Cloud Computing Mechanisms

Cloud infrastructure mechanisms

Cloud Infrastructure Mechanisms

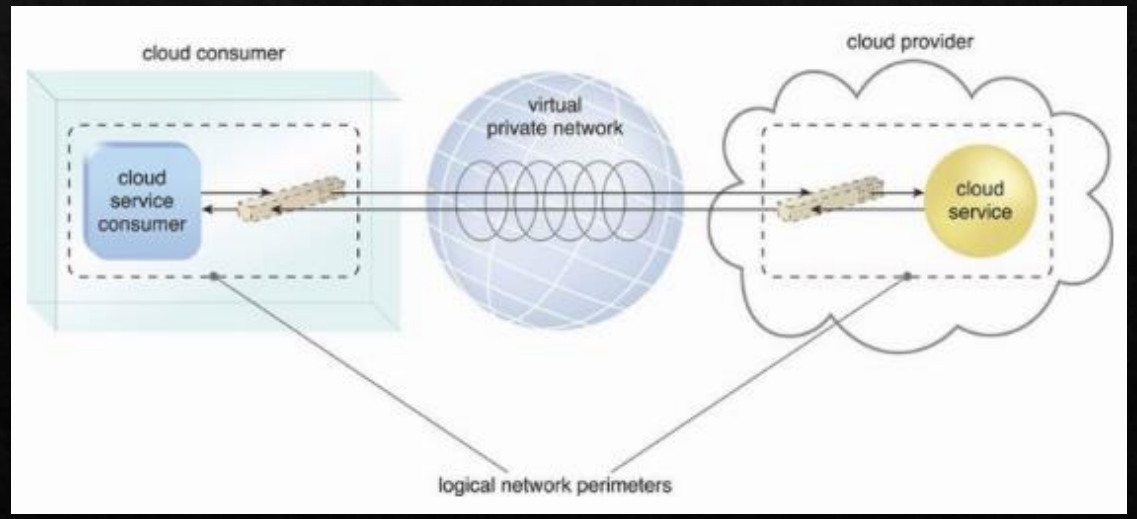
- Foundational building blocks of cloud environments, which comprises
  - Logical Network Perimeter
  - Virtual Server
  - Cloud Storage Device
  - Cloud Usage Monitor
  - Resource Replication
  - Read-Made Environment

Logical Network Perimeter

- An isolation of network environment establishing a virtual network boundary.
- Purposes?
  - isolate IT resources in a cloud from non-authorized users,
  - isolate IT resources in a cloud from non-users,
  - isolate IT resources in a cloud from cloud consumers, and
  - control the bandwidth that is available to isolated IT resources.

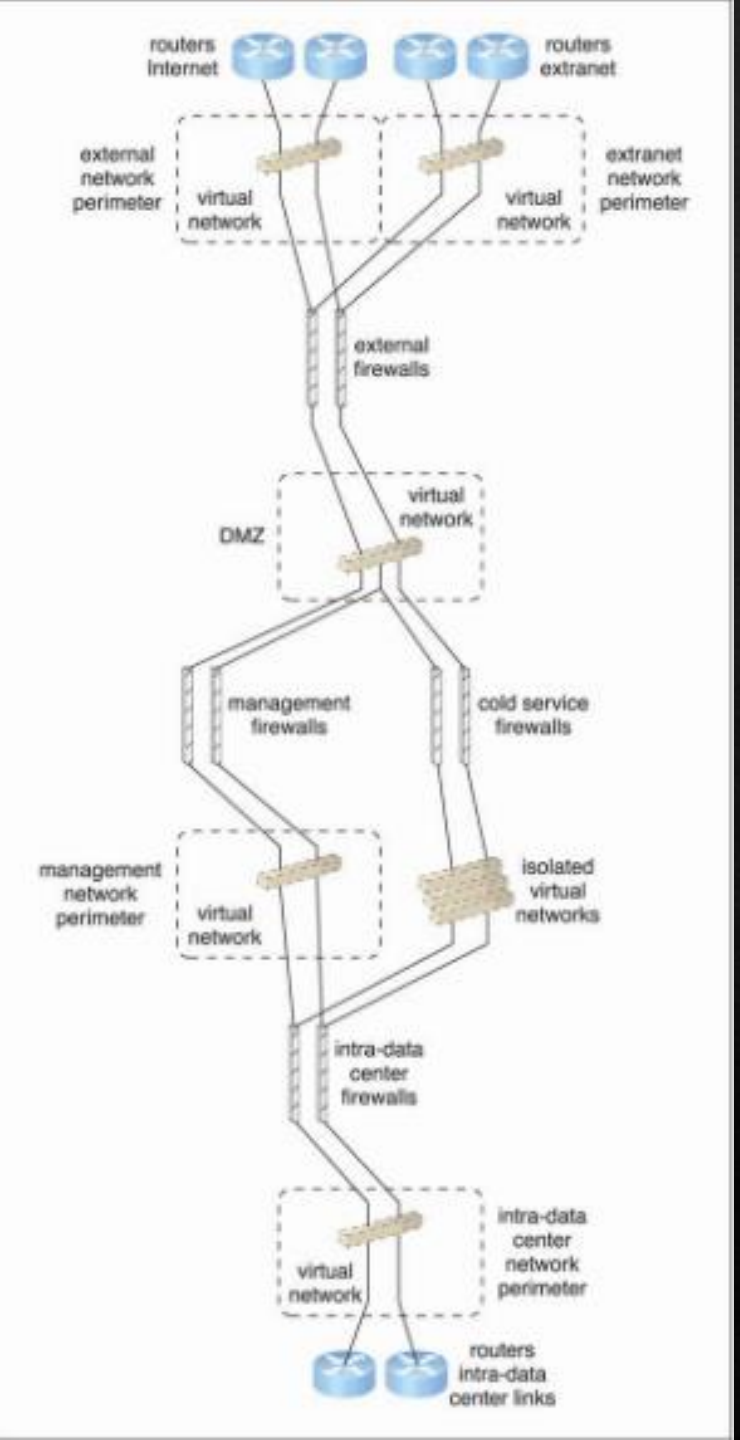
Logical Network Perimeter (2)

