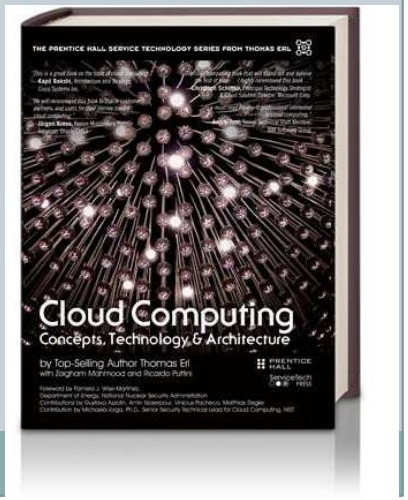
Unit 2: Cloud Computing

Concept, Technology & Architecture

Chapter 05

Cloud-Enabling Technology



Contents

- Contemporary technologies that realize modern- day cloud computing platforms and innovations are discussed, particularly data centers, virtualization, and Web-based technologies.
  - 5.1 Broadband Networks and Internet Architecture
  - 5.2 Data Center Technology
  - 5.3 Virtualization Technology
  - 5.4 Web Technology
  - 5.5 Multitenant Technology
  - 5.6 Service Technology
  - 5.7 Case Study Example

5.1 Broadband Networks and Internet Architecture

- Internet Service Providers (ISPs) (Figure 5.1 & 5.2)
  - Connectionless Packet Switching (Datagram Networks)
  - Router-Based Interconnectivity (Figure 5.3 & 5.4)

5.1 Broadband Networks and Internet Architecture

Connectionless Packet Switching (Datagram Networks)

- End-to-end (sender-receiver pair) data flows are divided into packets of a limited size that are received and processed through network switches and routers.
- Each packet carries the necessary location information, such as the Internet Protocol (IP) or Media Access Control (MAC) address.

Router-Based Interconnectivity

- A router is a device that is connected to multiple networks through which it forwards packets.
- Routers manage network traffic and gauge the most efficient hop for packet delivery.

Figure 5.1 Connectionless Packet Switching

- *Figure 5.1 - Two messages travel over dynamic network routes in this ISP internetworking configuration.*

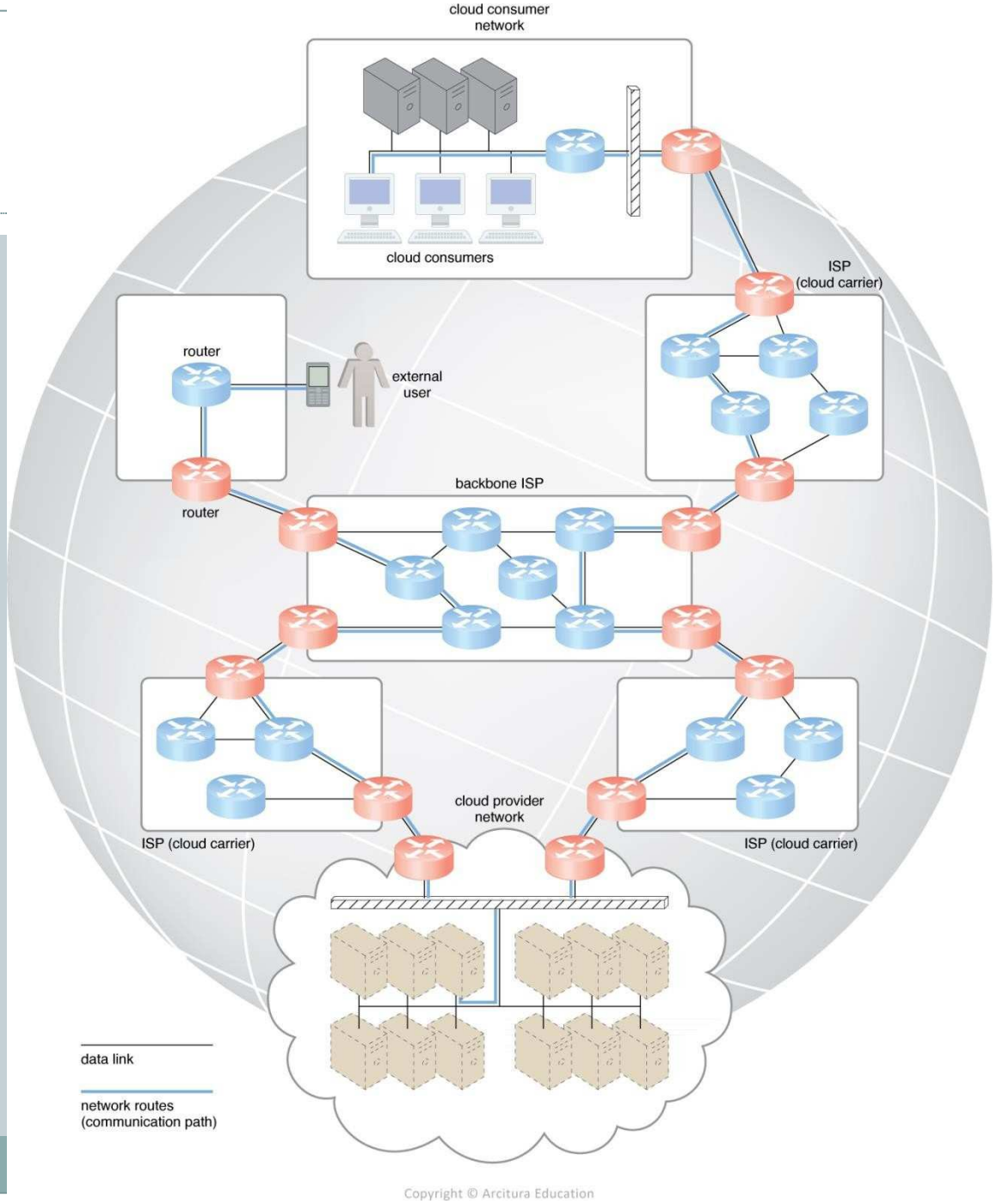
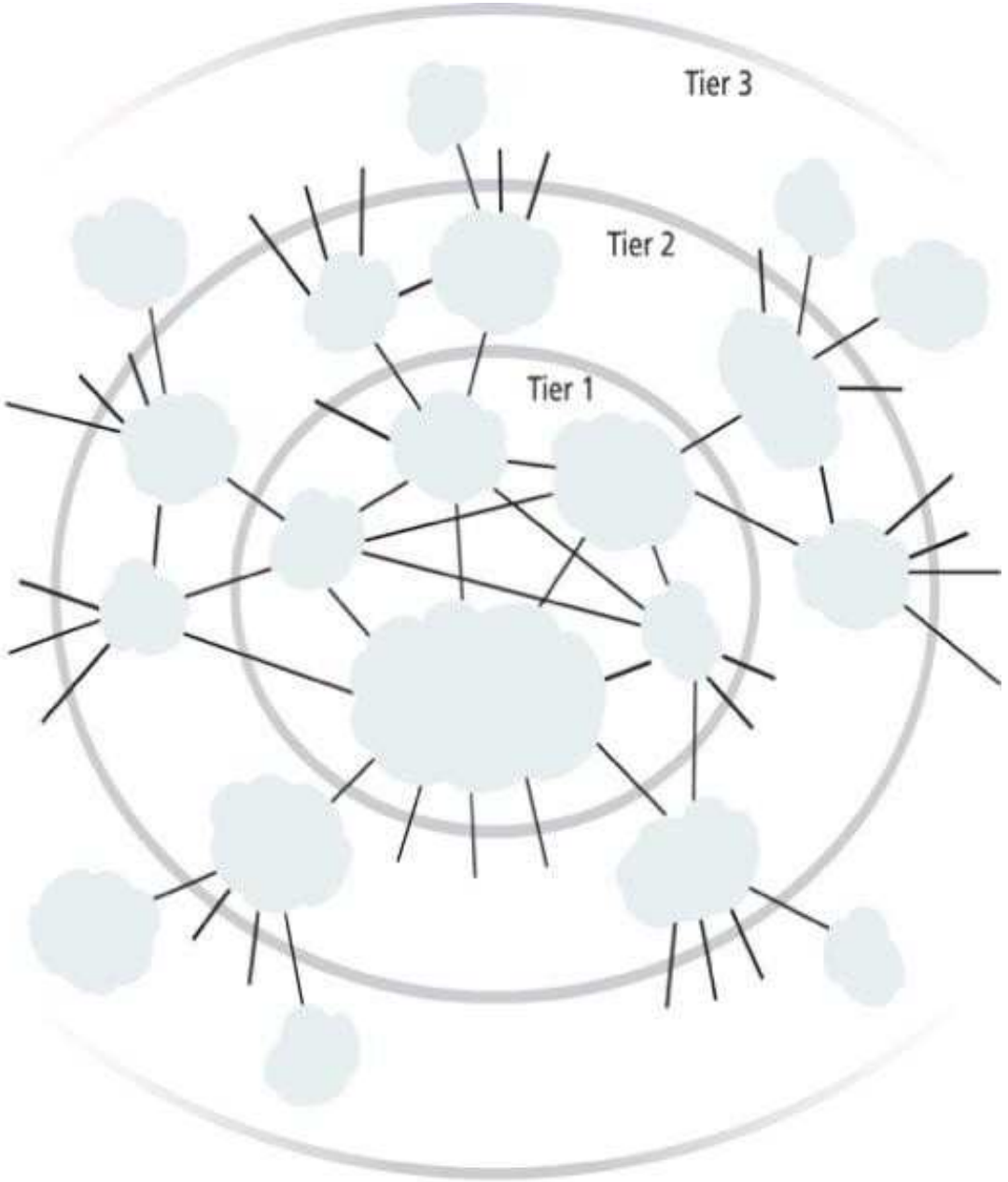


Figure 5.2

- *Figure 5.2 - An abstraction of the internetworking structure of the Internet.*



The core Tier 1 is made of large-scale, international cloud providers that oversee massive interconnected global networks, which are connected to Tier 2's large regional providers.

The interconnected ISPs of Tier 2 connect with Tier 1 providers, as well as the local ISPs of Tier 3.

Figure 5.3 Router-Based Interconnectivity

- *Figure 5.3 - Packets traveling through the Internet are directed by a router that arranges them into a message.*

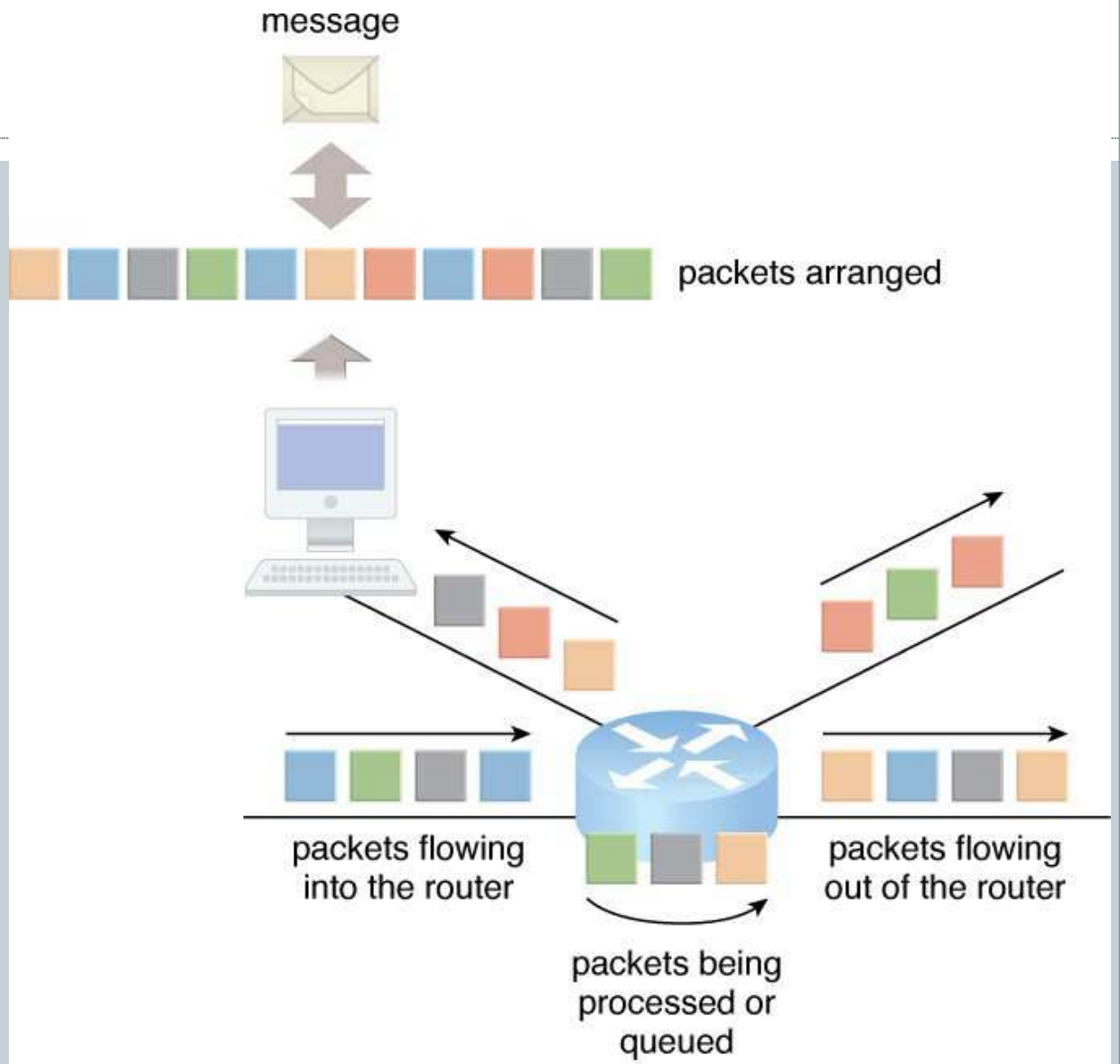
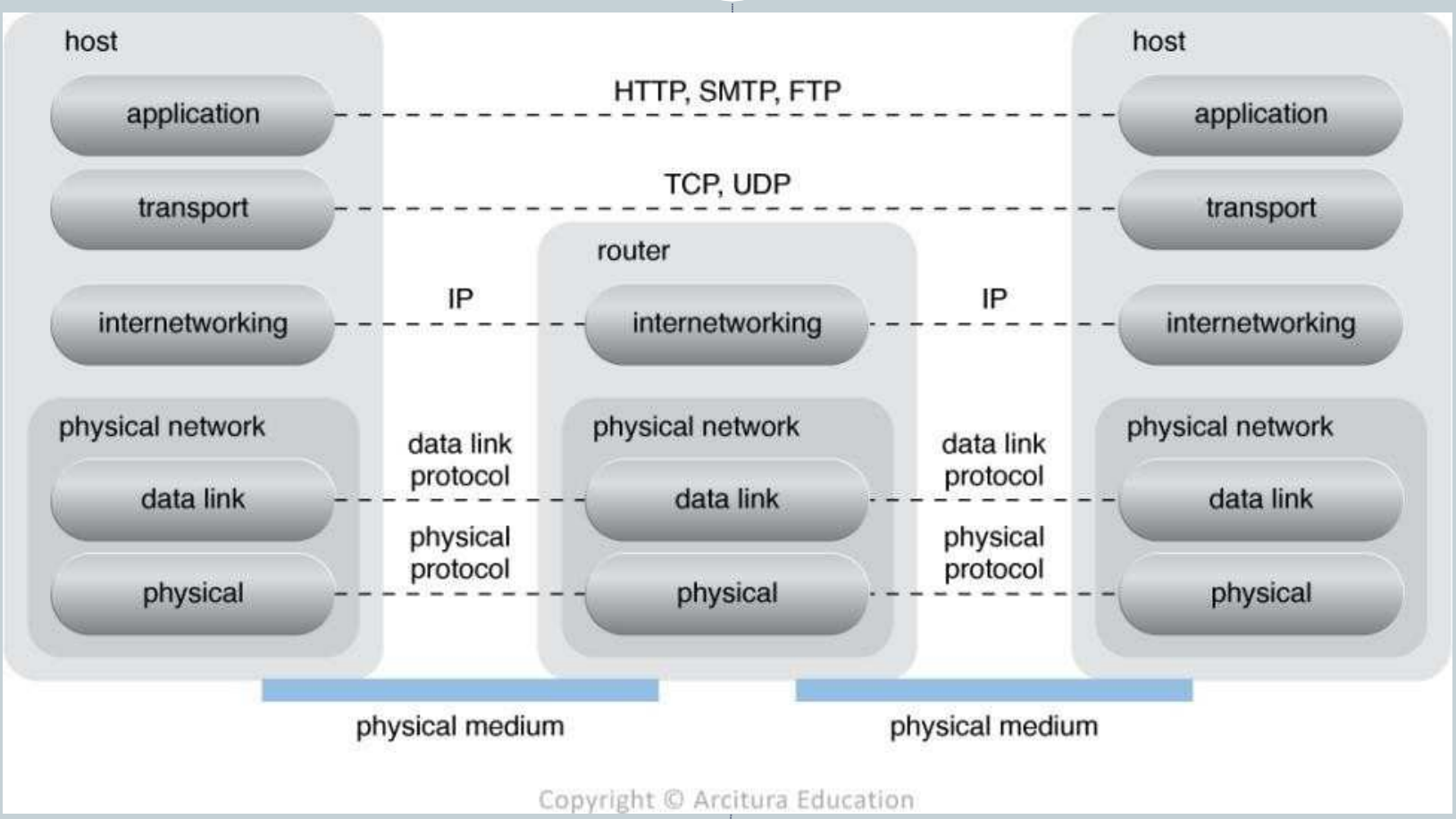


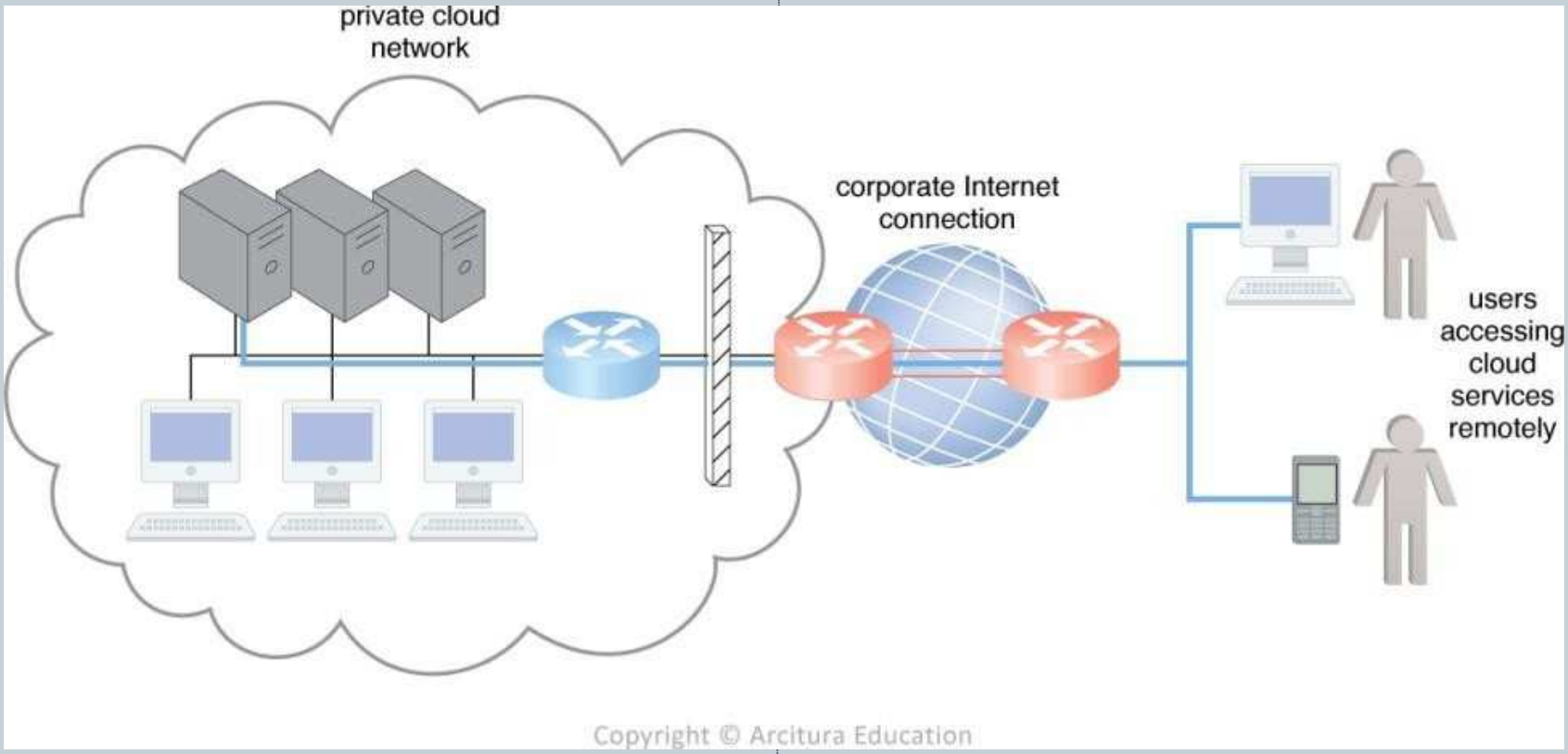
Figure 5.4



- *Figure 5.4 - A generic view of the Internet reference model and protocol stack.*

