Cloud Computing

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

With cloud computing, users can browse and select relevant cloud services, such as compute, software, storage, or a combination of these resources, via a portal. Cloud computing automates delivery of selected cloud services to the users. It helps organizations and individuals deploy IT resources at reduced total cost of ownership with faster provisioning and compliance adherence.

Cloud Enabling Technologies:

- **Grid computing** is a form of distributed computing that enables the resources of numerous heterogeneous computers in a network to work together on a single task at the same time. Grid computing enables parallel computing and is best for large workloads.
- **Utility computing** is a service-provisioning model in which a service provider makes computing resources available to customers, as required, an charges them based on usage. This is analogous to other utility services, such as electricity, where charges are based on the consumption.
- **Virtualization** is a technique that abstracts the physical characteristics of IT resources from resource users. It enables the resources to be viewed and managed as a pool and lets users create virtual resources from the pool. Virtualization provides better flexibility for provisioning of IT resources compared to provisioning in a non-virtualized environment. It helps optimize resource utilization and delivering resources more efficiently.
- **Service Oriented Architecture (SOA)** provides a set of services that can communicate with each other. These services work together to perform some activity or simply pass data among services.

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Characteristics of Cloud Computing:

1. **On-demand self-service:**

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

A cloud service provider publishes a service catalogue, which contains information about all cloud services available to consumers. The service catalogue includes information about service attributes, prices, and request processes. Consumers view the service catalogue via a web-based user

2. **Broad network access:**

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

3. **Resource pooling:**

The provider's computing resources are pooled to serve multiple consumers using a multitenant 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 (for example, country, state, or data center). Examples of resources include storage, processing, memory, and network bandwidth.

4. **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.

Consumers can leverage rapid elasticity of the cloud when they have a fluctuation in their IT resource requirements. For example, an organization might require double the number of web and application servers for a specific duration to accomplish a specific task. For the remaining period, they might want to release idle server resources to cut down the expenses. The cloud enables consumers to grow and shrink the demand for resources dynamically.

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5. 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 (for example, 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.

Benefits of Cloud Computing:

- **Reduced IT cost:** Cloud services can be purchased based on pay-per-use or subscription pricing. This reduces or eliminates the consumer's IT capital expenditure (CAPEX).
- **Business agility:** Cloud computing provides the capability to allocate and scale computing capacity quickly. Cloud computing can reduce the time required to provision and deploy new applications and services from months to minutes. This enables businesses to respond more quickly to market changes and reduce time-to-market.
- **Flexible scaling:** Cloud computing enables consumers to scale up, scale down, scale out, or scale in the demand for computing resources easily. Consumers can unilaterally and automatically scale computing resources without any interaction with cloud service providers. The flexible service provisioning capability of cloud computing often provides a sense of unlimited scalability to the cloud service consumers.
- **High availability:** Cloud computing has the capability to ensure resource availability at varying levels depending on the consumer's policy and priority. Redundant infrastructure components (servers, network paths, and storage equipment, along with clustered software) enable fault tolerance for cloud deployments. These techniques can encompass multiple data centers located in different geographic regions, which prevents data unavailability due to regional failures.

Cloud Service Models:

1) Infrastructure-as-a-Service
2) Platform-as-a-Service (PaaS)
3) Software-as-a-Service (SaaS

1) Infrastructure-as-a-Service:

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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 and deployed applications; and possibly limited control of select networking components (for example, host firewalls).

IaaS is the base layer of the cloud services stack (see Figure 13-1 [a]). It serves as the foundation for both the SaaS and PaaS layers.

Amazon Elastic Compute Cloud (Amazon EC2) is an example of IaaS that provides scalable compute capacity, on-demand, in the cloud. It enables consumers to leverage Amazon's massive computing infrastructure with no up-front capital investment.

2) **Platform-as-a-Service (PaaS):**

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. (See Figure 13-1 [b]).

PaaS is also used as an application development environment, offered as a service by the cloud service provider. The consumer may use these platforms to code their applications and then deploy the applications on the cloud. Because the workload to the deployed applications varies, the scalability of computing resources is usually guaranteed by the computing platform, transparently. Google App Engine and Microsoft Windows Azure Platform are examples of PaaS.

3) **Software-as-a-Service (SaaS):**

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 (for example, web-based e-mail), 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. (See Figure 13-1[c]).

In a SaaS model, applications, such as customer relationship management (CRM), e-mail, and instant messaging (IM), are offered as a service by the cloud service

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providers. The cloud service providers exclusively manage the required computing infrastructure and software to support these services.

The consumers may be allowed to change a few application configuration settings to customize the applications.

EMC Mozy is an example of SaaS. Consumers can leverage the Mozy console to perform automatic, secured, online backup and recovery of their data with ease. Salesforce.com is a provider of SaaS-based CRM applications, such as Sales Cloud and Service Cloud.

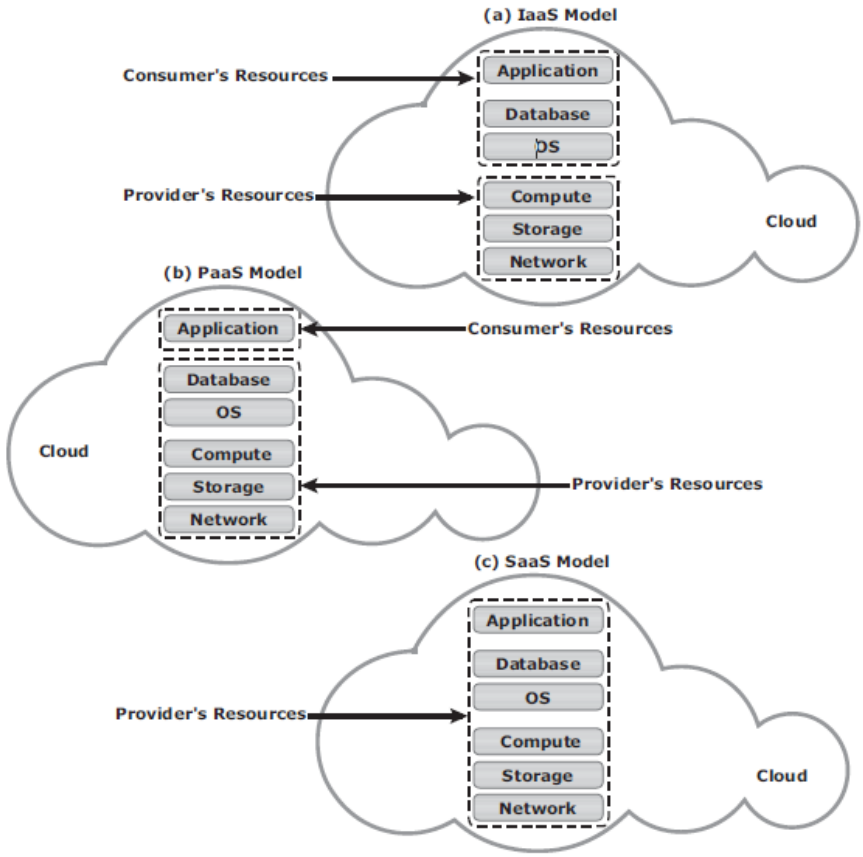

Figure 13-1: IaaS, PaaS, and SaaS models

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Cloud Deployment Models:

1) Public Cloud.
2) Private Cloud.
3) Community Cloud.
4) Hybrid Cloud.