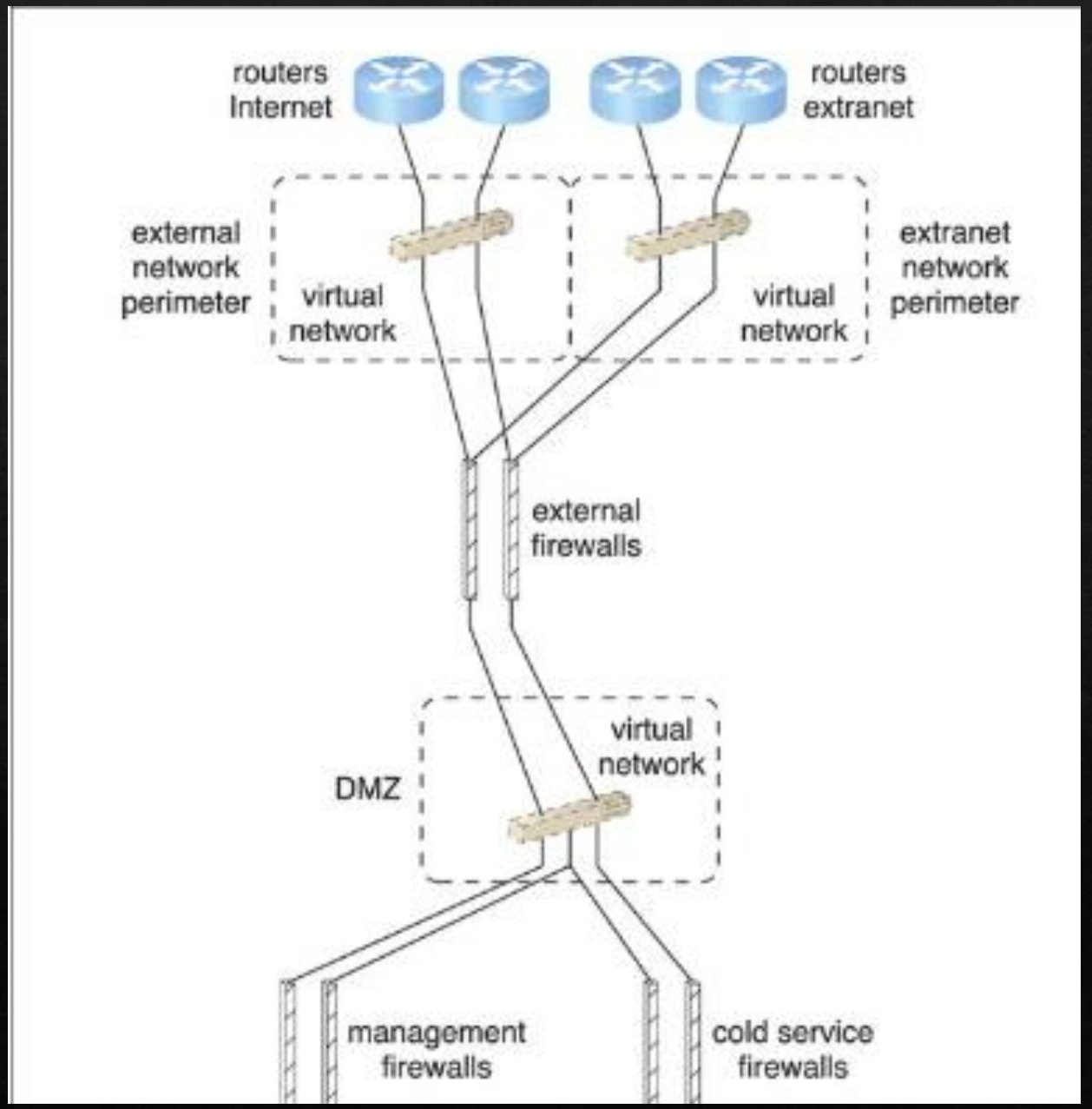
- Typically established via network devices that supply and control the connectivity of a data center (commonly deployed as virtualized IT environment), which includes
  - Virtual Firewall – actively filter incoming and outgoing traffic.
  - Virtual Network – isolates the network environment within the data center.