- Technical and Business Considerations (Figure 5.5 & 5.6)
  - Connectivity issues
  - Network bandwidth and latency issues
  - Cloud carrier and cloud provider selection

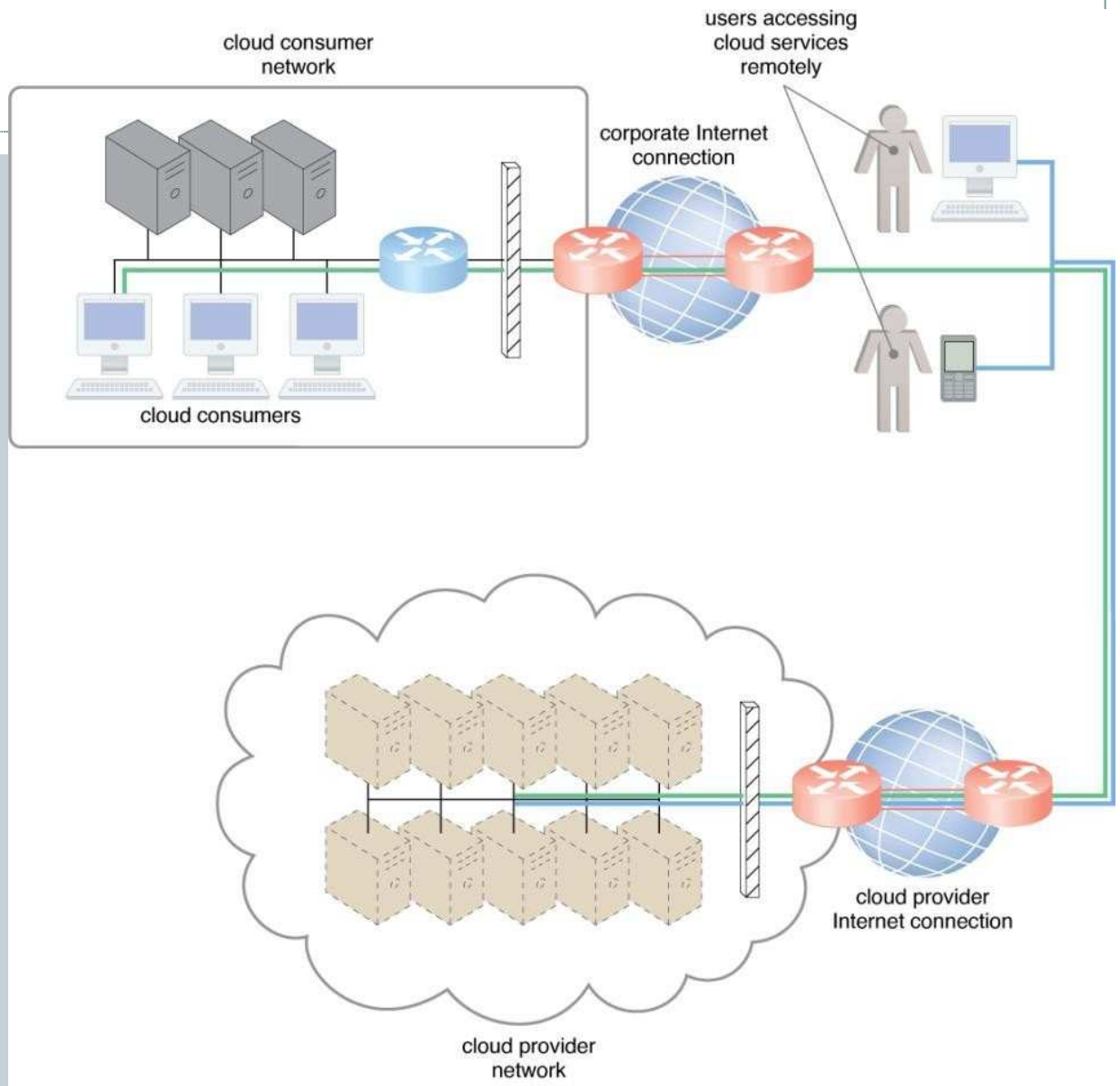
Figure 5.5



- *Figure 5.5 - The internetworking architecture of a private cloud. The physical IT resources that constitute the cloud are located and managed within the organization.*

Figure 5.6

- *Figure 5.6 - The internetworking architecture of an Internet-based cloud computing deployment model. The Internet is the connecting agent between non-proximate cloud consumers, roaming end-users, and the cloud provider's network.*



A comparison of on-premise and cloud-based internetworking

On-Premise IT Resources	Cloud-Based IT Resources
internal end-user devices access corporate IT services through the **corporate** network	internal end-user devices access corporate IT services through an **Internet** connection
internal users access corporate IT services through the corporate Internet connection while roaming in external networks	internal users access corporate IT services while roaming in external networks through the cloud provider's Internet connection
external users access corporate IT services through the **corporate Internet connection**	external users access corporate IT services through the **cloud provider's Internet connection**

Summary of Broadband Networks and Internet

- Cloud consumers and cloud providers typically use the **Internet** to communicate, which is based on a decentralized provisioning and management model and is not controlled by any centralized entities.
- The main components of internetworking architecture are connectionless packet switching and router-based interconnectivity, which use network routers and switches.
- Networks bandwidth and latency are characteristics that influences QoS, which is heavily impacted by network congestion.

5.2 **Data Center Technology** (1/2)

- Grouping IT resources in close proximity with one another allows for power saving, higher efficiency in sharing resources, and improve accessibility for IT personnel. Following issues are concerned:

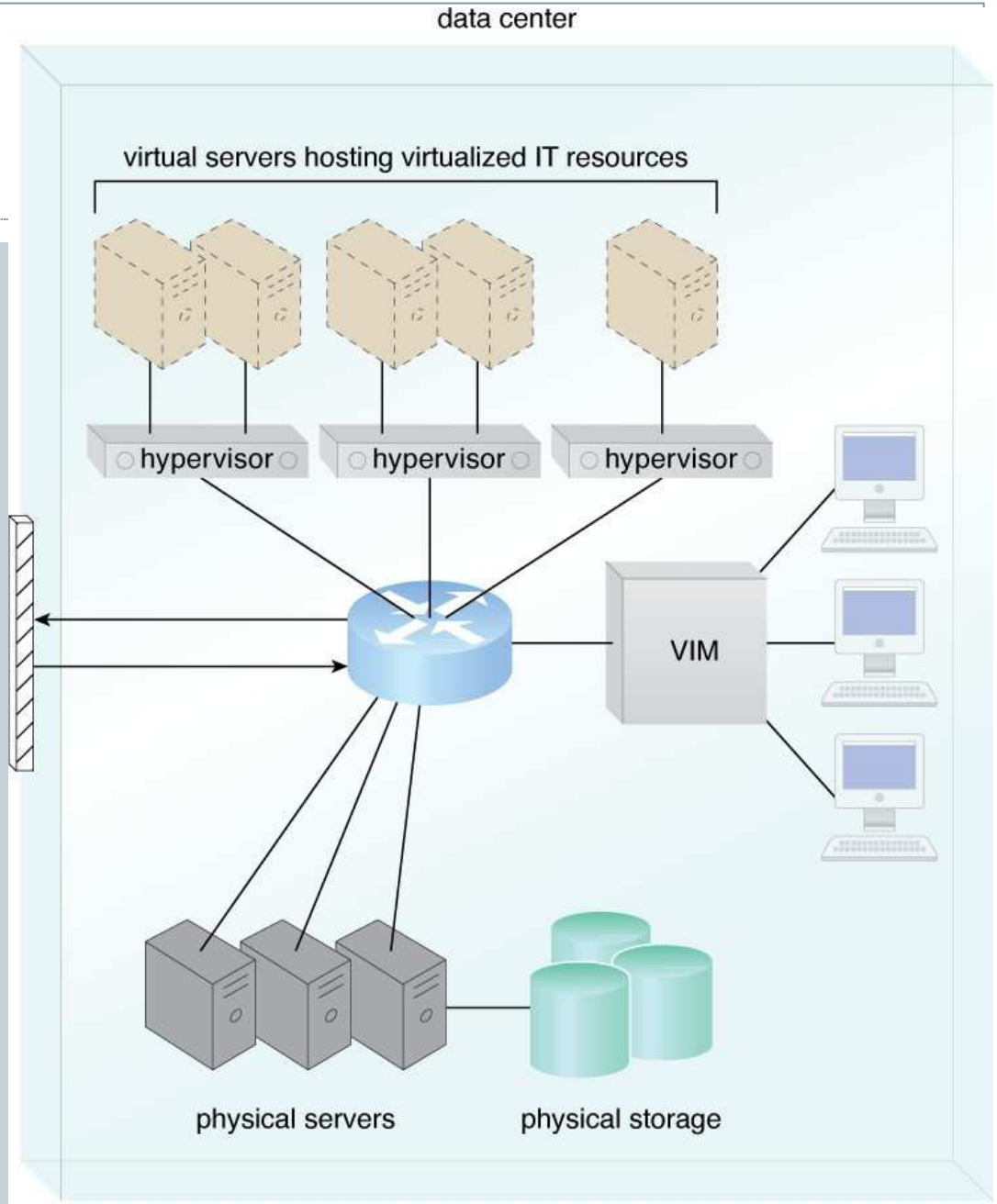
1. Virtualization (Figure 5.7)
2. Standardization and Modularity (enable economy of scale)
3. Automation (self-configuration, recovery)
4. Remote Operation and Management
5. High Availability (through redundancy)

5.2 Data Center Technology (2/2)

6. Security-Aware Design, Operation, and Management (outsourcing resources)
7. Facilities (power, cabling, cooling, fire protection,…)
8. Computing Hardware (standardized commodity servers)
9. Storage Hardware (array, hot-swapping, storage virtualization, fast data replication, SAN, NAS,…)
10. Network Hardware
    1) Carrier and External Networks Interconnection
    2) Web-Tier Load Balancing and Acceleration
    3) LAN Fabric
    4) ANS Fabric

Figure 5.7

- *Figure 5.7 - The common components of a data center working together to provide virtualized IT resources supported by physical IT resources.*



Summary Data Center Technology (1/2)

- A data center is a specialized IT infrastructure that houses centralized IT resources, such as servers, databases, and software systems.
- Data center IT hardware is typically comprises of standardized commodity servers of increased computing power and storage capacity, while storage system technologies include disk arrays and storage virtualization. Technologies used to increase storage capacity include DAS, SAN, and NAS.

Summary of Data Center Technology (2/2)

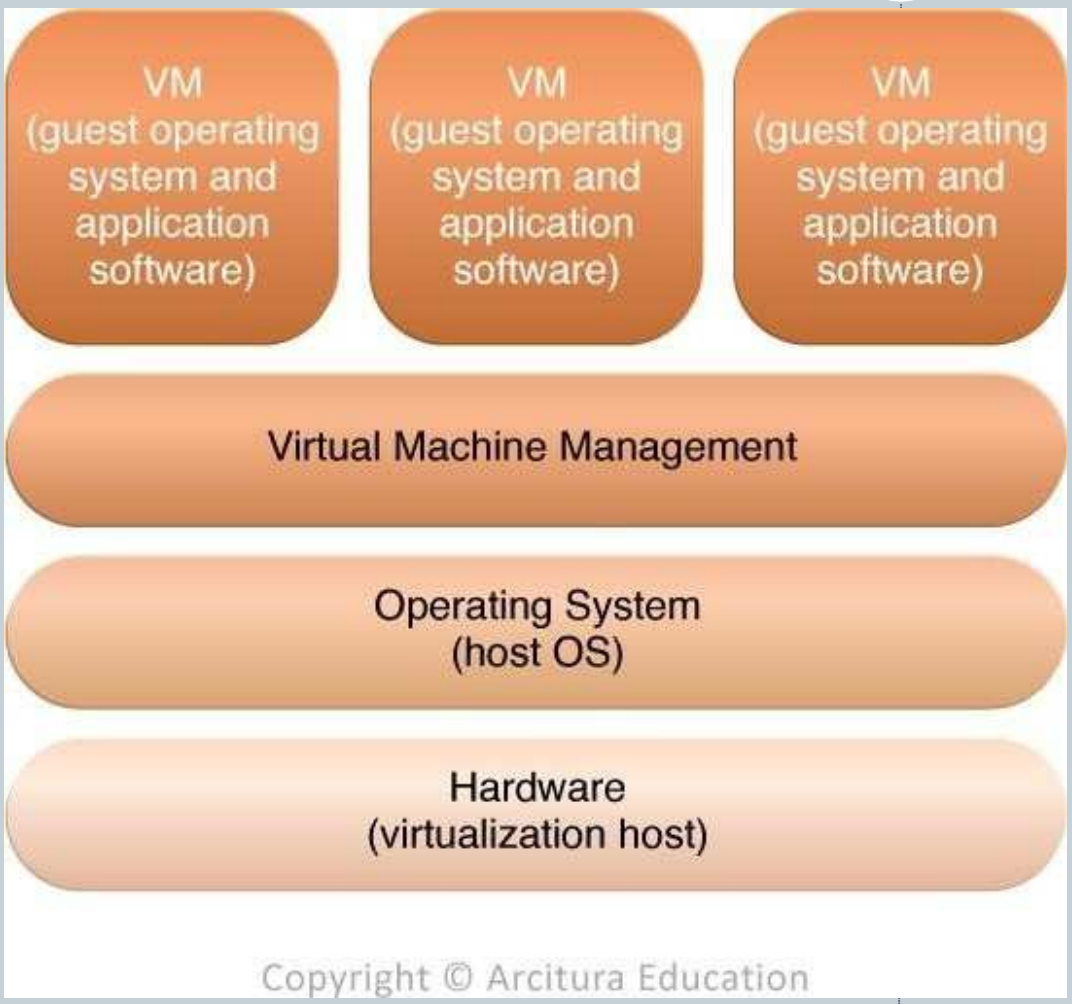
- Computing hardware technologies include rack-mounted server arrays and multi-core CPU architectures, while specialized high-capacity network hardware and technology, such as content-aware routing, LAN and SAN fabrics, and NAS gateways, are used to improve network connectivity.

5.3 **Virtualization Technology** (1/2)

- Most types of IT resources can be virtualized: servers, storage, network, power.
- Hardware Independence
- Server Consolidation
  - Different virtual servers share one physical server
- Resource Replication
  - Virtual disk images can be accessible using simple file operations, such as copy, move, and paste by the host's OS for replication purpose

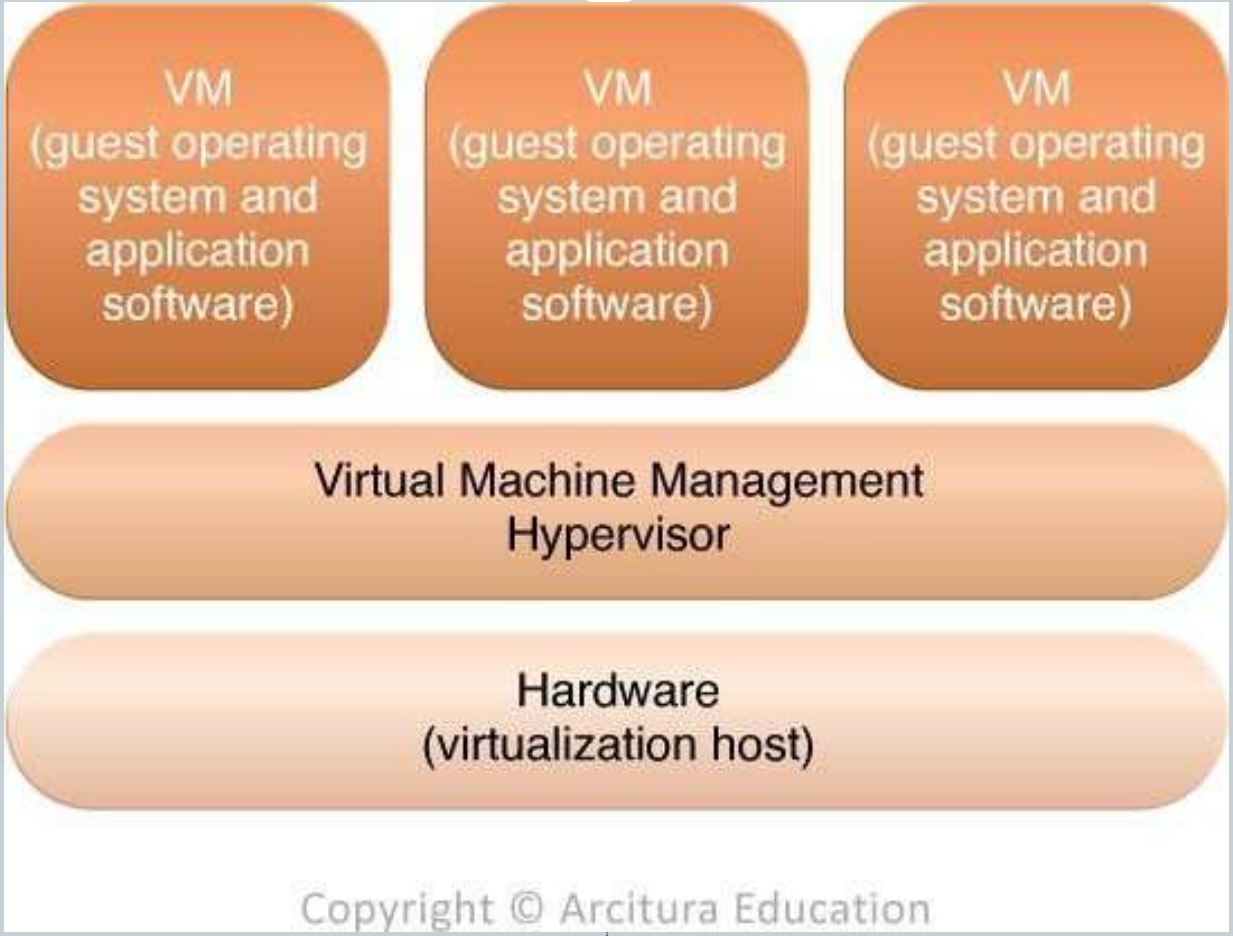
- Operating System-Based Virtualization (Figure 5.8)
- Hardware-Based Virtualization (Figure 5.9)
- Virtualization Management
  - Virtualization infrastructure management (VIM) collectively manage virtual IT resources running on a centralized module.
- Other Considerations
  - Performance overhead
  - Special hardware compatibility
  - Portability (Open Virtualization Format OVF)

Figure 5.8



- *Figure 5.8 - The different logical layers of operating system-based virtualization, in which the VM is first installed into a full host operating system and subsequently used to generate virtual machines.*