1) Public Cloud:

In a public cloud model, 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.

Consumers use the cloud services offered by the providers via the Internet and pay metered usage charges or subscription fees. An advantage of the public cloud is its low capital cost with enormous scalability. However, for consumers, these benefits come with certain risks: no control over the resources in the cloud, the security of confidential data, network performance, and interoperability issues.

Popular public cloud service providers are Amazon, Google, and Salesforce.com. Figure 13-2 shows a public cloud that provides cloud services to organizations and individuals.

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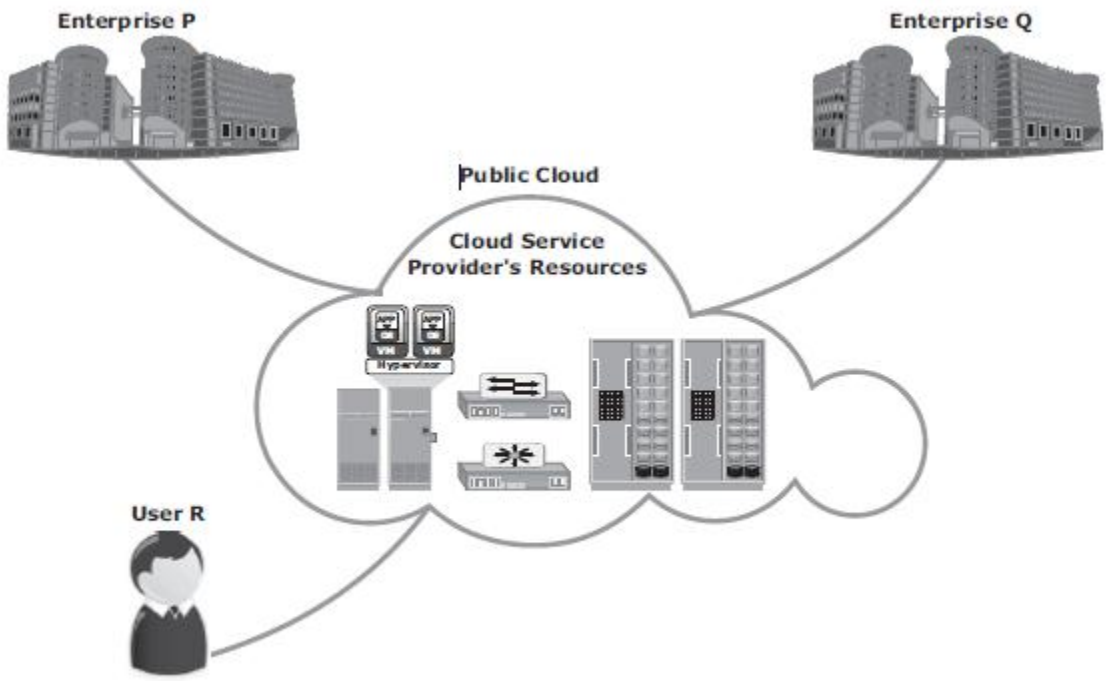

Figure 13-2: Public cloud

2) Private Cloud:

In a private cloud model, 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.

Following are two variations to the private cloud model:

- ***On-premise private cloud***: The on-premise private cloud, also known as internal cloud, is hosted by an organization within its own data centers (see Figure 13-3 [a]). This model enables organizations to standardize their cloud service management processes and security, although this model has limitations in terms of size and resource scalability. Organizations would also need to incur the capital and operational costs for the physical resources. This is best suited for organizations that require complete control over their applications, infrastructure configurations, and security mechanisms.
- ***Externally hosted private cloud:*** This type of private cloud is hosted external to an organization (see Figure 13-3 [b]) and is managed by a thirdparty organization. The third-party organization facilitates an exclusive cloud environment for a specific organization with full guarantee of privacy and confidentiality.

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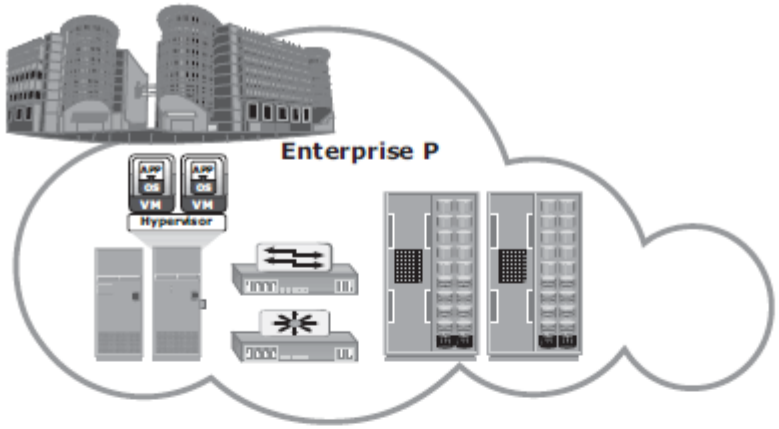
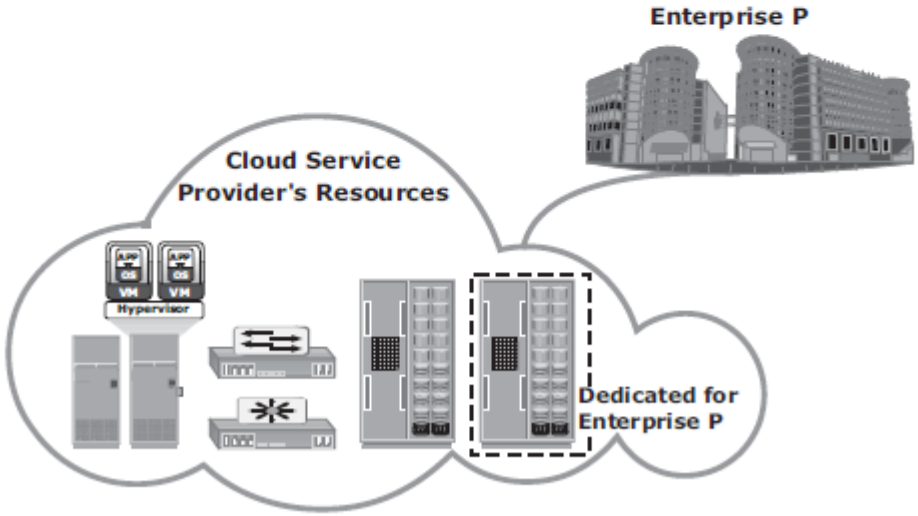


(a) On-Premise Private Cloud



(b) Externally Hosted Private Cloud

Figure 13-3: On-premise and externally hosted private clouds

3) Community Cloud:

In a community cloud model, the cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (for example, 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. (See Figure 13-4).