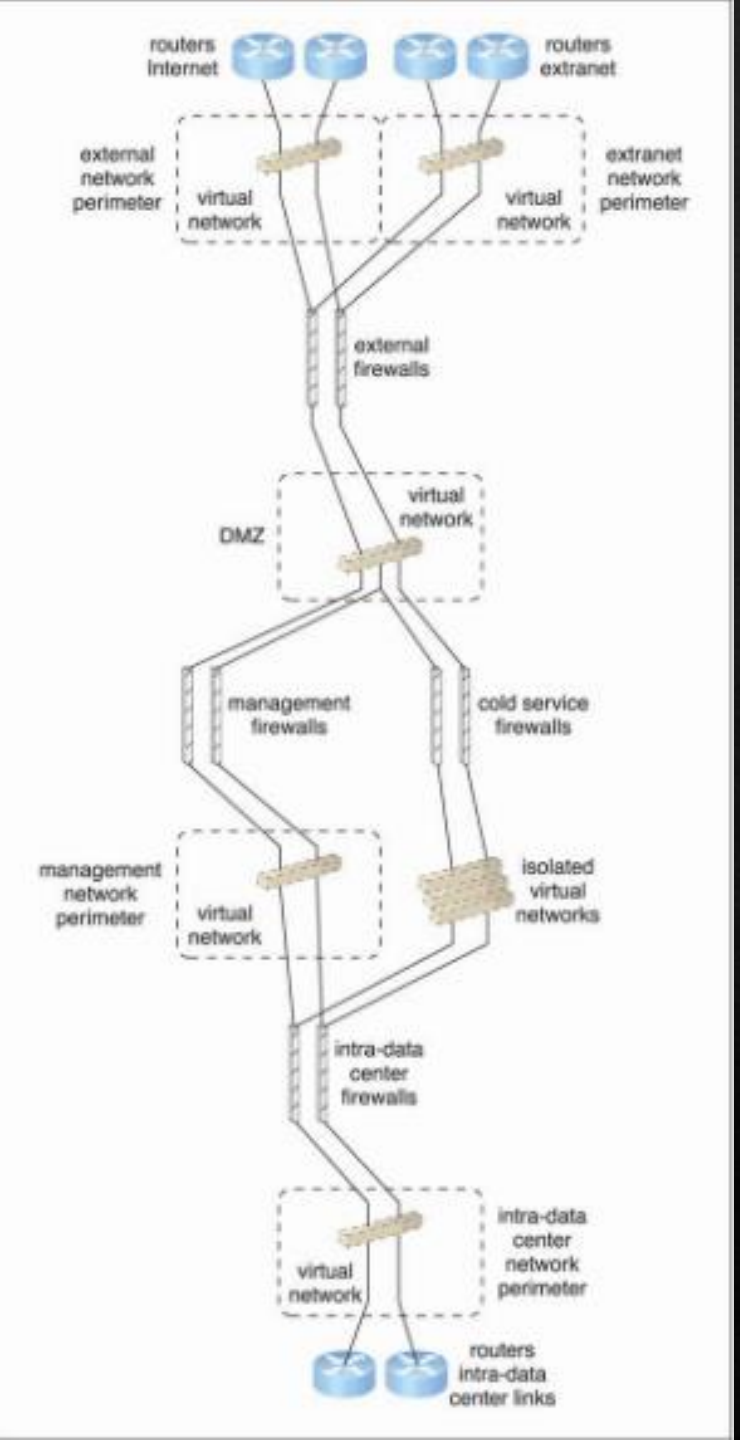


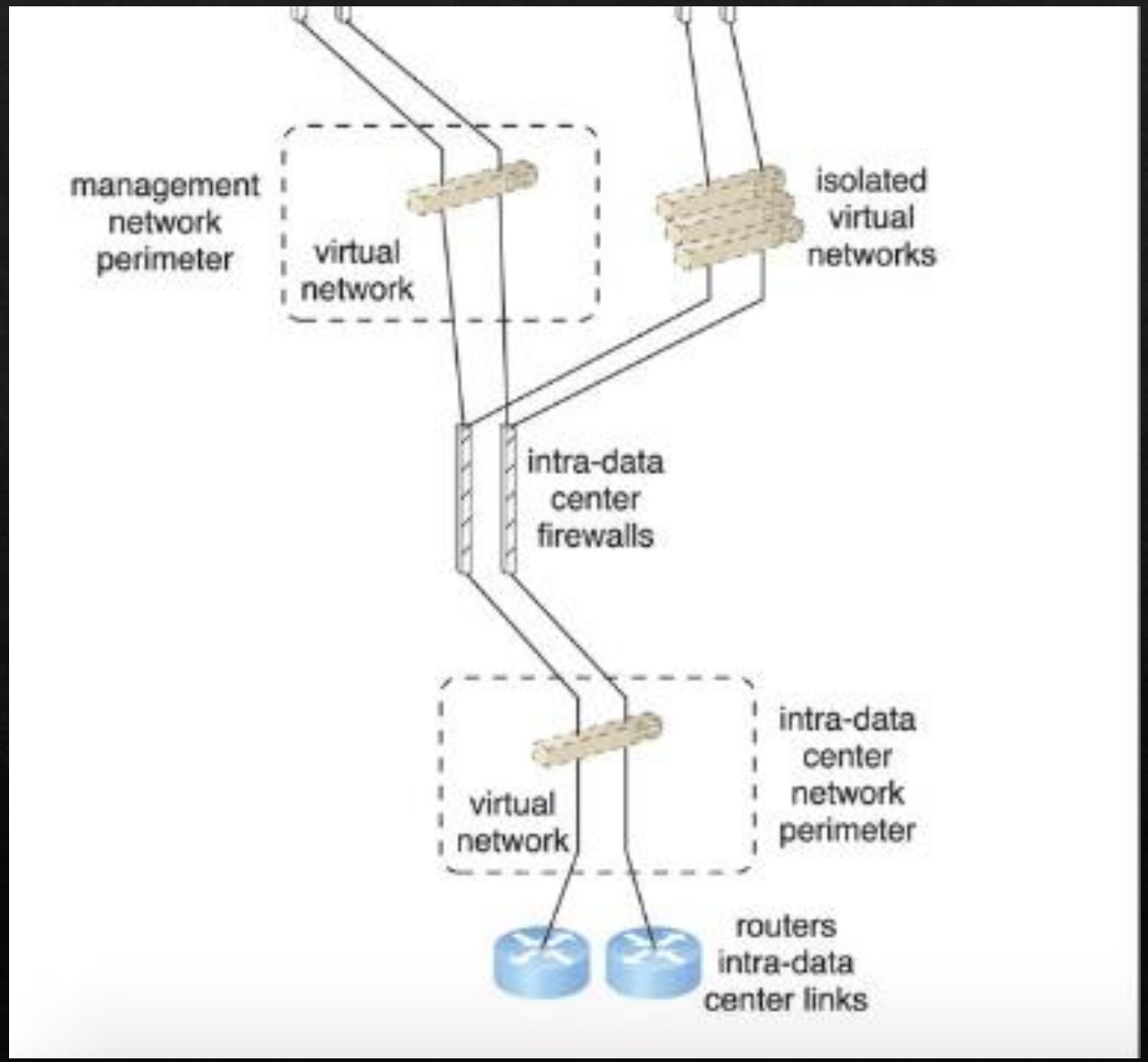
Case Study (DTGOV)

- Routers – connect the Internet and the extranet.
- DMZ zone – virtual network hosting the proxy servers.
- Management firewalls – isolate the management perimeter, providing management services.
- Cold service firewalls – isolate traffic to cloud-based IT resources.
- Intra-data center firewalls – filter network traffic to and from other data centers via routers.


routers
Internet
routers
extranet
external
network
perimeter
virtual
network
virtual
network
extranet
network
perimeter
external
firewalls
DMZ
virtual
network
management
firewalls
cold service
firewalls
management
network
perimeter
virtual
network
isolated
virtual
networks
intra-data
center
firewalls
virtual
network
intra-data
center
network
perimeter
routers
intra-data
center links

