Ability to handle increased workload	Automatic scaling based on demand
Response	Manual or planned scaling	Automatic and rapid response
Direction	Usually upward scaling	Both up and down scaling
Time Frame	Long-term capacity planning	Real-time demand response
Resource Usage	May have unused resources	Optimal resource utilization

Key Differences:

- **Scalability** focuses on capacity to grow, while **Elasticity** emphasizes automatic adjustment
- **Scalability** requires human intervention, **Elasticity** is automated
- **Scalability** is strategic planning, **Elasticity** is operational efficiency

Examples:

- **Scalability**: Adding more servers during expected traffic increase
- **Elasticity**: Auto-scaling groups that add/remove instances based on CPU usage

Mnemonic

"Scalability Plans, Elasticity Adapts"

Question 3(c) [7 marks]

Explain SDN (Software-Defined Networking) in data center with diagram.

Solution

```
graph TB
    subgraph "SDN Architecture"
        A[Applications Layer{br/Network Apps, Services]}
        B[Control Layer{br/SDN Controllerbr/OpenFlow Protocol]}
        C[Infrastructure Layer{br/OpenFlow Switches]}
        D[Physical Network Infrastructure]

        A {-.{-}|Northbound API| B}
        B {-.{-}|Southbound APIbr/OpenFlow| C}
        C {-{-} D}
    end
```

SDN Components:

Layer	Function	Examples
Application Layer	Network applications and services	Load balancers, firewalls, monitoring
Control Layer	Centralized network control and management	OpenDaylight, ONOS, Floodlight
Infrastructure Layer	Forwarding devices controlled by controller	OpenFlow switches, routers

Key Features:
- **Centralized Control**: Single point of network management
- **Programmability**: Network behavior defined through software
- **Abstraction**: Separation of control and data planes
- **Dynamic Configuration**: Real-time network policy changes

Benefits in Data Centers:
- **Flexibility**: Easy network configuration changes
- **Automation**: Programmable network management
- **Cost Reduction**: Commodity hardware usage
- **Innovation**: Rapid deployment of new services

Mnemonic

"Applications Control Infrastructure - Programmable Networks"

Question 3(a OR) [3 marks]

Identify and describe the key components of a data center.

Solution

Key Data Center Components:
- **Servers**: Computing resources running applications and services
- **Storage Systems**: Data storage arrays (SAN, NAS, DAS)
- **Network Equipment**: Switches, routers, load balancers for connectivity
- **Power Infrastructure**: UPS, generators, PDUs for reliable power
- **Cooling Systems**: HVAC systems maintaining optimal temperature
- **Security Systems**: Physical and logical access controls

Critical Infrastructure: Each component is essential for data center operation, with redundancy built-in for high availability and disaster recovery.

Mnemonic

"Servers Store Network Power Cool Secure"

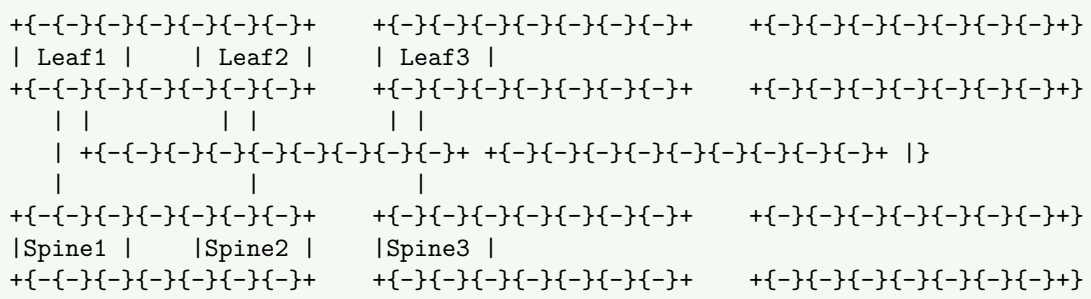
Question 3(b OR) [4 marks]

List data center network topologies and explain any one of them.

Solution

Data Center Network Topologies:
- Three-tier Architecture
- Spine-Leaf Architecture
- Fat Tree Topology
- Mesh Topology

Spine-Leaf Architecture (Detailed):



Characteristics:

- **Leaf switches** connect to servers and storage
- **Spine switches** provide inter-leaf connectivity

- **No leaf-to-leaf connections** - all traffic goes through spine
- **Equal path lengths** between any two endpoints
- **High bandwidth** and **low latency** design

Mnemonic

"Three Spine Fat Mesh"

Question 3(c OR) [7 marks]

Explain Infrastructure as Code (IaC) with its popular automation tools.