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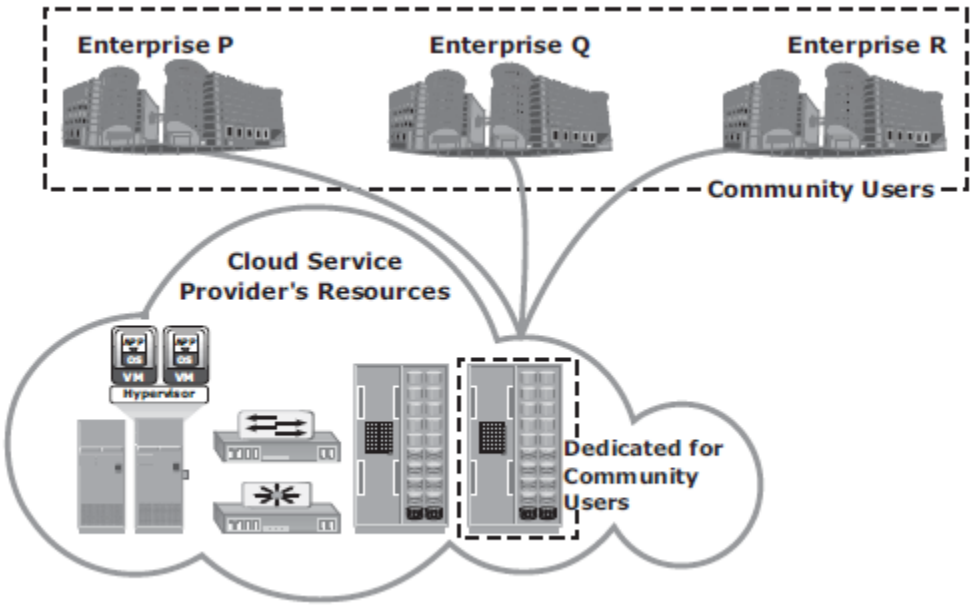

Figure 13-4: Community cloud

In a community cloud, the costs spread over to fewer consumers than a public cloud. Hence, this option is more expensive but might offer a higher level of privacy, security, and compliance.

The community cloud also offers organizations access to a vast pool of resources compared to the private cloud. An example in which a community cloud could be useful is government agencies. If various agencies within the government operate under similar guidelines, they could all share the same infrastructure and lower their individual agency's investment.

4) Hybrid Cloud:

In a hybrid cloud model, 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 (for example, cloud bursting for load balancing between clouds).

The hybrid model allows an organization to deploy less critical applications and data to the public cloud, leveraging the scalability and cost-effectiveness of the public cloud. The organization's mission-critical applications and data remain on the private cloud that provides greater security. Figure 13-5 shows an example of a hybrid cloud.

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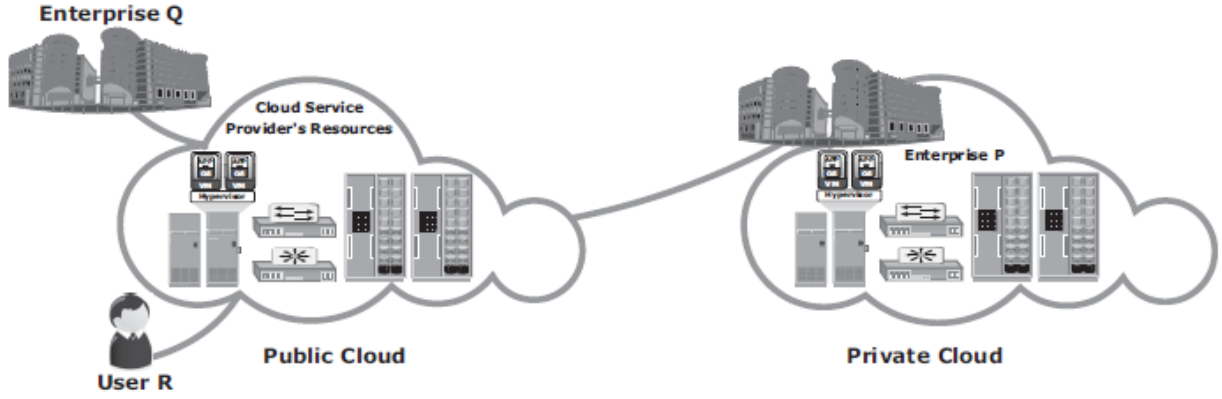

Figure 13-5: Hybrid cloud

Cloud Computing Infrastructure:

A cloud computing infrastructure is the collection of hardware and software that enables the five essential characteristics of cloud computing.

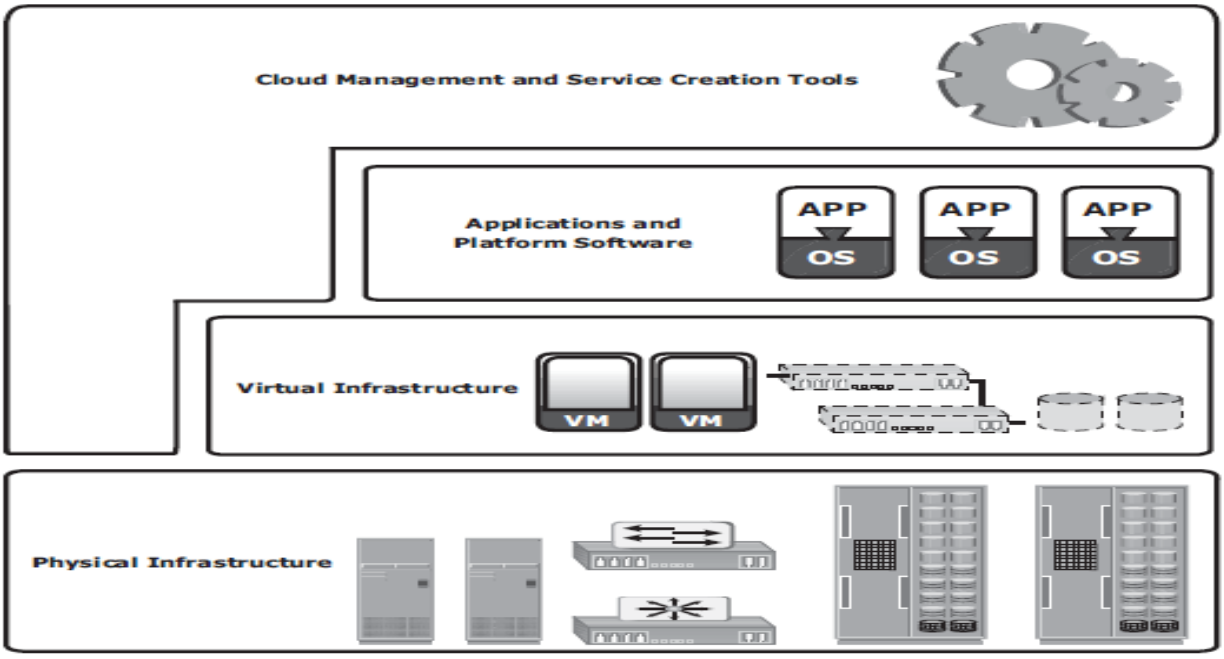

Figure 13-6: Cloud infrastructure layers

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Cloud computing infrastructure usually consists of the following layers:

- Physical infrastructure
- Virtual infrastructure
- Applications and platform software
- Cloud management and service creation tools

Physical Infrastructure:

The physical infrastructure consists of physical computing resources, which include physical servers, storage systems, and networks. Physical servers are connected to each other, to the storage systems, and to the clients via networks, such as IP, FC SAN, IP SAN, or FCoE networks.

Cloud service providers may use physical computing resources from one or more data centers to provide services. If the computing resources are distributed across multiple data centers, connectivity must be established among them.