Figure 5.9



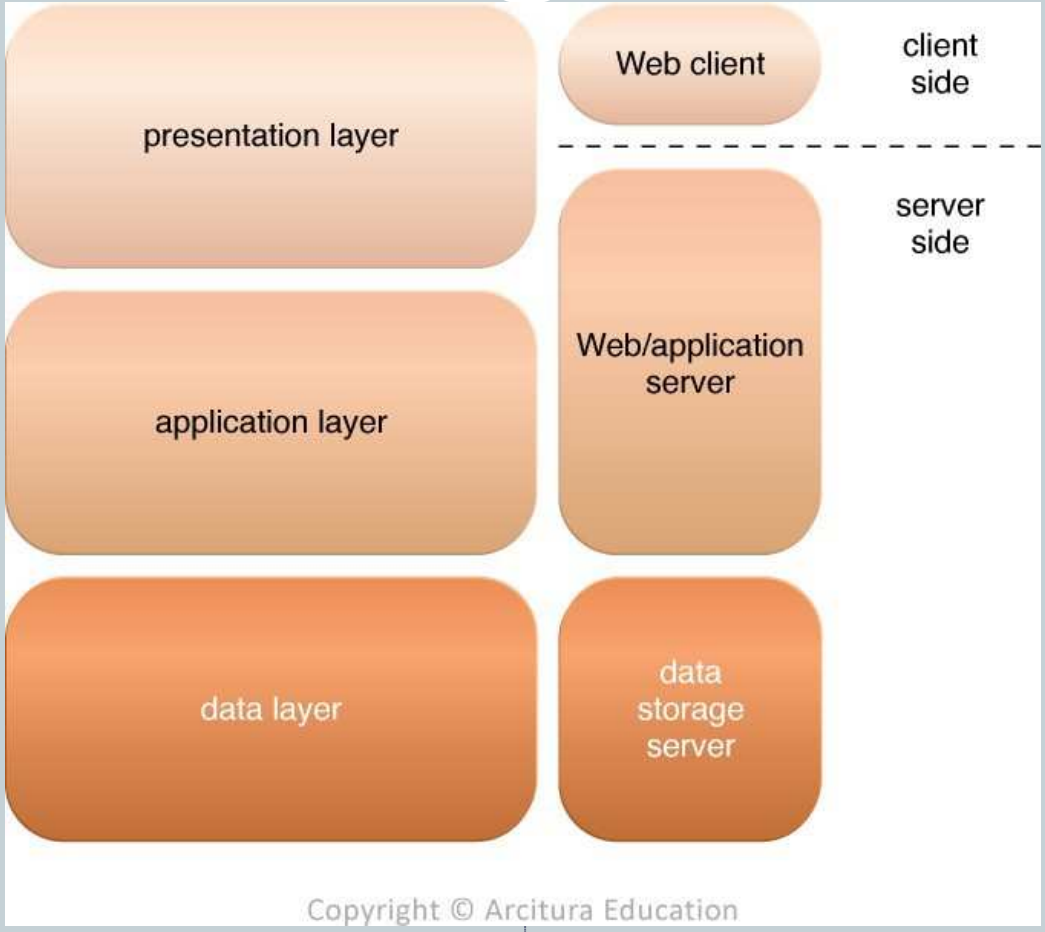
- *Figure 5.9 - The different logical layers of hardware-based virtualization, which does not require another host operating system*

Summary of Virtualization Technology

- Server virtualization is the process of abstracting IT hardware into virtual servers using virtualization software.
- Virtualization provides hardware independence, server consolidation, and resource replication, and further supports resource pooling and elastic scalability.
- Virtual servers are realized through either operating system-based or hardware-based virtualization.

- Basic Web Technology
  - Uniform Resource Locator (URL)
  - Hypertext Transfer Protocol (HTTP)
  - Markup Language (HTMP, XML)
- Web Applications (Figure 5.10)
  - Presentation layer (user interface)
  - Application layer (application logic in application server)
  - Data layer (data store in data server)

Figure 5.10



- *Figure 5.10 - The three basic architectural tiers of Web applications.*

Summary of Web Service

- Web technology is very commonly for cloud service implementations and for front-ends used to remotely manage cloud-based IT resources.
  - For instance, typical PaaS offerings have separate instances of the Web server, application server, and data server.
- Fundamental technologies of Web architecture include the URL, HTTP, HTML, and XML.

5.5 **Multitenant Technology**

- Multitenant – a single instance of an IT resource serves multiple consumers (tenants).
- Multitenant application architecture is often significantly more complex than that of single-tenant applications.
- Multi-tenant applications need to support the sharing of various artifacts by multiple users (including portals, data schemas, middleware, and databases), while maintaining security levels that segregate individual tenant operational environments.

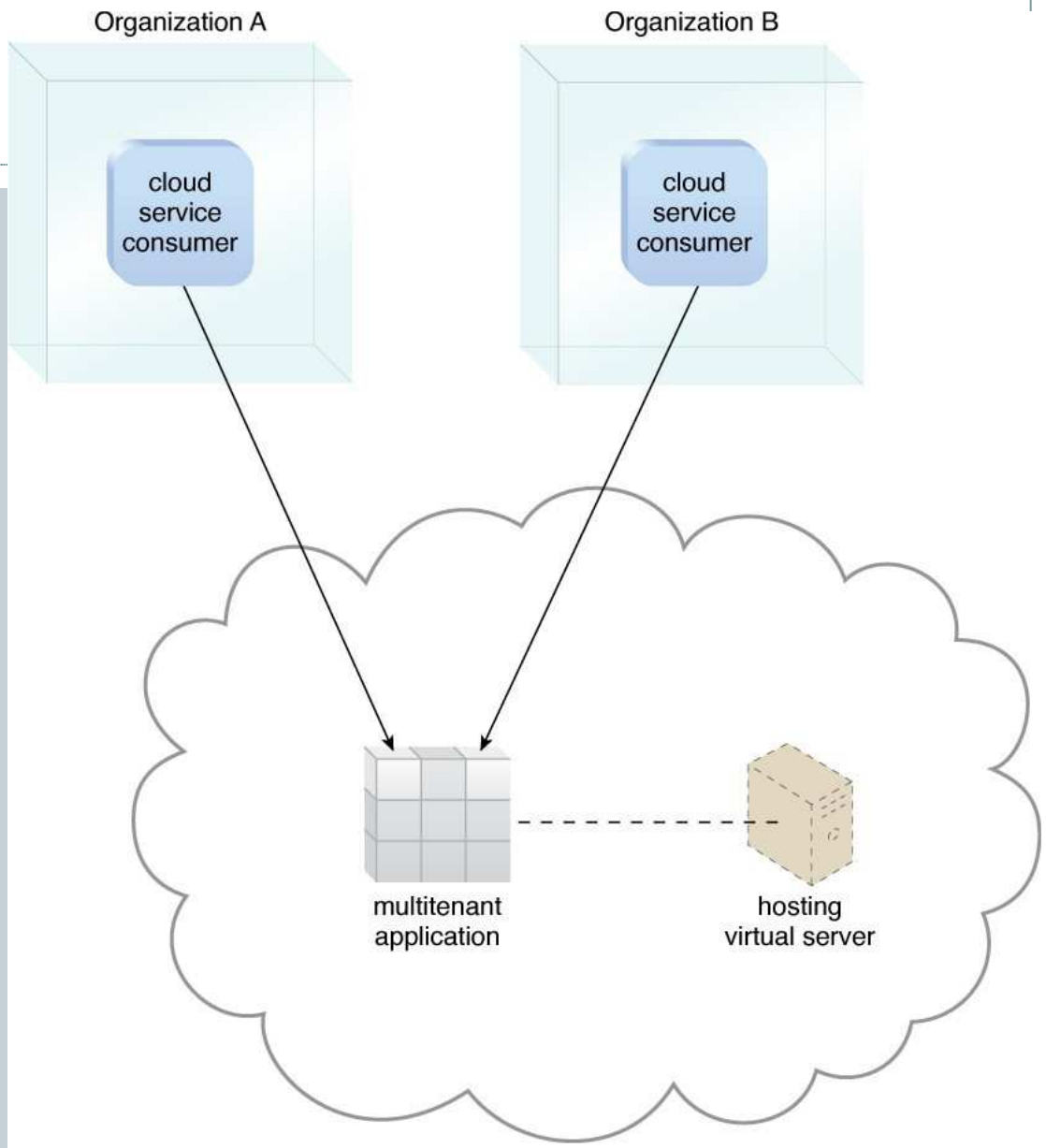
5.5 **Characteristics of Multitenant**

- Usage isolation
- Data security
- Recovery
- Application upgrades
- Scalability
- Metered usage
- Data tier isolation

- Multitenancy is sometimes mistaken for virtualization because the concept of multiple tenants is similar to the concept of virtualized instances.

Figure 5.11

- *Figure 5.11 - A multitenant application that is serving multiple cloud service consumers simultaneously.*



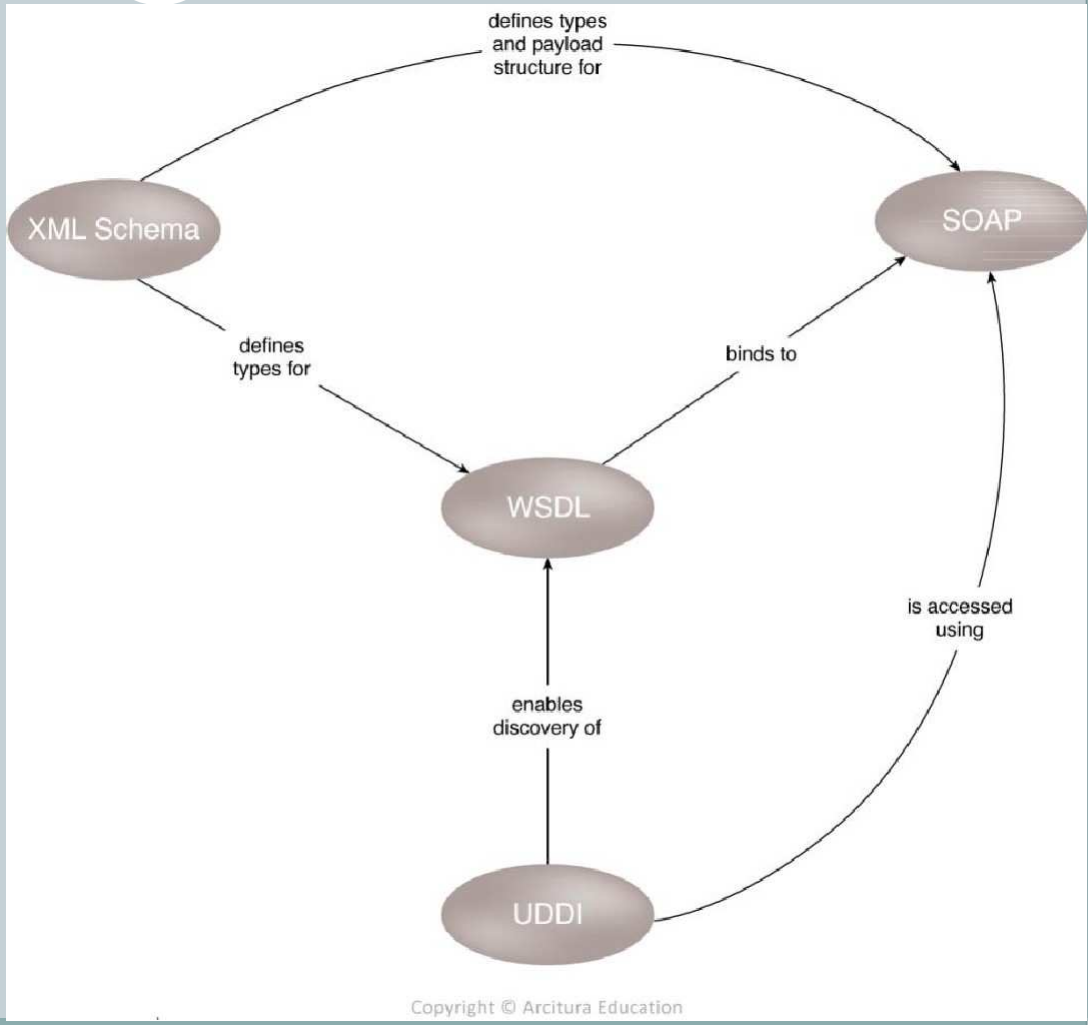
Multitenancy VS. Virtualization

- The differences lie in what is multiplied within a physical server acting as a host:
  - With virtualization:
    - Multiple virtual copies of the server environment can be hosted by a single physical serve. Each copy can be provided to different users, can be configured independently, and can contain its own operating system and applications.
  - With multitenancy:
    - A physical or virtual server hosting an application is designed to allow usage by multiple different users. Each user feels as though they have exclusive usage of the application.

- Along with XML, the core technologies behind Web services are represented by the following industry standards:
  - Web Service Description Language (WSDL)
  - XML Schema Definition Language (XML Schema)
  - SOAP (Simple Object Access Protocol)
  - Universal Description, Discovery, and Integration (UDDI)
- Note that: These 4 technologies collectively form the first generation of Web service technology. The 2nd generation (WS-*) addresses additional features, such as security, reliability, transactions, routing, and business process automation.

Figure 5.12

- *Figure 5.12 - An overview of how first-generation Web service technologies commonly relate to each other*



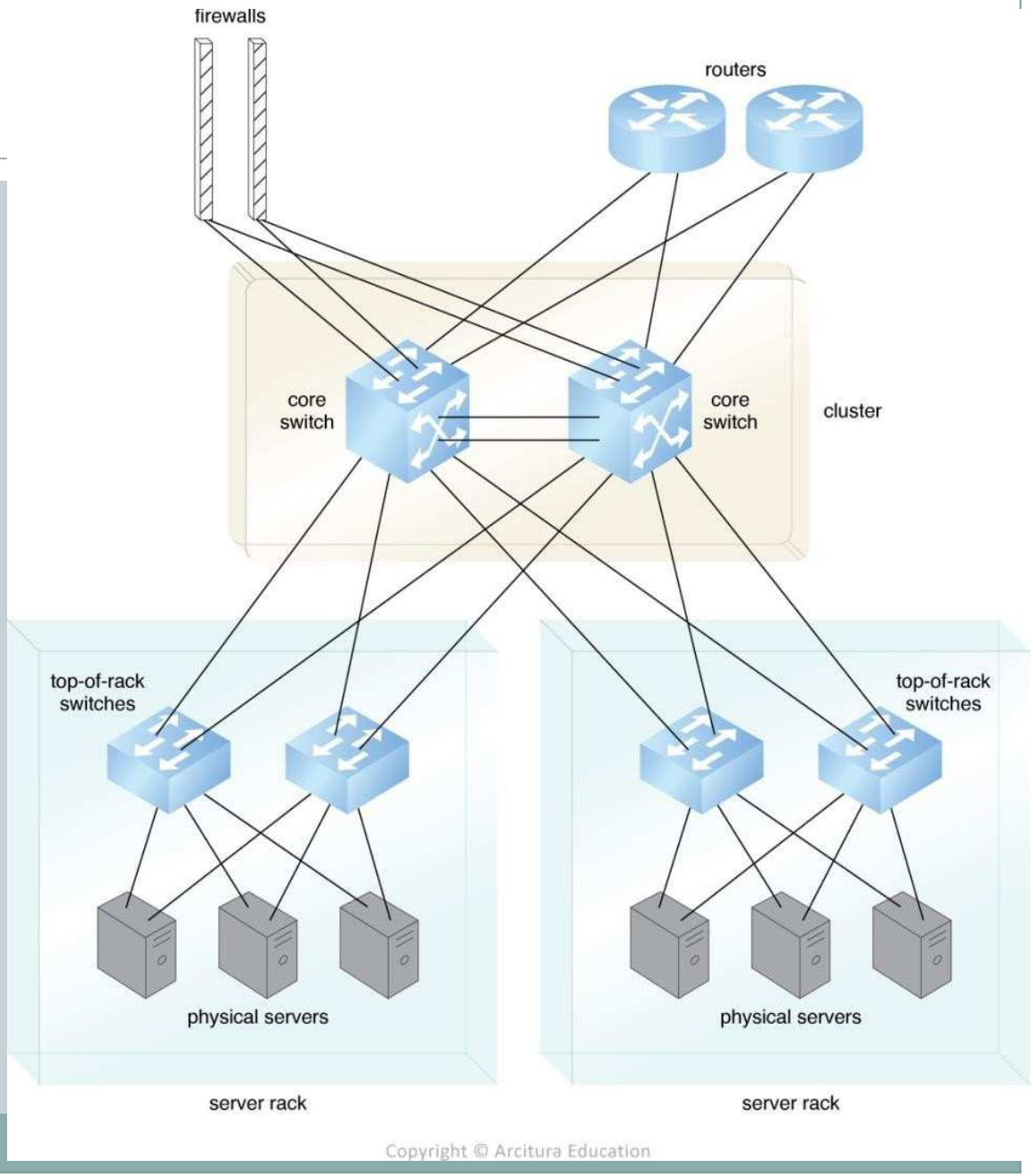
REST Service and Service Agents

- REST services are designed according to a set of constraints that shape the service architecture to emulate the properties of the WWW.
- Service agents are event-driven programs designed to intercept messages at runtime, either active agent or passive agent.
- Falling under the umbrella of service technology is the large of middle platform. Two main categories are the enterprise service bus (ESB) and the orchestration platform.

Summary of Service Technology

- Web-based services such as Web services and REST services rely on non-proprietary communications and technical interface definitions to establish standardized communications frameworks based on Web technology.
- Service agents provide event-driven runtime processing that can be applied to numerous functional areas within clouds.
- Service middleware, such as ESBs and orchestration platforms, can be deployed on clouds.