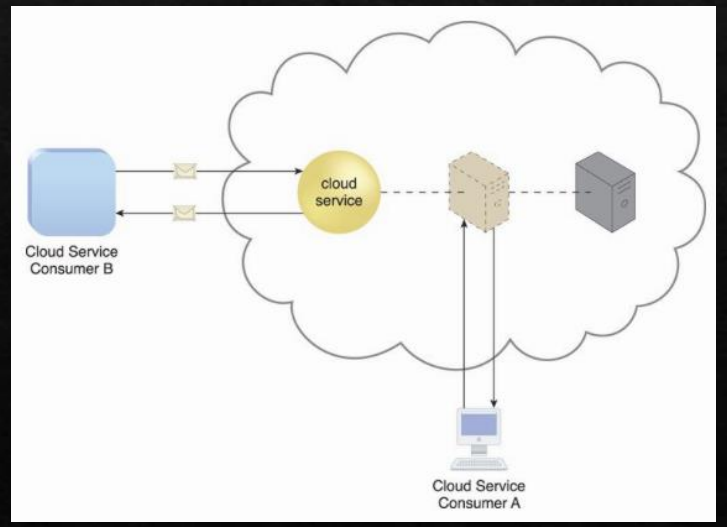

routers
Internet
routers
extranet
external
network
perimeter
virtual
network
virtual
network
extranet
network
perimeter
external
firewalls
DMZ
virtual
network
management
firewalls
cold service
firewalls

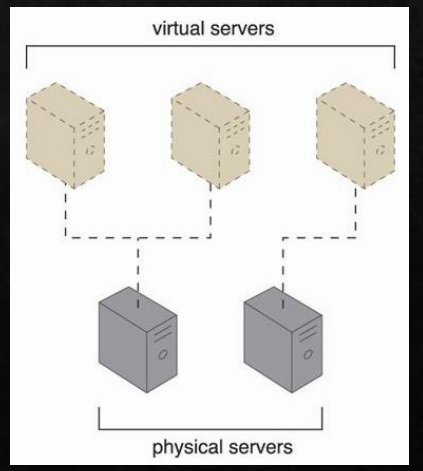

routers
Internet
routers
extranet
external
network
perimeter
virtual
network
virtual
network
extranet
network
perimeter
external
firewalls
DMZ
virtual
network
management
firewalls
cold service
firewalls
management
network
perimeter
virtual
network
isolated
virtual
networks
intra-data
center
firewalls
virtual
network
intra-data
center
network
perimeter
routers
intra-data
center links


management
network
perimeter
virtual
network
isolated
virtual
networks
intra-data
center
firewalls
virtual
network
intra-data
center
network
perimeter
routers
intra-data
center links