The connectivity enables the data centers in different locations to work as a single large data center. This enables migration of business applications and data across data centers and provisioning cloud services using the resources from multiple data centers.

Virtual Infrastructure:

Cloud service providers employ virtualization technologies to build a virtual infrastructure layer on the top of the physical infrastructure.

Virtualization enables fulfilling some of the cloud characteristics, such as resource pooling and rapid elasticity. It also helps reduce the cost of providing the cloud services. Some cloud service providers may not have completely virtualized their physical infrastructure yet, but they are adopting virtualization for better efficiency and optimization.

Virtualization abstracts physical computing resources and provides a consolidated view of the resource capacity. The consolidated resources are managed as a single entity called a resource pool.

Apart from resource pools, the virtual infrastructure also includes identity pools, such as VLAN ID pools and VSAN ID pools. The number of each type of pool and the pool capacity depend on the cloud service provider's requirement to create different cloud services.

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Virtual infrastructure also includes virtual computing resources, such as virtual machines, virtual storage volumes, and virtual networks. These resources obtain capacities, such as CPU power, memory, network bandwidth, and storage space from the resource pools.

The capacity is allocated to the virtual computing resources easily and flexibly based on the service requirement. Virtual networks are created using network identifiers, such as VLAN IDs and VSAN IDs from the respective identity pools. Virtual computing resources are used for creating cloud infrastructure services.

Applications and Platform Software:

This layer includes a suite of business applications and platform software, such as the OS and database. Platform software provides the environment on which business applications run.

Applications and platform software are hosted on virtual machines to create SaaS and PaaS. For SaaS, both the application and platform software are provided by cloud service providers. In the case of PaaS, only the platform software is provided by cloud service providers; consumers export their applications to the cloud.

Cloud Management and Service Creation Tools:

The cloud management and service creation tools layer includes three types of software:

- Physical and virtual infrastructure management software
- Unified management software
- User-access management software

Physical and virtual infrastructure management software:

- The physical and virtual infrastructure management software is offered by the vendors of various infrastructure resources and third-party organizations.
- For example, a storage array has its own management software. Similarly, network and physical servers are managed independently using network and compute management software respectively.
- This software provides interfaces to construct a virtual infrastructure from the underlying physical infrastructure.

Unified management software:

- Unified management software interacts with all standalone physical and virtual infrastructure management software.

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- It collects information on the existing physical and virtual infrastructure configurations, connectivity, and utilization. Unified management software compiles this information and provides a consolidated view of infrastructure resources scattered across one or more data centers.
- It allows an administrator to monitor performance, capacity, and availability of physical and virtual resources centrally.
- It software also provides a single management interface to configure physical and virtual infrastructure and integrate the compute (both CPU and memory), network, and storage pools.
- The unified management software passes configuration commands to respective physical and virtual infrastructure management software, which executes the instructions.
- The key function of the unified management software is to automate the creation of cloud services. It enables administrators to define service attributes such as CPU power, memory, network bandwidth, storage capacity, name and description of applications and platform software, resource location, and backup policy.
- When the unified management software receives consumer requests for cloud services, it creates the service based on predefined service attributes.

User-access management software

- The user-access management software provides a web-based user interface to consumers. Consumers can use the interface to browse the service catalogue and request cloud services.
- The user-access management software authenticates users before forwarding their request to the unified management software. It also monitors allocation or usage of resources associated to the cloud service instances.
- Based on the allocation or usage of resources, it generates a chargeback report. The chargeback report is visible to consumers and provides transparency between consumers and providers.

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Cloud Challenges:

1) Challenges for Consumers:

- If the business-critical data moves to a cloud model other than an on-premise private cloud**, consumers could lose absolute control of their sensitive data.**
- Cloud service providers might use multiple data centers located in different countries to provide cloud services. They might replicate or move data across these data centers to ensure high availability and load distribution. **Consumers may or may not know in which country their data is stored.**
- Cloud services can be accessed from anywhere via a network. However, network latency increases when the cloud infrastructure is not close to the access point**. A high network latency can either increase the application response time or cause the application to timeout.** This can be addressed by implementing stringent Service Level Agreements (SLAs) with the cloud service providers.
- **Cloud platform services may not support consumers' desired applications.** For example, a service provider might not be able to support highly specialized or proprietary environments, such as compatible OSs and preferred programming languages, required to develop and run the consumer's application.
- Another challenge is vendor lock-in: **the difficulty for consumers to change their cloud service provider.** A lack of interoperability between the APIs of different cloud service providers could also create complexity and high migration costs when moving from one service provider to another.

2) Challenges for Providers:

- Cloud service providers usually publish a service-level agreement (SLA) so that their consumers know about the availability of service, quality of service, downtime compensation, and legal and regulatory clauses. Alternatively, customer-specific SLAs may be signed between a cloud service provider and a consumer**.** SLAs typically mention **a penalty amount** if cloud service providers fail to provide the service levels. **Therefore, cloud service providers must ensure that they have adequate resources to provide the required levels of services.**
- Since the cloud resources are distributed and service demands fluctuate, **it is a challenge for cloud service providers to provision physical resources for peak demand of all consumers and estimate the actual cost of providing the services.**

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- Many software vendors do not have a cloud-ready software licensing model. The cloud **software licensing complexity** has been causing **challenges in deploying vendor software in the cloud**. This is also a challenge to the consumer.
- Cloud service providers usually offer proprietary APIs to access their cloud. However, **consumers might want open APIs or standard APIs to become the tenant of multiple clouds.** This is a challenge for cloud service providers because this requires agreement among cloud service providers.

Cloud Adoption Considerations:

1) Selection of a deployment model:

Risk versus convenience is a key consideration for deciding on a cloud adoption strategy. This consideration also forms the basis for choosing the right cloud deployment model.

A public cloud is usually preferred by individuals and start-up businesses. For them, the cost reduction offered by the public cloud outweighs the security or availability risks in the cloud. Small- and medium-sized businesses (SMBs) have a moderate customer base, and any anomaly in customer data and service levels might impact their business. Therefore, they may not be willing to deploy their tier 1 applications, such as Online Transaction Processing (OLTP), in the public cloud.

A hybrid cloud model fits in this case. The tier 1applications should run on the private cloud, whereas less critical applications such as backup, archive, and testing can be deployed in the public cloud.

Enterprises typically have a strong customer base worldwide. They usually enforce strict security policies to safeguard critical customer data. Because they are financially capable, they might prefer building their own private clouds.

2) Application suitability:

Not all applications are good candidates for a public cloud. This may be due to the incompatibility between the cloud platform software and the consumer applications, or maybe the organization plans to move a legacy application to the cloud.

Proprietary and mission critical applications are core and essential to the business. They are usually designed, developed, and maintained in-house. These applications often provide competitive advantages. Due to high security risk, organizations are unlikely to move these applications to the public cloud. These applications are good candidate for an on-premise private cloud.

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Nonproprietary and non-mission critical applications are suitable for deployment in the public cloud. If an application workload is network traffic-intensive, its performance might not be optimal if deployed in the public cloud. Also if the application communicates with other data center resources or applications, it might experience performance issues.