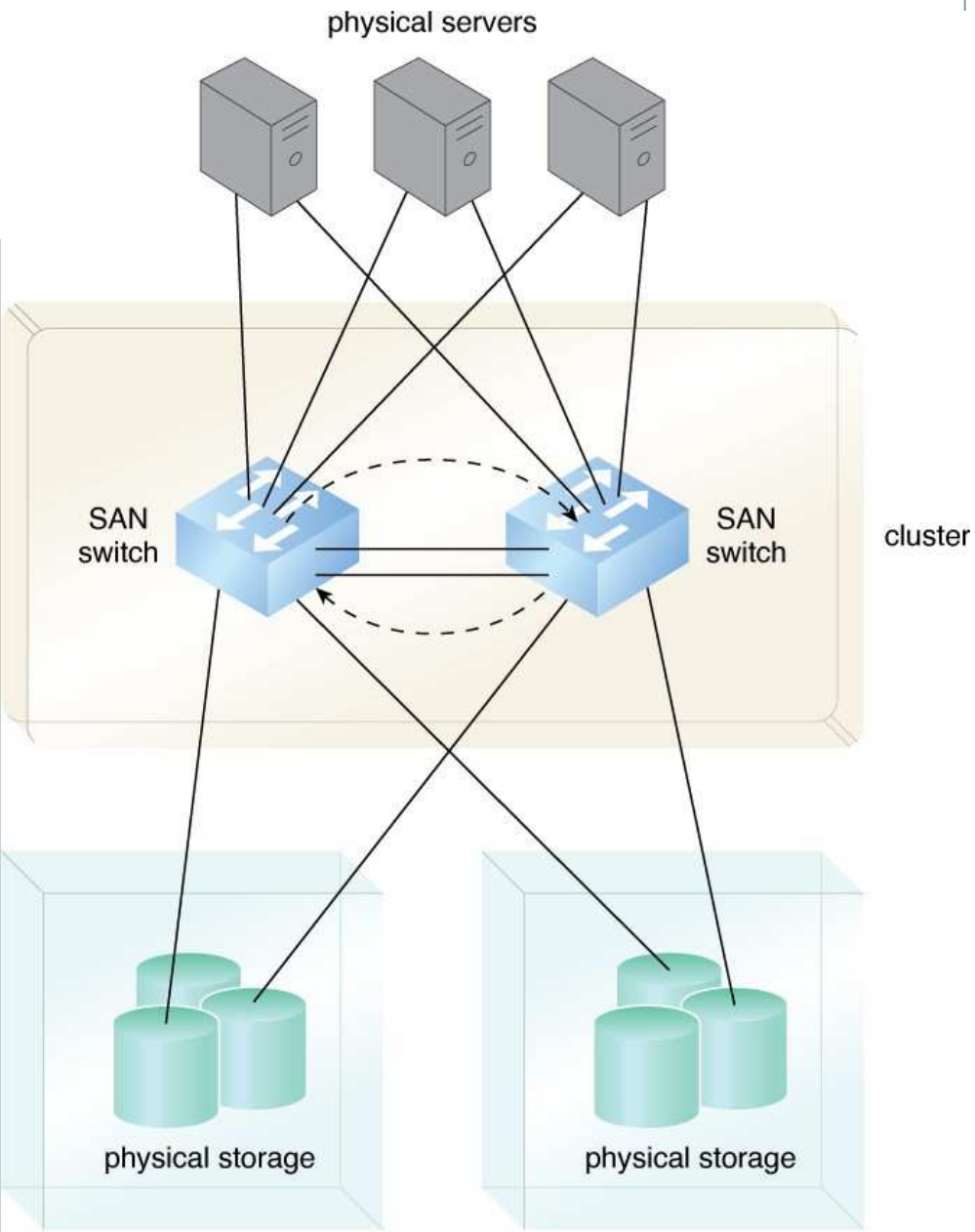
Figure 5.13



- *Figure 5.13 - A view of the server network connections inside the DTGOV data center.*

Figure 5.14

- *Figure 5.14 - A view of the storage system network connections inside the DTGOV data center.*

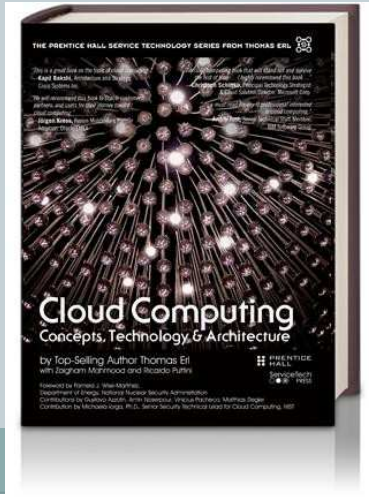


Cloud Computing

Concept, Technology & Architecture

Chapter 07

Cloud Infrastructure Mechanisms



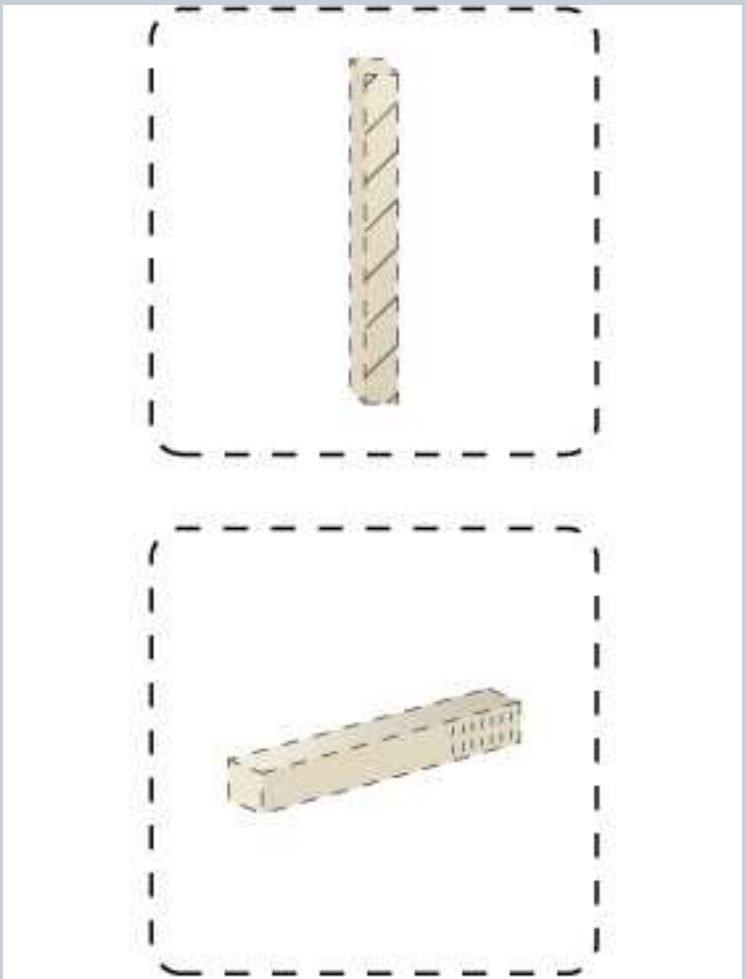
Contents

- Technology mechanisms foundational to cloud platforms are covered, including:
  - **7.1 Logical Network Perimeter**
  - **7.2 Virtual Server**
  - **7.3 Cloud Storage Device**
  - **7.4 Cloud Usage Monitor**
  - **7.5 Resource Replication**
  - **7.6 Ready-Made Environment**

7.1 Logical Network Perimeter

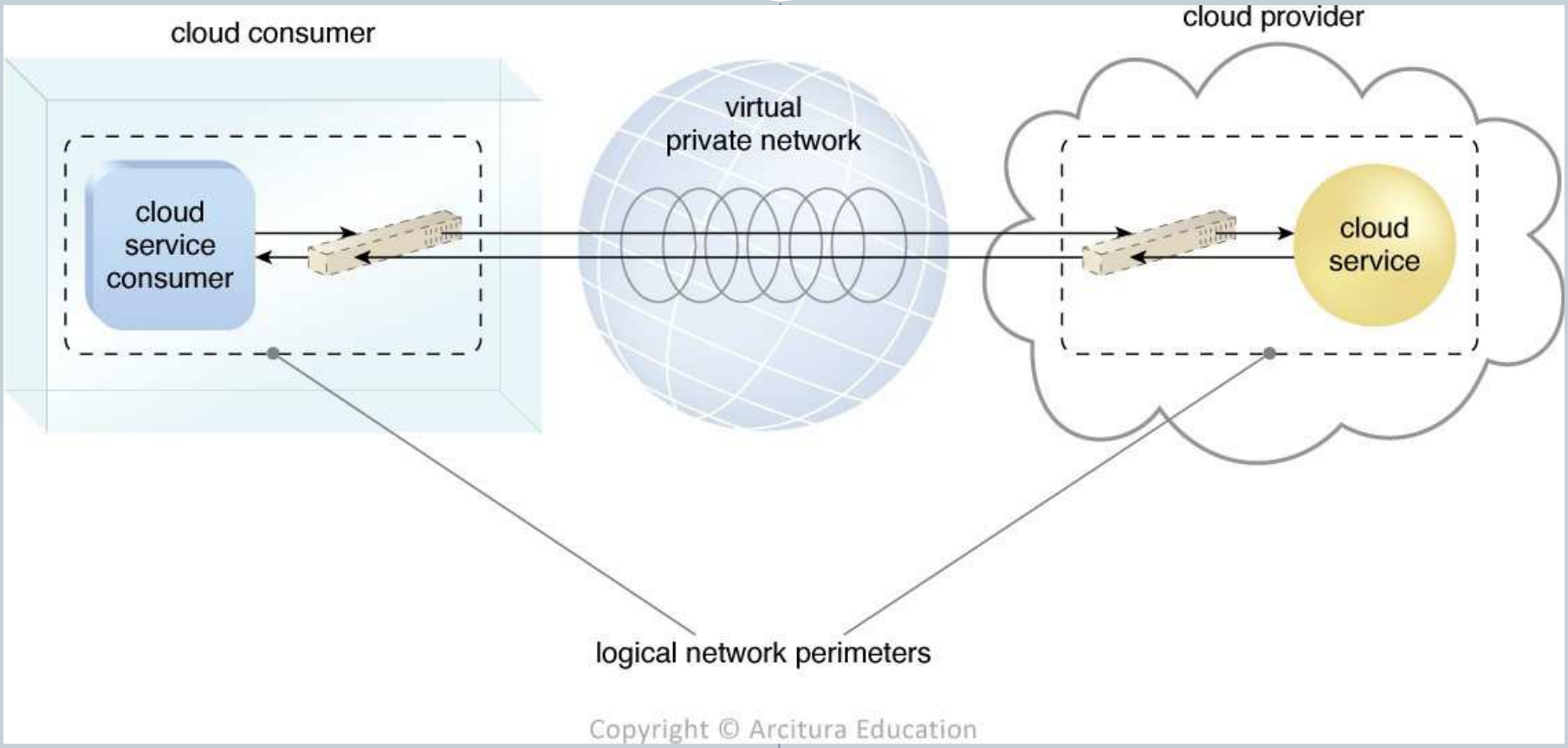
- The isolation of a network environment from the rest of communications network, the logical network perimeter establishes a virtual network boundary that can encompass and isolate a group of related cloud-based IT resources that may be physically distributed.
- Logical network perimeter can be implement to isolate IT resources in a cloud from cloud users and control the bandwidth via network devices by deploying virtual firewall and virtual network.

Figure 7.2



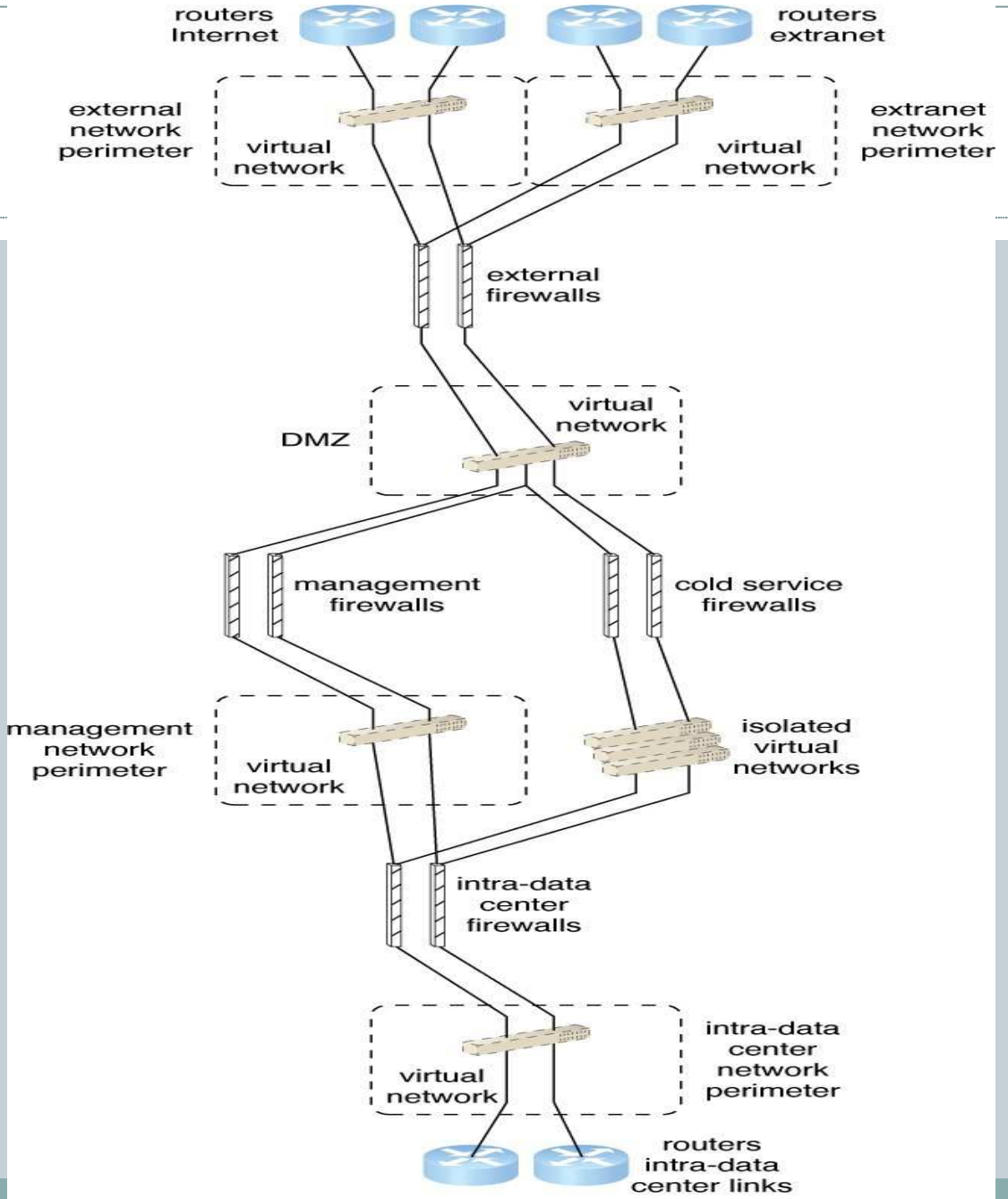
- *Figure 7.2 Virtual firewall (top) and virtual network. (bottom)*

Figure 7.3



- *Figure 7.3 – Two logical network perimeters surround the cloud consumer and cloud provider environments.*

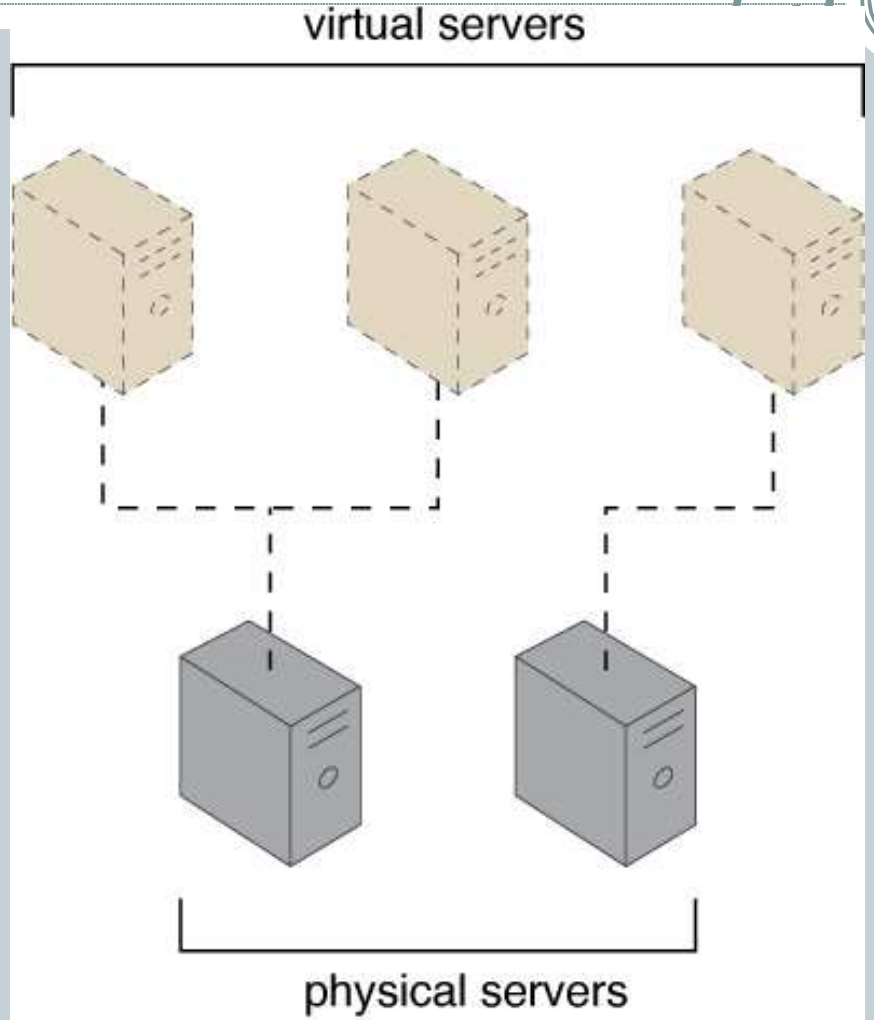
- *Figure 7.4 - A logical network layout is established through a set of logical network perimeters using various firewalls and virtual networks.*



7.2 Virtual Server

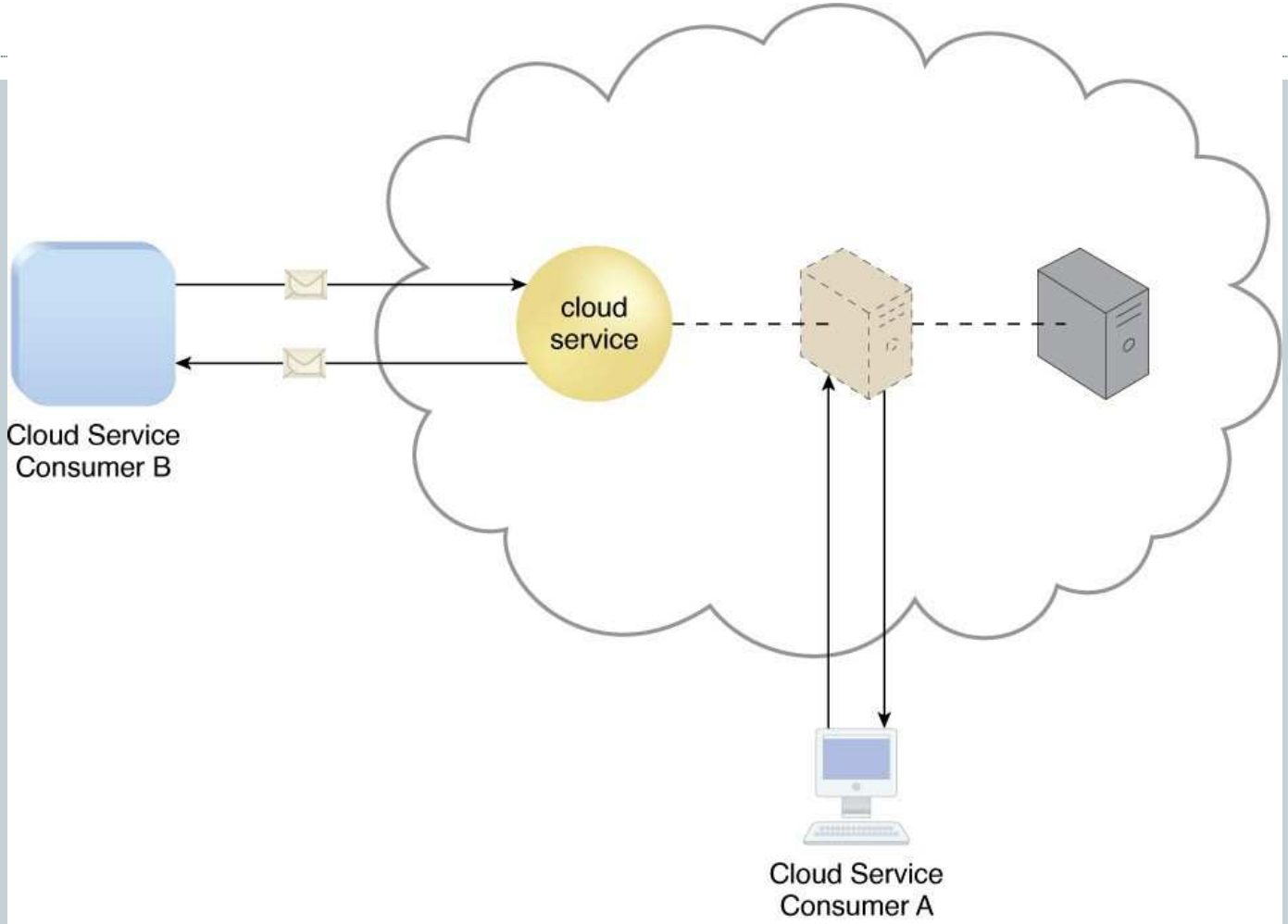
- A virtual server is a form of virtualization software that emulates a physical service.
- The virtual server represents the mode fundamental building block of cloud environment. The instantiation of virtual servers from image files is a resource allocation process that can be completed rapidly and on-demand.
- Cloud customers that install or lease virtual servers can customize their environments independently from other customers.

