Module: Introduction to Cloud Computing

Upon completion of this module, you should be able to:

- Define cloud computing
- Describe the essential cloud characteristics
- Discuss the key benefits of cloud computing
- Describe the cloud service models
- Describe cloud services brokerage
- Describe the cloud deployment models

Lesson: Cloud Computing Overview

This lesson covers the following topics:

- Definition of cloud computing
- Essential characteristics of cloud computing
- Key benefits of cloud computing

The Cloud Computing Phenomenon

- **Rapid Adoption**:
  Organizations are increasingly embracing cloud computing to enhance flexibility, scalability, and cost-effectiveness.
- **Disruptive Technology**:
  Cloud computing is recognized as a major technological disruptor, expected to redefine how IT services are delivered in the next decade.
- **Business Innovation**:
  Cloud enables businesses to optimize operations and create new business models, fostering greater innovation and efficiency.
- **Influence of Modern Trends**:
  The growth of mobility, Big Data, and social media is accelerating the adoption of cloud computing, as these trends require flexible and scalable infrastructure.

What is Cloud Computing?

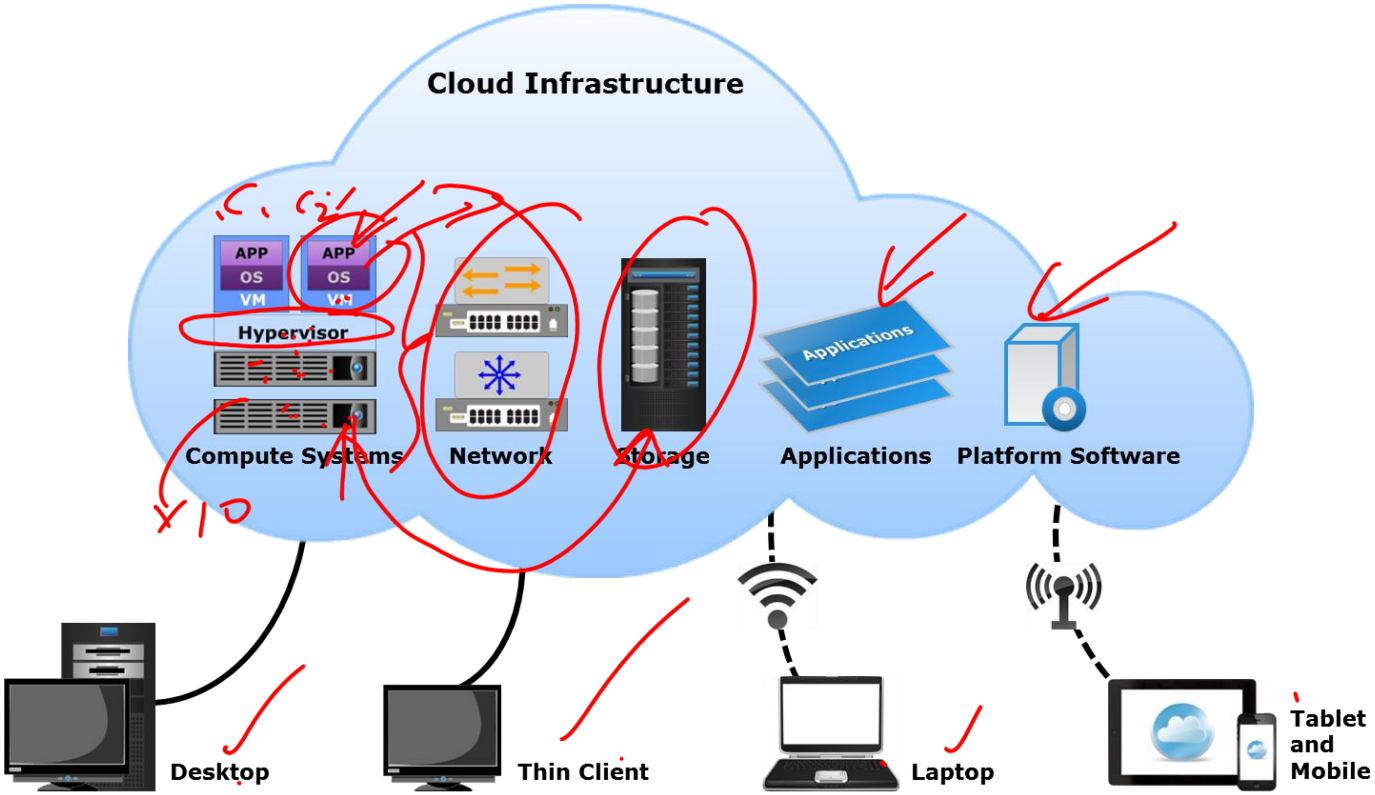
Cloud Computing

A model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources, (e.g., servers, storage, networks, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

– U.S. National Institute of Standards and Technology, Special Publication 800-145

- A cloud is a collection of network-accessible IT resources
  - Consists of shared pools of hardware and software resources deployed in data centers
- Cloud model enables consumers to hire a provider's IT resources as a service

What is Cloud Computing? (Cont'd)



Essential Cloud Characteristics

- On-demand self-service
- Broad network access
- Resource pooling
- Rapid elasticity
- Measured service

On-demand Self-service

On-demand Self-service

A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider.

– U.S. National Institute of Standards and Technology, Special Publication 800-145

- Consumers use a web-based self-service portal to view a service catalog and request cloud services
- Enables consumers to provision cloud services in a simple and flexible manner
  - Reduces the time needed to provision new or additional IT resources
  - Simple Example Google Colab

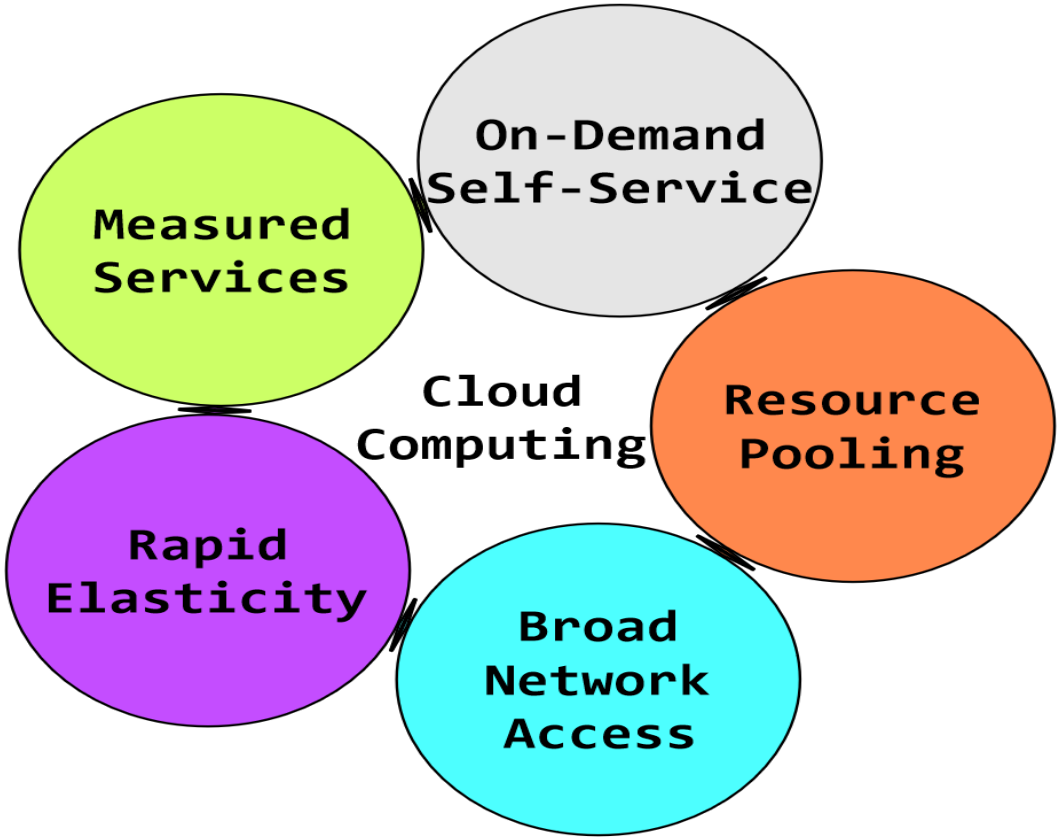
Broad Network Access

Broad Network Access

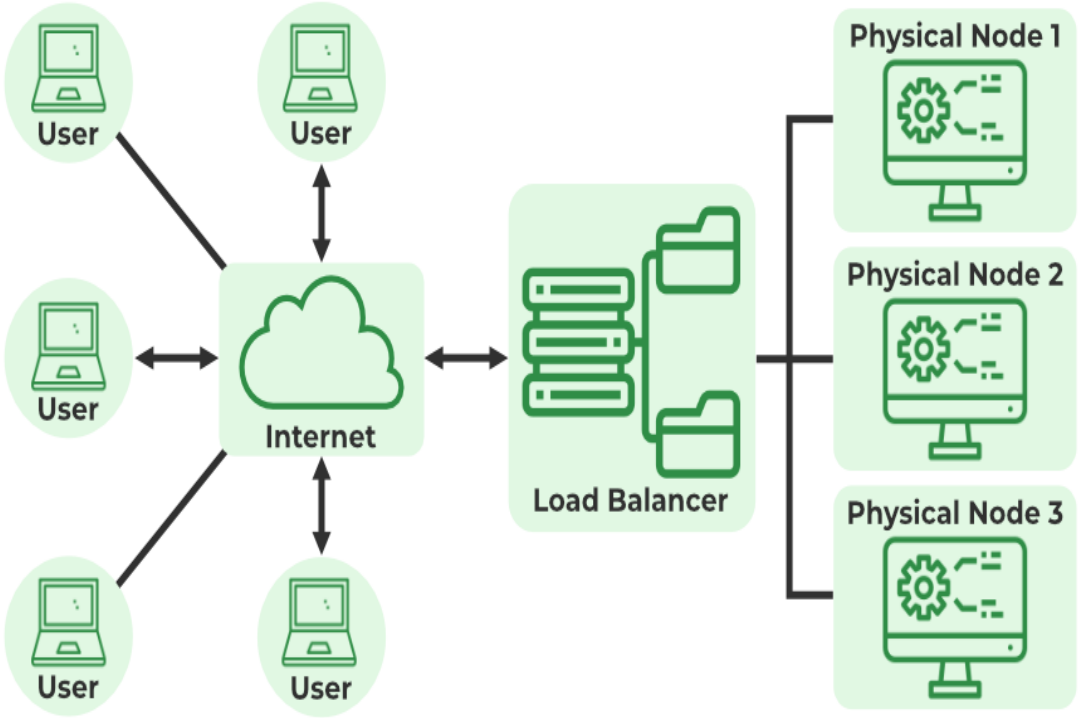
Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms, (e.g., mobile phones, tablets, laptops, and workstations).

– U.S. National Institute of Standards and Technology, Special Publication 800-145

- Consumers access cloud services on any client/end-point device from anywhere over a network
- Standard mechanisms support the use of heterogeneous client platforms
  - OSI and TCP/IP protocols
  - SOAP (Simple Object Access Protocol) and
  - REST (Representational State Transfer) web services


On-Demand
Self-Service
Measured
Services
Cloud
Computing
Resource
Pooling
Rapid
Elasticity
Broad
Network
Access

Resource Pooling



- **<u>Computing resources</u> are pooled to serve multiple Clients**
- **Sense of location independence**
- Resources include
  - Storage,
  - Processing,
  - Memory, and
  - Network bandwidth.

Resource Pooling

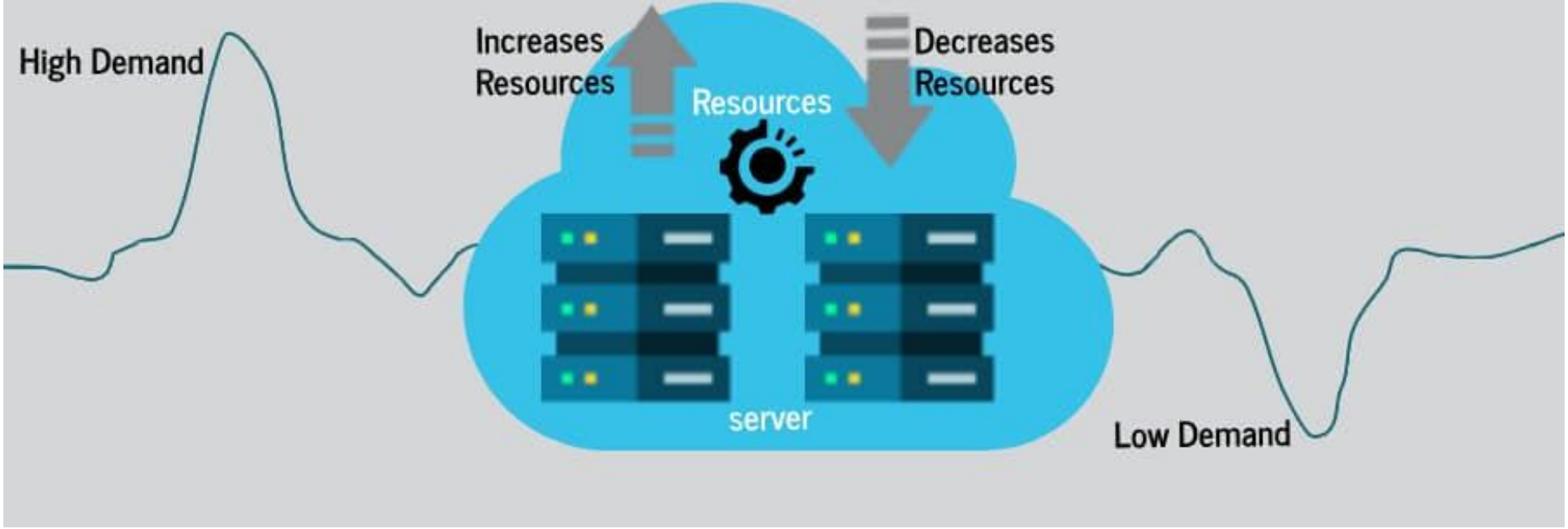
Resource Pooling

- The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand.
- There is a **sense of location independence** in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter).
- Examples of resources include storage, processing, memory, and network bandwidth.

– U.S. National Institute of Standards and Technology, Special Publication 800-145

- Enables providers to improve resource utilization and to flexibly provision and reclaim resources

Rapid Elasticity in Cloud Computing



Rapid Elasticity

Rapid Elasticity

> Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time.
>
> *– U.S. National Institute of Standards and Technology, Special Publication 800-145*

- Consumers can adapt to variations in workloads and maintain required performance levels
- Consumers may be able to avoid excessive costs from over-provisioning resources

Measured Service

Measured Service

- Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts).
- Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service.

– U.S. National Institute of Standards and Technology, Special Publication 800-145

- Enables billing of cloud services
- Resource monitoring helps providers with capacity and service planning

Cloud Computing Benefits

Benefit	Description
Business agility	• Enables quick resource provisioning • Facilitates innovation • Reduces time-to-market
Reduces IT costs	• Reduces up-front capital expenditure (CAPEX) • Improves resource utilization • Reduces energy and space consumption
High availability	• Ensures resource availability based on consumer's requirements • Enables fault tolerance

Cloud platforms like AWS and Azure can detect failed virtual machines and automatically restart or replace them.