Virtual Servers

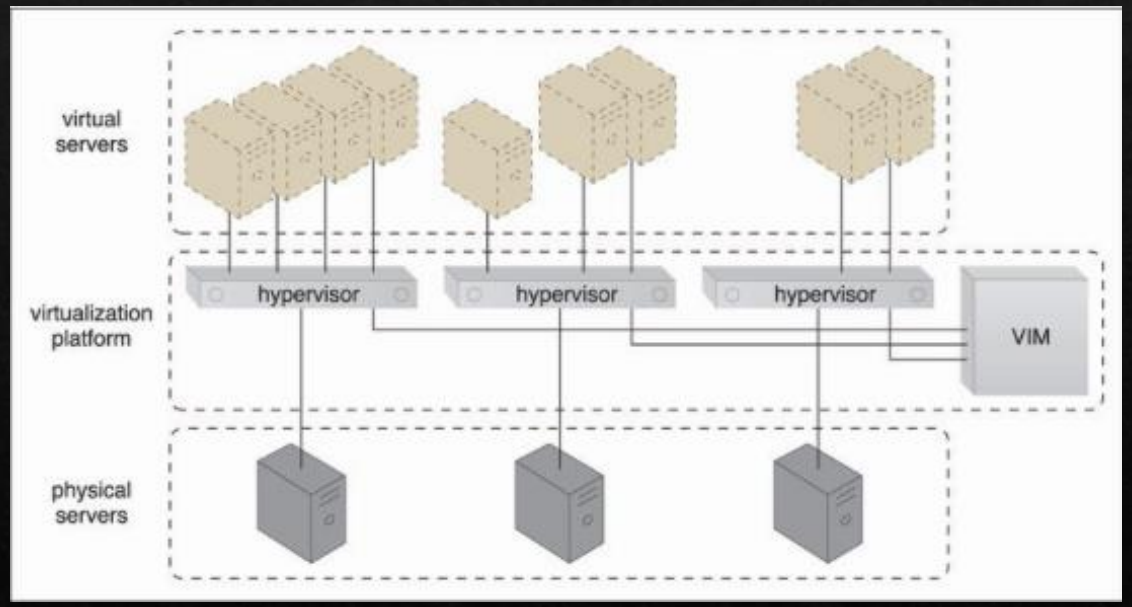
- A form of virtualization software that emulates a physical server.
- Used by a cloud provider for resources sharing.
- Virtual server = virtual machine





Case Study (DTGOV) Continued.

- DTGOV offers several types of pre-made VM images for its customers.
- VM images = virtual disk images used by a hypervisor to boot virtual servers.
- Template virtual servers.