3) **Financial advantage:**

A careful analysis of financial benefits provides a clear picture about the cost-savings in adopting the cloud. The analysis should compare both the Total Cost of Ownership (TCO) and the Return on Investment (ROI) in the cloud and - environment and identify the potential cost benefit.

While calculating TCO and ROI, organizations and individuals should consider the expenditure to deploy and maintain their own infrastructure versus cloud-adoption costs. While calculating the expenditures for owning infrastructure resources, organizations should include both the capital expenditure (CAPEX) and operation expenditure network equipment, real estate, and so on.

The OPEX includes the cost incurred for power and cooling, personnel, maintenance, backup, and so on. These expenditures should be compared with the operation cost incurred in adopting cloud computing. The cloud adoption cost includes the cost of migrating to the cloud, cost to ensure compliance and security, and usage or subscription fees. Moving applications to the cloud reduces CAPEX, except when the cloud is built on-premise.

4) **Selection of a cloud service provider:**

The selection of the provider is important for a public cloud. Consumers need to find out how long and how well the provider has been delivering the services. They also need to determine how easy it is to add or terminate cloud services with the service provider.

The consumer should know how easy it is to move to another provider, when required. They must assess how the provider fulfills the security, legal, and privacy requirements. They should also check whether the provider offers good customer service support.

5) **Service-level agreement (SLA):** Cloud service providers typically mention quality of service (QoS) attributes such as throughput and uptime, along with cloud services. The

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QoS attributes are generally part of an SLA, which is the service contract between the provider and the consumers.

The SLA serves as the foundation for the expected level of service between the consumer and the provider. Before adopting the cloud services, consumers should check whether the QoS attributes meet their requirements.

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Virtualization Appliances

Black Box Virtualization:

- A virtualization appliance is an intelligent processing platform that attaches to storage or a storage network.
- A virtualization appliance may be implemented on optimized hardware or as software that runs on a standard Wintel processor.
- Virtualization appliances can accommodate a variety of heterogeneous operating systems, host platforms, and storage targets from different vendors.
- Appliances may support Fibre Channel, iSCSI, or proprietary protocols for host access and Fibre Channel, iSCSI, SCSI, SATA, or SAS for storage.

In-Band Virtualization Appliances:

- In-band virtualization appliances combine control information and data transport over the same path.
- The in-band virtualization device resides directly between servers and storage.
- An in-band virtualization appliance using Fibre Channel may require two separate fabrics for server and storage connectivity.
- An in-band appliance is a target to the client servers and an initiator to the back-end storage devices.
- Potential performance bottlenecks for in-band virtualization may be overcome with processing speed and cache memory.
- The in-band virtualization appliance itself will become a bottleneck for storage transactions, particularly as the traffic load from multiple servers increases.
- One significant advantage of in-band storage virtualization is its ability to enforce physical separation between servers and storage. Because the appliance is the intermediary between initiators and targets, it prevents servers from independently and inadvertently discovering and attaching to SAN based storage assets, as might occur in a conventional SAN

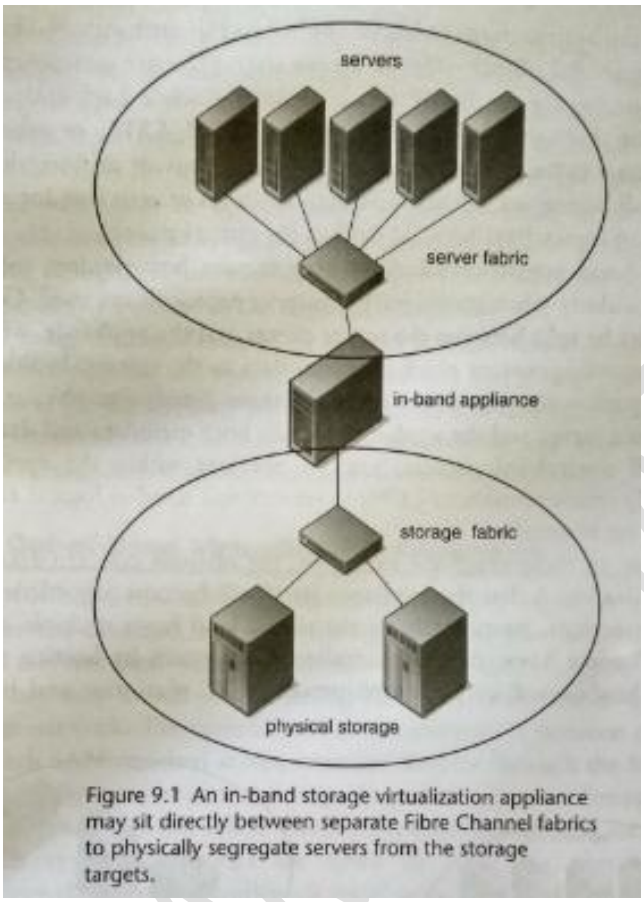

Figure 9.1 An in-band storage virtualization appliance may sit directly between separate Fibre Channel fabrics to physically segregate servers from the storage targets.

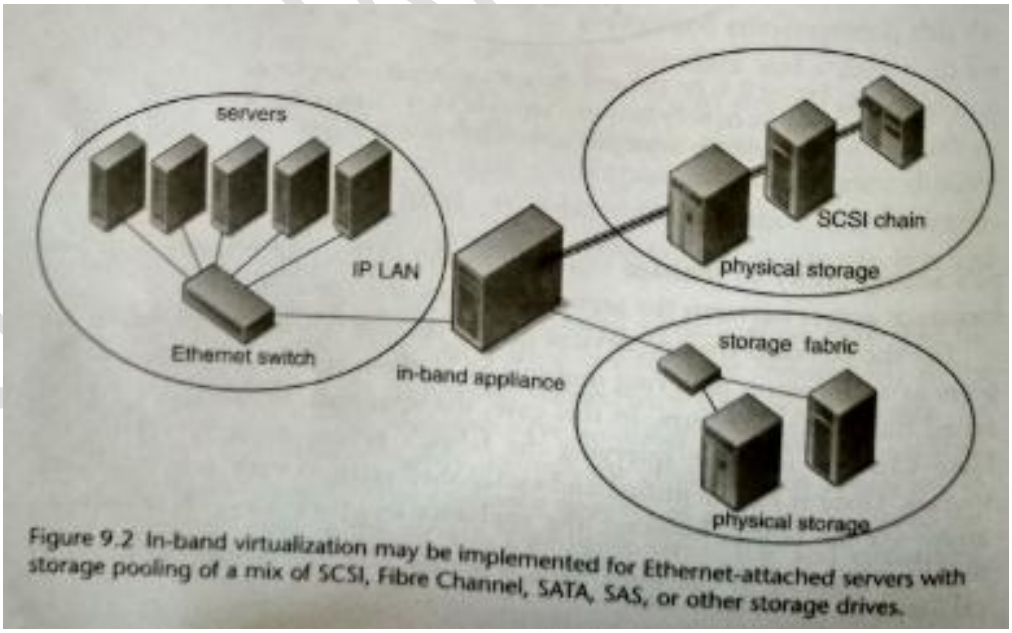

Figure 9.2 In-band virtualization may be implemented for Ethernet-attached servers with storage pooling of a mix of SCSI, Fibre Channel, SATA, SAS, or other storage drives.