Cloud Computing Benefits (Cont'd)

Benefit	Description
Business continuity	• Reduces impact of downtime • Example: Cloud-based backup
Flexible scaling	• Enables scaling of resources to meet demand • Unilateral and automatic resource scaling
Flexibility of access	• Enables access to services from anywhere • Eliminates dependency on a specific end-point device

Cloud Computing Benefits (Cont'd)

Benefit	Description
Application development and testing	• Enables application development and testing at a greater scale • Enables testing on multiple platforms
Simplified infrastructure management	• Consumers manage only those resources that are required to access cloud services
Increased collaboration	• Enables sharing and simultaneous access of resources and information
Masked complexity	• Intricacies of IT operations are hidden from end users

Lesson Summary

During this lesson the following topics were covered:

- Definition of cloud computing
- Essential cloud characteristics
- Cloud computing benefits

Lesson: Cloud Service Models and Cloud Services Brokerage

This lesson covers the following topics:

- Infrastructure as a Service
- Platform as a Service
- Software as a Service
- Cloud services brokerage

Introduction to Cloud Service Models

- A cloud service model specifies the services and the capabilities provided to consumers
- NIST specifies three primary cloud service models:
  - Infrastructure as a Service (IaaS)
  - Platform as a Service (PaaS)
  - Software as a Service (SaaS)

Infrastructure as a Service

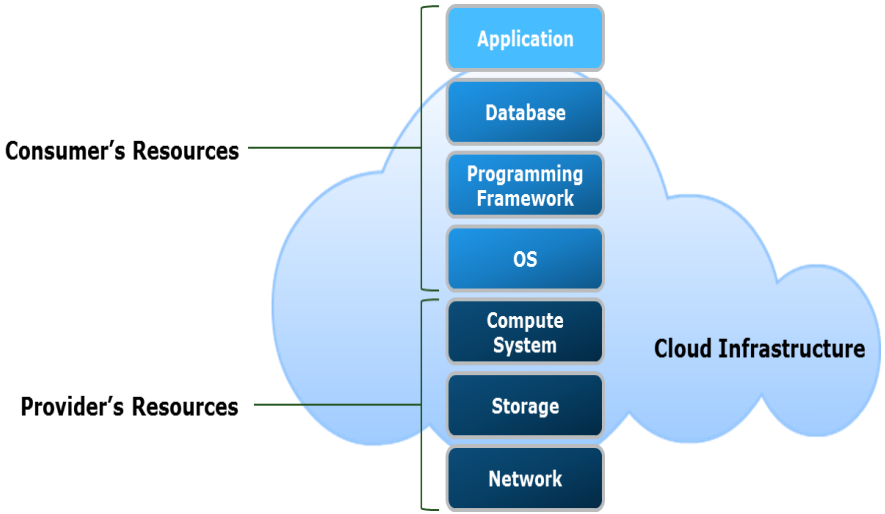
- **Definition:** Provides virtualized computing resources over the internet, such as servers, storage, and networking.
- **Control:**
  - **Customer controls:** Operating System, applications, middleware.
  - **Provider controls:** Physical infrastructure (servers, storage, networking).
- **Purpose:** To allow users to create their own IT environment on top of rented infrastructure.
- **Examples:** Amazon EC2, Microsoft Azure VMs, Google Compute Engine.

Infrastructure as a Service

Infrastructure as a Service

The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications.
The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of selecting networking components , (e.g., host firewalls).

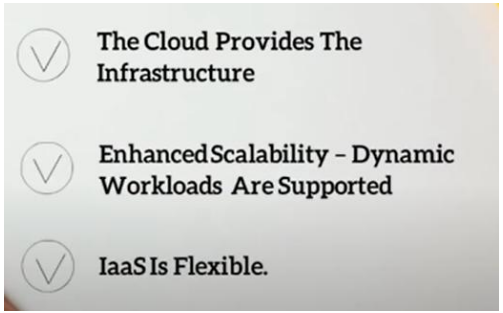
– U.S. National Institute of Standards and Technology, Special Publication 800-145



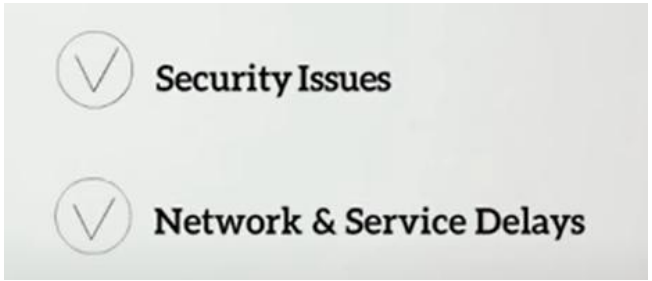

3 IAAS
INFRASTRUCTURE AS A SERVICE
This Services Offers The Computing Architecture & Infrastructure, All Computing Resources But In A Virtual Environment So That Multiple Users Can Access Them. Resources Include; Data Storage, Virtualization, Servers & Networking.
IAAS
Most Vendors Are Responsible For Managing The Above Four resources.
User Will Be Responsible For Handling Other Resources Such As Applications, Data, Runtime & Middleware.


IaaS Products & Services
GOGRID
amazon web services
EC2
Popular IaaS Providers
rackspace

Pros


The Cloud Provides The Infrastructure
Enhanced Scalability – Dynamic Workloads Are Supported
IaaS Is Flexible.

Cons


Security Issues
Network & Service Delays

Infrastructure as a Service - Examples

- Amazon.com
- Rackspace
- GoGrid
- IBM
- HP
- Microsoft

Platform as a Service

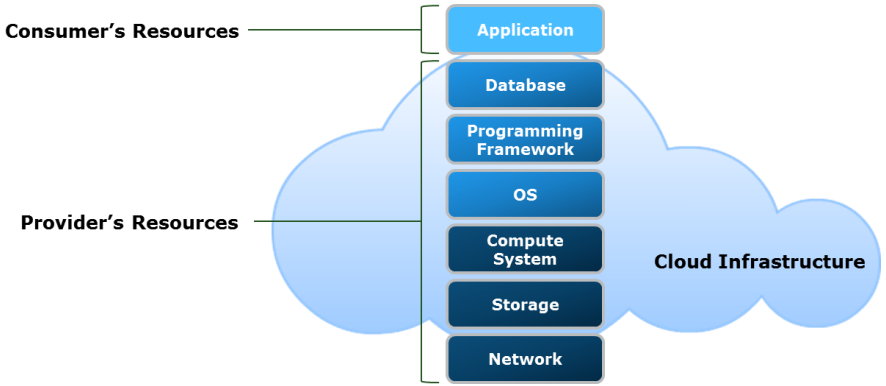
- **Definition:** Provides a platform for application development and deployment, including tools, libraries, and runtime environments.
- **Control:**
  - **Customer controls:** Applications and data.
  - **Provider controls:** Infrastructure, OS, middleware, runtime.
- **Purpose:** To allow developers to build, test, and deploy applications without managing underlying infrastructure.
- **Examples:** Google App Engine, Microsoft Azure App Services, Heroku.

Platform as a Service

Platform as a Service

- The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider.
- The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment.

– U.S. National Institute of Standards and Technology, Special Publication 800-145



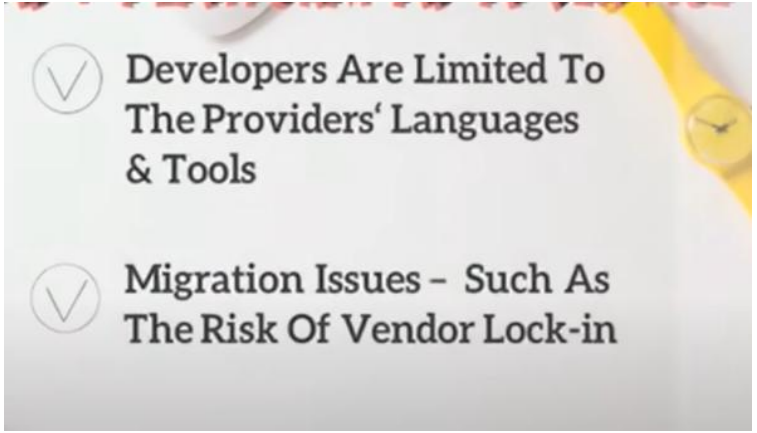

2 PaaS
Platform as a Service
This Service Is Made Up Of A Programming Language Execution Environment, An Operating System, A Web Server & A Database.
Encapsulate The environment Where Users Can Build, Compile & Run Their Programs Without Worrying Of The Underlying Infrastructure.
In This Model, You Manage Data & The Application Resources; All Other Resources Are Managed By The Vendor.
PAAS


PaaS Products & Services
heroku
Windows Azure
AWS Elastic Beanstalk
amazon web services
Popular PaaS Providers
Google app engine

Pros


Cost Effective Rapid Development (It's Scalable)
Faster Market For Developers
Easy Deployment Of Web Applications
Private Or Public Deployment Is Possible

Cons


Developers Are Limited To The Providers' Languages & Tools
Migration Issues – Such As The Risk Of Vendor Lock-in

Platform as a Service - Examples

- Google App Engines
- Microsoft Azure platform
- SalesForce.

Software as a Service

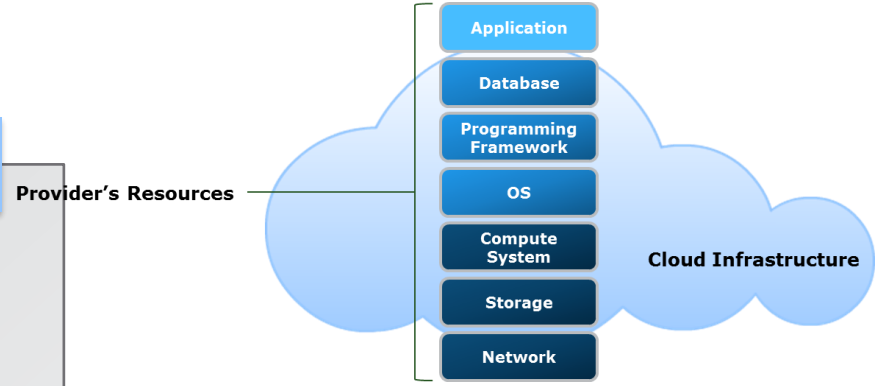
- **Definition:** Provides ready-to-use applications over the internet on a subscription basis.
- **Control:**
  - **Customer controls:** Only application configuration and user-specific settings.
  - **Provider controls:** Everything else (infrastructure, platform, and the application itself).
- **Purpose:** To deliver software to end-users without requiring installation or maintenance.
- **Examples:** Gmail, Google Workspace, Salesforce, Microsoft Office 365.

Software as a Service

Software as a Service

- The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure.
- The applications are accessible from various client devices through either a thin client interface, such as a web browser, (e.g., web-based email, or a program interface).
- The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.

– U.S. National Institute of Standards and Technology, Special Publication 800-145



1 SaaS Software as a Service

On-Demand Service

Pay Per Use Of Application Software To Users.

Independent Platform.

Don't Need To Install The Software On Your PC.

Runs A Single Instance Of The Software.

Available For Multiple End Users.

Cloud Computing Cheap.

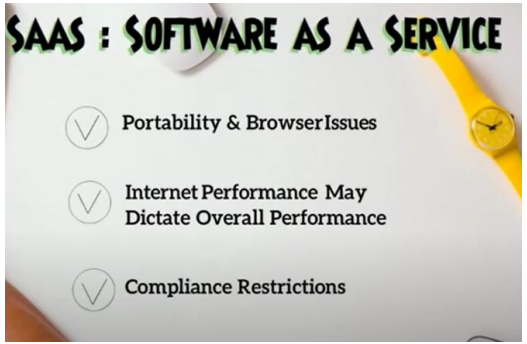
Computing Resources Managed By Vendor.

Accessible Via A Web Browser
Or Lightweight Client Applications.

Software as a Service- Examples

- Pixlr – Image Editor
- Jaycut – Video Editor
- Aviary – Powerful Online Creation Tools
- EmployEase, NetSuite, SalesForce – Business Tools
- Google, Microsoft and Zoho give online word processor, spreadsheet & Presentations

Cons:




Elastic Beanstalk
AUTOMATIC SCALING
amazon EC2
LOAD BALANCING
MONITORING
amazon web services
When It Comes To Companies Using Cloud Computing, AWS Takes The Lead. This Cloud Computing Company Offers IaaS and PaaS Services To Its Customers.
Amazon's AWS [Amazon Web Services]


iCloud
It Allows You To Backup & Store All Your Multimedia & Other Documents Online. This Content Is Then Seamlessly Integrated Onto All Your Devices/Apps In Case You Access It From Them.
iCloud By Apple


Microsoft
Office 365
Windows Azure
This Cloud Is Used & Offered By Microsoft. It Offers IaaS, PaaS, & SaaS For Its Enterprise Software & Developer Tools. If You Have Ever Used Office 365 Products, Then You Have Used SaaS.
Microsoft Azure by Microsoft


The Google Cloud Platform Is A Universal Cloud For Google's Vast Ecosystem & Also For Other Products Such As Microsoft Office.
It Allows Collaboration, Storage Of Data & Also Other Services Offered By Its Cloud Computing Suite.
Google Cloud


IBMSmartCloud
IBM Smart Cloud

Cloud Services Brokerage (CSB)

Cloud Services Brokerage

Cloud services brokerage (CSB) is an IT role and business model in which a company or other entity adds value to one or more (public or private) cloud services on behalf of one or more consumers of that service.

– Gartner IT Glossary

- CSB is provided by a cloud broker
  - An entity that acts as an intermediary between cloud consumers and providers
- Cloud broker manages the use, performance, and delivery of cloud services

Categories of Cloud Services Brokerage

Service intermediation

The broker enhances and adds value to a given service

Service aggregation

The broker combines and integrates multiple services into one or more new services

Service arbitrage

Similar to service aggregation except that the services being aggregated may vary

Cloud Services Brokerage (CSB)

- **Service Intermediation**
  - Improves a given service by adding value-added features like identity management, performance reporting, security enhancements, etc.
  - **Example:** A CSB adds Single Sign-On (SSO) or monitoring tools to SaaS services.
- **Service Aggregation**
  - Combines multiple services (from one or more providers) into a single new service.
  - Handles **data integration, security, and connectivity** between combined services.
  - **Example:** A CSB aggregates multiple SaaS apps into one platform for unified access.
- **Service Arbitrage**
  - Selects services from multiple providers and offers the **best fit or cost-effective option dynamically**.
  - **Example:** Choosing storage services based on real-time pricing changes.

Lesson Summary

During this lesson the following topics were covered:

- Infrastructure as a Service (IaaS)
- Platform as a Service (PaaS)
- Software as a Service (SaaS)
- Cloud services brokerage (CSB)

Lesson: Cloud Deployment Models

This lesson covers the following topics:

- Public cloud
- Private cloud
- Community cloud
- Hybrid cloud

Introduction to Cloud Deployment Models

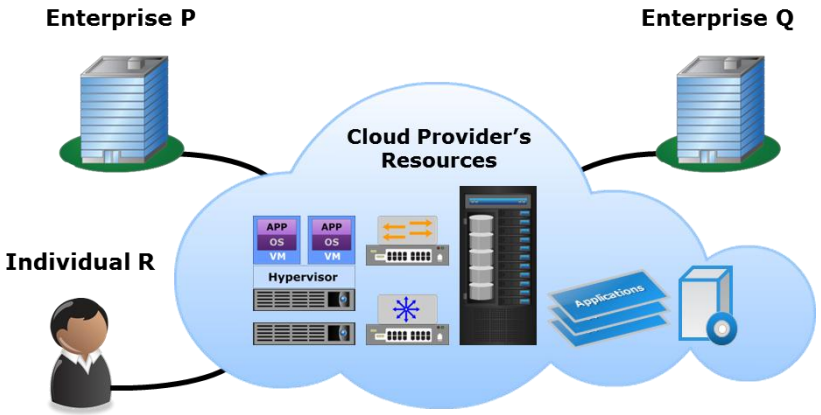
- A cloud deployment model specifies how a cloud infrastructure is built, managed, and accessed
- NIST specifies four primary cloud deployment models:
  - Public
  - Private
  - Community
  - Hybrid

Public Cloud

Public Cloud

The cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.

– U.S. National Institute of Standards and Technology, Special Publication 800-145



Private Cloud

Private Cloud

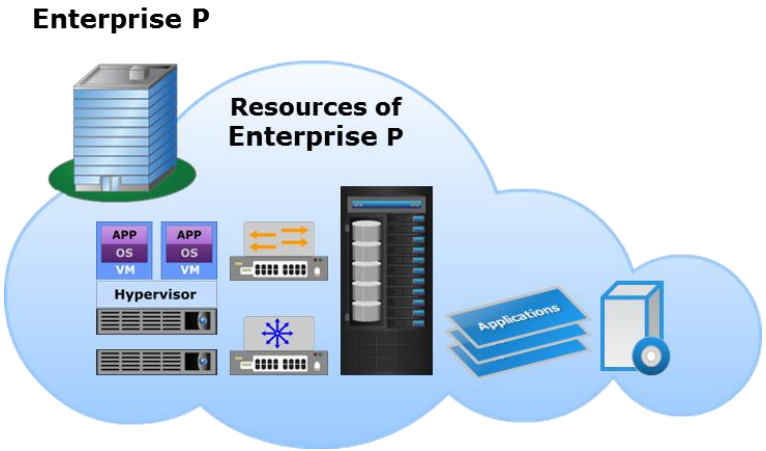
The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (for example, business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.