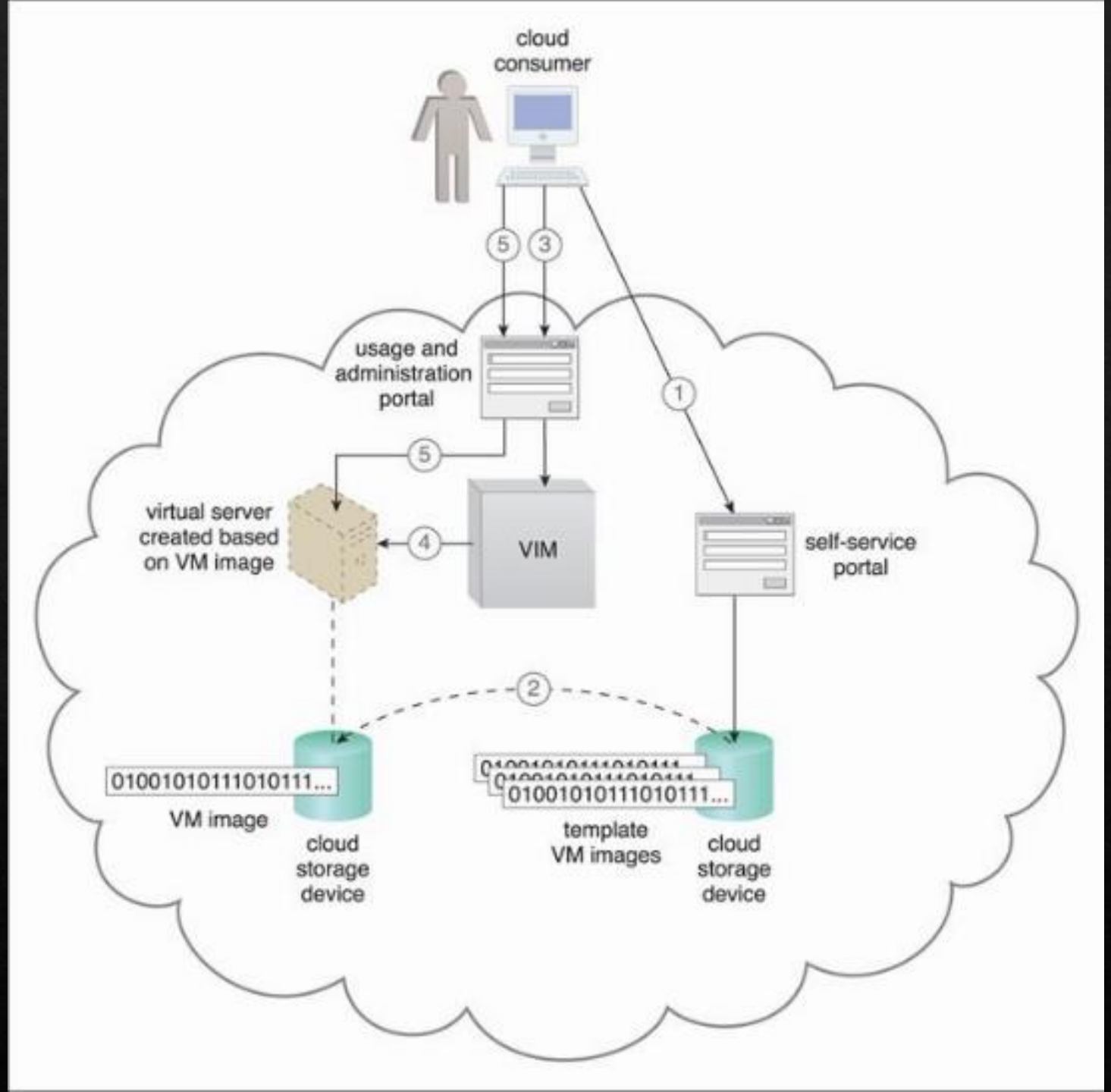


Case Study (DTGOV) Continued

- Template Virtual Servers (may include pre-installed software/applications) examples:
- **Small Virtual Server Instance** – 1 virtual processor core, 4 GB of virtual RAM, 20 GB of storage space in the root file system
- **Medium Virtual Server Instance** – 2 virtual processor cores, 8 GB of virtual RAM, 20 GB of storage space in the root file system
- **Large Virtual Server Instance** – 8 virtual processor cores, 16 GB of virtual RAM, 20 GB of storage space in the root file system
- **Memory Large Virtual Server Instance** – 8 virtual processor cores, 64 GB of virtual RAM, 20 GB of storage space in the root file system
- **Processor Large Virtual Server Instance** – 32 virtual processor cores, 16 GB of virtual RAM, 20 GB of storage space in the root file system
- **Ultra-Large Virtual Server Instance** – 128 virtual processor cores, 512 GB of virtual RAM, 40 GB of storage space in the root file system

Case Study (DTGOV) Continued

- Additional storage capacity can be added to a virtual server by attaching a virtual disk from a cloud storage device.
- Cloud consumer can choose the most suitable virtual server template from the list of available configurations.
- The allocated VM image is updated whenever the cloud consumer customizes the virtual server.
- VIM creates the virtual server instance from the appropriate physical server.