Figure 7.5



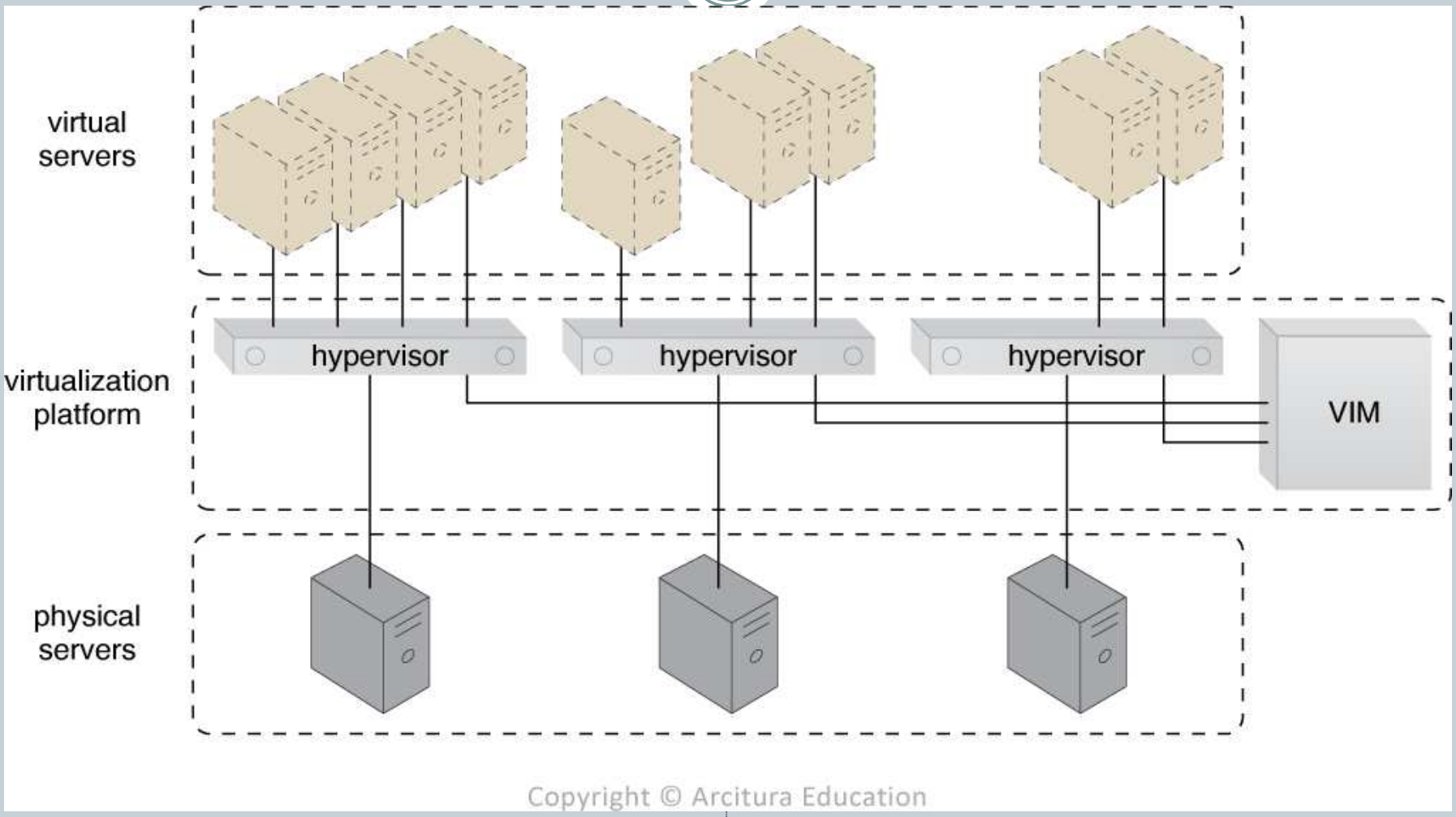
- *Figure 7.5 - The first physical server hosts two virtual servers, while the second physical server hosts one virtual server.*

Figure



- *Figure 7.6 - A virtual server hosts an active cloud service and is further accessed by a cloud consumer for administrative purposes.*

Figure 7.7



- *Figure 7.7 - Virtual servers are created via the hypervisor and VIM.*

7.3 Cloud Storage Device (1/3)

- The cloud storage device mechanism represents storage devices that are designed specifically for cloud-based provisioning.
- Cloud storage devices are commonly able to provide fixed-increment capacity allocation in support of the pay-per-use mechanism.
- The primary concern related to cloud storage is the security, integrity, and confidentiality.

7.3 Cloud Storage Device (2/3)

- There are several levels in providing common logical units of data storage:
  - files – located in a folder
  - Blocks – lowest level of storage closest to the HW
  - Datasets – table-based, delimited, or record collection
  - Objects – web-based resources

7.3 Cloud Storage Device (3/3)

- According to different storage levels, there are three kinds of interfaces implemented:
  - Network storage interfaces – files or blocks
  - Object storage interfaces – web resources
  - Databasre storage interfaces – relational or non-relational (NoSQL)

Figure 7.9

- *Figure 7.9 - Different cloud service consumers utilize different technologies to interface with virtualized cloud storage devices. (Adapted from the CDMI Cloud Storage Reference Model.)*

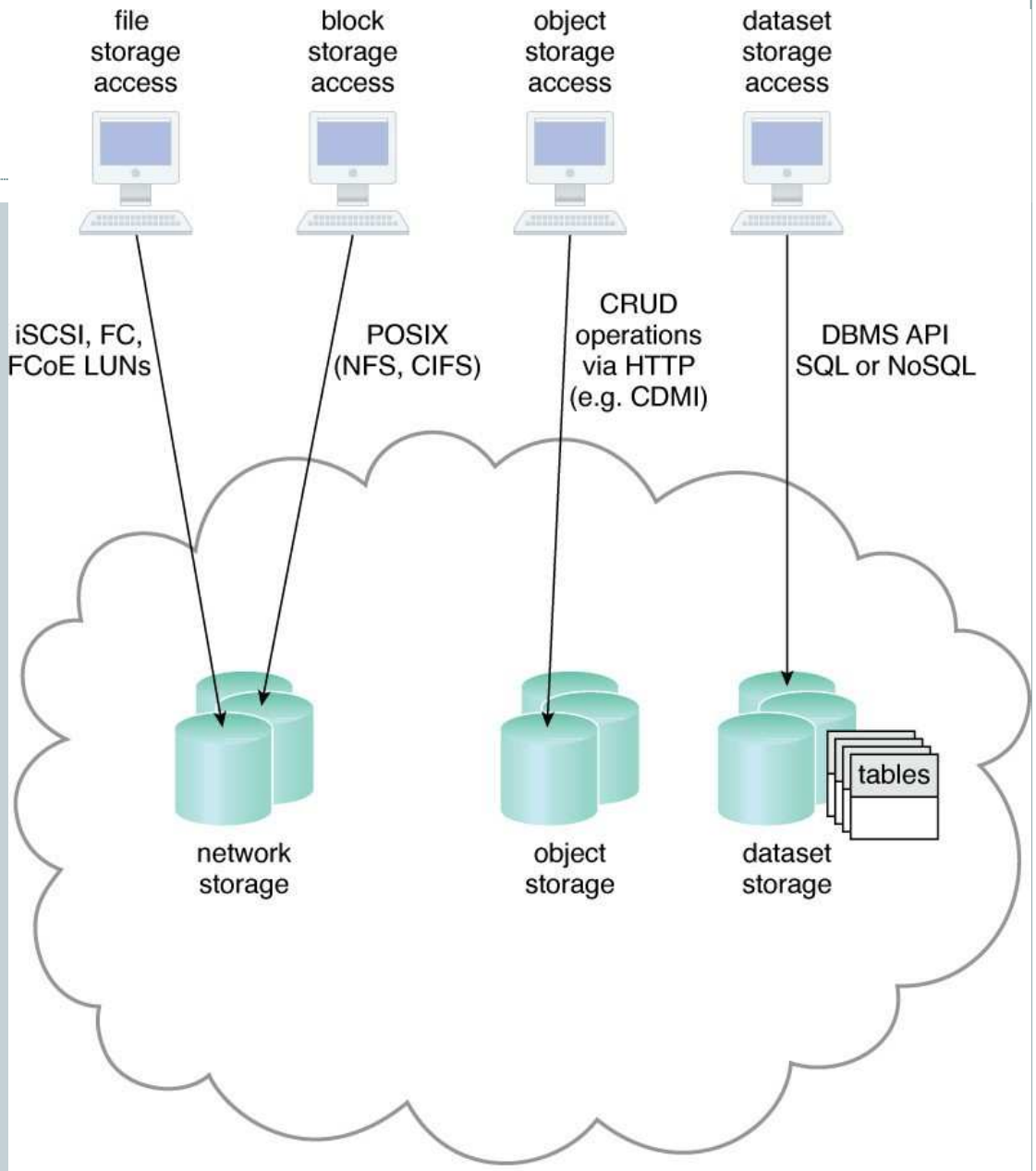
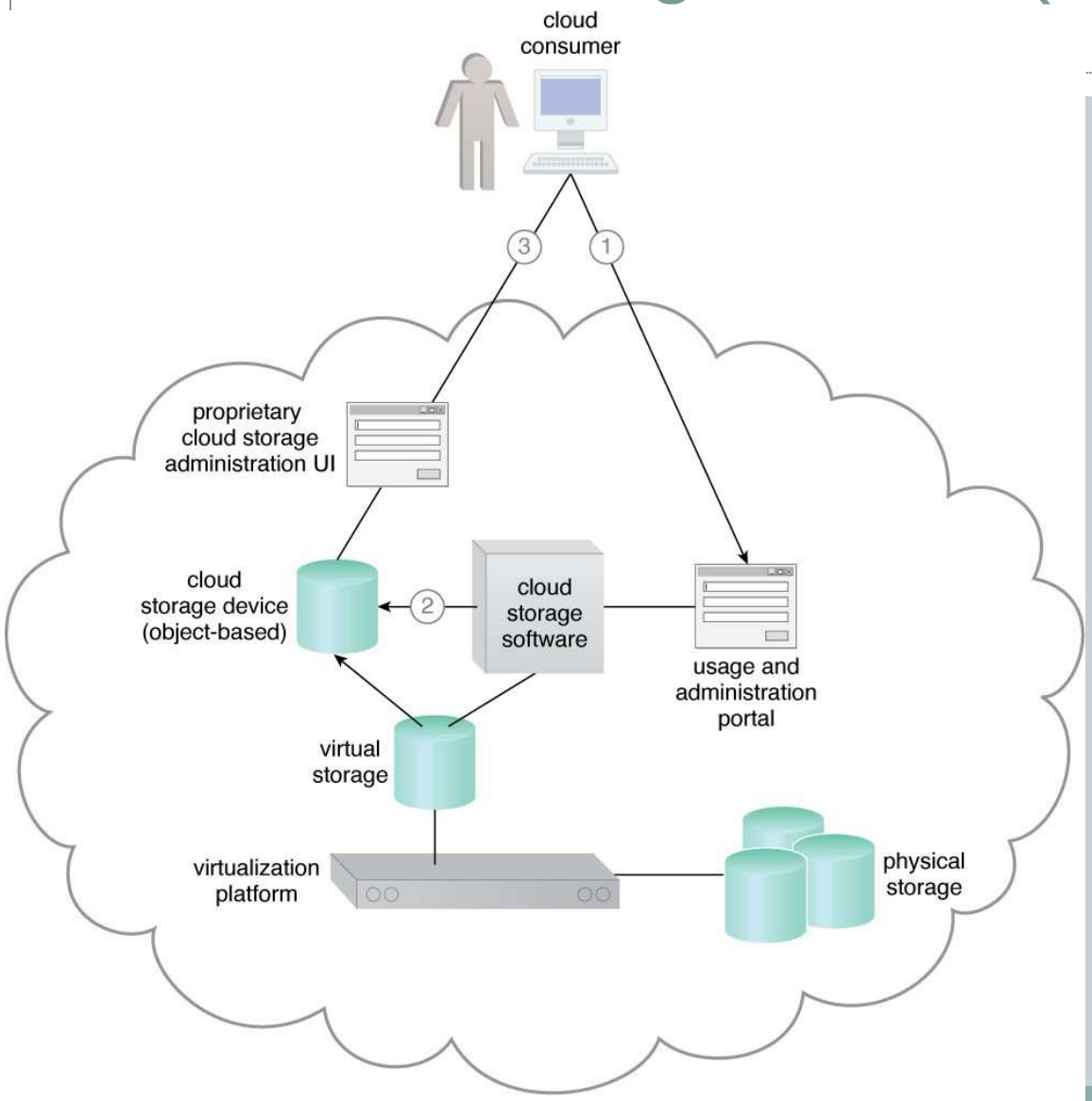
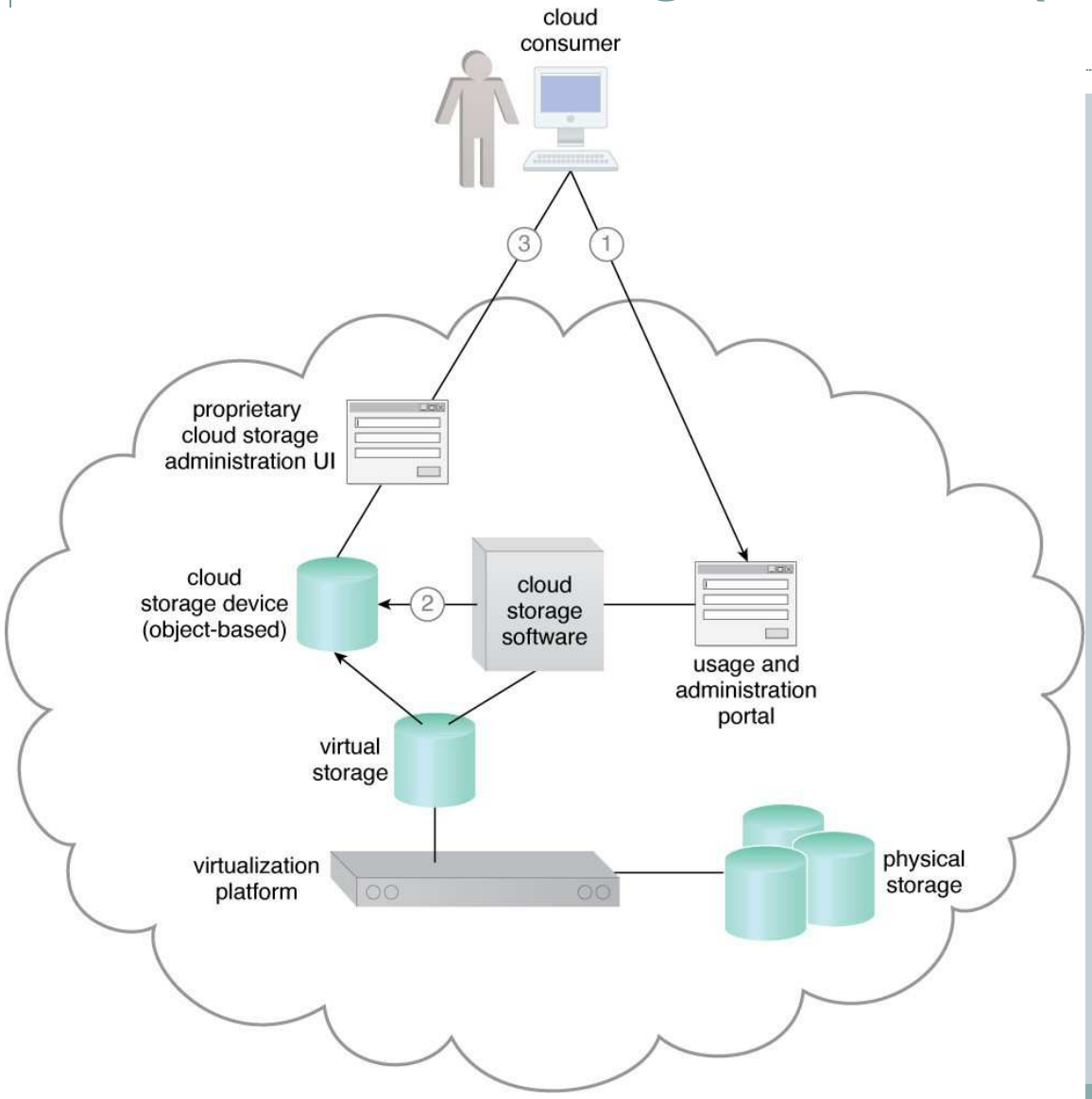


Figure 7.10 (1/3)



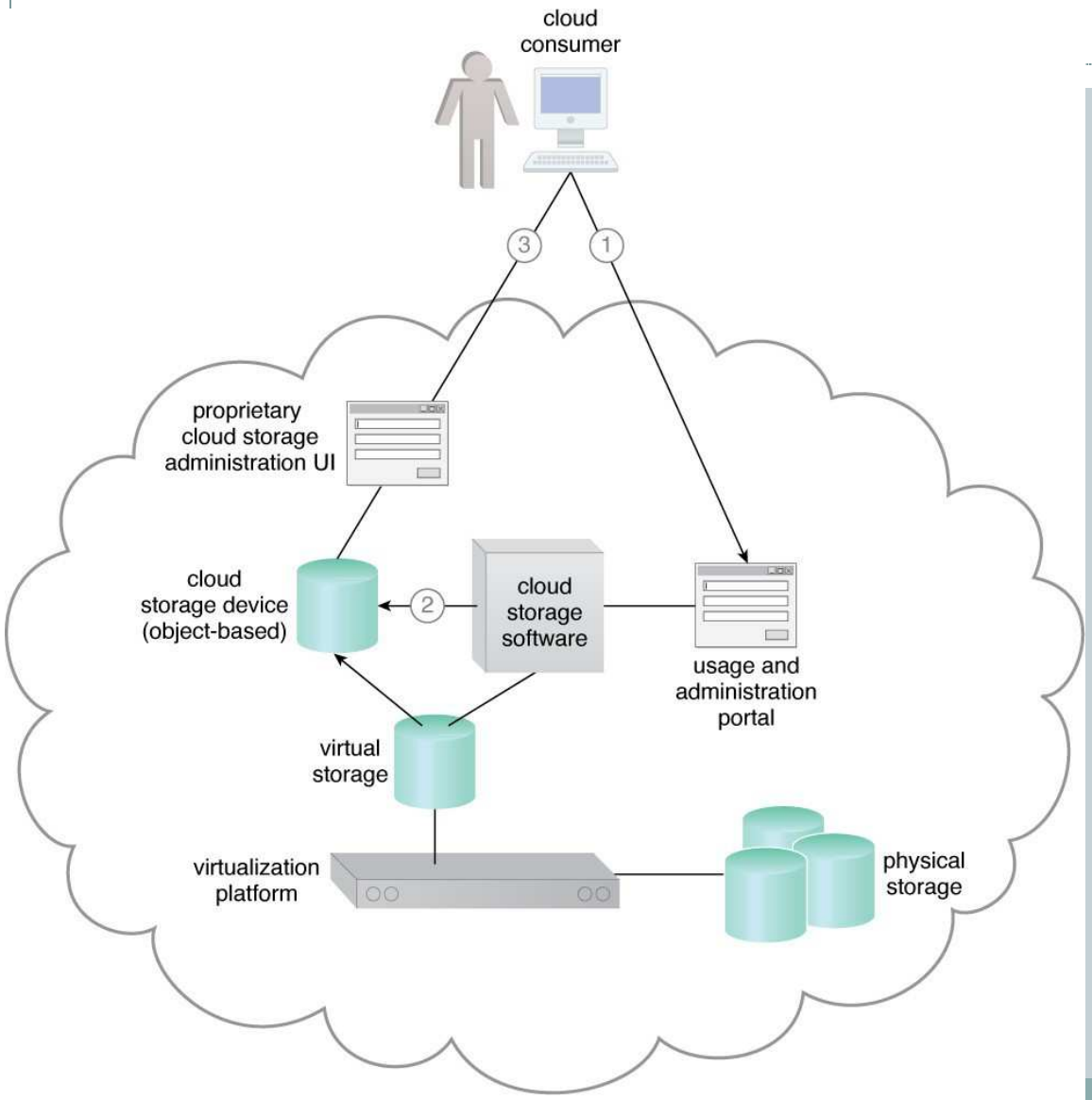
- *The cloud service consumer interacts with management tools to create the cloud storage device and define appropriated access control policies for each data object (1).*

Figure 7.10 (2/3)