– U.S. National Institute of Standards and Technology, Special Publication 800-145

- There are two variants of private cloud:
  - On-premise
  - Externally-hosted

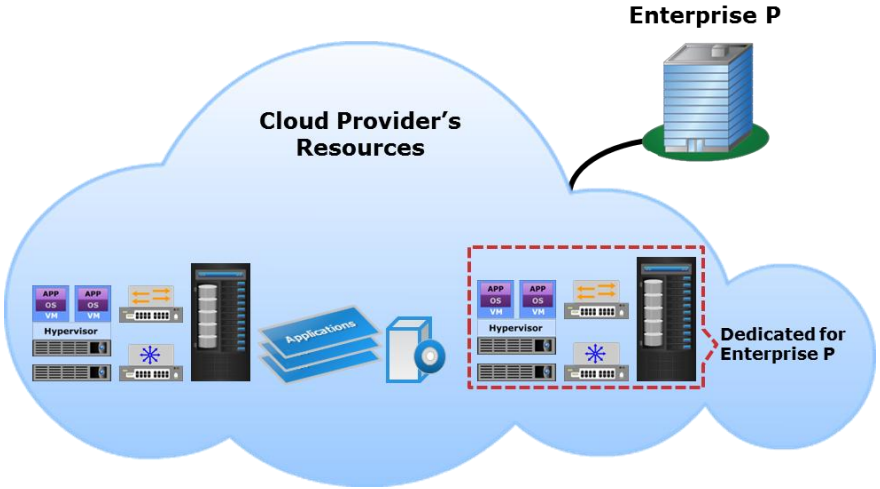
On-premise Private Cloud

- Cloud infrastructure is deployed by an organization on its data centers within its premises
  - Provides complete control over the infrastructure and data
  - Enables standardization of IT resources, processes, and services



Externally-hosted Private Cloud

- Cloud implementation is outsourced to an external provider
- Cloud is hosted on the provider's premises and the consumers connect to it over a secure network
  - Access policies isolate the cloud resources from other tenants



Community Cloud

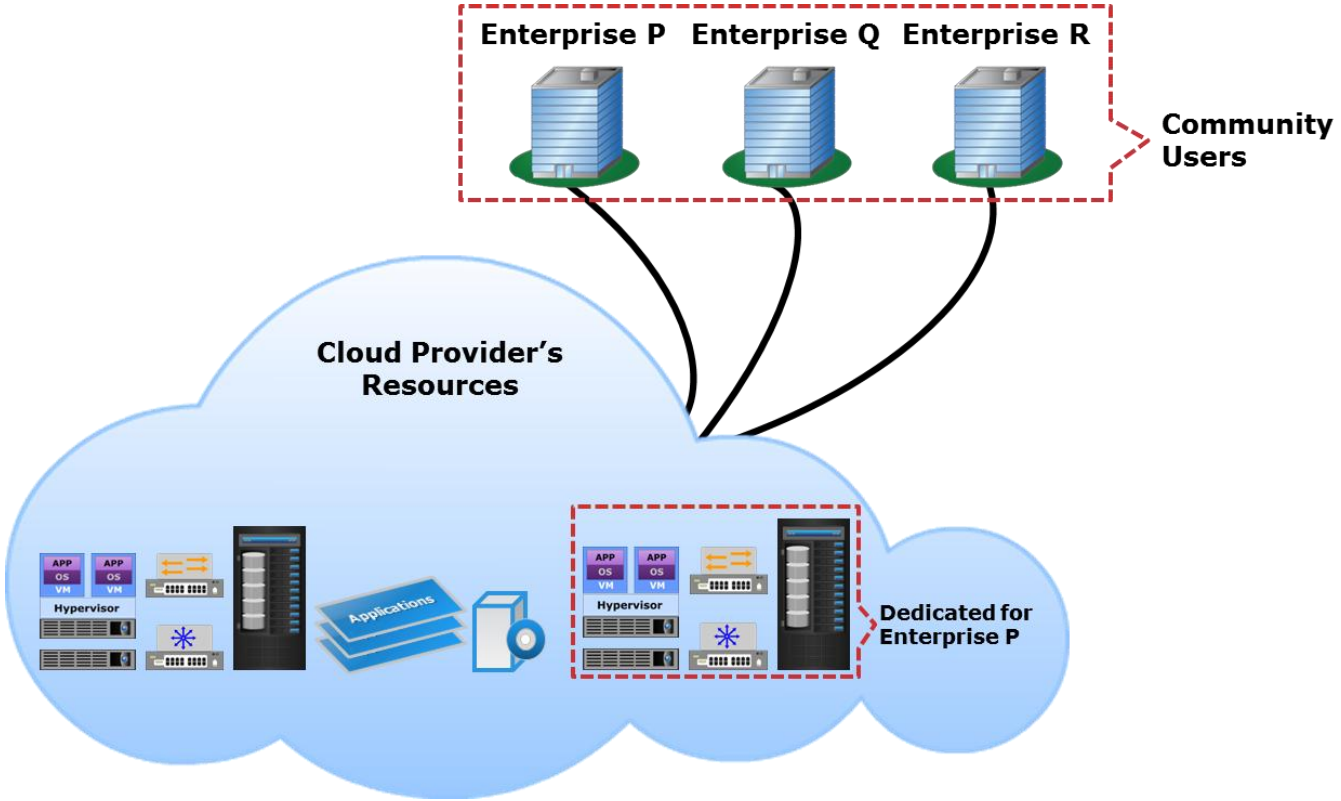
Community Cloud

The cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises.

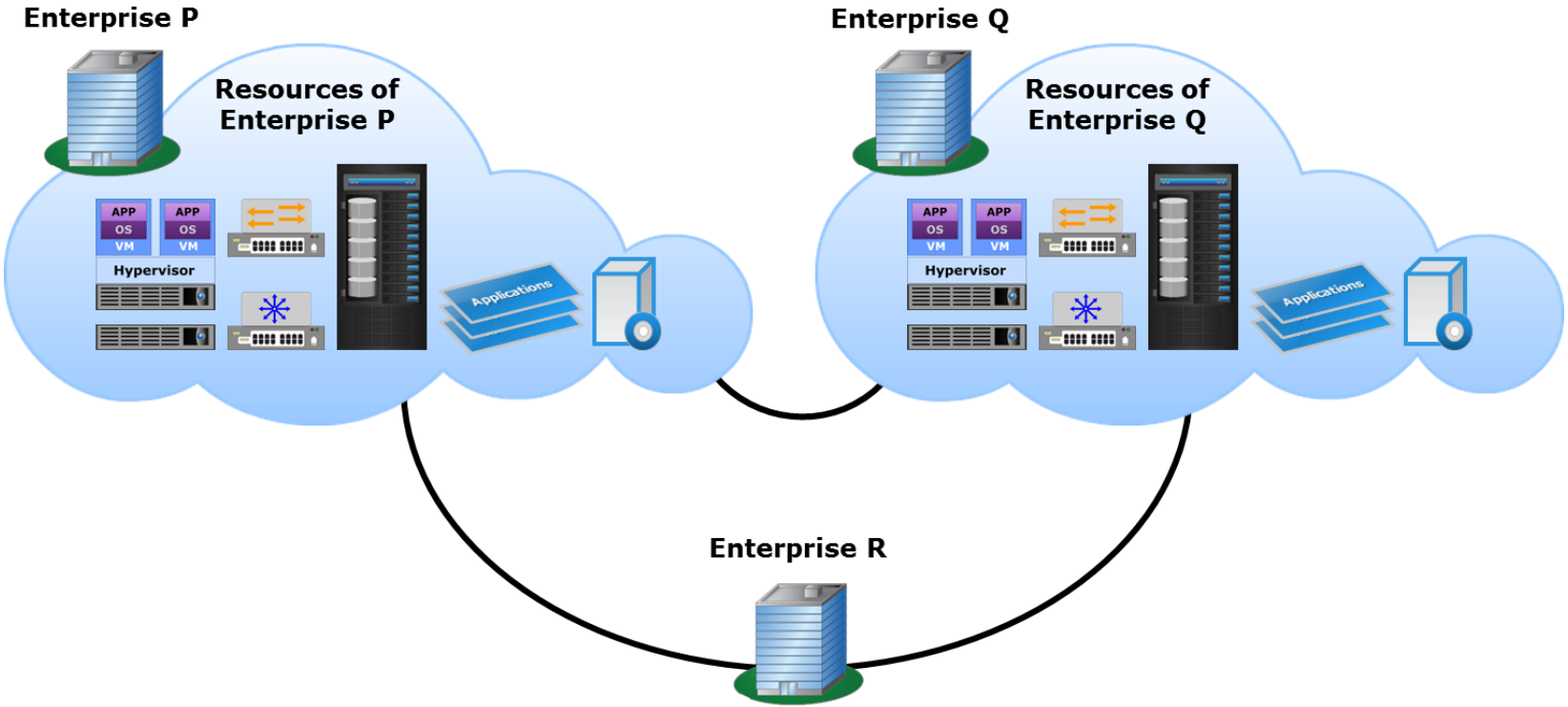
– U.S. National Institute of Standards and Technology, Special Publication 800-145

- There are two variants of community cloud:
  - On-premise
  - Externally-hosted

Externally-hosted Community Cloud



On-premise Community Cloud

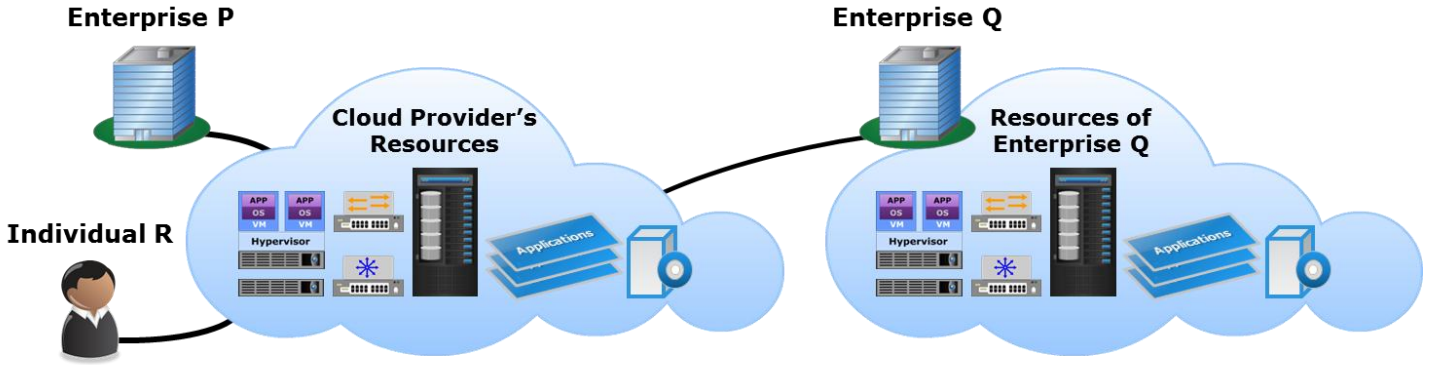


Hybrid Cloud

Hybrid Cloud

The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

– U.S. National Institute of Standards and Technology, Special Publication 800-145



Hybrid Cloud Model Use Cases

Use case	Description
Cloud bursting	Provisioning resources for a limited time from a public cloud to handle peak workloads
Web application hosting	Hosting less critical applications such as e-commerce applications on the public cloud
Migrating packaged applications	Migrating standard packaged applications such as email to the public cloud
Application development and testing	Developing and testing applications in the public cloud before launching them

Lesson Summary

During this lesson the following topics were covered:

- Public cloud
- Private cloud: on-premise and externally-hosted
- Community cloud: on-premise and externally-hosted
- Hybrid cloud and its use cases

VMware vCHS, Pivotal Cloud Foundry, and EMC Mozy

vCHS	Cloud Foundry	Mozy
• Hybrid cloud service • Provides IaaS for migrating / extending workloads to public cloud, application development, and disaster recovery	• Open-source PaaS project • Supports multiple cloud deployment models, programming languages, and database systems	• SaaS solution for secure, cloud-based online backup and recovery • Provides automatic and scheduled backups

Module Summary

Key points covered in this module:

- Definition of cloud computing
- Essential cloud characteristics
- Key benefits of cloud computing
- Cloud service models
- Cloud services brokerage
- Cloud deployment models

Module: Building the Cloud Infrastructure

Upon completion of this module, you should be able to:

- Describe the cloud computing reference model
- Describe various factors to consider while building a cloud infrastructure
- Strategic Impact, Risk Impact, Financial Impact

Lesson: Cloud Computing Reference Model

This lesson covers the following topics:

- Layers of cloud computing reference model
- Entities and functions of each layer
- Cross-layer functions of cloud computing reference model

What is a Reference Model?

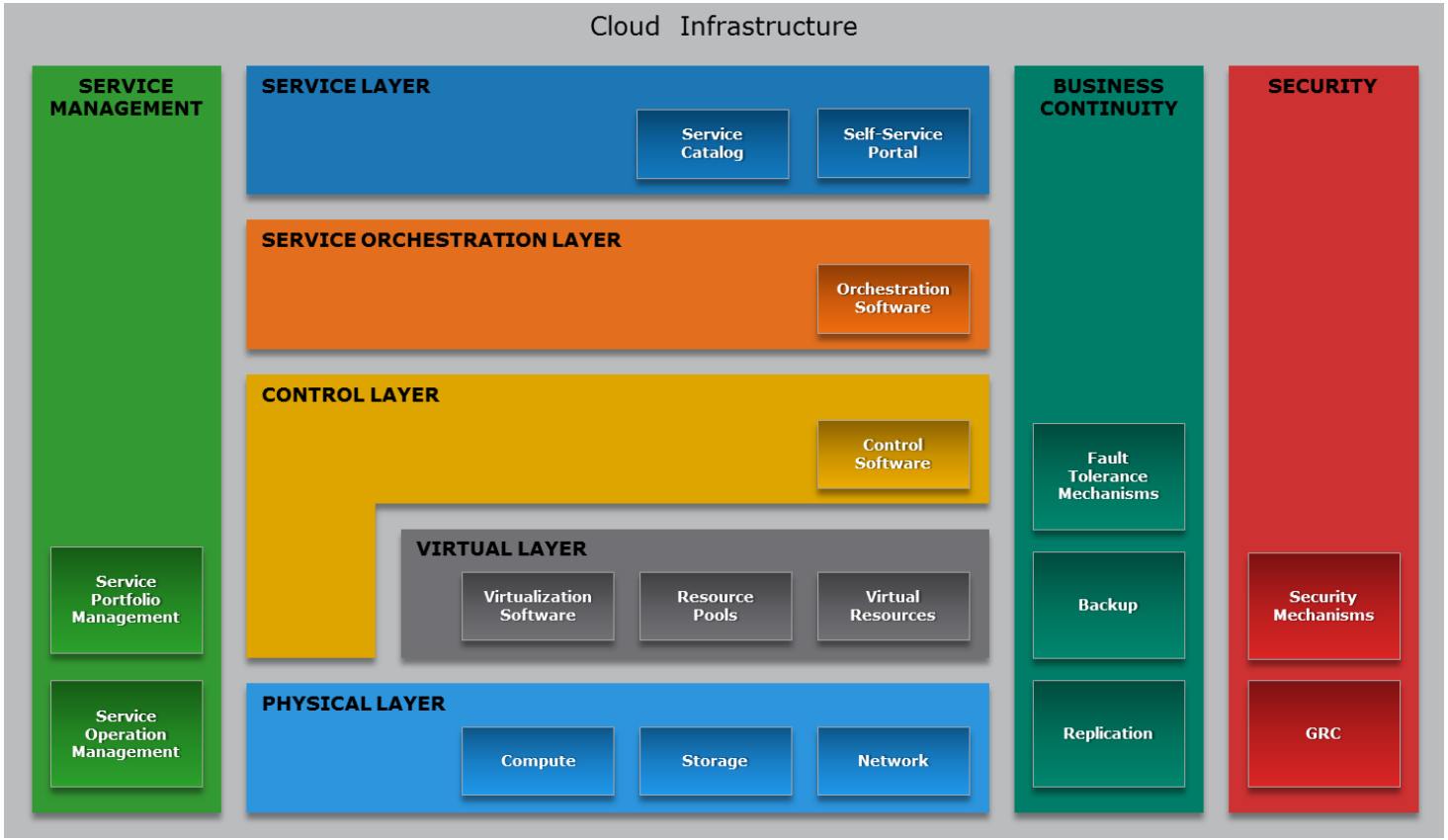
Reference Model

- A reference model is an abstract framework for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting that environment.
- It is based on a small number of unifying concepts and may be used as a basis for education and explaining standards.
- It is not directly tied to any standards, technologies, or other concrete implementation details, but it does seek to provide a common semantics that can be used unambiguously across and between different implementations.