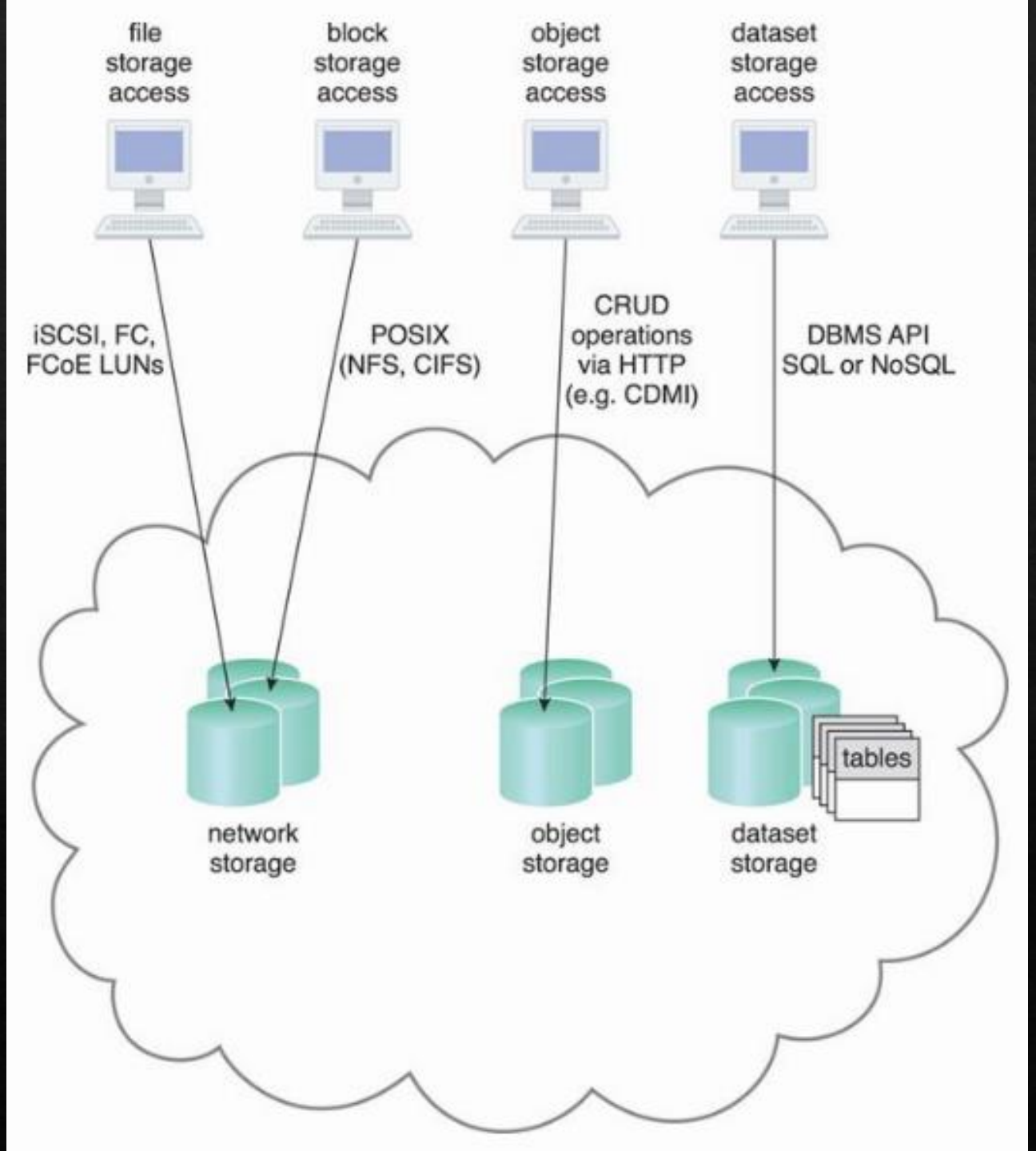

cloud
consumer
5
3
usage and
administration
portal
1
5
virtual server
created based
on VM image
4
VIM
self-service
portal
2
01001010111010111...
VM image
cloud
storage
device
01001010111010111...
template
VM images
cloud
storage
device

Cloud Storage Devices Mechanism

- Storage devices designed specifically for cloud-based environment.
- Instances of these storage could be virtualized.
- Able to provide fix-increment capacity allocation in support of pay-per-use mechanism.
- Primary concern - CIA

Cloud Storage Levels

- Files – Collections of data are grouped into files that are located in folders.
- Blocks – The lowest level of storage and the closest to the hardware, a block is the smallest unit of data that is still individually accessible.
- Datasets – Sets of data are organized into a table-based, delimited, or record format.
- Objects – Data and its associated metadata are organized as Web-based resources.