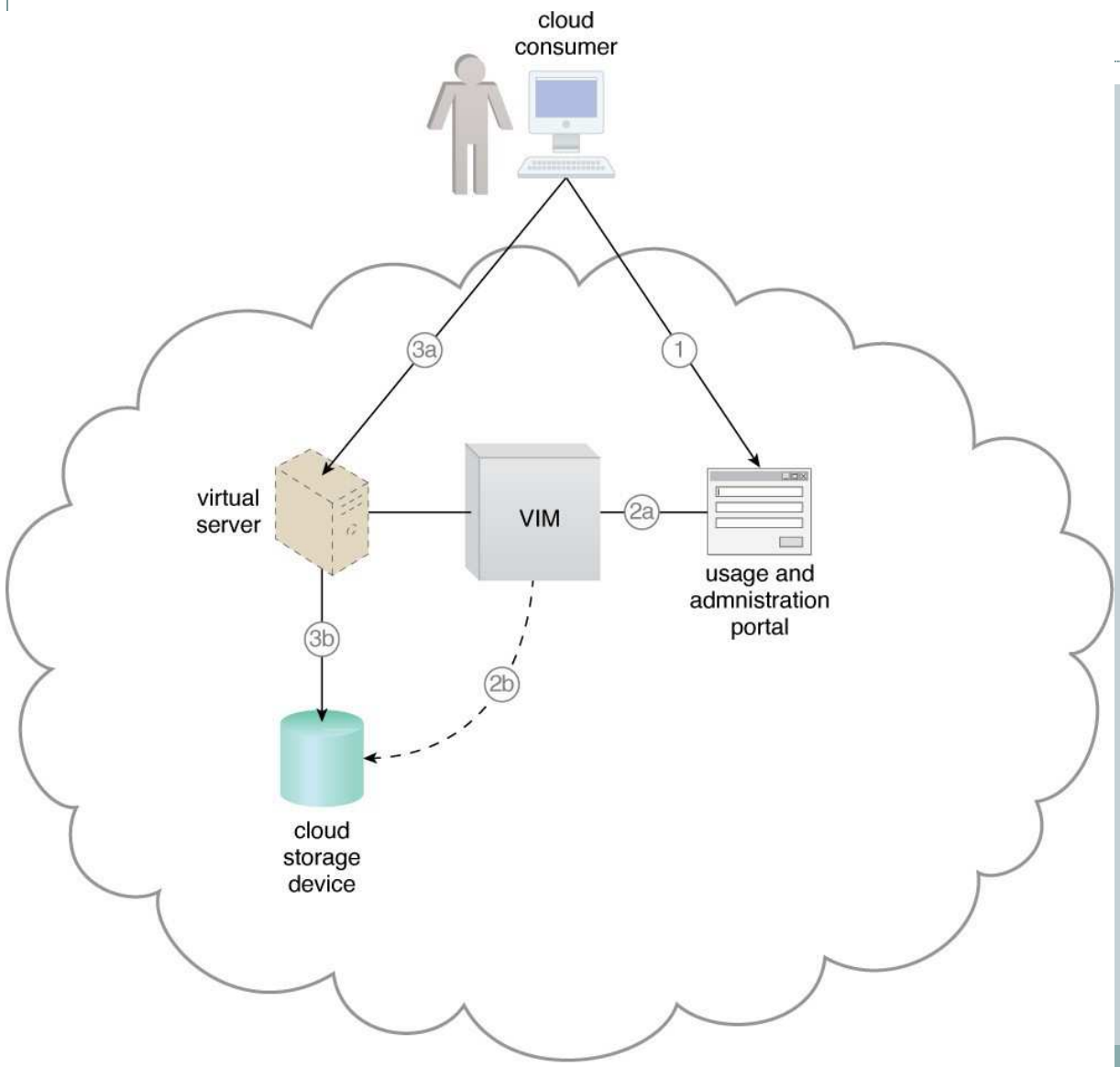
- *The management tools interact with the cloud storage software to create a cloud storage device instance and apply the required access policy to its data objects (2).*

Figure 7.10 (3/3)



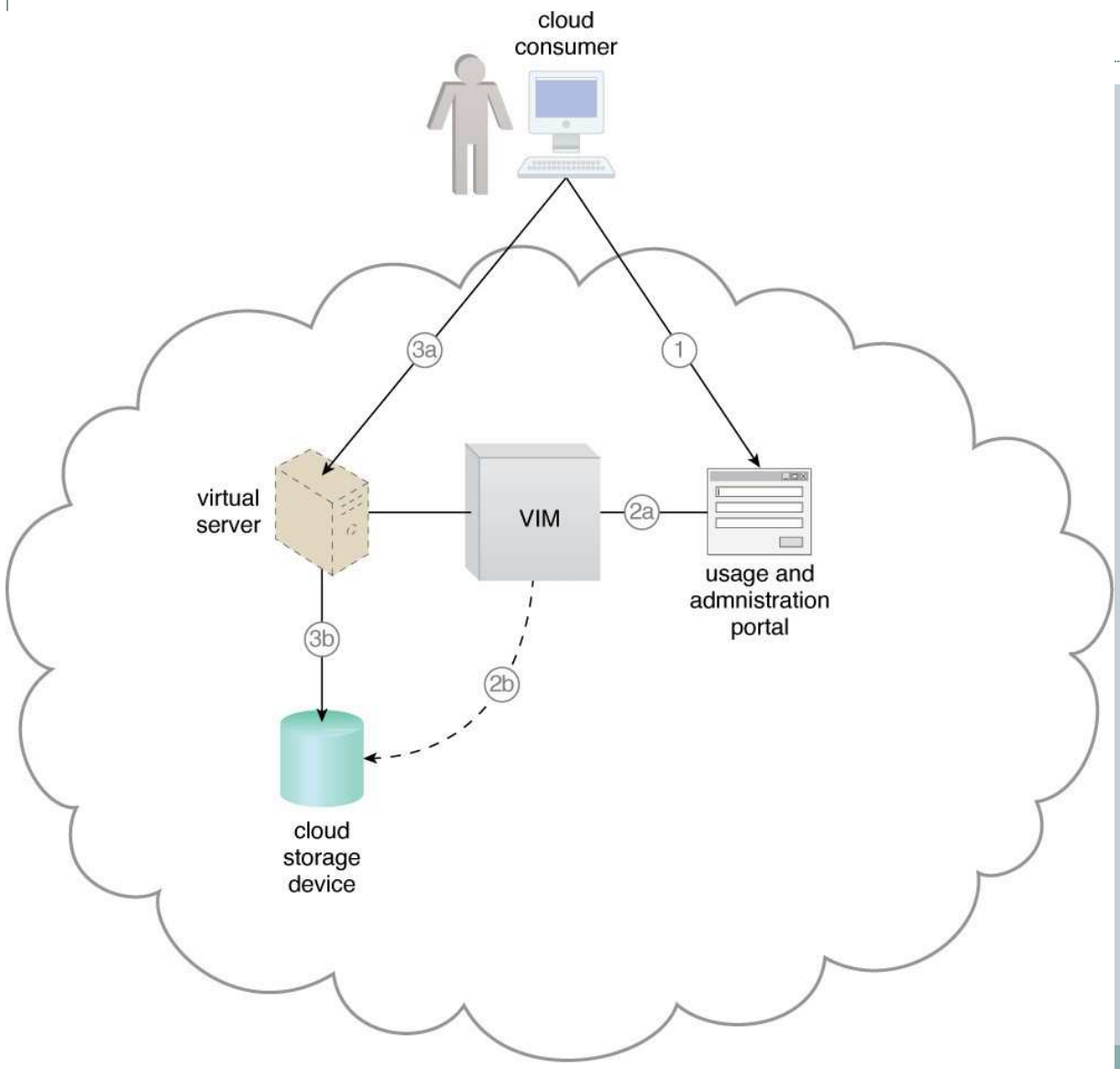
- *Each data object is assigned to a cloud storage device and all of the data objects are stored in the same virtual storage volume. The cloud service consumer uses the cloud storage device interface to access data objects (3).*

Figure 7.11



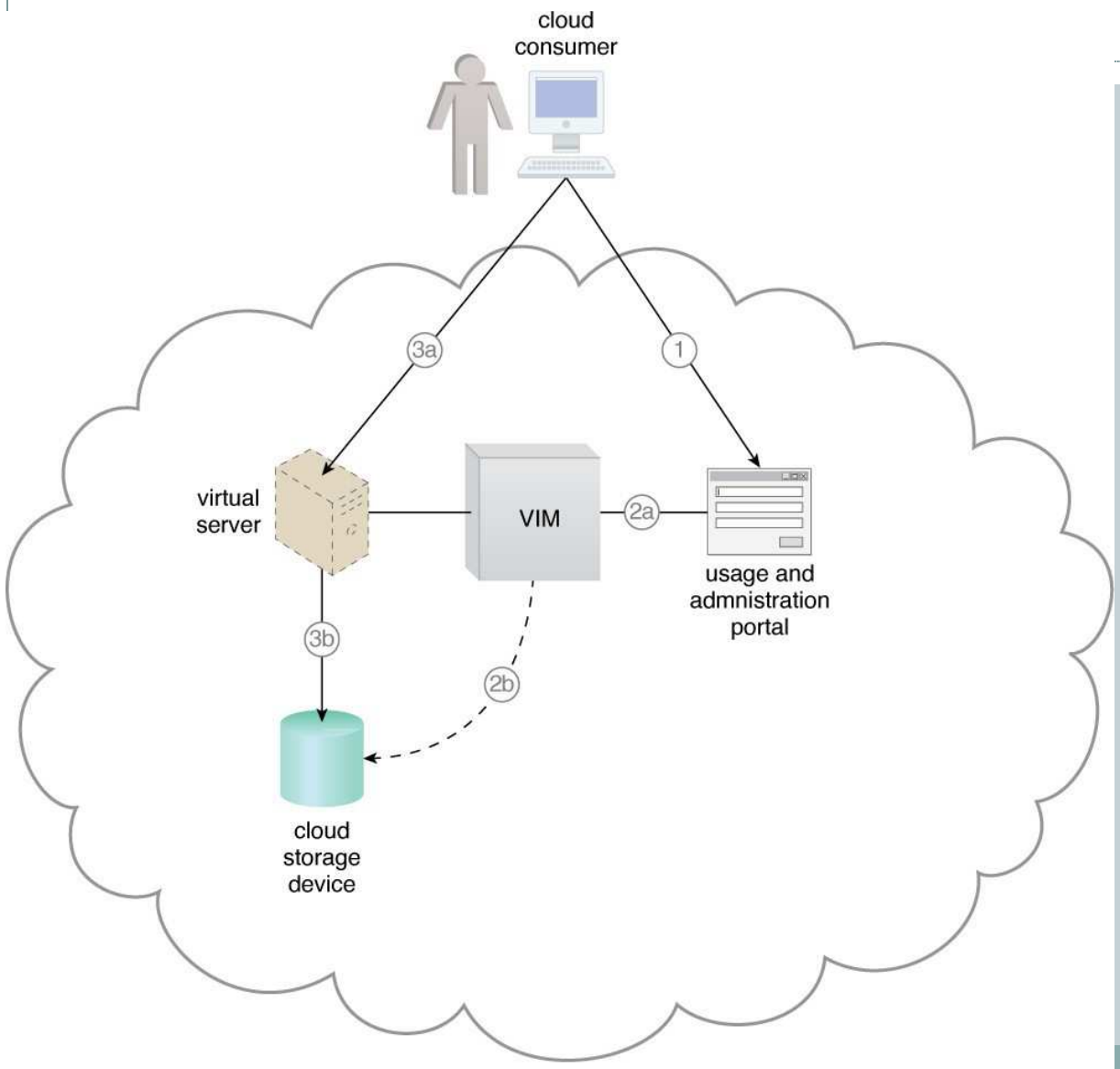
- *The cloud service consumer uses management tools to create and assign a cloud storage device to an existing virtual server (1).*

Figure 7.11 (2/3)



- *The management tools interact with the VIM software (2a), which creates and configures the appropriate LUN (2b).*

Figure 7.11 (3/3)



- *Each cloud storage device uses a separate LUN controlled by the virtualization platform. The cloud service consumer uses the virtual server (3a) to access the cloud storage device (3b).*

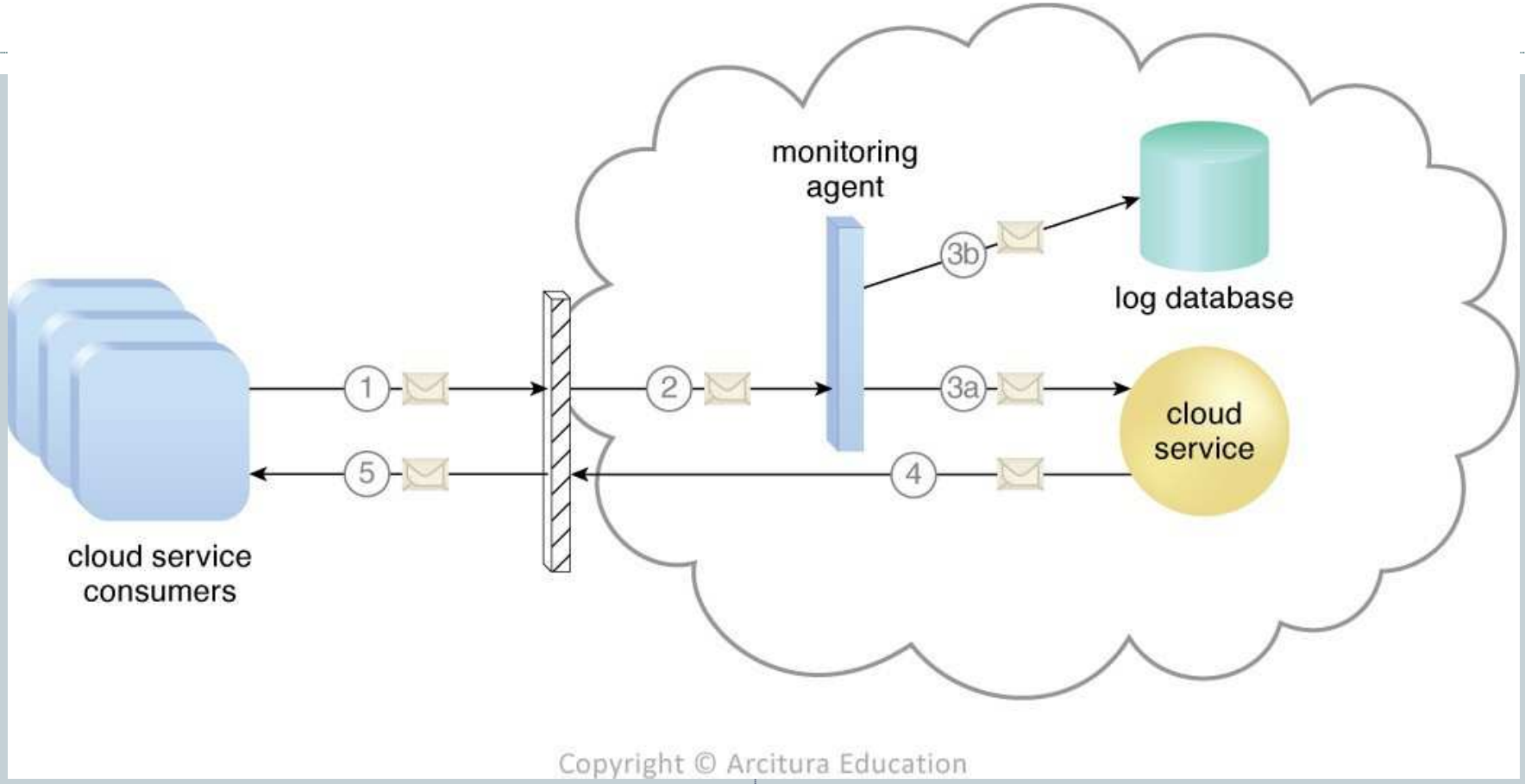
7.4 Cloud Usage Monitor (1/2)

- The cloud usage monitor mechanism is a lightweight and autonomous software program responsible for collecting and processing IT resource usage.
- Three common agent-based implementation formats:
  - monitoring agent
  - Resource agent
  - Polling agent

7.4 Cloud Usage Monitor (2/2)

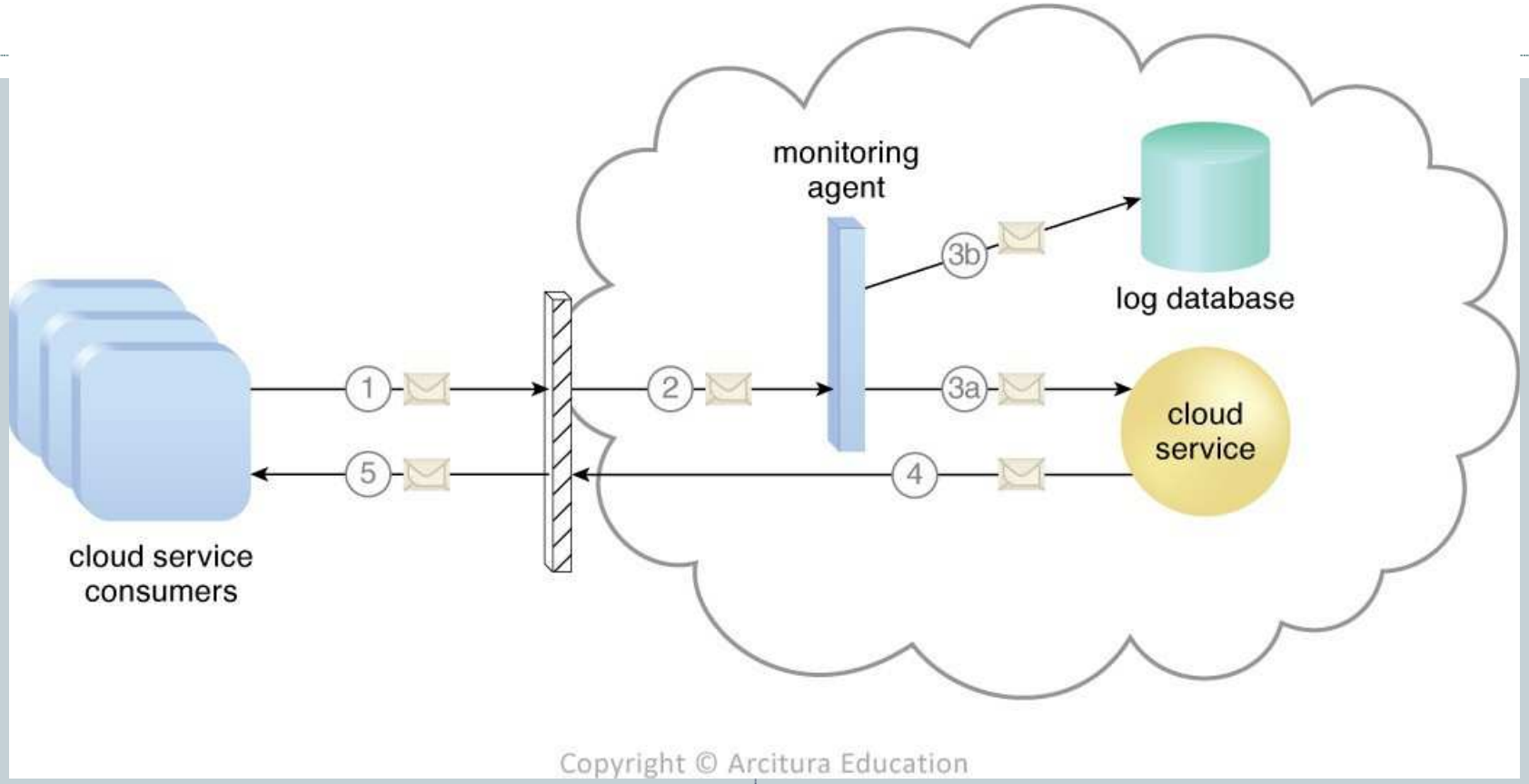
- Each monitor agent can be designed to forward collected usage data to a log database for post- processing and reporting purposes.
- monitoring agent is usually an event-driven program to network traffic and message metrics.
- resource agent monitors usage metrics based on pre-defined, observable events at the resource software level, such as initiating, suspending, resuming, and vertical scaling.
- polling agent polls IT resources to periodically monitor IT resource status, eg. up or down time.