- Organization for the Advancement of Structured Information Standard (OASIS)

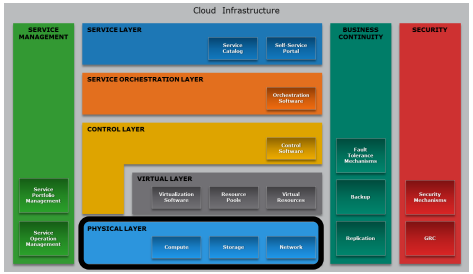
- Facilitates efficient communication of system details between stakeholders
- Provides a point of reference for system designers to extract system specifications

Cloud Computing Reference Model



Cloud Computing Layer

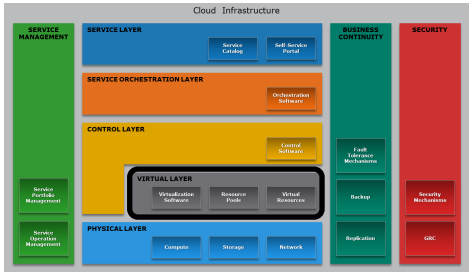
Physical Layer



- Foundation layer of the cloud infrastructure
- Specifies entities that operate at this layer:
  - Compute systems, network devices, and storage devices
  - Operating environment, protocol, tools, and processes
- **Functions of physical layer:**
  - Executes requests generated by virtualization and control layer

Cloud Computing Layer

Virtual Layer



- Deployed on the physical layer
- Specifies entities that operate at this layer:
  - Virtualization software
  - Resource pools
  - Virtual resources
- **Functions of virtual layer:**
  - Abstracts physical resources and makes them appear as virtual resources
    - Enables multitenant environment, thereby improving utilization
  - Executes the requests generated by control layer

When is the Virtual Layer Not Necessary?

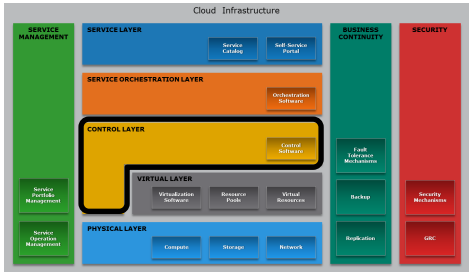
- The virtual layer is not required under the following conditions:
  - When **bare-metal provisioning** is used, meaning applications or services are deployed directly on **physical hardware** without any virtualization.
  - In scenarios where **performance-sensitive applications** require direct access to hardware without the overhead of virtualization (e.g., HPC systems).
  - When **virtualization technology is not implemented** or desired due to cost, complexity, or security reasons.

Does the Control Layer Directly Depend on the Physical Layer in This Case?

- Yes. If the virtual layer is absent:
  - The **control layer** will interact directly with the **physical layer**.
  - Control mechanisms will manage **physical resources** (compute, storage, and network) instead of virtual resources.
  - This model is more common in **traditional data centers** or **bare-metal cloud offerings**.

Cloud Computing Layer

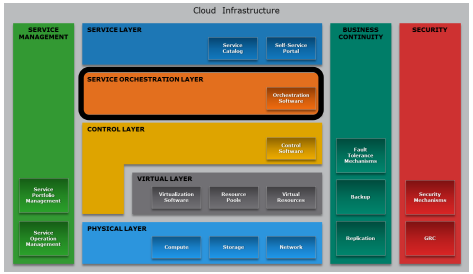
Control Layer



- Deployed either on virtual layer or on physical layer
- Specifies entities that operate at this layer – control software
- **Functions of control layer:**
  - Enables resource configuration and resource pool configuration
  - Enables resource provisioning
  - Executes requests generated by service layer
  - Exposes resources to and supports the service layer
  - Collaborates with the virtualization software and enables
    - Resource pooling and creating virtual resources
    - Dynamic allocation of resources
    - Optimized utilization of resources

Cloud Computing Layer

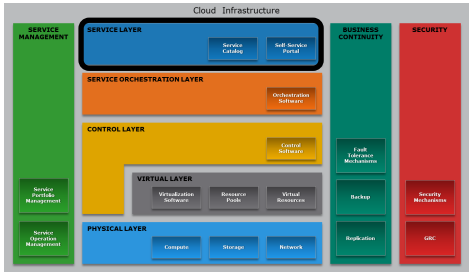
Service Orchestration Layer



- Specifies the entities that operate at this layer:
  - Orchestration software
- Functions of orchestration layer:
  - Provides workflows for executing automated tasks
  - Interacts with various entities to invoke provisioning tasks

Cloud Computing Layer

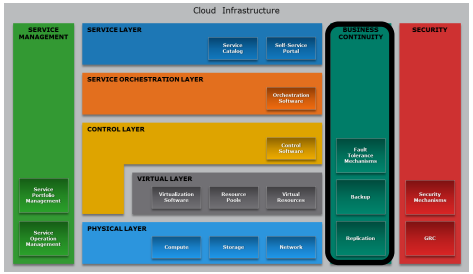
Service Layer



- Consumers interact and consume cloud resources via this layer
- Specifies the entities that operate at this layer:
  - Service catalog
  - Self-service portal
- **Functions of service layer:**
  - Stores information about cloud services in service catalog and presents them to the consumers
  - Enables consumers to access and manage cloud services via a self-service portal

Cross-layer Function

Business Continuity



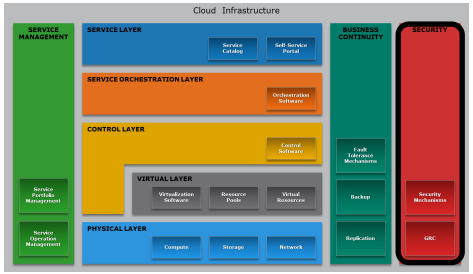
- Specifies adoption of measures to mitigate the impact of downtime:

Measures	Description
Proactive	• Business impact analysis • Risk assessment • Technology solutions deployment (backup and replication)
Reactive	• Disaster recovery • Disaster restart

- Enables ensuring the availability of services in line with SLA
- Supports all the layers to provide uninterrupted services

Cross-layer Function

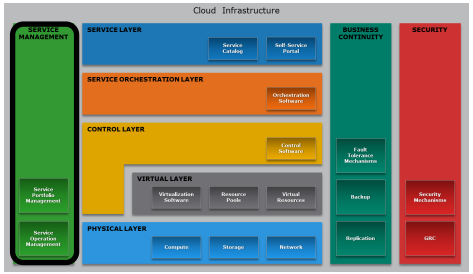
Security



- Specifies the adoption of:
  - Administrative mechanisms
    - Security and personnel policies
    - Standard procedures to direct safe execution of operations
  - Technical mechanisms
    - Firewall
    - Intrusion detection and prevention systems
    - Antivirus
- Deploys security mechanisms to meet GRC requirements
- Supports all the layers to provide secure services

Cross-layer Function

Service Management



- Specifies adoption of activities related to:

Activities	Description
Service portfolio management	• Defines service roadmap, service features, and service levels • Establishes budgeting and pricing • Deals with consumers in supporting activities • Performs market research • Collects information about competitors
Service operation management	• Enables infrastructure configuration and resource provisioning • Enables problem resolution • Enables capacity and availability management • Enables compliance conformance • Enables monitoring cloud services and their constituent elements

Lesson Summary

During this lesson the following topics were covered:

- Cloud computing reference model
- Entities and functions of the five layers
- Activities of the three cross-layer functions

Lesson: Options for Building a Cloud Infrastructure

This lesson covers the following topics:

- Greenfield and brownfield deployment options
- Technology solutions for building a cloud infrastructure

Deployment Options

Greenfield Deployment Option

It is typically used when an infrastructure does not exist and an organization has to build the cloud infrastructure starting from the physical layer.

Brownfield Deployment Option

It is used when some of the infrastructure entities exist, which can be transformed to cloud infrastructure by deploying the remaining entities required for the cloud infrastructure.

Brownfield Deployment Option

- **Definition**

  A brownfield deployment is used when some infrastructure entities already exist and can be transformed into a cloud infrastructure by adding the remaining required entities.

- **Example Scenario**
  - Organization has an **existing data center with:**
    - Physical Layer
    - Virtual Layer
    - Control Layer
  - Data center also includes:
    - Business Continuity (BC)
    - Security
    - Service Management

    But limited to a a non-cloud environment.

- **Transformation Requirements**
  - Deploy Service Orchestration Layer
  - Deploy Service Layer
  - Upgrade BC. Security, and Service Management to support cloud operations

Solutions for Building Cloud Infrastructure

- Two solutions for building cloud infrastructure:
  - Integrating best-of-Technology cloud infrastructure components
  - Cloud-ready converged infrastructure

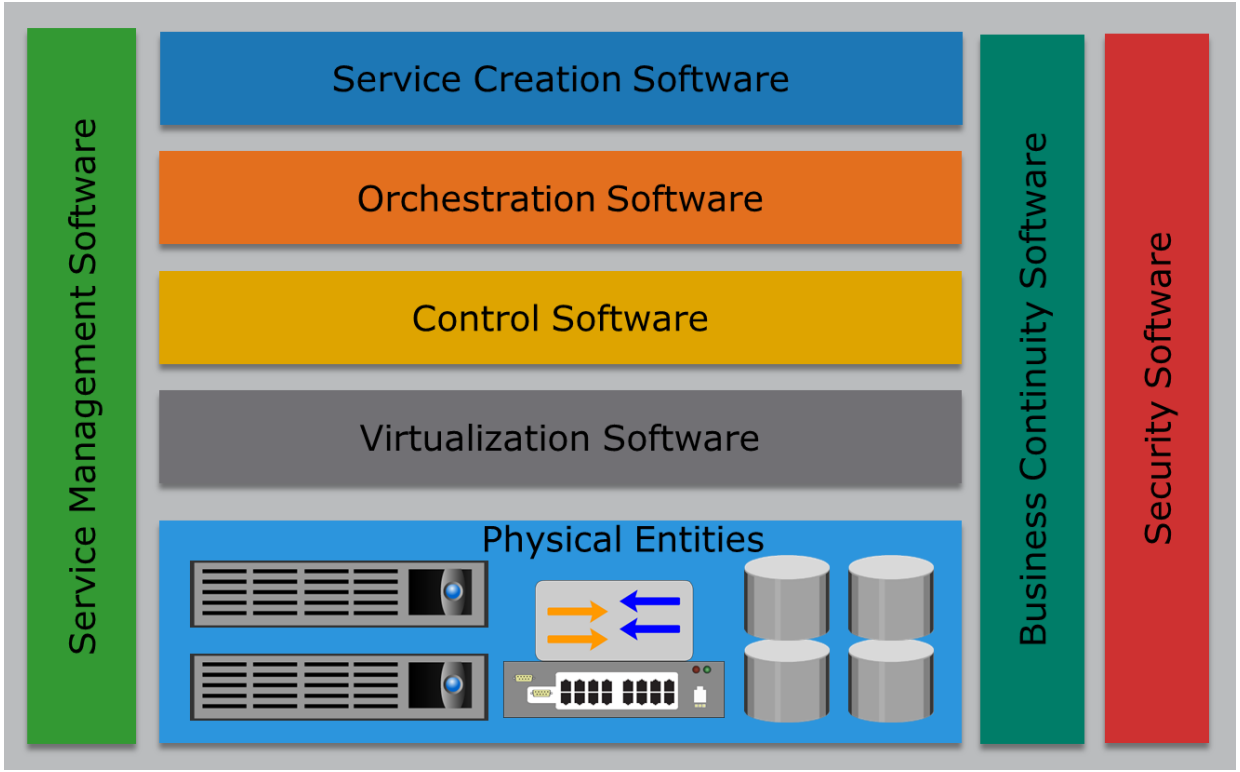
Solutions for Building Cloud Infrastructure

Integrating Best-of-Technology Cloud Infrastructure Components

- Built by integrating multi-vendor infrastructure components
- Enables repurposing the existing infrastructure components
- Requires spending a significant amount of IT staff time on:
  - Evaluating individual and disparate hardware components
  - Installing and integrating infrastructure components
  - Testing hardware, middleware, and software
  - Checking compatibility of all the components
- Enables organizations to choose and switch vendors easily

Solutions for Building Cloud Infrastructure

Cloud-ready Converged Infrastructure



Lesson Summary

During this lesson the following topics were covered:

- Greenfield and brownfield deployment options
- Best-of-breed cloud infrastructure components
- Cloud-ready converged infrastructure

Lesson: Considerations for Building a Cloud Infrastructure

This lesson covers the following topics:

- Factors to consider while building a cloud infrastructure

Factors to Consider while Building a Cloud Infrastructure

- Governance
- Organization
- Finance
- Tools
- Service-level agreement and service contract

- Avoiding vendor lock-in
- Software licensing concerns
- Service model considerations
- Migration
- Testing

Governance

Governance

Governance is the active distribution of **decision-making rights** and **accountability** among different stakeholders in an organization. It also describes the rules and procedures for making and monitoring those decisions to determine and achieve the desired behaviors and results.

- IT governance enables the service provider to:
  - Ensure IT resources are implemented and used according to policies and procedures
  - Ensure the resources are properly controlled and maintained
  - Ensure the resources are providing value to the organization
- Instituting IT governance involves establishing a review board

Organization

New Roles in Cloud

Service Manager

- Key interface between clients and IT staff
- Understands consumers' needs and industry trends
- Ensures IT delivers cost-competitive services
- Manages consumers' expectations of product offerings

Account Manager

- Supports service managers in service planning, development, and deployment

Cloud Architect

- Creates detailed designs for the cloud infrastructure

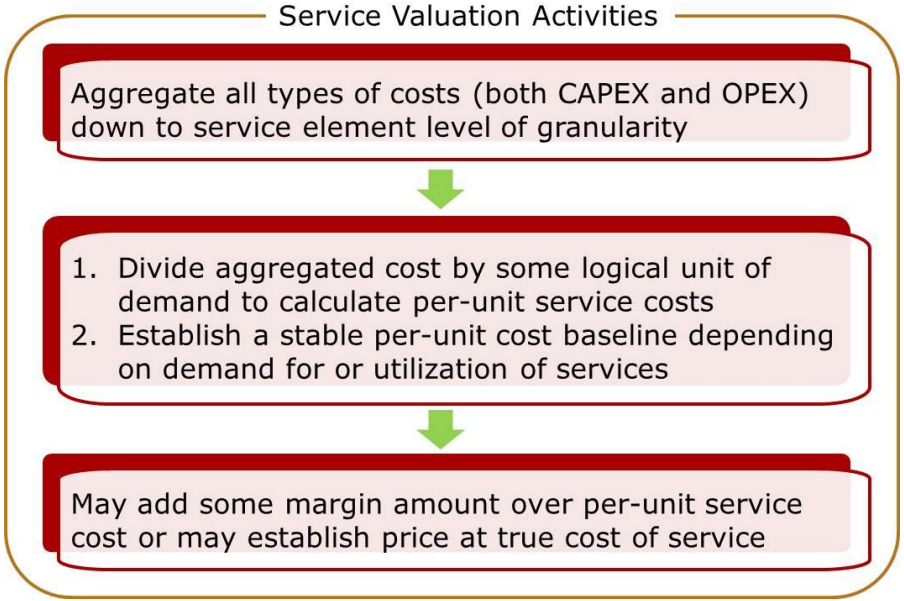
Service Operations Manager

- Streamlines service delivery and execution
- Coordinates with architecture team to define technology roadmaps and ensure SLOs are met

Finance

Service Valuation

- Determines the price (or chargeback) that a service consumer is expected to pay to meet the provider's business goal



- Recovery of cost
- Profit
- ROI goal
- Reinvestment goal

ROI- Return on Interest; CAPEX: Capital Expenditure; OPEX: Operational Expenditure

Finance

Chargeback Models

- Define how consumers need to pay for the consumed services

Model	Description
Pay-as-you-go	• Metering and pricing is based on consumption of resources • Consumers do not pay for unused resources
Subscription by time	• Cost of providing a service for a subscription period is divided among a predefined number of consumers
Subscription by peak usage	• Consumers are billed according to their peak usage of IT resources for a subscription period
Fixed cost or pre-pay	• Consumers commit needed resources upfront for committed period • Consumers pay fixed charge periodically through a billing cycle regardless of the utilization of resources
User-based	• Billing is based on the number of users logged in

Tools

- Tools play an important role in building a cloud infrastructure:
  - Virtualization and orchestration software
  - Security and business continuity software
  - Self-service portal software
- Other tools that should be considered specially when deploying hybrid cloud, community cloud, or brokerage service:
  - Cloud integration tools
  - Application Programing Interface (API)
  - Specialized connection
  - Transformation and business logic programs

Tools

- **Virtualization Software**

Virtualization software allows multiple virtual machines (VMs) or environments to run on a single physical machine by abstracting hardware resources.

- **VMware vSphere**
- **Microsoft Hyper-V**
- **Oracle VirtualBox**
- **KVM (Kernel-based Virtual Machine)**
- **Citrix XenServer**

- **Orchestration Software**

Orchestration software automates the coordination and management of complex IT tasks, including provisioning, configuration, and lifecycle management of applications and services in a cloud environment.