Out-of-Band Virtualization Appliances:

- Out-of-band virtualization separates control information paths from data paths.
- An out-of-band appliance attaches to a storage network as a peer node.
- In an out-of-band virtualization solution, servers access data directly through the SAN.
- Out-of-band virtualization may require host-resident software or hard ware to maintain virtualization block address mapping.
- Out-of-band virtualization typically requires no change to the SAN in infrastructure design

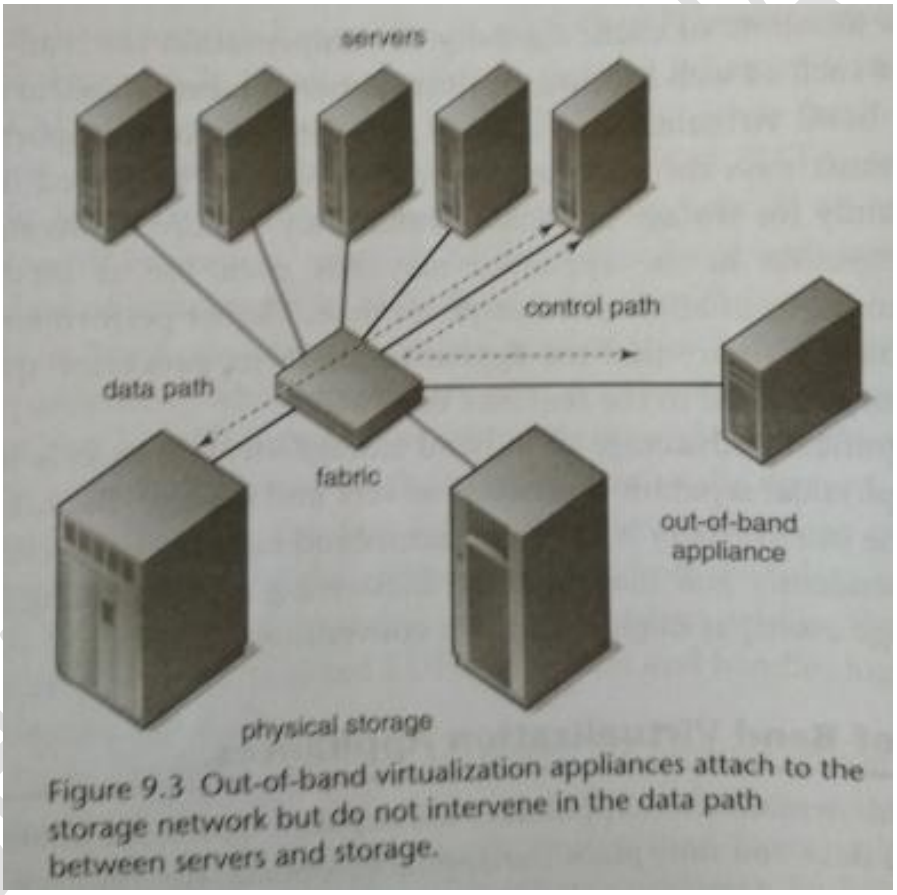

Figure 9.3 Out-of-band virtualization appliances attach to the storage network but do not intervene in the data path between servers and storage.

High Availability for Virtualization Appliances:

- A single virtualization appliance represents a potential single point of failure.
- High availability for virtualization appliances requires dual pathing through the SAN and redundant appliances for failover.
- In an active active configuration, redundant appliances may perform load balancing as well as failover capability
- Redundant appliances exchange status via an Ethernet or Fibre Channel heartbeat protocol

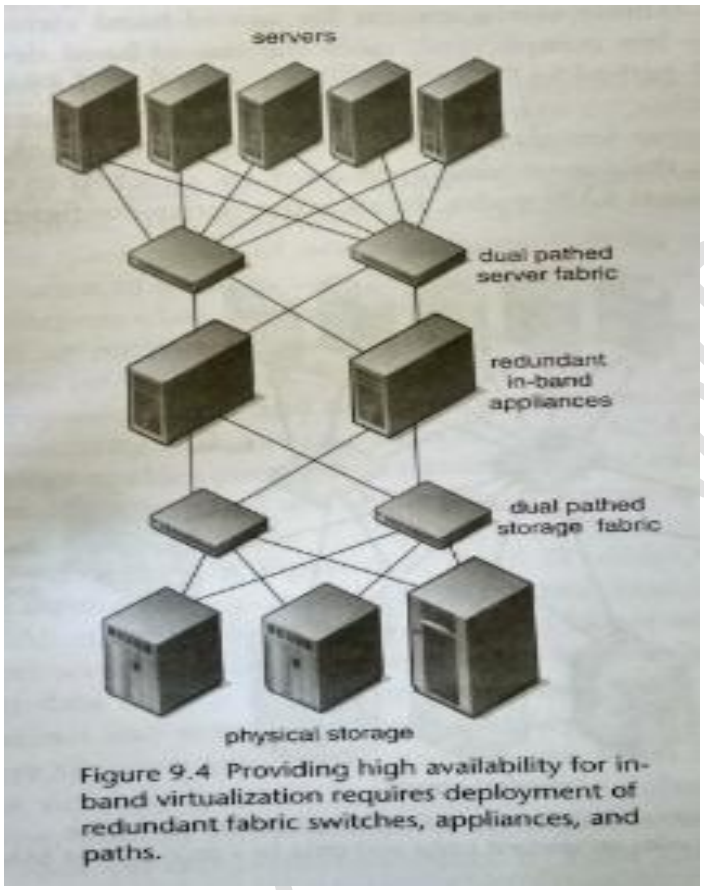

Figure 9.4 Providing high availability for in-band virtualization requires deployment of redundant fabric switches, appliances, and paths.

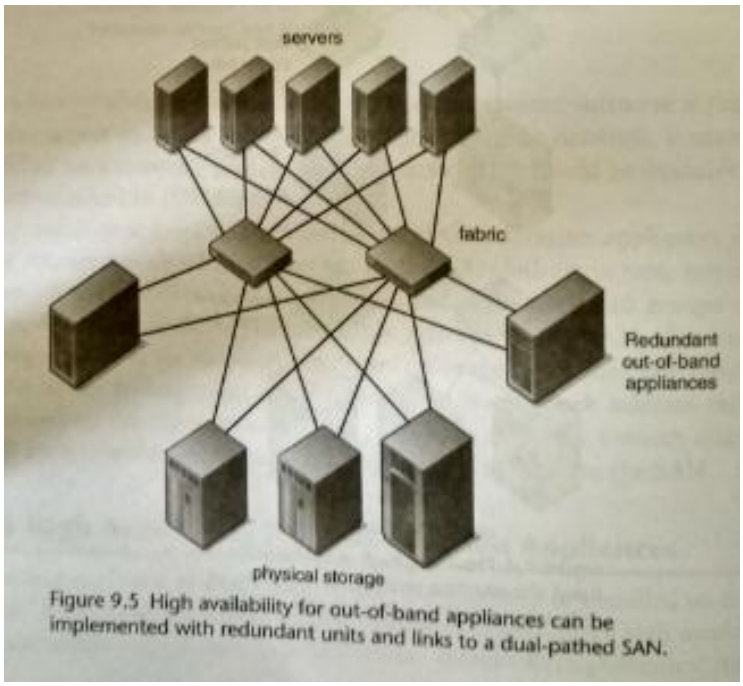

Figure 9.5 High availability for out-of-band appliances can be implemented with redundant units and links to a dual-pathed SAN.