Solution

Infrastructure as Code (IaC) is the practice of managing and provisioning computing infrastructure through machine-readable definition files rather than manual processes.

Key Principles:

Principle	Description	Benefits
Declarative	Define desired state, not steps	Predictable outcomes
Version Control	Infrastructure definitions in Git	Change tracking, rollback
Automation	Automated deployment and updates	Reduced human errors
Consistency	Same configuration across environments	Reliable deployments

Popular IaC Tools:

Tool	Type	Description	Use Case
Terraform	Declarative	Multi-cloud infrastructure provisioning	Cross-platform deployments
Ansible	Imperative	Configuration management and automation	Server configuration
CloudFormation	Declarative	AWS-specific infrastructure templates	AWS resource management
Puppet	Declarative	Configuration management	Enterprise automation
Chef	Imperative	Infrastructure automation platform	Complex deployments

IaC Benefits:

- **Speed**: Faster deployment and scaling
- **Consistency**: Identical environments across stages
- **Cost Control**: Resource optimization and tracking
- **Reliability**: Reduced configuration drift
- **Collaboration**: Shared infrastructure definitions

Implementation Example:

```
# Terraform example
resource "aws_instance" "web_server" {
  ami           = "ami-12345678"
  instance_type = "t2.micro"
  tags = {
    Name = "WebServer"
  }
}
```

Mnemonic

"Terraform Ansible CloudFormation Puppet Chef"

Question 4(a) [3 marks]

Define cloud storage. Write example of cloud storage services.

Solution

Cloud Storage is a service that allows users to store, access, and manage data on remote servers over the internet instead of local storage devices.
Examples of Cloud Storage Services:

Provider	Service	Type	Use Case
Amazon	S3 (Simple Storage Service)	Object Storage	Web applications, backup
Google	Google Drive	File Storage	Personal, collaboration
Microsoft	Azure Blob Storage	Object Storage	Enterprise applications
Dropbox	Dropbox	File Sync	File sharing, sync
iCloud	Apple iCloud	Personal Cloud	iOS device backup

Key Benefits: Accessibility, scalability, cost-effectiveness, automatic backup

Mnemonic

"Amazon Google Microsoft Dropbox Apple"

Question 4(b) [4 marks]

Differentiate between data consistency and durability.

Solution

Aspect	Data Consistency	Data Durability
Definition	All nodes see same data simultaneously	Data persists despite system failures
Focus	Data accuracy and synchronization	Data preservation and recovery
Challenge	Concurrent access conflicts	Hardware failures, disasters
Solutions	ACID properties, eventual consistency	Replication, backups, redundancy
Examples	Bank transactions, inventory updates	File backups, disaster recovery

Data Consistency: Ensures all database nodes contain identical data at any given time, crucial for applications requiring real-time accuracy.
Data Durability: Guarantees that committed data remains available even after system crashes, power failures, or hardware malfunctions.
Trade-offs: Strong consistency may impact performance, while high durability requires additional storage costs.

Mnemonic

"Consistency Synchronizes, Durability Survives"

Question 4(c) [7 marks]

Explain types of cloud storage in detail.

Solution

Storage Type	Description	Use Cases	Examples
Object Storage	Stores files as objects with metadata	Web apps, content distribution	Amazon S3, Google Cloud Storage
Block Storage	Raw block-level storage for databases	High-performance databases	Amazon EBS, Azure Disk
File Storage	Traditional hierarchical file system	File sharing, content management	Amazon EFS, Azure Files

Detailed Explanation:
Object Storage:
- **Structure**: Flat namespace with unique object identifiers
- **Scalability**: Virtually unlimited capacity
- **Access**: REST APIs, web interfaces
- **Benefits**: Cost-effective, globally accessible, metadata support

Block Storage:
- **Structure**: Raw storage blocks attached to compute instances
- **Performance**: High IOPS, low latency
- **Access**: Direct block-level access
- **Benefits**: High performance, database optimization

File Storage:
- **Structure**: Traditional directory/folder hierarchy
- **Sharing**: Multi-user concurrent access
- **Access**: Standard file system protocols (NFS, SMB)
- **Benefits**: Familiar interface, application compatibility

Selection Criteria:
- **Performance requirements**: Block for databases, Object for web
- **Access patterns**: File for shared access, Object for web apps
- **Cost considerations**: Object cheapest, Block most expensive

Mnemonic

"Objects Scale, Blocks Perform, Files Share"

Question 4(a OR) [3 marks]

Define cloud databases. Write example of cloud database services.