- **Kubernetes** (for container orchestration)
- **OpenStack Heat**
- **Apache Mesos**
- **Terraform** (Infrastructure as Code tool)
- **Cloudify**

Tools

- **Security Software**

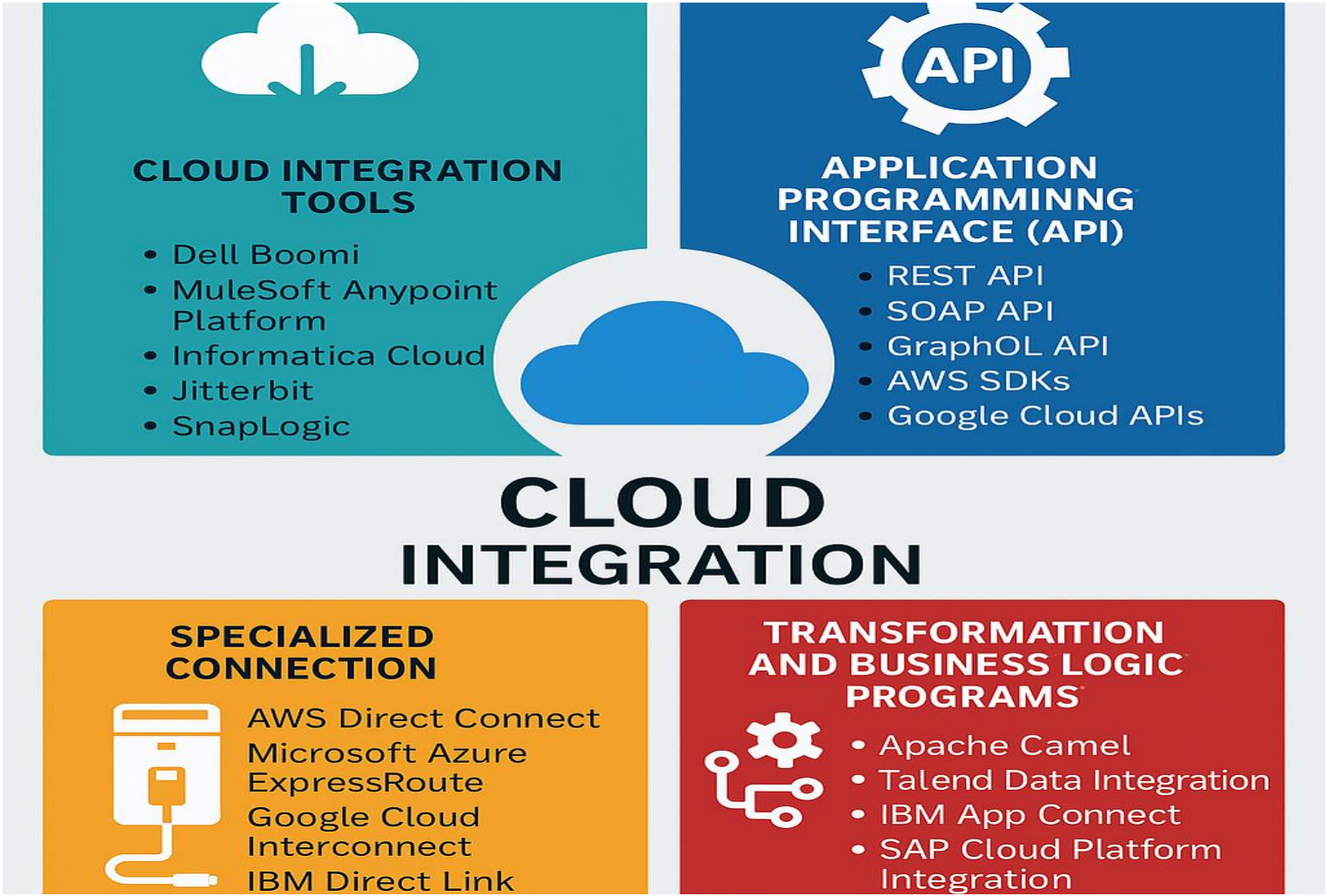
Security software ensures data protection, compliance, and access control in a cloud environment.

- **Symantec Cloud Workload Protection**
- **McAfee Cloud Security**
- **Trend Micro Deep Security**
- **Palo Alto Prisma Cloud**
- **AWS Identity and Access Management (IAM)**
- **Azure Security Center**

- **Business Continuity (BC) Software**

BC software helps ensure **service availability and disaster recovery** in case of failures or disasters.

- **Veeam Backup & Replication**
- **Zerto**
- **Acronis Cyber Protect**
- **Commvault**
- **Carbonite**
- **Azure Site Recovery**
- **AWS Elastic Disaster Recovery**


CLOUD INTEGRATION TOOLS
• Dell Boomi
• MuleSoft Anypoint Platform
• Informatica Cloud
• Jitterbit
• SnapLogic
API
APPLICATION PROGRAMMINNG INTERFACE (API)
• REST API
• SOAP API
• GraphOL API
• AWS SDKs
• Google Cloud APIs
CLOUD INTEGRATION
SPECIALIZED CONNECTION
AWS Direct Connect
Microsoft Azure ExpressRoute
Google Cloud Interconnect
IBM Direct Link
TRANSFORMATTION AND BUSINESS LOGIC PROGRAMS
• Apache Camel
• Talend Data Integration
• IBM App Connect
• SAP Cloud Platform Integration

Service-level Agreement and Legal Contract

Service-level Agreement

A contract negotiated between a provider and a consumer that specifies various parameters and metrics such as cost, service availability, maintenance schedules, performance levels, service desk response time, and consumer's and provider's responsibilities.

- Key points that must be included in a legal contract are:
  - Business level policies such as data privacy, data ownership, security, and jurisdiction
  - Availability and performance metrics
  - Disaster Recovery plan, exit plan, and penalties for not meeting SLA
  - How unexpected incidents and prolonged service outage will be handled

Avoid Vendor Lock-in

Vendor Lock-in

A situation where a consumer is unable to move readily from the current provider to another.

- Causes for vendor lock-in includes:
  - High migration cost
  - Application requires significant re-engineering for migration
  - Lack of open standards
  - Restrictions or burdensome penalties imposed by the current provider
- Vendor lock-in can be prevented by:
  - Using open standard tools, APIs, and file formats
  - Including appropriate exit clause in the agreement

Software Licensing Concerns

- Typically, relevant to IaaS and PaaS models
- Consumers can use their existing license if it is cloud enabled
- If consumer's existing license is not cloud enabled then:
  - Paying additional fees may get their license cloud enabled
  - May use software provided by the service provider
- Providers must work to understand the software license rights and its usage:
  - Prevents any non-compliance and violation of license agreements

Considerations for SaaS

- Software as a Service:
  - Ensures the software offered are thoroughly tested
  - Ensures the new features and functionalities are developed to the software to meet consumer’s needs
  - Ensures applications are scalable and can handle increasingly larger consumer workloads
  - Ensures the applications are resilient and can withstand failures such as
    - Underlying component failure
    - Dependent service failure
  - Ensures the consumers are provided a secure environment

Considerations for PaaS and IaaS

- Platform as a Service:
  - Provides application development platform to the consumers
  - Supports large variety of OS, application development tools, and deployment tools
  - Ensures the consumers are provided a secure environment
  - Provides the consumer the required computing resources to operate the application
- Infrastructure as a Service:
  - Provides the consumer the required infrastructure resources to deploy their OS, application, and data
  - Ensures that the consumers are provided a secure environment

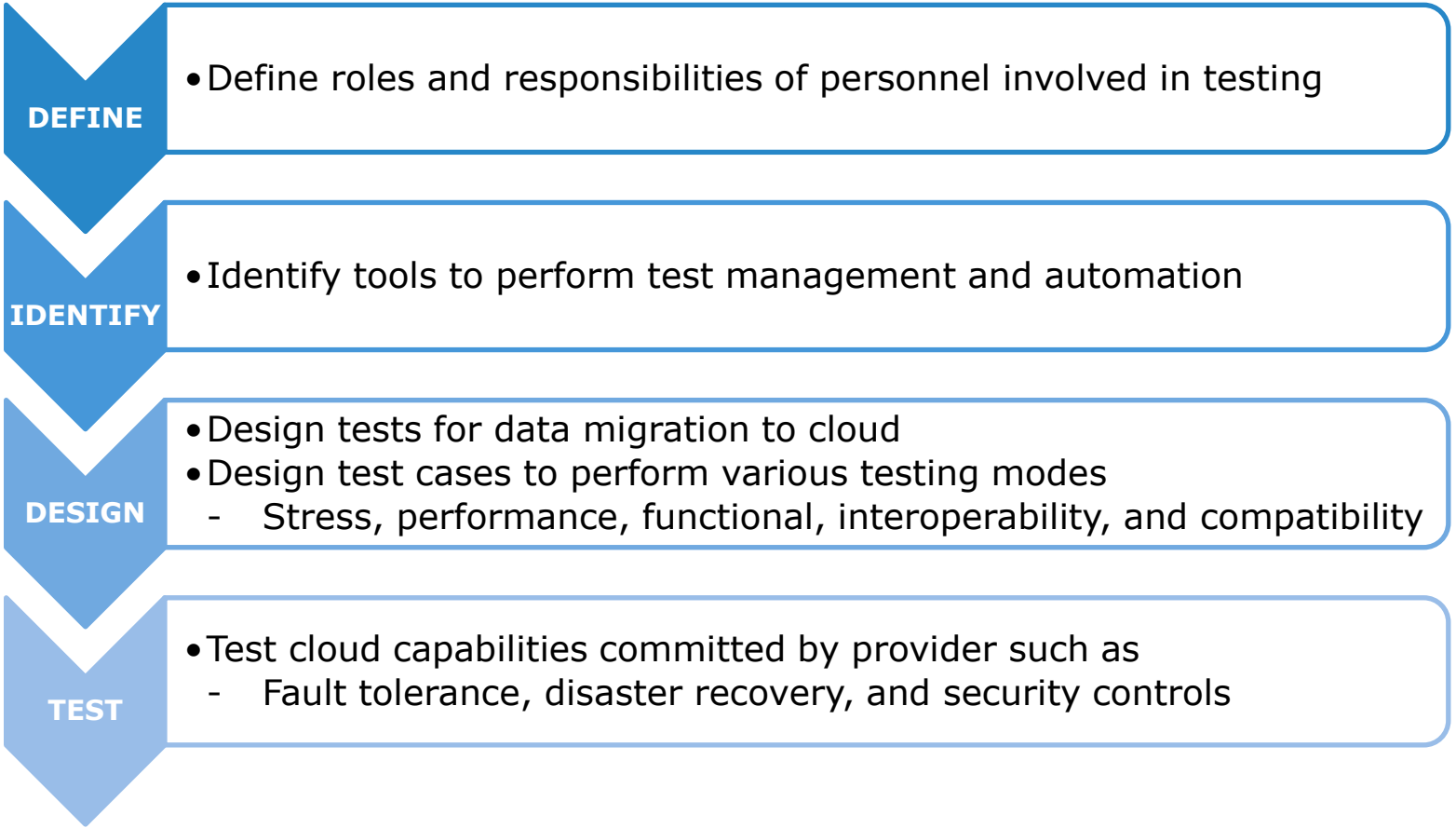
Migration

- Consumer may plan to migrate application or only data
- Two application migration strategies are:

Migration Strategy	Description
Forklift	• Entire application is migrated at once instead of in parts • Good for tightly coupled or self contained applications
Hybrid migration strategy	• Applications and its components are moved in parts • Lower-risk approach to migrate applications to the cloud • Good for application that have loosely coupled components

- For migrating data to cloud:
  - Consider copying data to cloud using replication technology
  - Consider factors such as network bandwidth, data security and integrity, and jurisdiction

Testing


DEFINE
• Define roles and responsibilities of personnel involved in testing
IDENTIFY
• Identify tools to perform test management and automation
DESIGN
• Design tests for data migration to cloud
• Design test cases to perform various testing modes
- Stress, performance, functional, interoperability, and compatibility
TEST
• Test cloud capabilities committed by provider such as
- Fault tolerance, disaster recovery, and security controls

Lesson Summary

During this lesson the following topics were covered:

- Governance and organization considerations
- Finance and tools considerations
- SLAs and vendor lock-in considerations
- Software and licensing considerations
- Considerations for service models
- Migration and testing considerations

Module Summary

Key points covered in this module:

- Cloud computing reference model
- Greenfield and brownfield deployment options
- Best-of-breed cloud infrastructure components
- Cloud-ready converged infrastructure
- Key factors to consider while building a cloud infrastructure

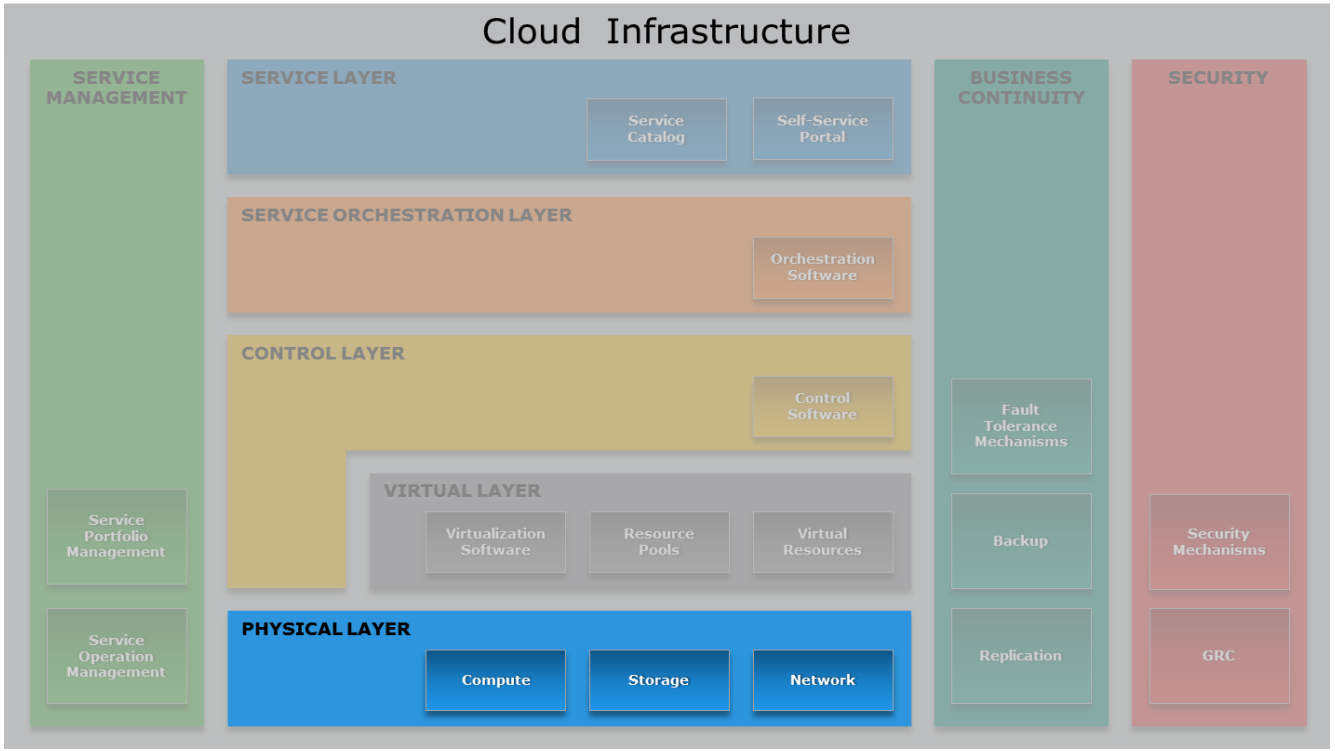
Unit-2 Module: Physical Layer

Upon completion of this module, you should be able to:

- Describe compute system components and types
- Describe storage system architectures
- Describe network connectivity and the types of network communication

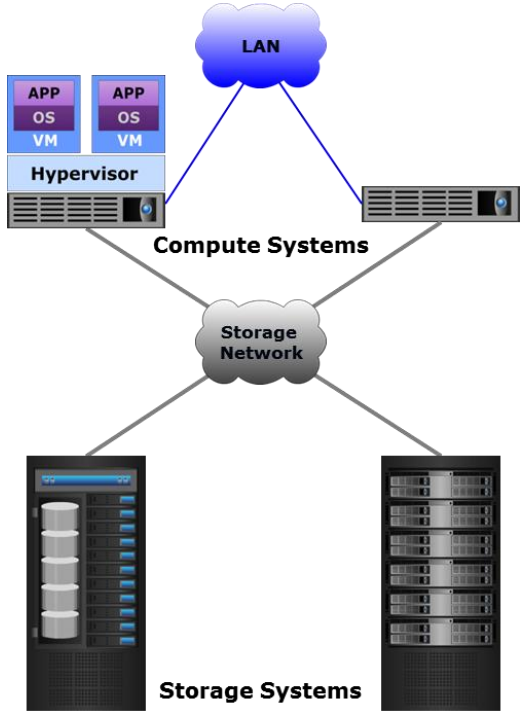
Cloud Computing Reference Model

Physical Layer



Physical Layer Overview

- The physical layer comprises physical compute, storage, and network resources
- Compute systems execute software of providers and consumers
- Storage systems store business and application data
- Networks connect compute systems with each other and with storage systems
  - Networks also connect multiple data centers or multiple clouds to one another



Lesson: Compute System

This lesson covers the following topics:

- Key components of a compute system
- Software deployed on compute systems
- Types of compute systems

Introduction to Compute System

- A computing platform (hardware, firmware, and software) that runs platform and application software
  - Executes the provider's as well as the consumers' software
  - Typically x86-based servers or hosts
- Compute systems are provided to consumers in two ways:
  - Shared hosting: Multiple consumers share compute systems
  - Dedicated hosting: Individual consumers have dedicated compute systems
- Typically providers use compute virtualization and offer compute systems in the form of virtual machines

Key Components of a Compute System

Processor	• An IC that executes software programs by performing arithmetical, logical, and input/output operations
Random-Access Memory	• A volatile data storage device containing the programs for execution and the data used by the processor
Read-Only Memory	• A semiconductor memory containing boot, power management, and other device-specific firmware
Motherboard	• A PCB that holds the processor, RAM, ROM, network and I/O ports, and other integrated components, such as GPU and NIC
Chipset	• A collection of microchips on a motherboard to manage specific functions, such as processor access to RAM and to peripheral ports

Software Deployed on Compute Systems

Self-service portal	• Enables consumers to view and request cloud services
Platform software	• Includes the software that the provider offers through PaaS
Application software	• Includes the applications that the provider offers through SaaS
Virtualization software	• Enables resource pooling and creation of virtual resources
Cloud management software	• Enables a provider to manage the cloud infrastructure and services
Consumer software	• Includes a consumer's platform software and business applications

Types of Compute Systems

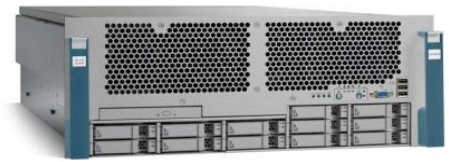
- Tower compute system
- Rack-mounted compute system
- Blade compute system

Tower Compute System

- Built in an upright enclosure called a “tower”
- Has integrated power supply and cooling
- A group of towers occupies significant floor space, requires complex cabling, and generates noise from cooling units
- Deploying in large environments may involve substantial expenditure

Rack-mounted Compute System

- Designed to be fixed on a frame called a "rack"
  - A rack is a standardized enclosure with mounting slots for vertically stacking compute systems
- Simplifies network cabling, consolidates network equipment, and reduces floor space use
- Administrators may use a console mounted on the rack to manage the compute systems



Blade Compute System

- Comprises an electronic circuit board with only the core processing components
- Multiple blades are housed in a blade chassis
  - The chassis provides integrated power supply, cooling, networking, and management
- Blades are interconnected via a high speed bus
- Modular design increases compute system density and scalability

Lesson Summary

During this lesson the following topics were covered:

- Key components of a compute system
- Software deployed on compute systems
- Types of compute systems: tower, rack-mounted, and blade

Lesson: Storage System

This lesson covers the following topics:

- Types of storage devices
- Redundant Array of Independent Disks (RAID)
- Storage system architectures

Introduction to Storage System

- A storage system is the repository for saving and retrieving electronic data
- Providers offer storage capacity along with compute systems, or as a service
  - Storage as a Service enables data backup and long-term data retention
- Cloud storage provides massive scalability and rapid elasticity of storage resources
- Typically, a provider uses virtualization to create storage pools that are shared by multiple consumers

Types of Storage Devices

Magnetic disk drive	• Stores data on a circular disk with a ferromagnetic coating • Provides random read/write access • Most popular storage device with large storage capacity
Solid-state (flash) drive	• Stores data on a semiconductor-based memory • Very low latency per I/O, low power requirements, and very high throughput
Magnetic tape drive	• Stores data on a thin plastic film with a magnetic coating • Provides only sequential data access • Low-cost solution for long term data storage
Optical disc drive	• Stores data on a polycarbonate disc with a reflective coating • Write Once and Read Many capability: CD, DVD, BD • Low-cost solution for long-term data storage

Redundant Array of Independent Disks (RAID)

RAID

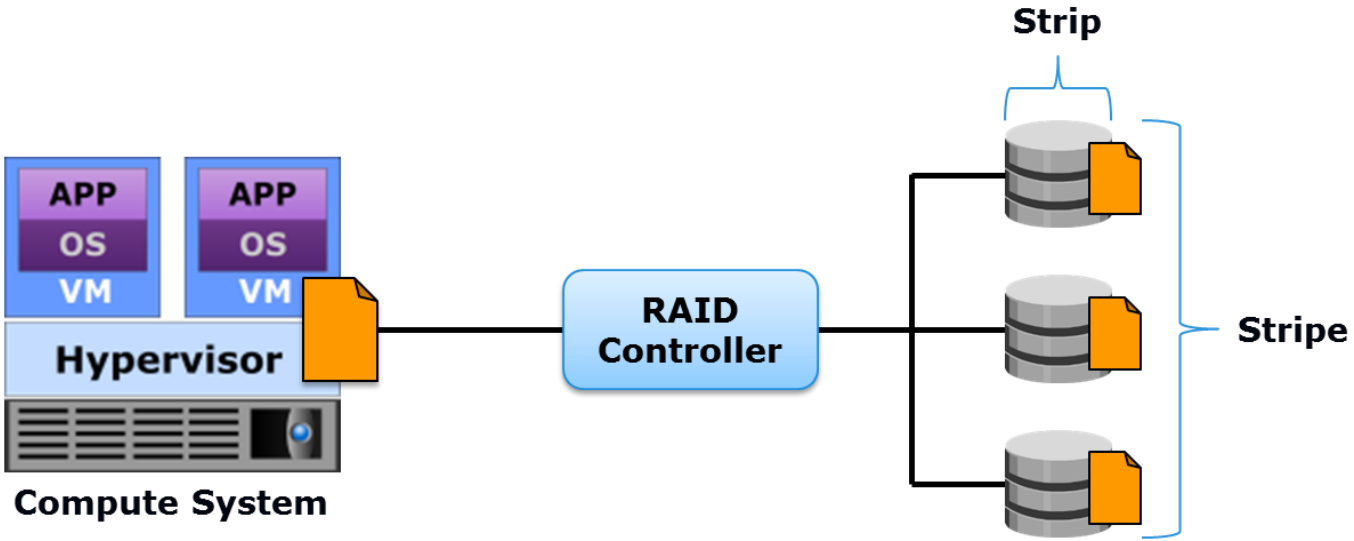
A storage technology in which data is written in blocks across multiple disk drives that are combined into a logical unit called a RAID group.

- Improves storage system performance by serving I/Os from multiple drives simultaneously
- Provides data protection against drive failures
- Three key techniques used for RAID: striping, mirroring, and parity

RAID Technique: Striping

Striping

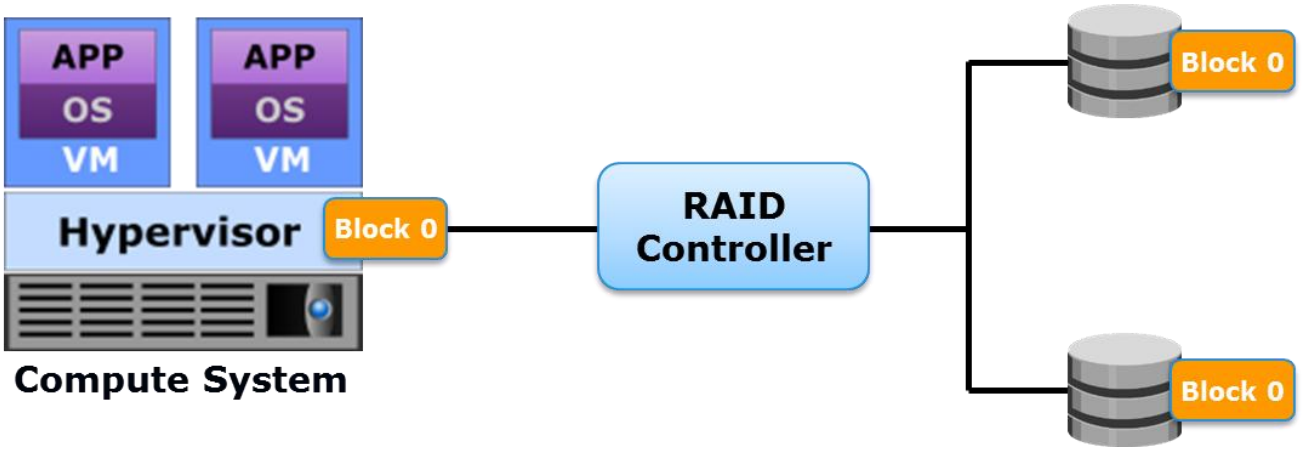
A RAID technique to spread data across multiple drives in order to use the drives in parallel.



RAID Technique: Mirroring

Mirroring

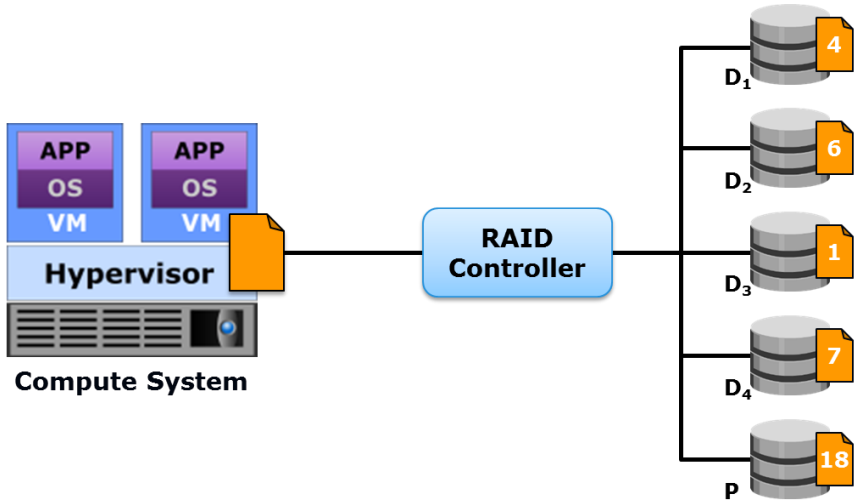
A RAID technique to store the same data simultaneously on two different drives, yielding two copies of the data.



RAID Technique: Parity

Parity

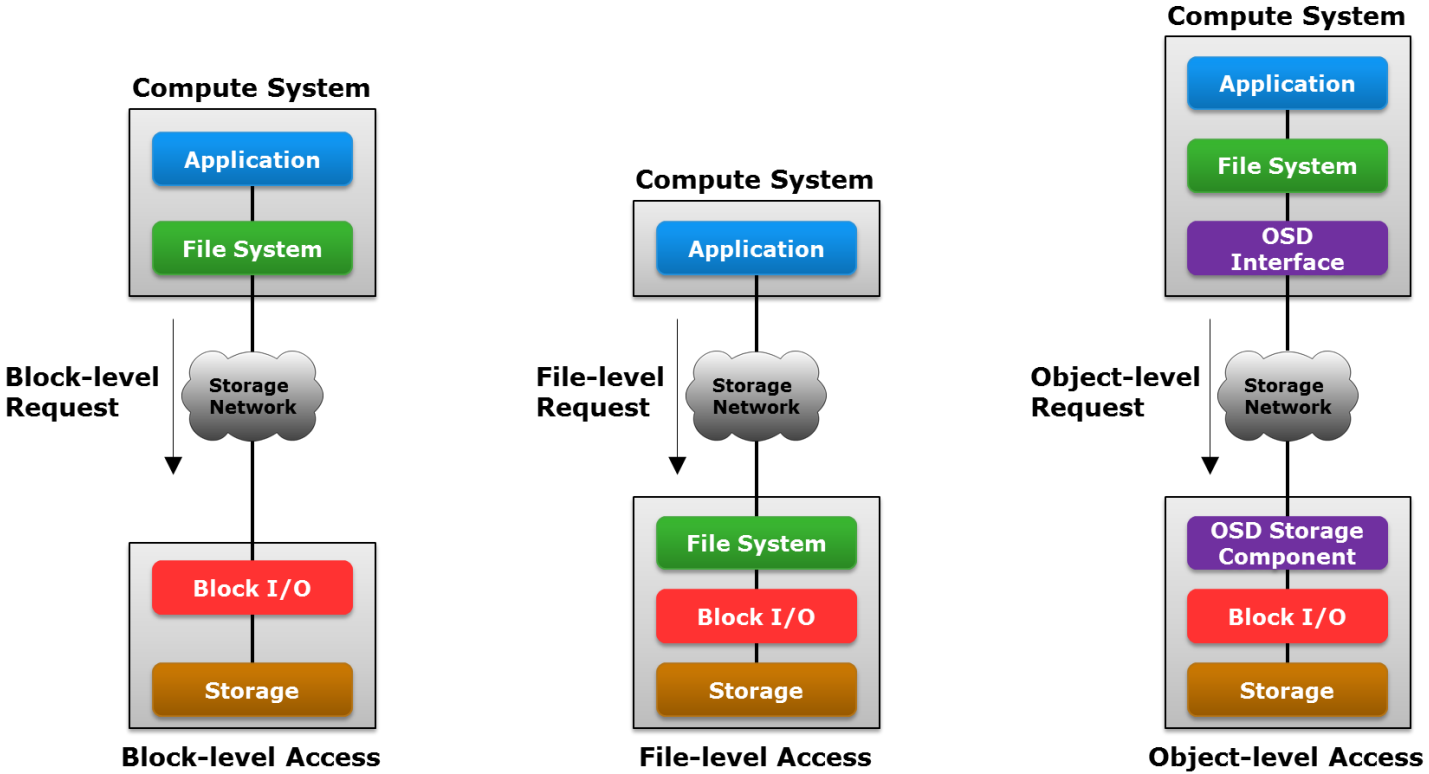
A RAID technique to protect striped data from drive failure by performing a mathematical operation on individual strips and storing the result on a portion of the RAID group.



Common RAID Levels

RAID 0	• Striped set with no fault tolerance
RAID 1	• Disk mirroring
RAID 1+0	• Nested RAID (striping and mirroring)
RAID 3	• Striped set with parallel access and a dedicated parity disk
RAID 5	• Striped set with independent disk access and distributed parity
RAID 6	• Striped set with independent disk access and dual distributed parity

Data Access Methods

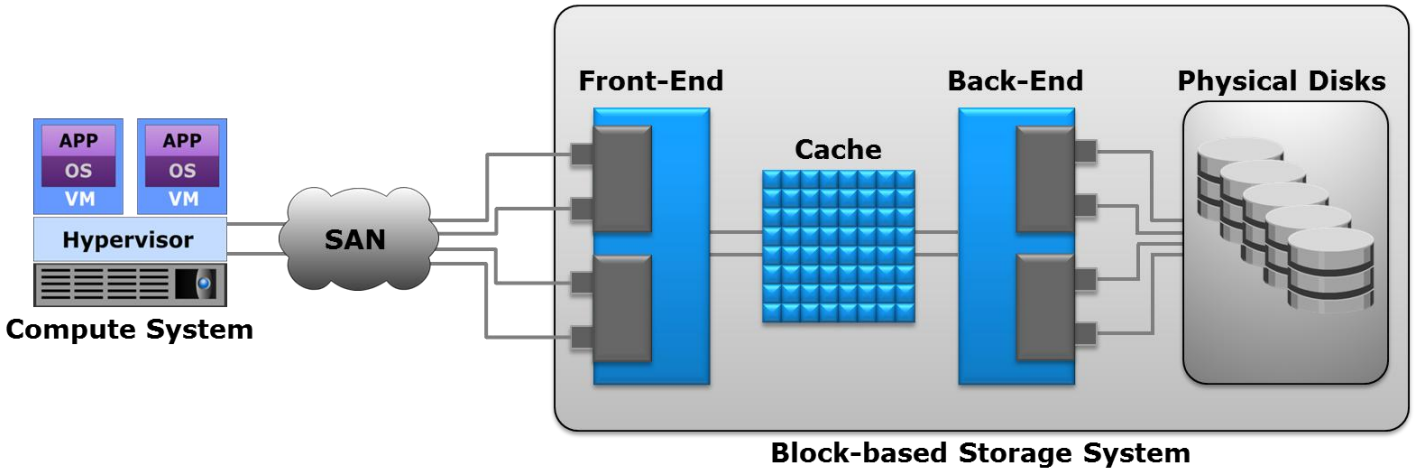


Storage System Architecture

- Storage system architectures are based on the data access methods
- Common storage system options are:
  - Block-based
  - File-based
  - Object-based
  - Unified