Referred Book: Storage Virtualization, Author: Clark Tom, Publisher: Pearson

Appliances for Mass Consumption:

- The combination of isCSI and virtualization technology is enabling low-cost but sophisticated shared storage solutions.
- Economical iSCSi virtualization appliances may repurpose legacy direct-attached storage to provide virtualized shared storage.
- Lowcost iSCSI virtualization appliances provide a migration path from small to large shared storage networking

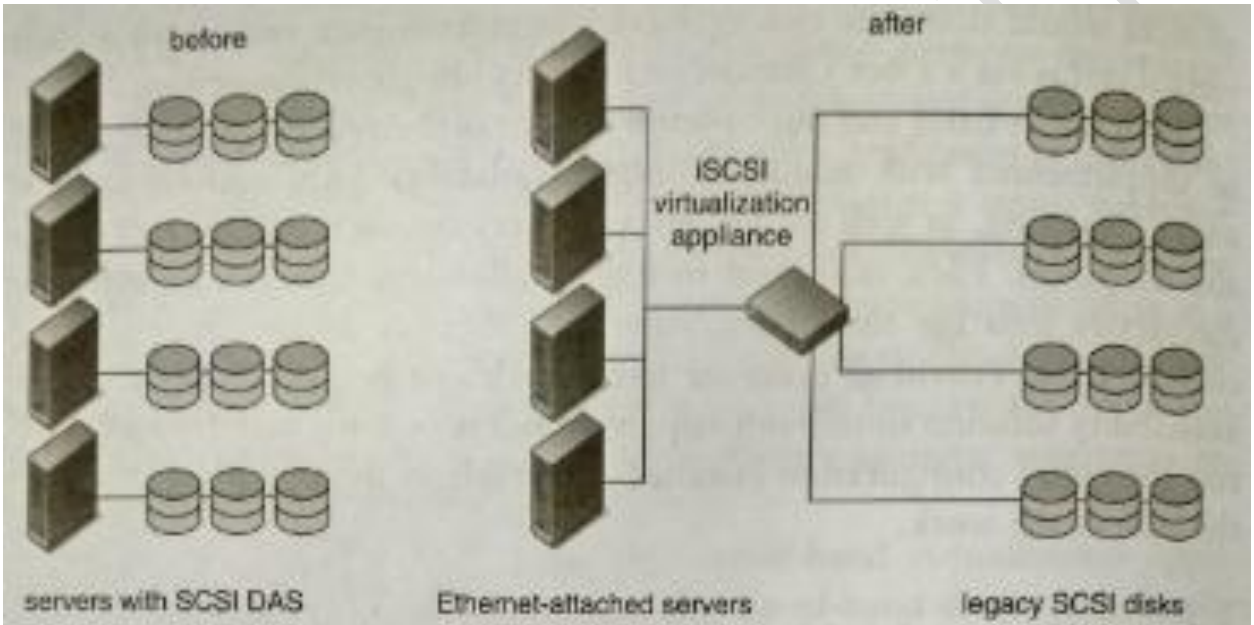

Figure 9.6 Low-cost storage virtualization is available through appliances that provide iSCSI host access and basic storage pooling capability.

Storage Automation and Virtualization

Policy-Based Storage Management:

- Policy-based management encompasses all IT resources, including applications, computer platforms, networks, and storage.
- Policy management is necessary for aligning underlying technology to business requirements.
- The SNIA Storage Management Interface Specification (SMIS) establishes a common management structure for heterogeneous SANs.
- The common information model (CIM) defines management objects for a wide diversity of network and compute resources.
- CIM objects are managed through the web-based enterprise management (WBEM) protocol.
- The CIM Schema includes policy classes for automating IT processes.
- CIM provides a Storage Configuration Service model for creating and manipulating virtualized resources.
- CIM storage services and policy objects may be combined to provide automated storage virtualization.
- Policy management is based on a hierarchy of policies that span from upper layer interfaces to underlying physical resources.
- Policy-based management transforms the physical SAN into a collection of services supporting business application requirements

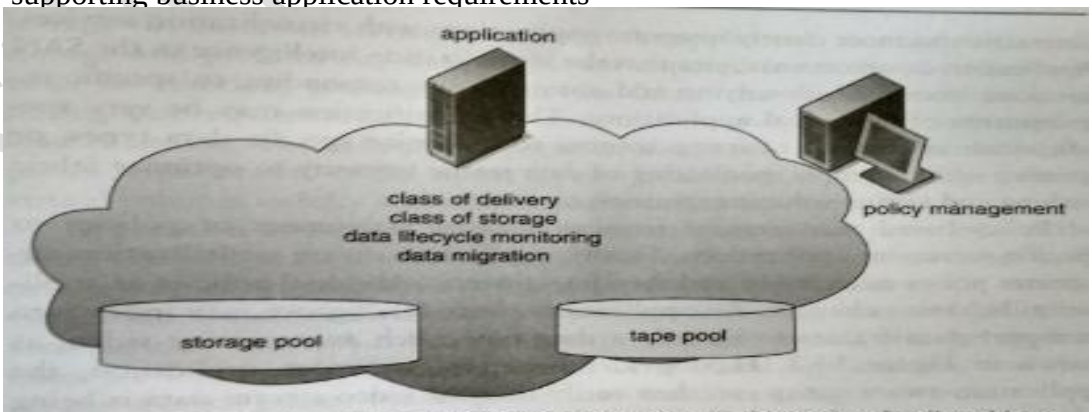

Figure 13.2 Policy-based management is predicated on a hierarchy of policy objects that govern different aspects of a virtualized infrastructure. Services under policy enforcement must be coordinated to accomplish the overall policy goal.

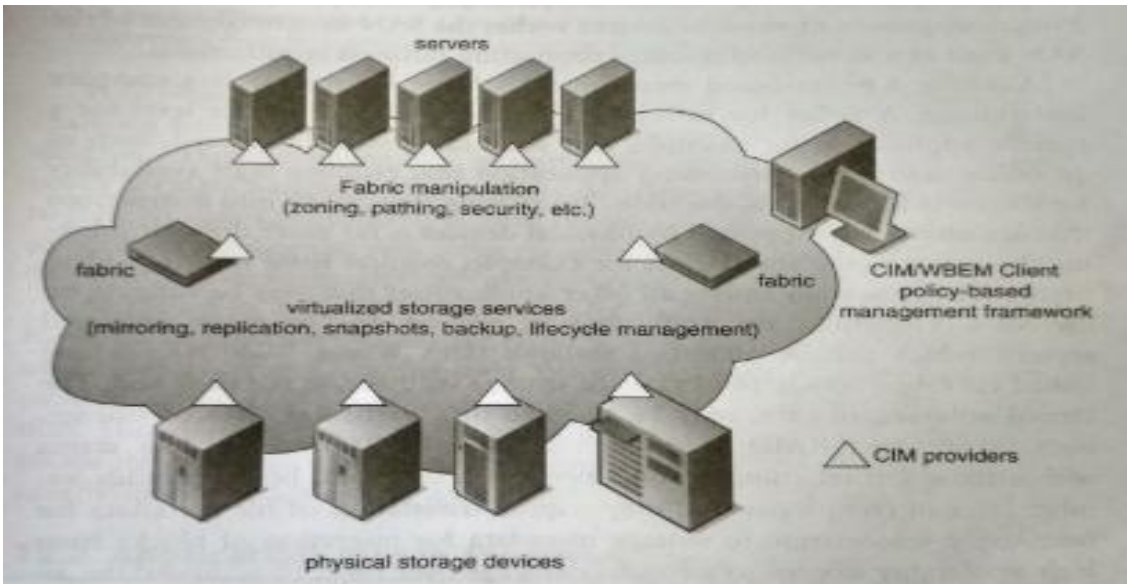

Figure 13.1 Homogeneous management of a heterogeneous SAN via CIM is provided by vendor-supplied CIM providers in all SAN components. Abstracting vendor proprietary capabilities into uniform vendor-neutral features enables the fabric and its storage assets to be treated as a single entity whose behavior is determined by higher level business requirements.