Figure 7.12



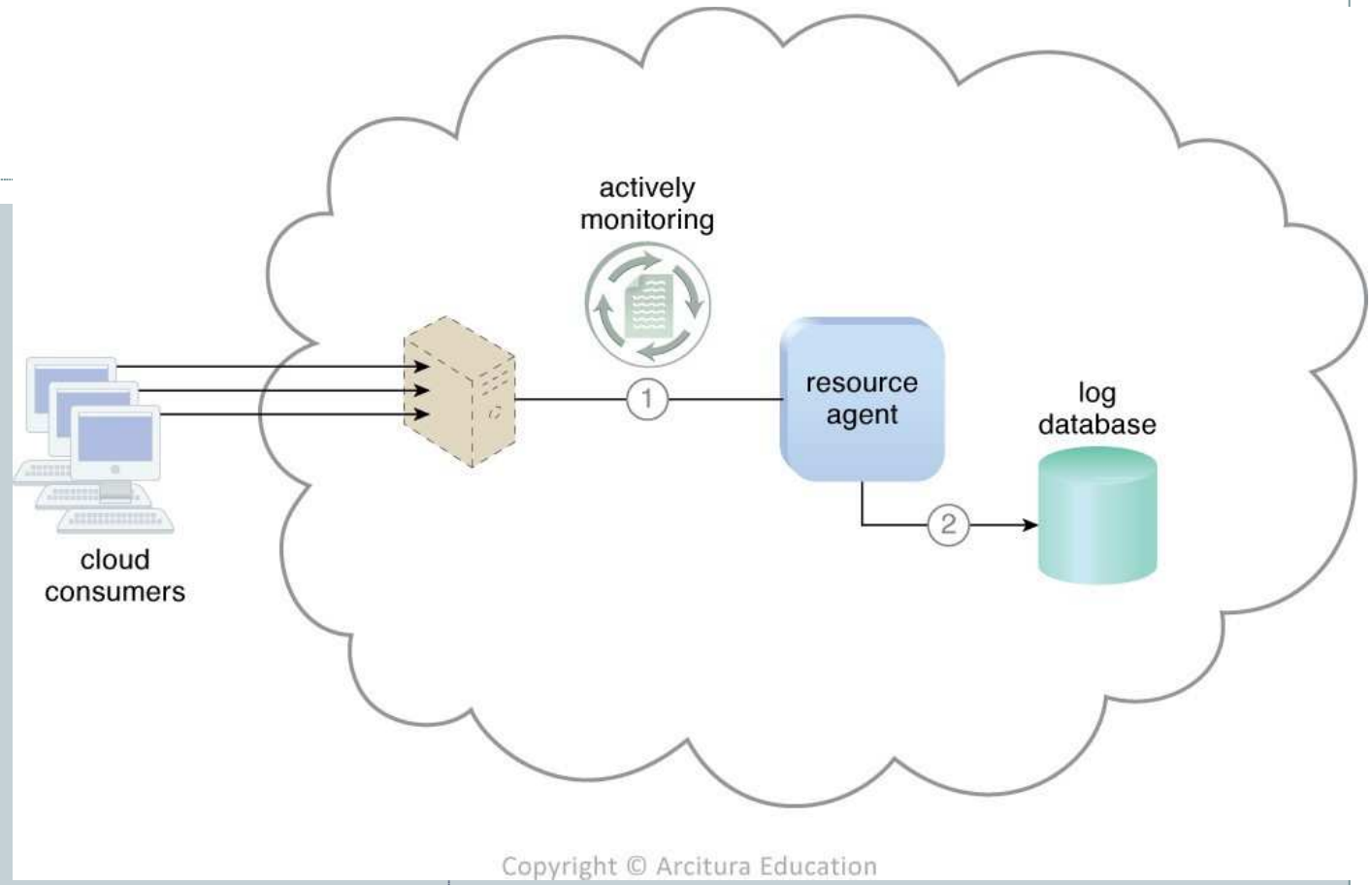
- *A cloud service consumer send a request message to a cloud service (1).*
- *The monitoring agent intercepts the message to collect relevant usage data (2) before allowing it to continue to the cloud service (3a).*

Figure 7.12 (2/2)



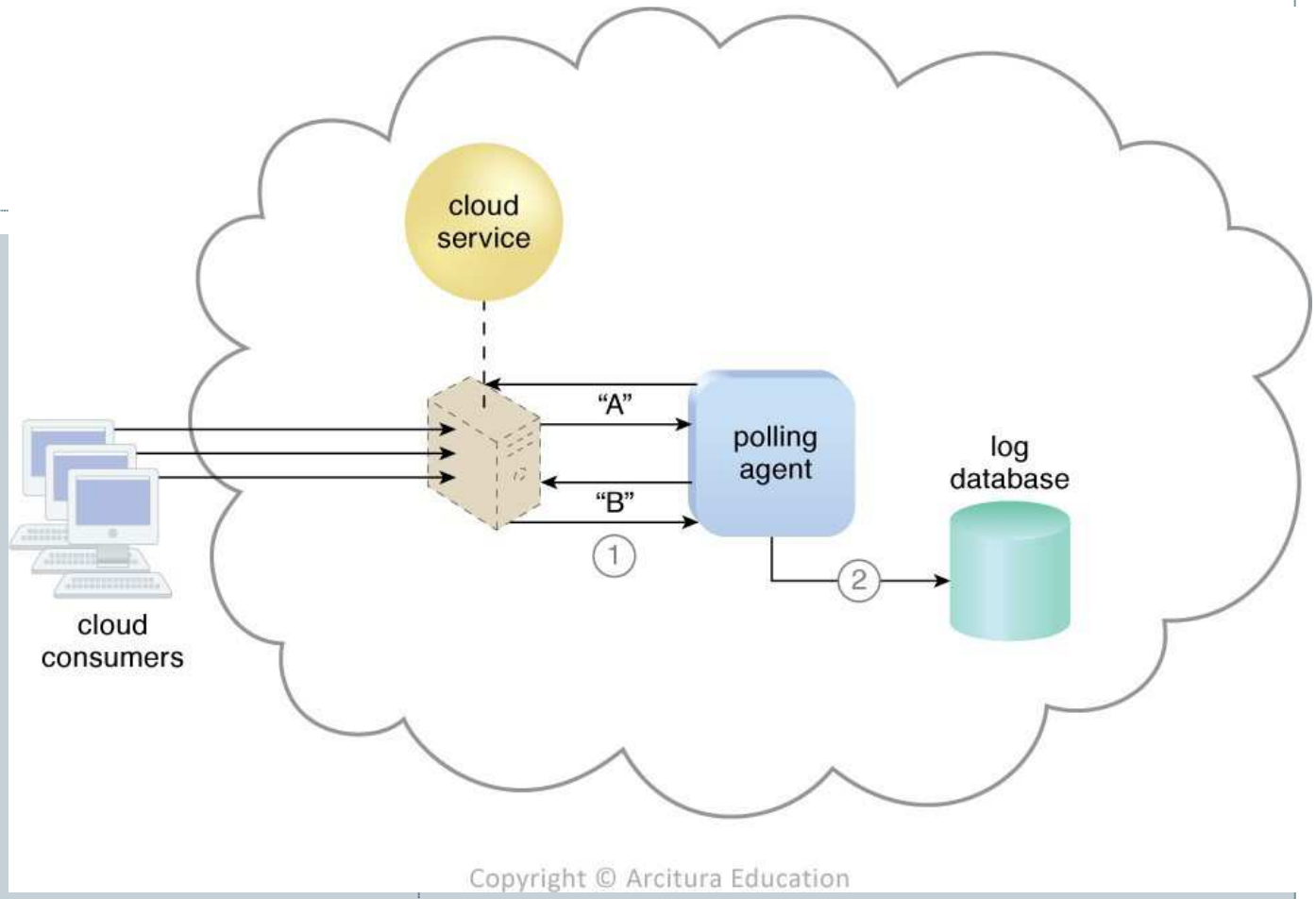
- *The monitoring agent stores the collected usage data in a log database (3b).*
- *The cloud service replies with a response message (4) that is sent back to the cloud service consumer without being intercepted by the monitoring agent (5).*

Figure 7.13



- *The resource agent is actively monitoring a virtual server and detects an increase in usage (1).*
- *The resource agent receives a notification from the underlying resource management program that the virtual server is being scaled up and stores the collected usage data in a log database, as per its monitoring metrics (2).*

Figure 7.14

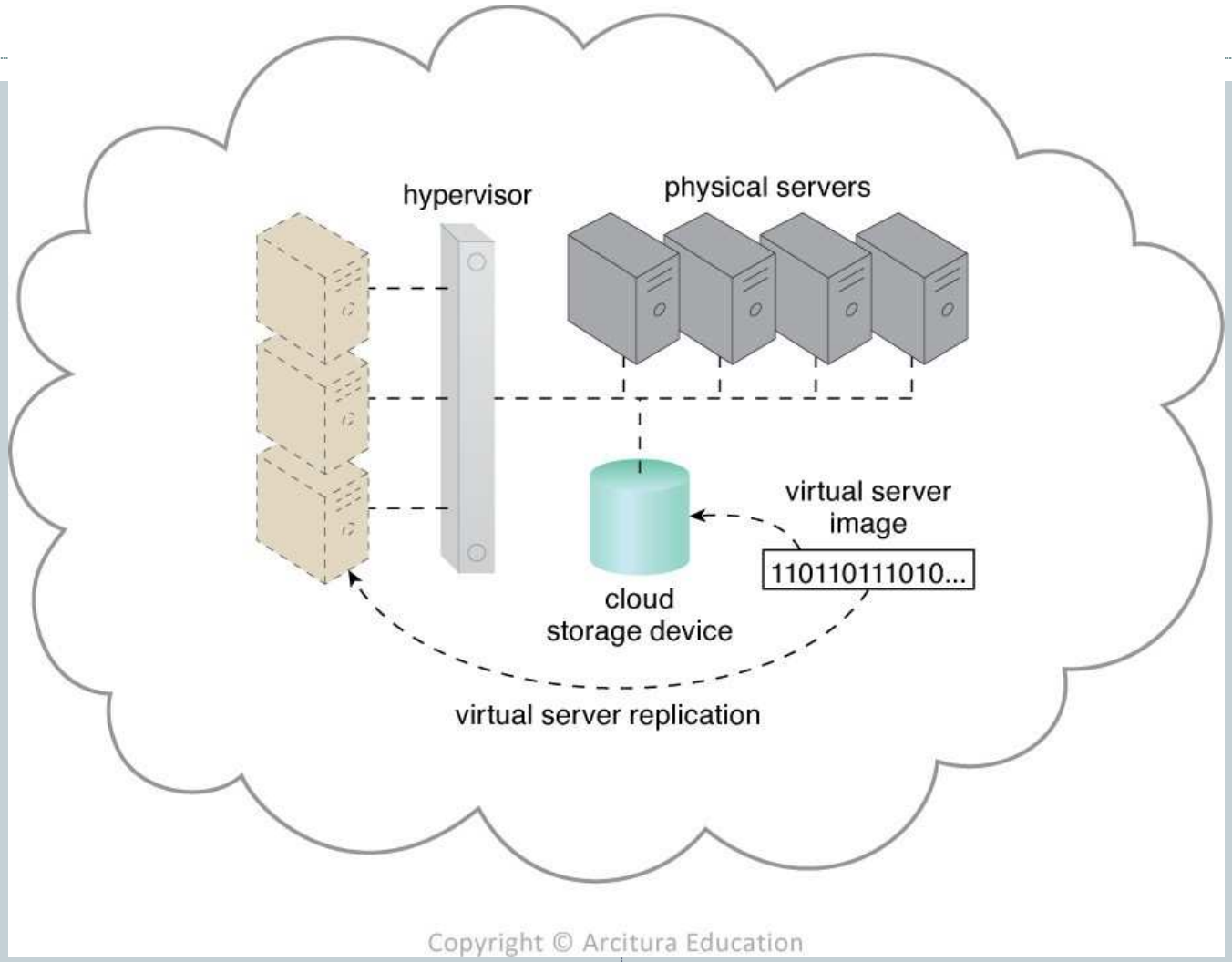


- *Figure 7.14 - A polling agent monitors the status of a cloud service hosted by a virtual server by sending periodic polling request messages and receiving polling response messages that report usage status "A" after a number of polling cycles, until it receives a usage status of "B" (1), upon which the polling agent records the new usage status in the log database (2).*

7.5 Resource Replication

- Replication is usually performed when resource's availability and performance need to be enhanced.
- Resource replication mechanism usually uses virtualization technology to replicate cloud-based IT resources.

Figure



- *Figure 7.16 - The hypervisor replicates several instances of a virtual server.*

Figure 7.17

- *Figure 7.17 - A high availability virtual server is running in Data Center A. VIM instances, in Data Center A and Data Center B, are executing the coordination function that allows detection of failure conditions. Storage of VM images is replicated between data centers, as a consequence of the high availability configuration.*

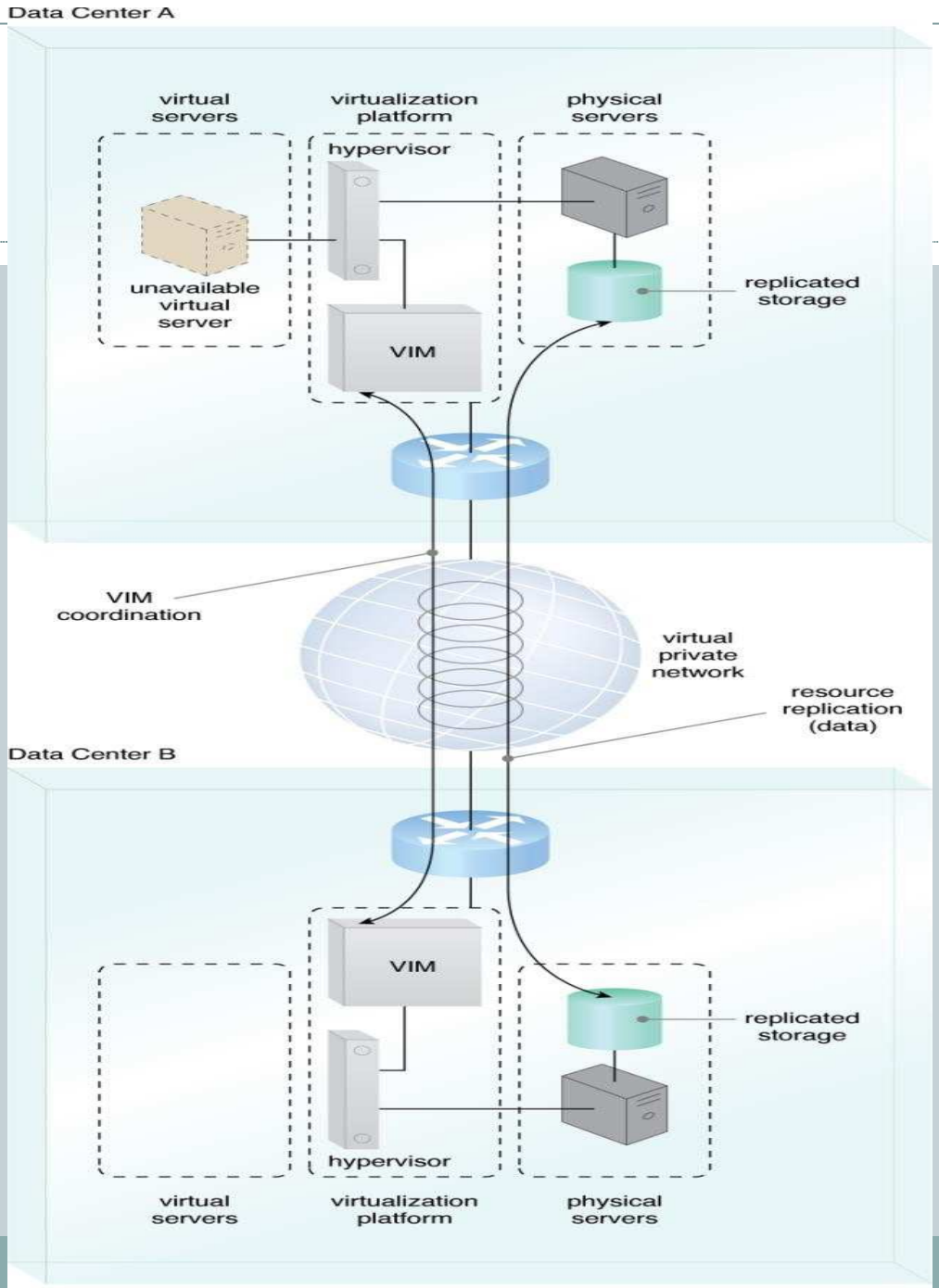


Figure 7.18

- *Figure 7.18 - The virtual server becomes unavailable in Data Center A. VIM in Data Center B detects the failure condition and starts to reallocate the high availability server from Data Center A into Data Center B.*