Solution

Cloud Databases are database services hosted and managed by cloud providers, offering scalability, high availability, and reduced administration overhead.
Examples of Cloud Database Services:

Provider	Service	Type	Features
Amazon	RDS (Relational Database Service)	SQL	MySQL, PostgreSQL, Oracle
Google	Cloud SQL	SQL	Managed MySQL, PostgreSQL
Microsoft	Azure SQL Database	SQL	SQL Server in cloud
MongoDB	Atlas	NoSQL	Managed MongoDB
Amazon	DynamoDB	NoSQL	Key-value, document store

Benefits: Automatic scaling, backup management, security updates, global availability

Mnemonic

"Amazon Google Microsoft MongoDB"

Question 4(b OR) [4 marks]

Describe data scaling and replication.

Solution

Data Scaling:

Scaling Type	Description	Method	Benefits
Vertical Scaling	Increase server capacity	Add CPU, RAM, storage	Simple, no code changes
Horizontal Scaling	Add more servers	Distribute across nodes	Better fault tolerance

Data Replication:

Replication Type	Description	Use Case	Consistency
Master-Slave	One write node, multiple read nodes	Read-heavy workloads	Eventual consistency
Master-Master	Multiple write nodes	High availability	Conflict resolution needed
Peer-to-Peer	All nodes equal	Distributed systems	Complex consistency

Key Benefits:
- **Scaling**: Handle increased load and data volume
- **Replication**: Improve availability and disaster recovery
- **Performance**: Distribute load across multiple systems
- **Fault Tolerance**: Continue operations despite failures

Mnemonic

"Vertical Horizontal, Master Slave Peer"

Question 4(c OR) [7 marks]

Explain types of cloud databases.

Solution

Database Type	Description	Examples	Use Cases
Relational (SQL)	Structured data with ACID properties	MySQL, PostgreSQL, Oracle	Financial systems, ERP
Document	JSON-like document storage	MongoDB, CouchDB	Content management, catalogs
Key-Value	Simple key-value pairs	Redis, DynamoDB	Caching, session storage

Column-Family	Wide-column storage	Cassandra, HBase	Time-series, IoT data
Graph	Nodes and relationships	Neo4j, Amazon Neptune	Social networks, recommendations

SQL vs NoSQL Comparison:

Aspect	SQL Databases	NoSQL Databases
Schema	Fixed schema	Flexible schema
Scaling	Vertical scaling	Horizontal scaling
ACID	Full ACID compliance	BASE properties
Queries	SQL language	Various query methods
Consistency	Strong consistency	Eventual consistency

Selection Criteria:

- **Data Structure**: Structured data $\rightarrow SQL, Unstructured \rightarrow NoSQL$
- **Scalability**: Horizontal scaling $\rightarrow NoSQL$
- **Consistency**: Strong consistency $\rightarrow SQL$
- **Complexity**: Complex queries $\rightarrow SQL, Simpleaccess \rightarrow NoSQL$

Cloud Database Services:

- **Amazon**: RDS (SQL), DynamoDB (NoSQL), DocumentDB (Document)
- **Google**: Cloud SQL, Firestore, BigTable
- **Microsoft**: Azure SQL, Cosmos DB

Mnemonic

"Relational Document Key Column Graph"

Question 5(a) [3 marks]

Define cloud security. List out various Challenges for Cloud Security.

Solution

Cloud Security refers to the policies, technologies, applications, and controls utilized to protect virtualized IP, data, applications, services, and infrastructure associated with cloud computing.

Cloud Security Challenges:

- **Data breaches and privacy concerns**
- **Identity and access management complexity**
- **Insider threats and privileged user access**
- **Compliance and regulatory requirements**
- **Shared responsibility model confusion**
- **API security vulnerabilities**

Key Challenge Areas: Each challenge requires specific security strategies and tools to mitigate risks and ensure data protection in cloud environments.

Mnemonic

"Data Identity Insider Compliance Shared API"

Question 5(b) [4 marks]

Write a short note on Identity Management and Access Control.