Application-Aware Storage Virtualization:

- Policy-based management provides a foundation for tighter integration of applications and storage virtualization.
- An application-aware virtualization entity must identify specific application data types and launch the appropriate policies for data handling.
- Application aware virtualization must respond to changing application needs, such as capacity requirements and lifecycle management.
- Wire-speed frame analysis is required to maintain storage performance levels

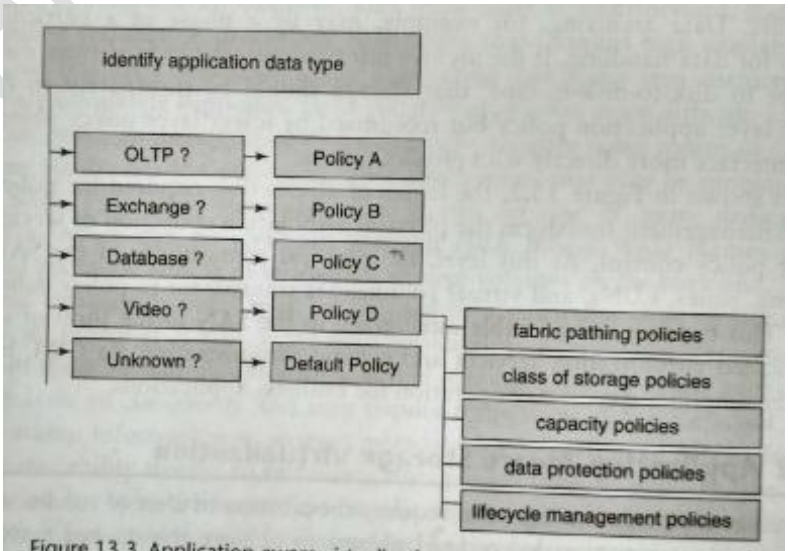

Figure 13.3 Application-aware virtualization requires identification of the upper layer application based on data characteristics and enforcement of a policy hierarchy to apply the appropriate storage services over time.

Virtualization-Aware Applications:

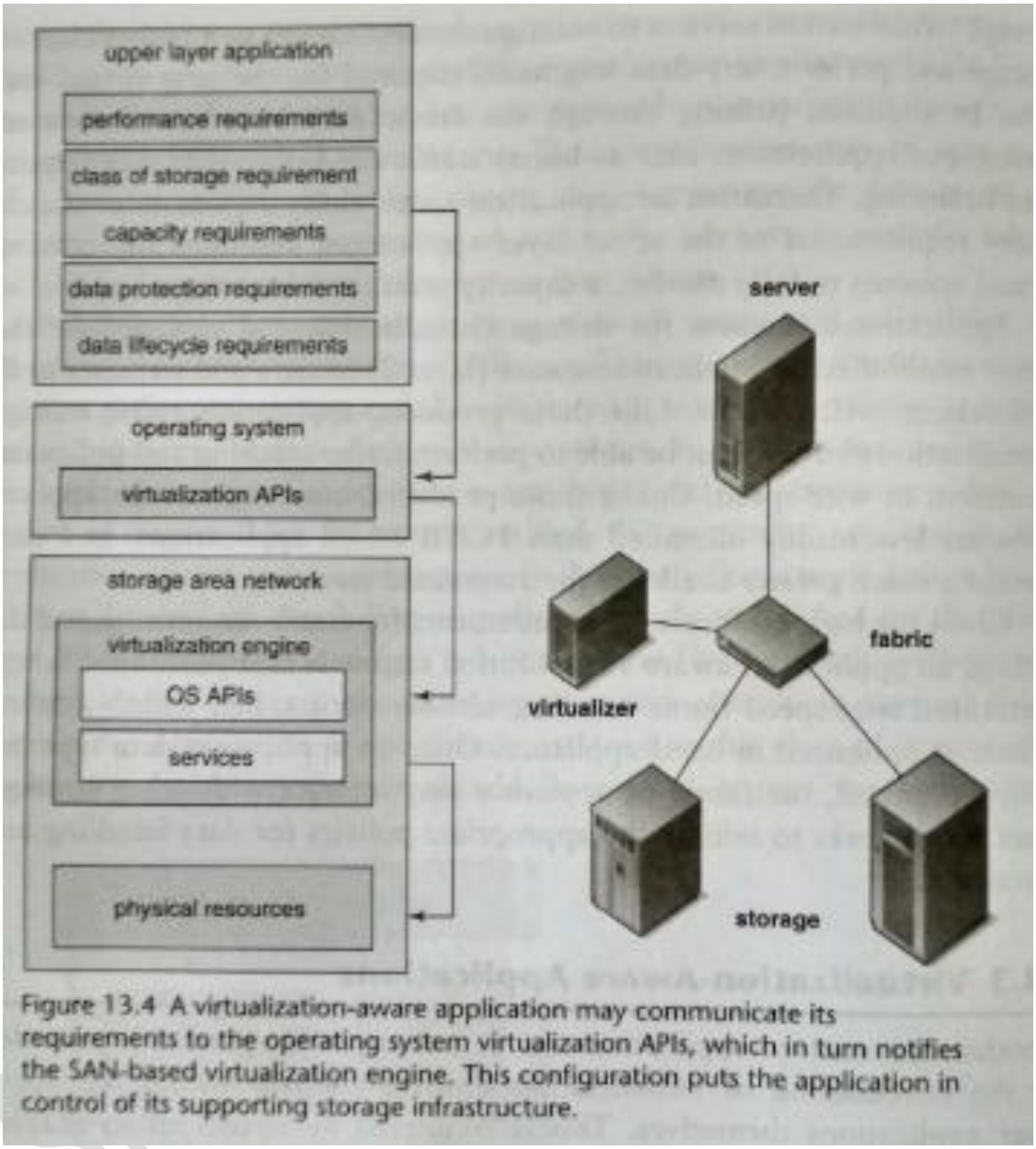

Figure 13.4 A virtualization-aware application may communicate its requirements to the operating system virtualization APIs, which in turn notifies the SAN-based virtualization engine. This configuration puts the application in control of its supporting storage infrastructure.

- Virtualization APIs with an operating system enable upper layer applications to communicate requirements to storage virtualization entities in the SAN.
- Virtualization-awareness facilitates the integration of applications and infrastructure by enabling the application to define its own storage requirements.
- Virtualization-aware applications expand the scope of storage intelligence beyond the SAN.