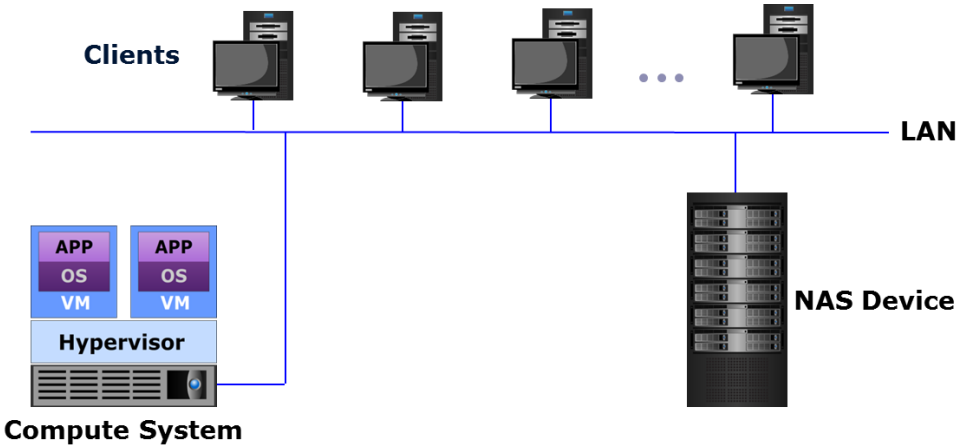
Block-based Storage System

- Enables creating and assigning storage volumes to compute systems
  - Compute system discovers the volumes as local drives
  - Required file system can be created on the volumes



File-based Storage System

- A dedicated, high performance file server with storage (also known as Network-attached Storage)
- Enables clients to share files over an IP network
  - Supports data sharing for UNIX and Windows users
- Uses a specialized OS that is optimized for file I/O

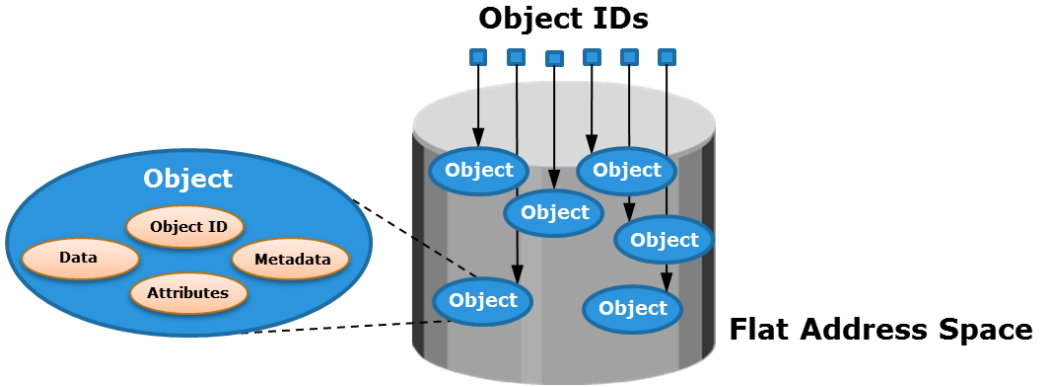


NAS Deployment Options

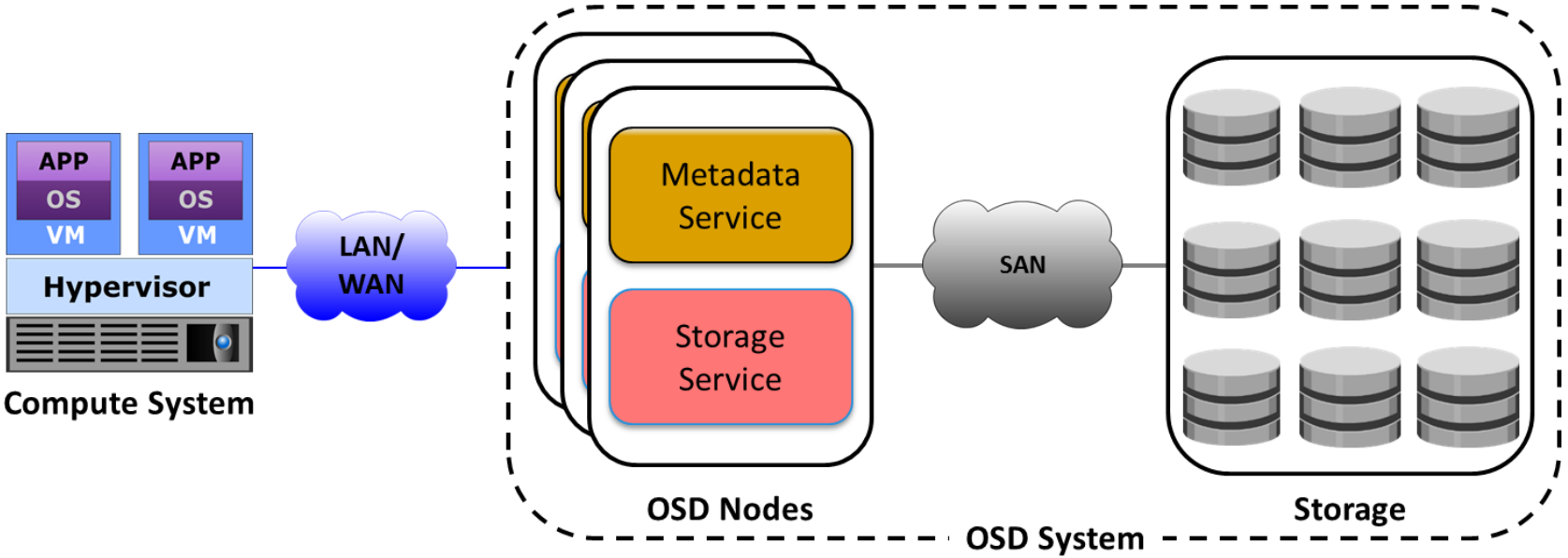
- The two common NAS deployment options are:
  - Traditional NAS (scale-up NAS)
  - Scale-out NAS
- Traditional NAS
  - Capacity and performance of a single system is scaled by upgrading or adding NAS components
- Scale-out NAS
  - Multiple processing and storage nodes are pooled in a cluster that works as a single NAS device
  - Addition of nodes scales cluster capacity and performance without disruption

Object-based Storage System

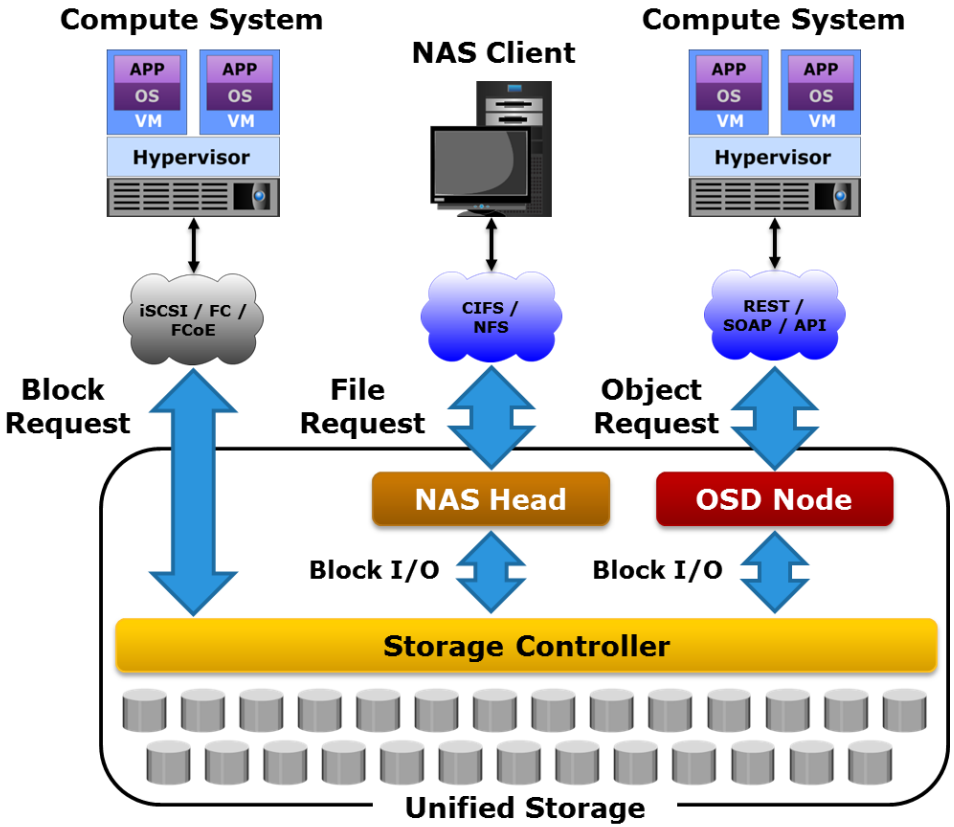
- Stores file data in the form of objects based on data contents and attributes
  - Uses a flat, non-hierarchical address space
- Object contains user data, related metadata, and user-defined attributes
  - Objects are uniquely identified using object ID



Object-based Storage System (Cont'd)



Unified Storage System



Lesson Summary

During this lesson the following topics were covered:

- Types of persistent data storage devices
- RAID and RAID techniques: striping, mirroring, and parity
- Storage system architectures: block-based, file-based, object-based, and unified

Lesson: Network

This lesson covers the following topics:

- Types of network communication
- Compute-to-compute communication
- Compute-to-storage communication
- Storage area network (SAN) classification
- Inter-cloud communication

Introduction to Networking

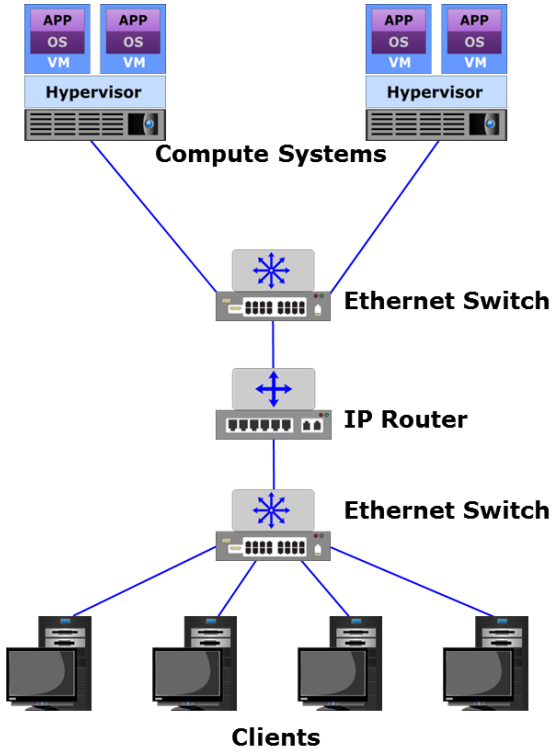
- Networking enables data transfer and sharing of IT resources between nodes across geographic regions
- Cloud consumers require a reliable and secure network to connect to a cloud and access cloud services
- Network connectivity also enables resource aggregation and service mobility across cloud data centers
- Multiple clouds may be inter-connected to enable workloads to be moved or distributed
  - For example: cloud bursting in a hybrid cloud model

Types of Network Communication

- Based on the nodes connected by a network, the network communication is broadly categorized as:
  - Compute-to-compute communication
  - Compute-to-storage communication
  - Inter-cloud communication

Compute-to-compute Communication

- Interconnecting physical compute systems enables compute-to-compute communication
- Compute-to-compute communication typically uses IP-based protocols
- Compute systems connect to a network through physical network card(s)
- Physical switches and routers are common interconnecting devices



Compute-to-storage Communication

Storage Area Network (SAN)

A network that interconnects storage systems with compute systems, enabling the compute systems to access and share the storage systems.

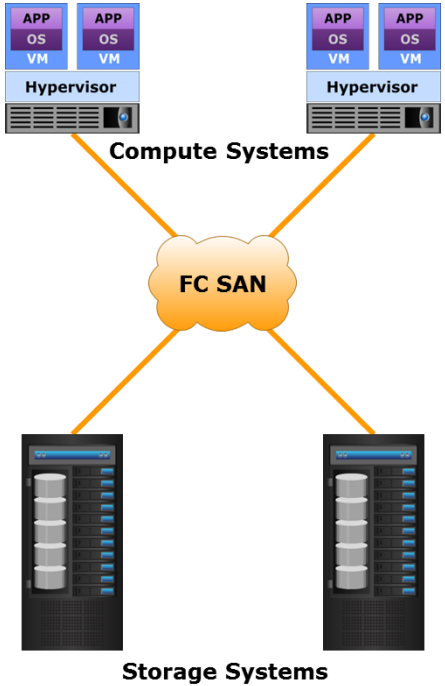
- Based on the protocols they support, SANs can be classified as:
  - Fibre Channel SAN (FC SAN)
  - Internet Protocol SAN (IP SAN)
  - Fibre Channel over Ethernet SAN (FCoE SAN)

FC SAN

FC SAN

A SAN that uses Fibre Channel (FC) protocol to transport data, commands, and status information between compute and storage systems.

- FC provides block-level access to storage
- FC offers data transfer speeds up to 16 Gbps
- Theoretically, an FC SAN can connect approximately 15 million nodes



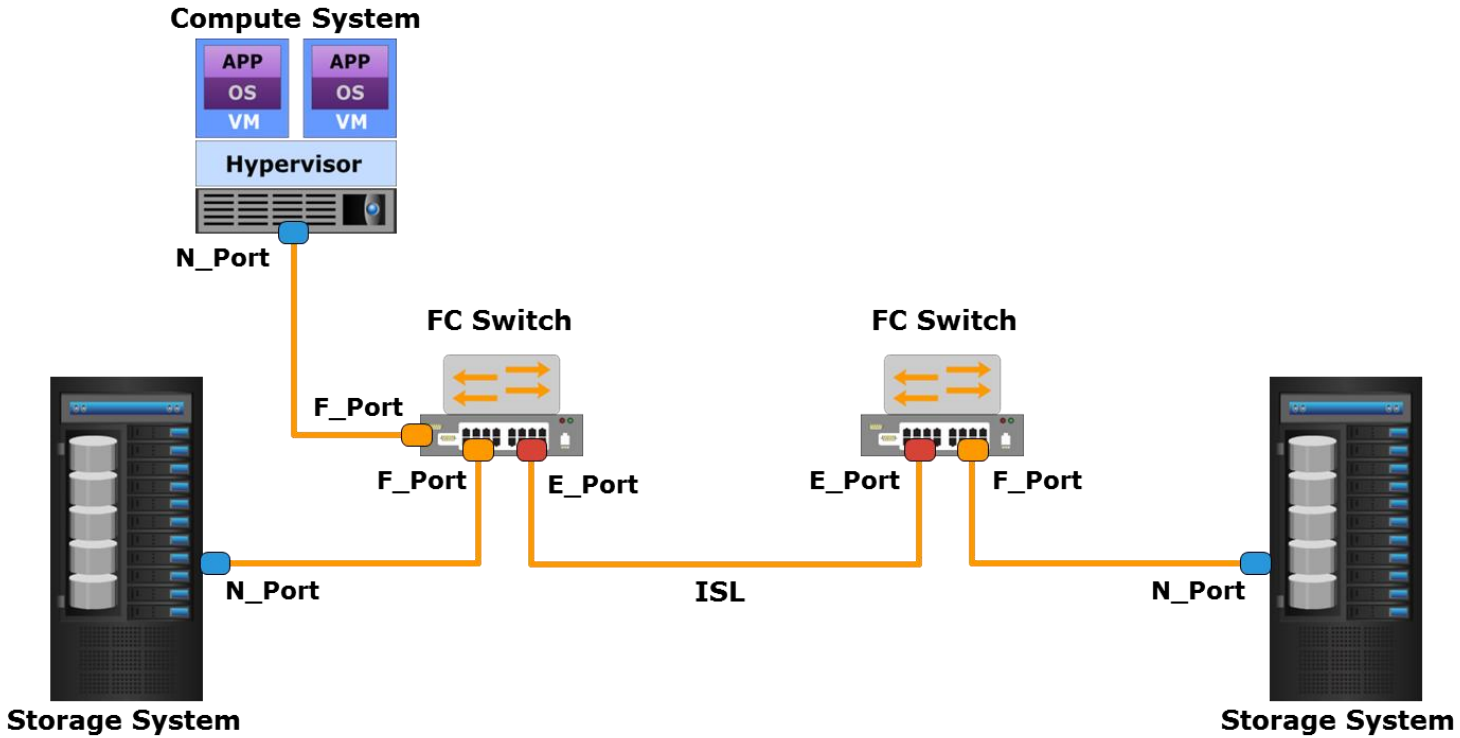
FC SAN Components

Network adapters	• Provide physical interface to a node for communicating with other nodes • Examples: FC HBAs and storage system front-end adapters
Cables and connectors	• Optical fiber cables are predominantly used to provide connectivity • Connectors enable cables to be swiftly connected to and disconnected from ports
Interconnecting devices	• FC switches and directors • Directors have a modular design, a higher port count, and better fault-tolerance • Switches either have a fixed port count or a modular design