Solution

Identity and Access Management (IAM):

Component	Description	Function
Authentication	Verify user identity	Username/password, MFA, biometrics
Authorization	Grant appropriate permissions	Role-based access control (RBAC)
Accounting	Track user activities	Audit logs, compliance reporting

Access Control Models:

- **Role-Based Access Control (RBAC)**: Users assigned roles with specific permissions
- **Attribute-Based Access Control (ABAC)**: Dynamic permissions based on attributes
- **Mandatory Access Control (MAC)**: System-enforced security policies

Best Practices:

- **Principle of least privilege**: Minimum necessary access
- **Multi-factor authentication**: Enhanced security verification
- **Regular access reviews**: Periodic permission audits
- **Zero trust model**: Verify every access request

Mnemonic

"Authenticate Authorize Account"

Question 5(c) [7 marks]

Explain the technologies used for data security in cloud.

Solution

Technology	Purpose	Description	Implementation
Encryption	Data protection	Converts data to unreadable format	AES-256, RSA encryption
Key Management	Secure key storage	Centralized key lifecycle management	AWS KMS, Azure Key Vault
Digital Signatures	Data integrity	Verify data authenticity	PKI certificates
Access Controls	Permission management	Role-based access restrictions	IAM policies, RBAC
Network Security	Traffic protection	Secure data transmission	VPN, TLS/SSL, firewalls
Data Loss Prevention	Prevent data leaks	Monitor and control data movement	DLP tools, content inspection
Backup & Recovery	Data availability	Disaster recovery planning	Automated backups, replication

Security Implementation Layers:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Application Security{br/{}Code security, input validation] }
    B[Data Security{br/{}Encryption, tokenization]}
    C[Network Security{br/{}Firewalls, VPN, SSL/TLS]}
    D[Infrastructure Security{br/{}Physical security, hypervisor]}

    A {-{-}{} B {-}{-}{} C {-}{-}{} D}
{Highlighting}
{Shaded}
```

Key Security Practices:

- **Data at Rest**: Encrypt stored data using strong encryption algorithms
- **Data in Transit**: Secure transmission using TLS/SSL protocols
- **Data in Use**: Protect data during processing with secure enclaves
- **Key Rotation**: Regular cryptographic key updates
- **Compliance**: Meet regulatory requirements (GDPR, HIPAA, SOX)

Emerging Technologies:

- **Homomorphic Encryption**: Compute on encrypted data
- **Zero-Knowledge Proofs**: Verify without revealing data
- **Confidential Computing**: Protect data during processing

Mnemonic

"Encrypt Keys Sign Control Network Prevent Backup"

Question 5(a OR) [3 marks]

Define serverless computing. List out advantages of serverless computing.

Solution

Serverless Computing is a cloud execution model where cloud providers dynamically manage server allocation and scaling, allowing developers to focus solely on code without server management.

Advantages of Serverless Computing:

- **No server management**: Cloud provider handles infrastructure
- **Automatic scaling**: Scales up/down based on demand automatically
- **Pay-per-use pricing**: Only pay for actual execution time
- **Faster development**: Focus on business logic, not infrastructure
- **High availability**: Built-in fault tolerance and redundancy
- **Reduced operational overhead**: No patching, monitoring servers

Popular Examples: AWS Lambda, Azure Functions, Google Cloud Functions

Mnemonic

"No Automatic Pay Faster High Reduced"

Question 5(b OR) [4 marks]

Differentiate between edge and fog computing.

Solution

Aspect	Edge Computing	Fog Computing
Location	At network edge, close to devices	Between cloud and edge devices
Processing	Local processing on edge devices	Distributed processing across nodes
Latency	Ultra-low latency	Low to medium latency
Connectivity	Direct device connection	Hierarchical network structure
Use Cases	IoT sensors, autonomous vehicles	Smart cities, industrial automation
Examples	Smartphone apps, smart cameras	Router-based processing, gateways

Key Differences:

- **Edge** brings compute directly to data source
- **Fog** creates a distributed computing layer
- **Edge** optimizes for immediate response
- **Fog** provides broader area coverage

Benefits of Both:

- Reduced bandwidth usage to cloud
- Improved response times
- Enhanced privacy and security
- Better reliability for critical applications

Mnemonic

"Edge Direct, Fog Distributed"

Question 5(c OR) [7 marks]

Define Containers. Explain steps to create image and execute the docker container with example.

Solution

Containers are lightweight, portable packages that include application code, runtime, system tools, libraries, and settings needed to run an application consistently across different environments.

Docker Container Creation Steps:

```
flowchart LR
    A[Write Dockerfile] {-{-} B[Build Docker Image]}
    B {-{-} C[Run Docker Container]}
    C {-{-} D[Manage Container Lifecycle]}

    A1[FROM base\_image{br/COPY app\_filesbr/RUN install\_commandsbr/CMD start\_command] {-}{-} A}
    B1[docker build {-t image\_name .] {-}{-} B}
    C1[docker run {-p port:port image\_name] {-}{-} C}
    D1[docker ps{br/docker stopbr/docker start] {-}{-} D}
```

Step-by-Step Process:

1. Create Dockerfile:

```
\# Base image
FROM node:14{-alpine}

\# Set working directory
WORKDIR /app

\# Copy package files
COPY package*.json ./

\# Install dependencies
```

```
RUN npm install

\# Copy application code
COPY . .

\# Expose port
EXPOSE 3000

\# Start command
CMD ["npm", "start"]
```

2. Build Docker Image:

```
\# Build image from Dockerfile
docker build {-t} my{-web{-}app:latest .}

\# List images
docker images
```

3. Run Docker Container:

```
\# Run container with port mapping
docker run {-d} {-p} 8080:3000 {-{-}name} web{-app my{-}web{-}app:latest}

\# Check running containers
docker ps
```

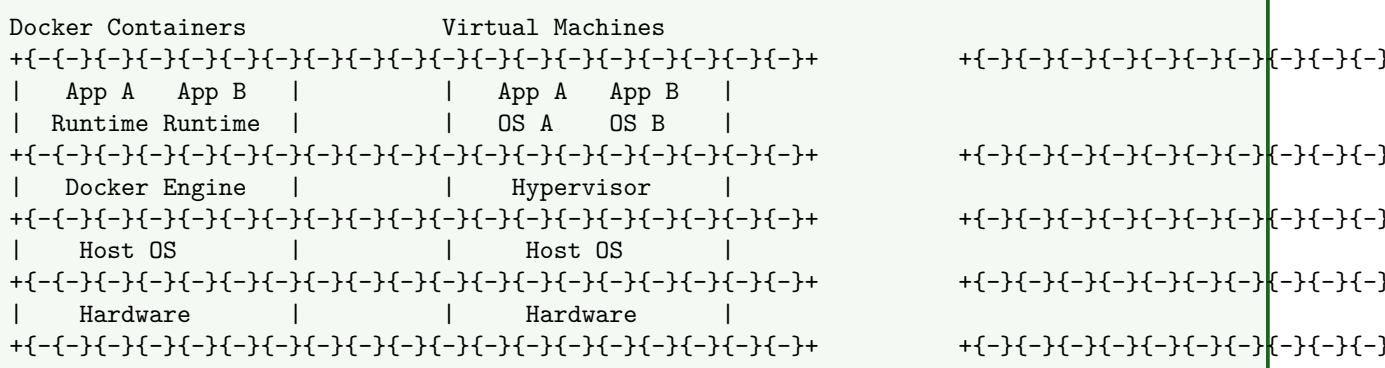
4. Container Management:

Command	Purpose	Example
docker ps	List running containers	`docker ps -a`
docker stop	Stop container	`docker stop web-app`
docker start	Start stopped container	`docker start web-app`
docker logs	View container logs	`docker logs web-app`
docker exec	Execute command in container	`docker exec -it web-app /bin/sh`

Container Benefits:

- **Portability**: Run anywhere Docker is installed
- **Consistency**: Same environment across development/production
- **Isolation**: Applications run independently
- **Efficiency**: Share OS kernel, lightweight compared to VMs
- **Scalability**: Easy horizontal scaling with orchestration

Docker vs VM Comparison:



Common Docker Commands:

- **Image Management**: `docker pull`, `docker push`, `docker rmi`
- **Container Operations**: `docker create`, `docker kill`, `docker rm`
- **System Info**: `docker info`, `docker version`, `docker system df`

Example Use Case: A web application with Node.js backend can be containerized to ensure consistent deployment across development, testing, and production environments, eliminating "works on my machine" issues.

Container Orchestration: For production deployments, use orchestration tools like:

- **Kubernetes**: Advanced container orchestration
- **Docker Swarm**: Native Docker clustering
- **Amazon ECS**: AWS container service

Mnemonic

"Create Build Run Manage - Dockerfile Commands Lifecycle"