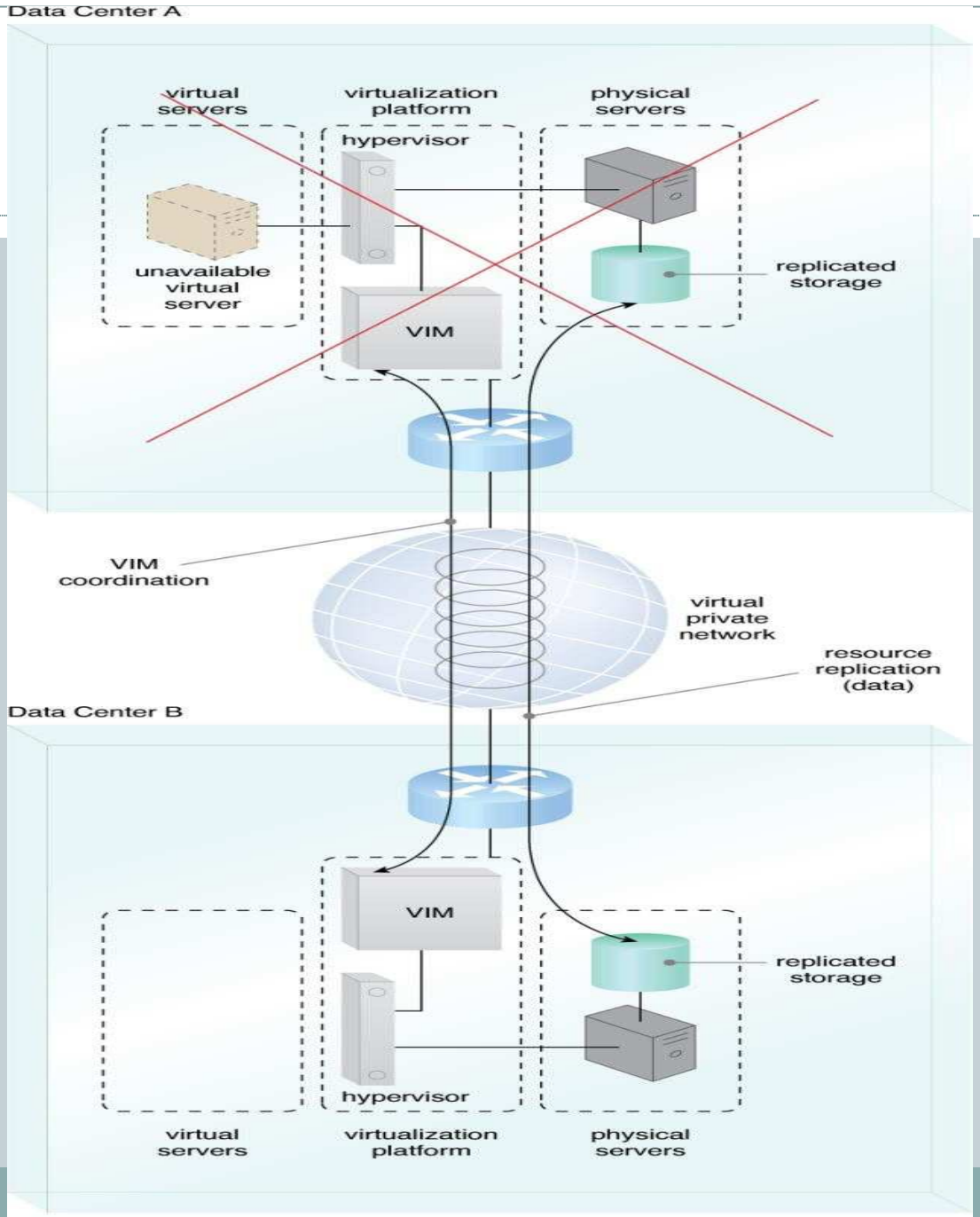
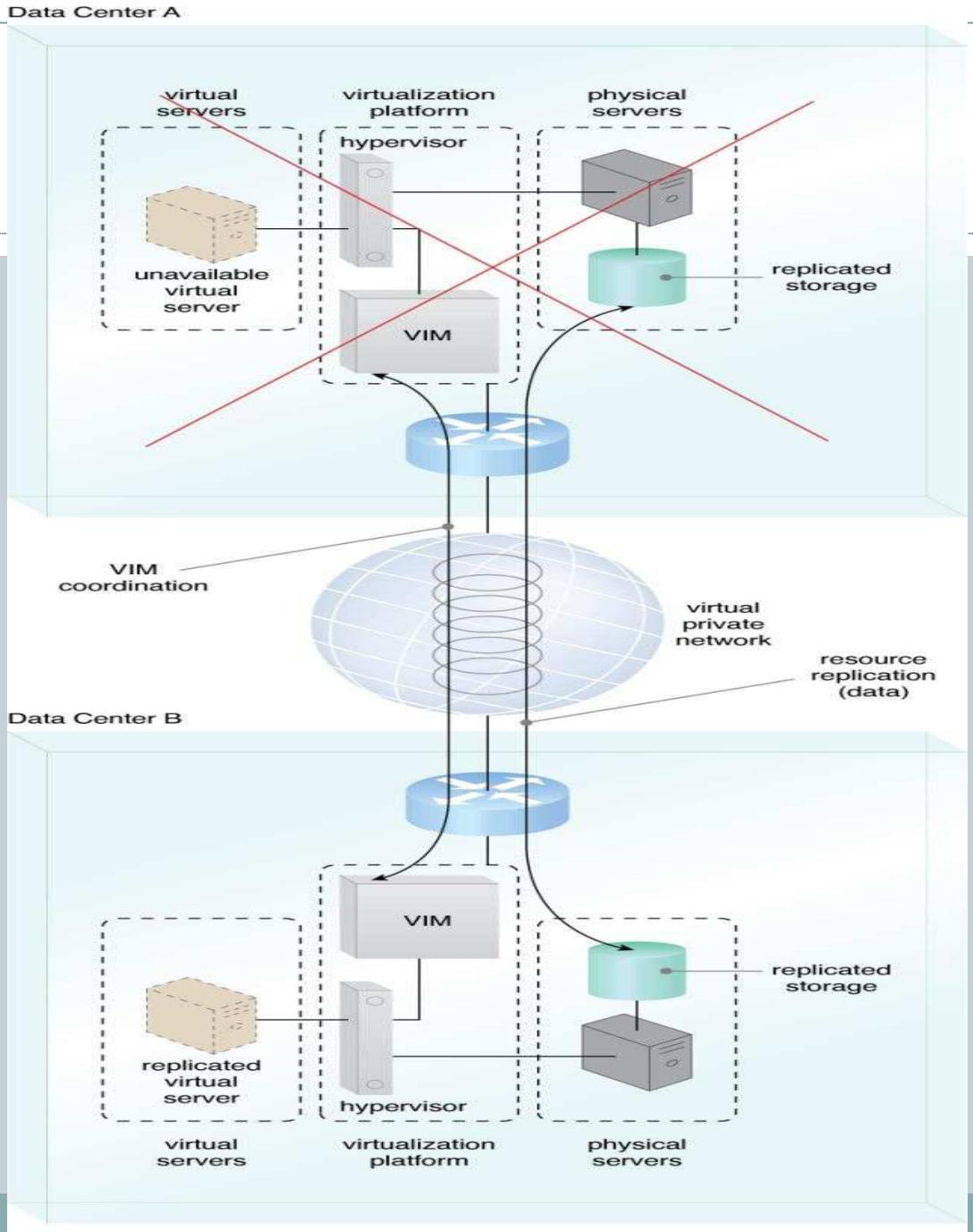


Figure 7.19

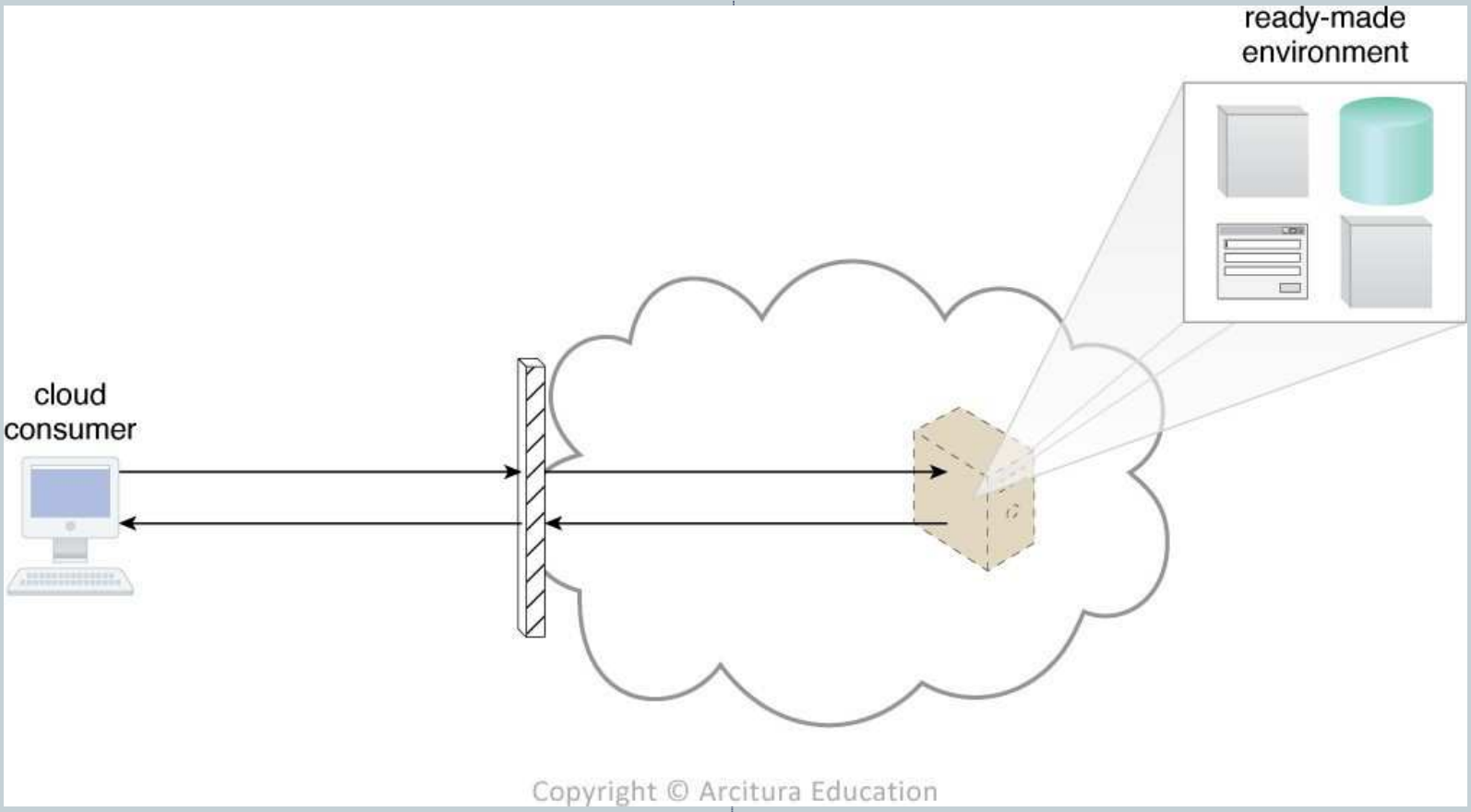
- *Figure 7.19 - A new instance of the virtual server is created in Data Center B and the service becomes available.*



7.6 Ready-Made Environment

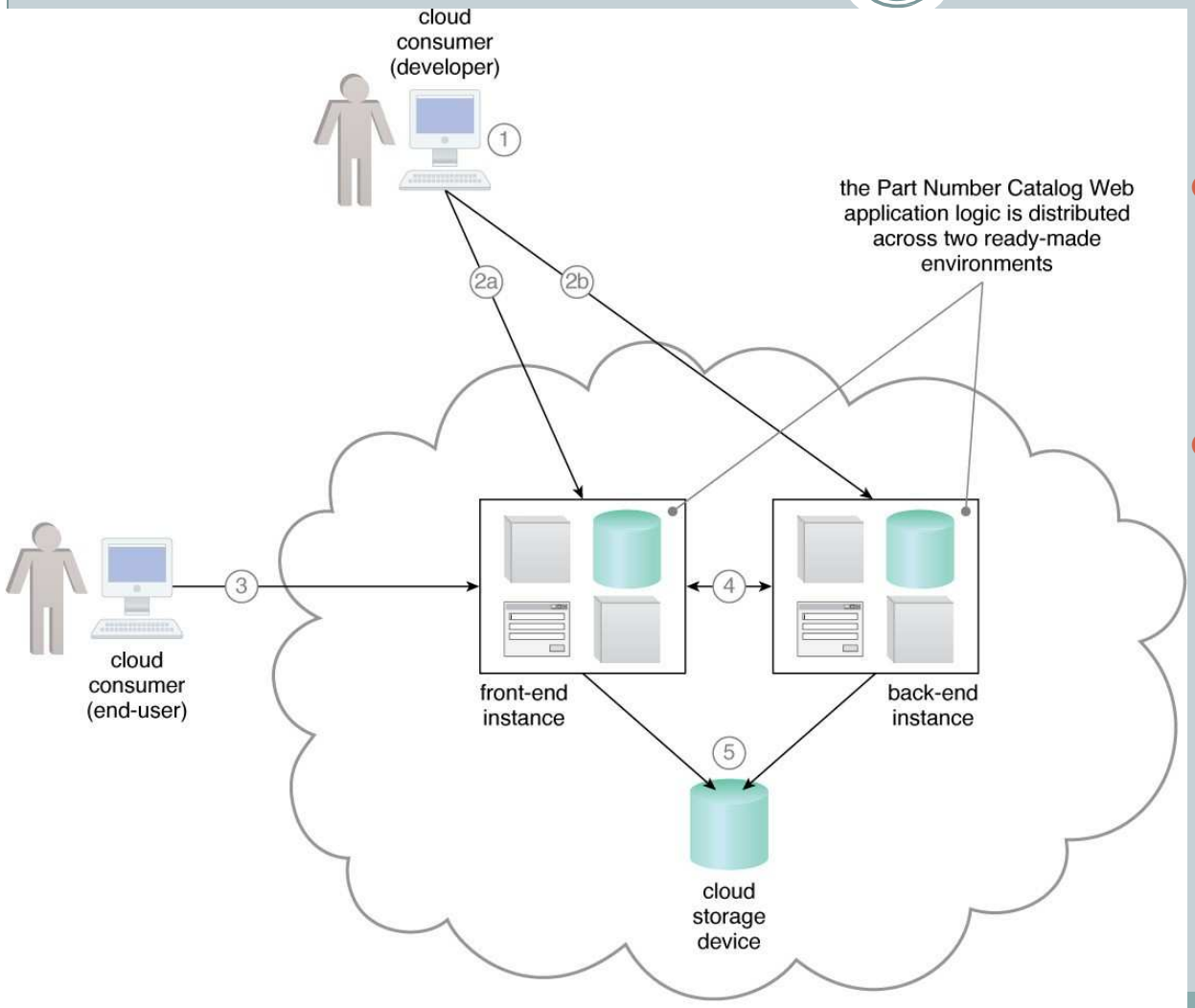
- The ready-made environment mechanism is a defining component of the PaaS cloud delivery model that represents a platform comprised of a set of already installed IT resources, ready to be used and customized by a cloud consumer.
- Ready-made environments are utilized by cloud consumers to remotely develop and deploy their own services and applications within a cloud by providing with a complete software development kit (SDK).
- Typical ready-made environments include pre-installed IT resources, eg. database, middleware, governance tools.

Figure 7.20



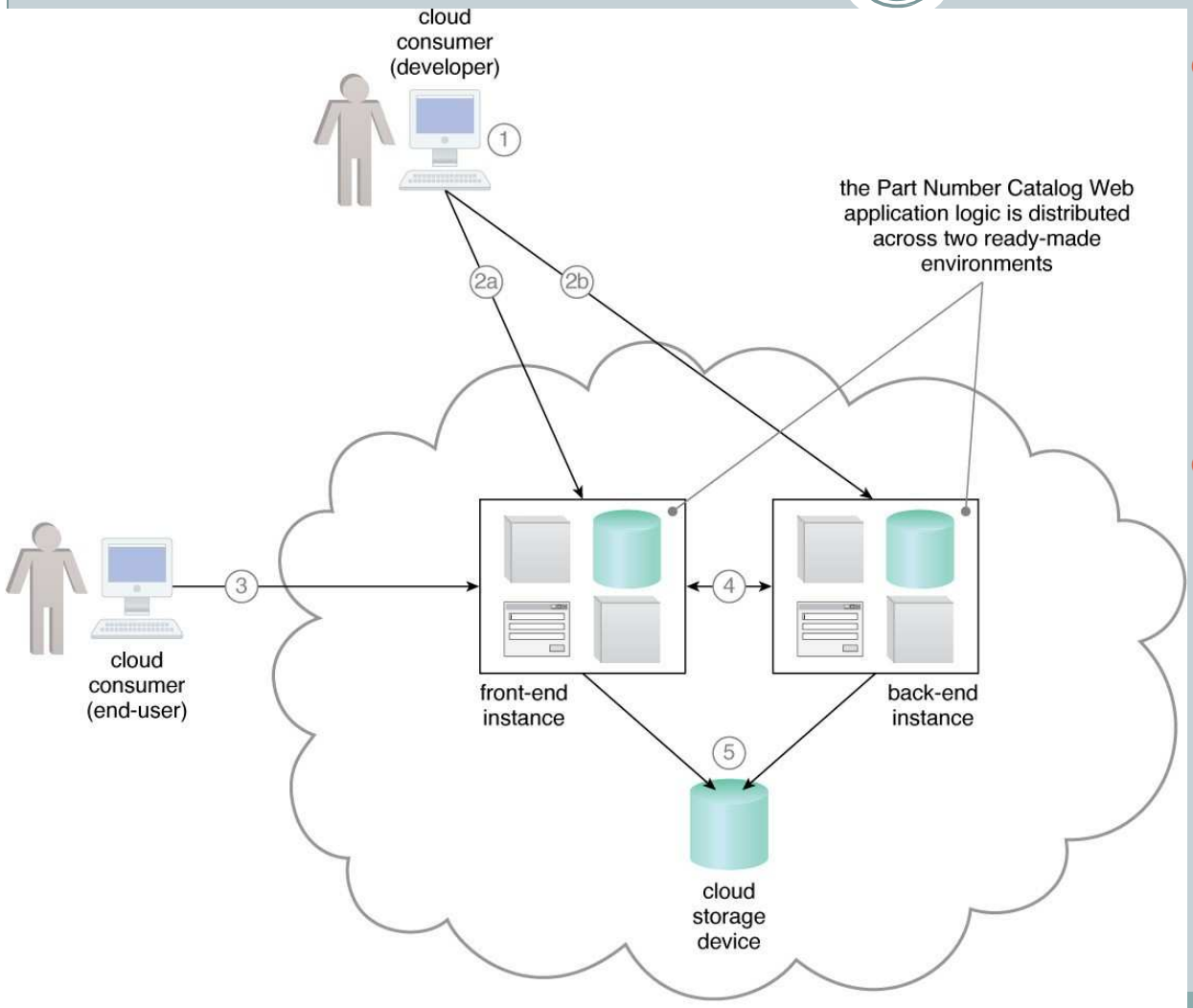
- *Figure 7.20 - A cloud consumer accesses a ready-made environment hosted on a virtual server.*

Figure 7.21 (1/3)



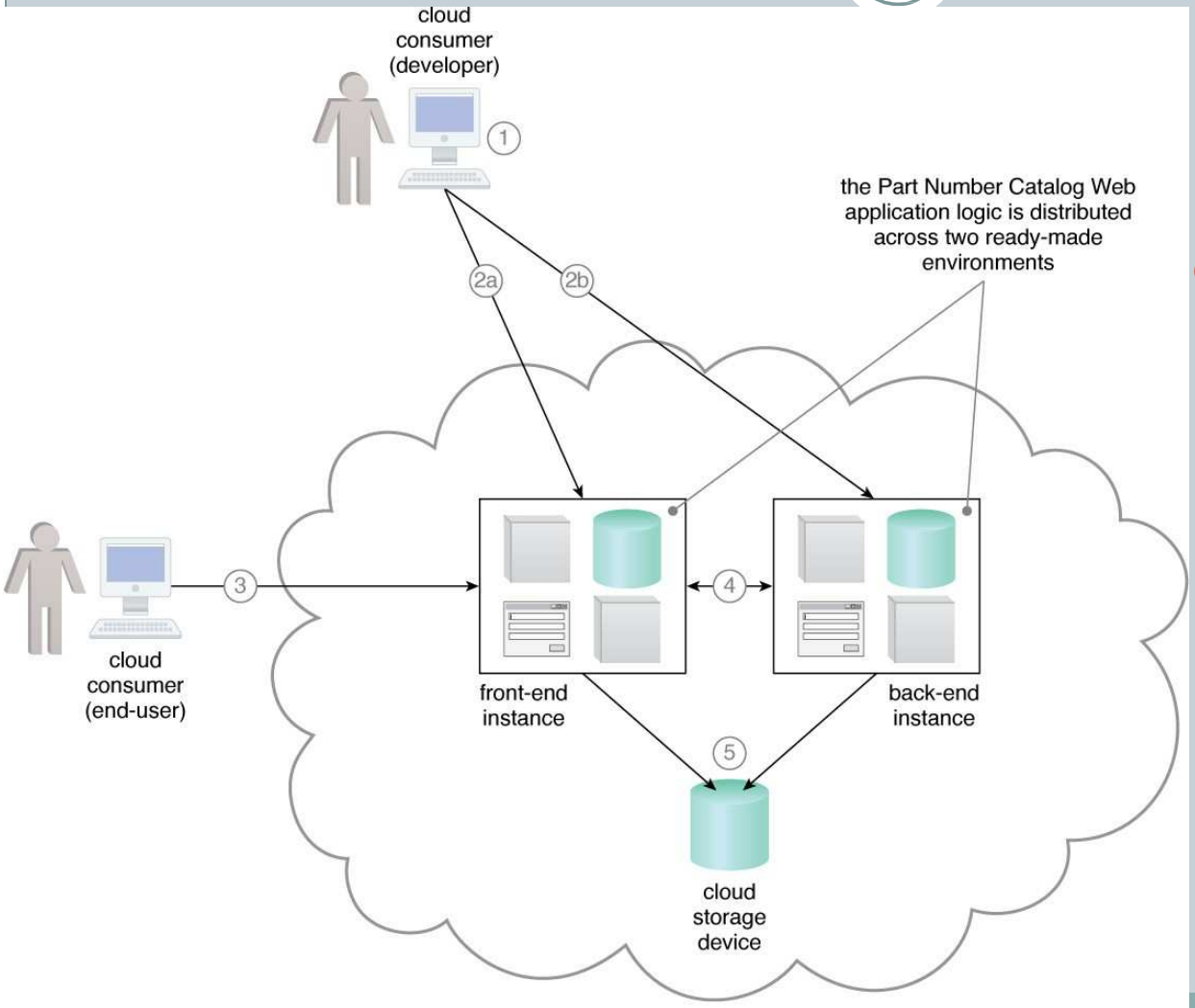
- *The cloud developer uses the provided SDK to develop the Web application (1).*
- *The application software is deployed on the Web platform that was established by the two ready-made environments called the frontend instance (2a) and the backend instance (2b).*

Figure 7.21 (2/3)



- *The application is made available for end-users and one accesses the application interface at the frontend instance (3).*
- *The software running in the frontend instance invokes a long-running task at the backend instance that corresponds to the processing required by the end-user (4).*

Figure 7.21 (3/3)



- *The application software deployed at both the frontend and backend instances is backed by a cloud storage device that implements persistent storage of the application data (5).*