Fabric Connect and Addressing

- A fabric created with FC switches connects all nodes and enables them to communicate
- Each switch in a fabric contains a unique domain identifier (ID)
- Each network adapter is physically identified by a 64-bit World Wide Node Name (WWNN)
- Each adapter port is physically identified by a 64-bit World Wide Port Name (WWPN)
- Each adapter port in a fabric has a unique 24-bit FC address
  - Fabric assigns FC addresses to adapter ports dynamically

Fabric Port Types



Zoning

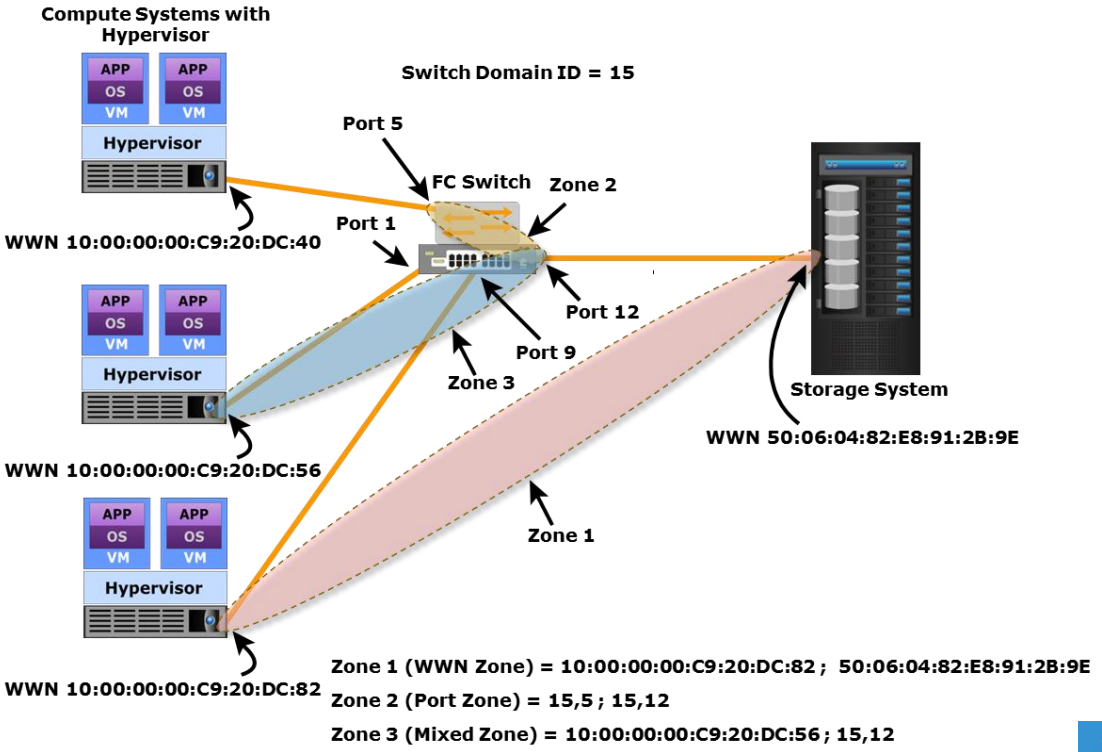
Zoning

An FC switch function that enables node ports within a fabric to be logically segmented into groups and to communicate with each other within the group.

- Both node ports and switch ports can be zone members
- Benefits:
  - Provides access control
  - Restricts RSCN traffic

Types of Zoning

- WWN zoning
- Port zoning
- Mixed zoning



IP SAN

IP SAN

A SAN that uses Internet Protocol (IP) for the transport of storage traffic. It transports block I/O over an IP-based network.

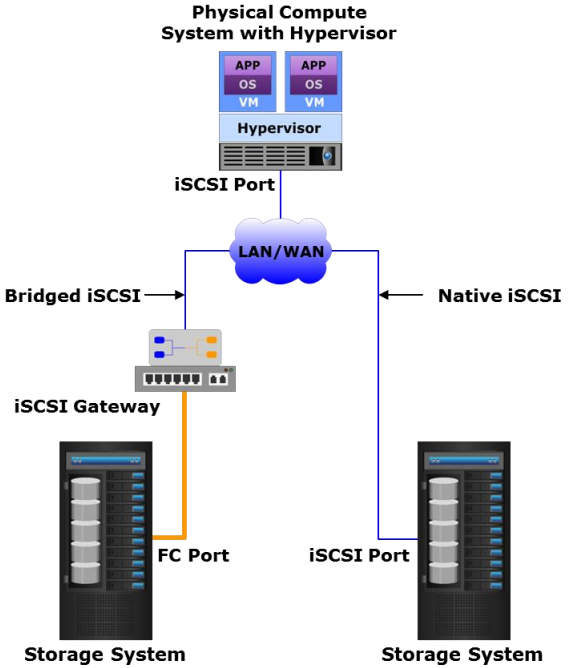
- Key drivers of IP SAN are:
  - Leveraging an existing IP-based network instead of building a new FC SAN infrastructure
  - Many robust, mature security options are available for IP networks
  - Many long-distance, disaster recovery (DR) solutions already leverage IP-based networks
- Two primary IP SAN protocols are: iSCSI and FCIP

iSCSI Networking

iSCSI

iSCSI encapsulates SCSI commands and data into IP packets that are transported over an IP-based network.

- iSCSI network components are:
  - iSCSI initiators
    - Example: iSCSI HBA
  - iSCSI targets
    - Example: storage system with iSCSI port (Native iSCSI)
    - Example: iSCSI gateway (Bridged iSCSI)
  - IP-based network



iSCSI Name

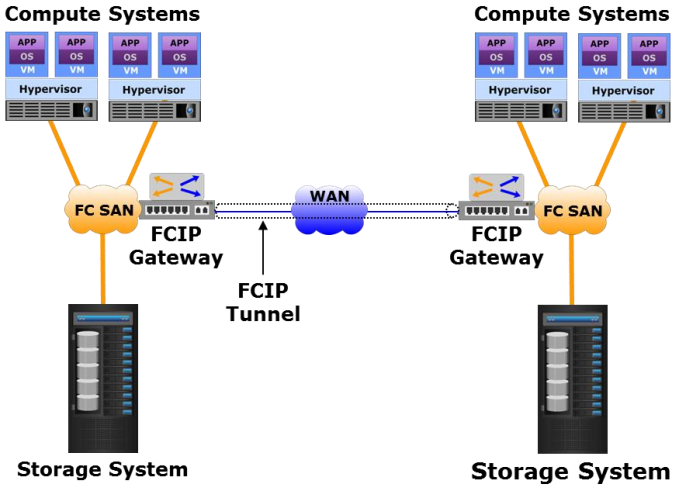
- iSCSI name is a unique iSCSI identifier that identifies initiators and targets in an iSCSI network
- The two common types of iSCSI names are:
  - iqn: iSCSI Qualified Name
    - Example: iqn.2014-02.com.example:*optional_string*
  - eui: Extended Unique Identifier
    - Example: eui.0300732A32598D26

FCIP Networking

FCIP

FCIP is an encapsulation of FC frames into IP packets that are transported between disparate FC SANs over an IP-based network through FCIP tunnel.

- An FCIP entity (e.g. FCIP gateway) exists at either end of an FCIP tunnel
  - Encapsulates FC into IP
  - Transfers IP packets to remote gateway
  - Decapsulates FC from IP
- Widely used in disaster recovery implementations



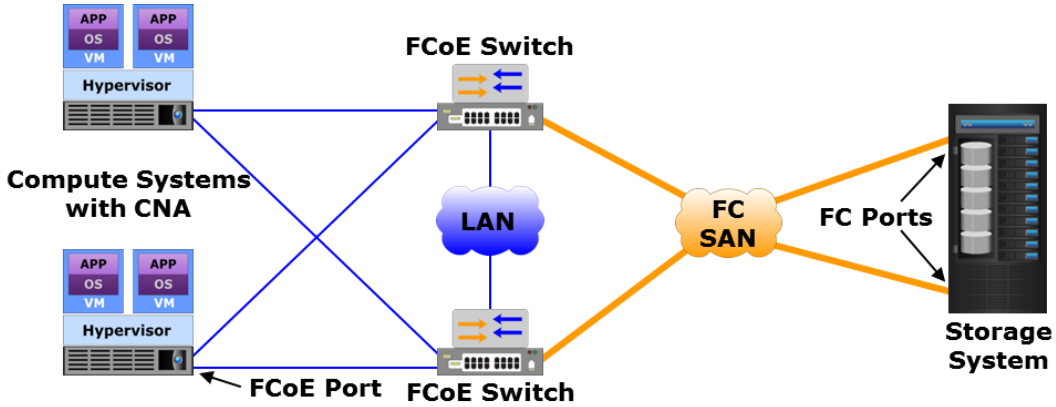
FCoE SAN

FCoE SAN

A converged enhanced Ethernet (CEE) network that uses the FCoE protocol to transport FC data along with regular Ethernet traffic over high speed Ethernet links. FCoE encapsulates FC frames into Ethernet frames.

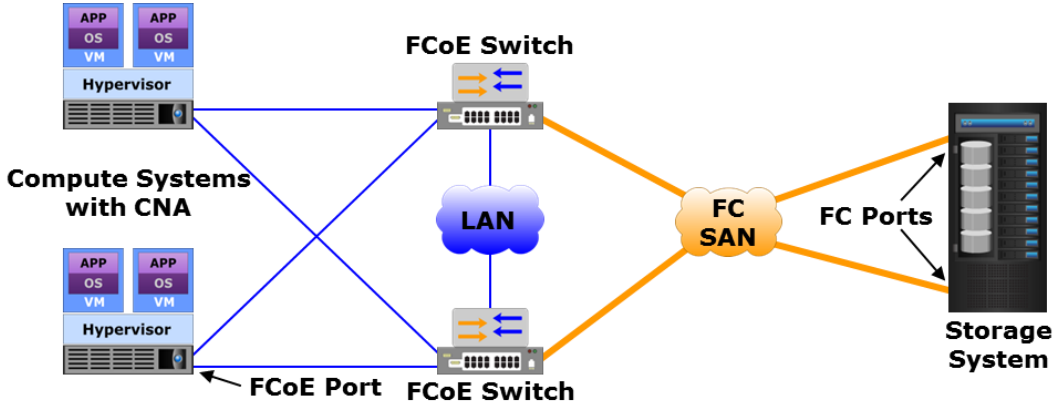
- Transfers both compute-to-compute and FC storage traffic using the same network components
  - Reduces complexity of managing multiple discrete networks
  - Reduces the number of adapters, cables, and switches, along with power and space consumption required in a data center
- Based on an enhanced Ethernet standard that ensures lossless transmission of FC traffic over Ethernet

FCoE SAN Components: CNA and S/W FCoE Adapter



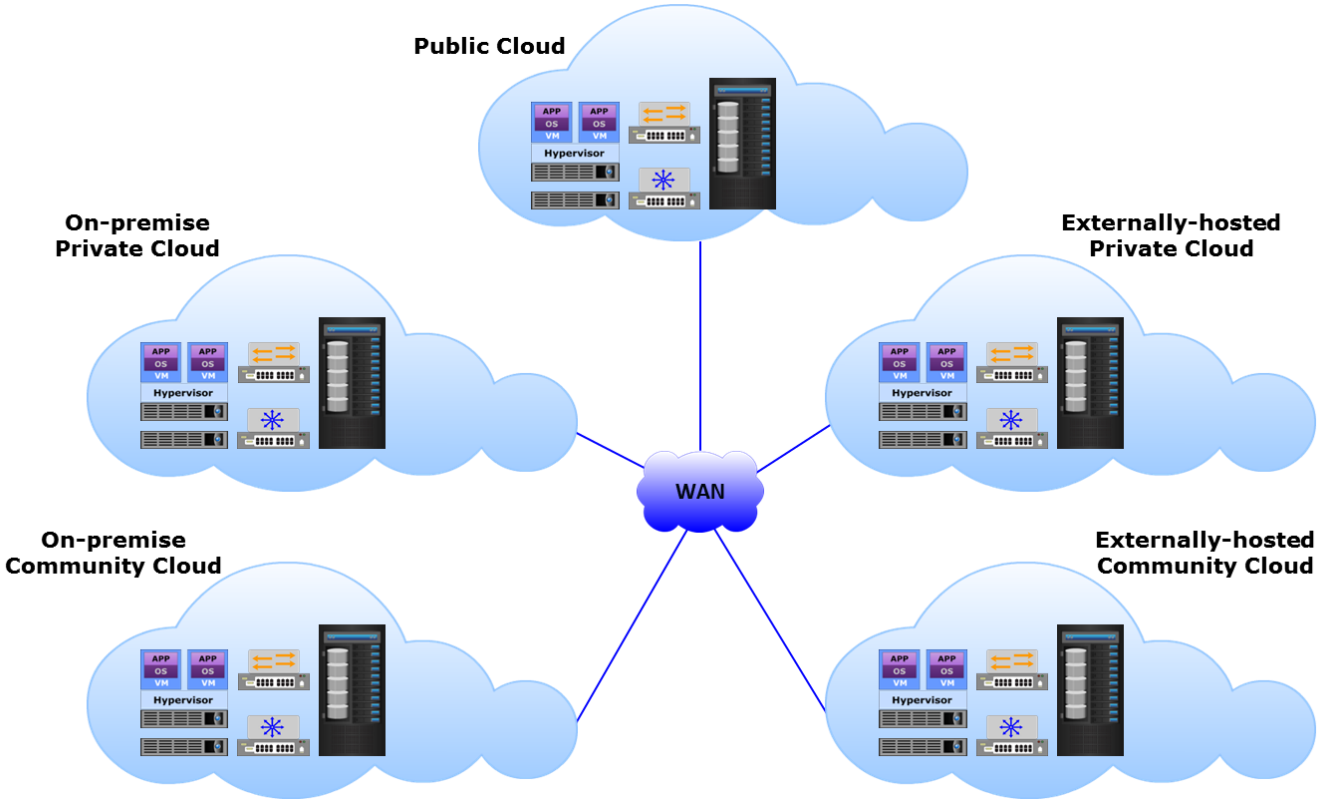
Component	Description
Converged network adapter (CNA)	• Provides functionality of both NIC and FC HBA in a single device • Encapsulates FC traffic onto Ethernet frames (FCoE traffic) • Consolidates both FC and regular Ethernet traffic over CEE links
Software FCoE adapter	• A software on the compute system performs FCoE processing • Supported NICs transfer both FCoE and regular Ethernet traffic

FCoE SAN Components: FCoE Switch and Storage Port



Component	Description
FCoE switch	• Contains Fibre Channel Forwarder (FCF), Ethernet Bridge, and a set of ports for FC, Ethernet, or FCoE connectivity • FCF encapsulates FC frames into Ethernet frames (FCoE frames) and decapsulates FCoE frames to FC frames
FCoE storage port	• Connects to FCoE switch, enabling end-to-end FCoE environment

Inter-cloud Communication



Lesson Summary

During this lesson the following topics were covered:

- Types of network communication
- Compute-to-compute communication
- Compute-to-storage communication (SAN)
- FC SAN, IP SAN, and FCoE SAN components and architectures
- Inter-cloud communication

Concepts in Practice

- EMC VMAX
- EMC VNX
- EMC ECS Appliance
- EMC Isilon
- EMC Atmos
- EMC XtremIO
- EMC Connectrix

EMC VMAX, EMC VNX, and EMC ECS Appliance

VMAX	VNX	ECS Appliance
• Family of high-end enterprise storage platforms • Block-based storage systems for mission-critical applications • High performance, reliability, availability, and scalability	• Family of unified storage platforms - Consolidates block, file, and object access • Built for SMBs and enterprises • Supports file (NFS and CIFS), FC, iSCSI, and FCoE access	• Hyper-scale storage infrastructure • Supports block, file, object, and HDFS • Provides multi-tenancy, self-service portal, and metering capabilities

EMC Isilon and EMC Atmos

Isilon	Atmos

• Scale-out NAS storage platform
• Enables pooling multiple nodes to construct a clustered NAS system
• OneFS operating environment creates single file system across the cluster
	• Scale-out object-based cloud storage platform
	  - Stores data as objects
	• Seamless scale out
	• Key cloud features include:
	  - Global namespace
	  - REST API-driven storage
	  - Multi-tenancy, metering, and self-service across tenants
	  - Metering and chargeback

EMC XtremIO and EMC Connectrix

XtremIO

- All-flash, block-based, scale-out enterprise storage array
- Uses a clustered design to grow capacity and performance as required
- A powerful OS (XIOS) manages the storage cluster
- Simplified and efficient provisioning and management

Connectrix

- Family of networked storage connectivity products including:
  - Enterprise directors
  - Departmental switches
  - Multi-purpose switches
- Multi-purpose switches support FC, iSCSI, FCIP, and FCoE protocols

Module Summary

Key points covered in this module:

- Compute system components and types
- Types of storage devices, RAID techniques, and storage system architectures
- Network connectivity and the types of network communication