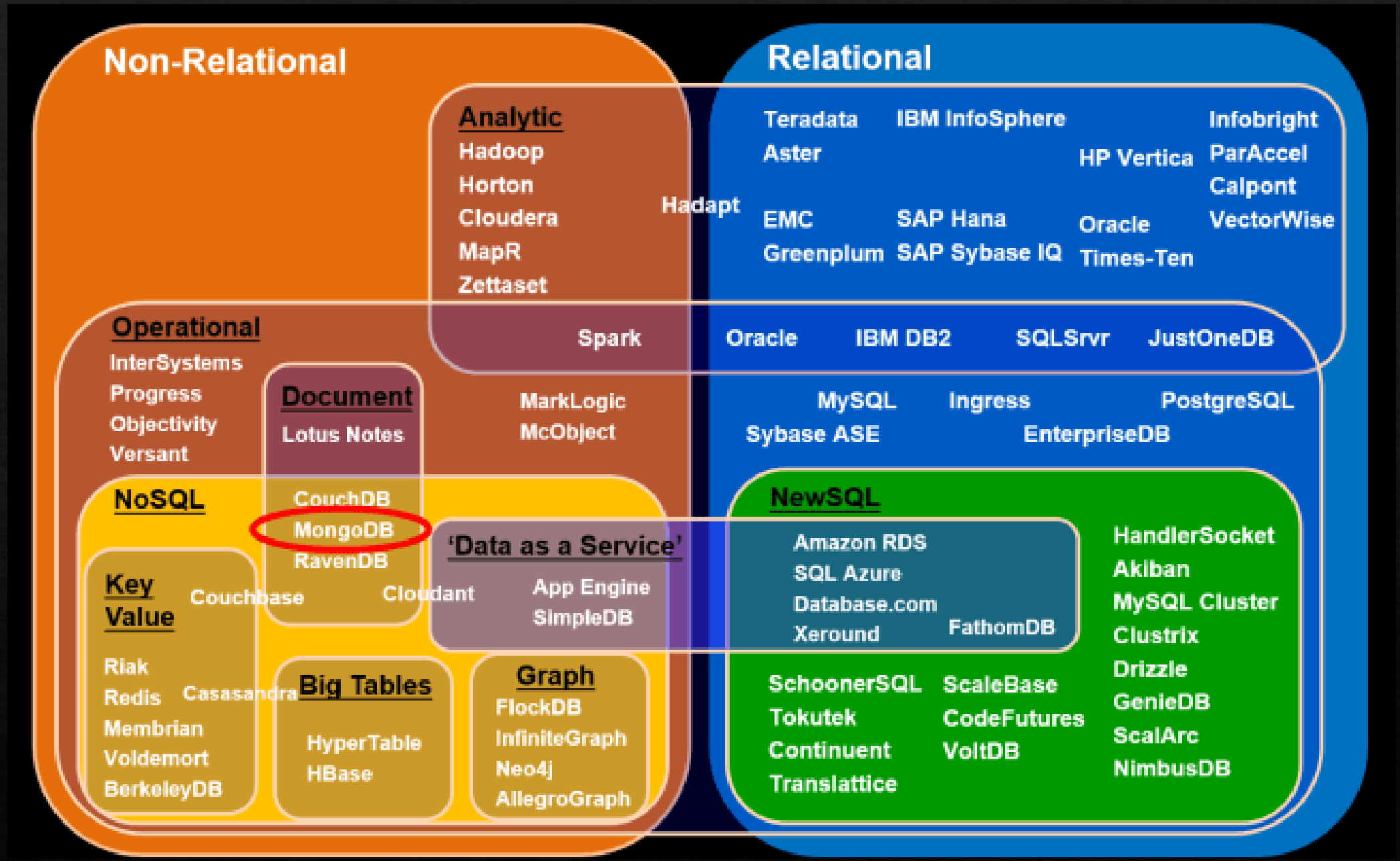

file storage access
block storage access
object storage access
dataset storage access
iSCSI, FC, FCoE LUNs
POSIX (NFS, CIFS)
CRUD operations via HTTP (e.g. CDMI)
DBMS API SQL or NoSQL
tables
network storage
object storage
dataset storage

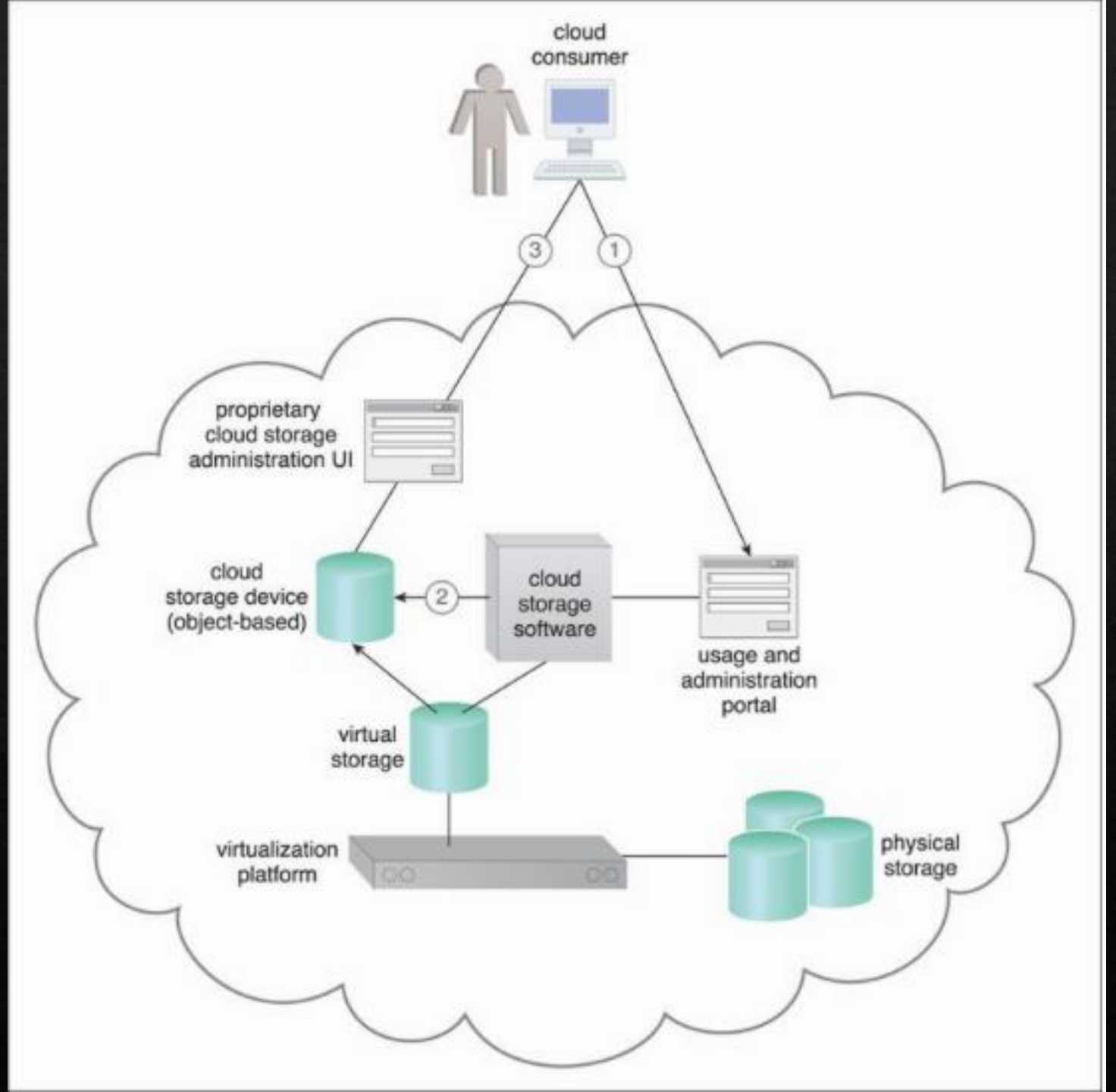
Technical Interfaces to Storage

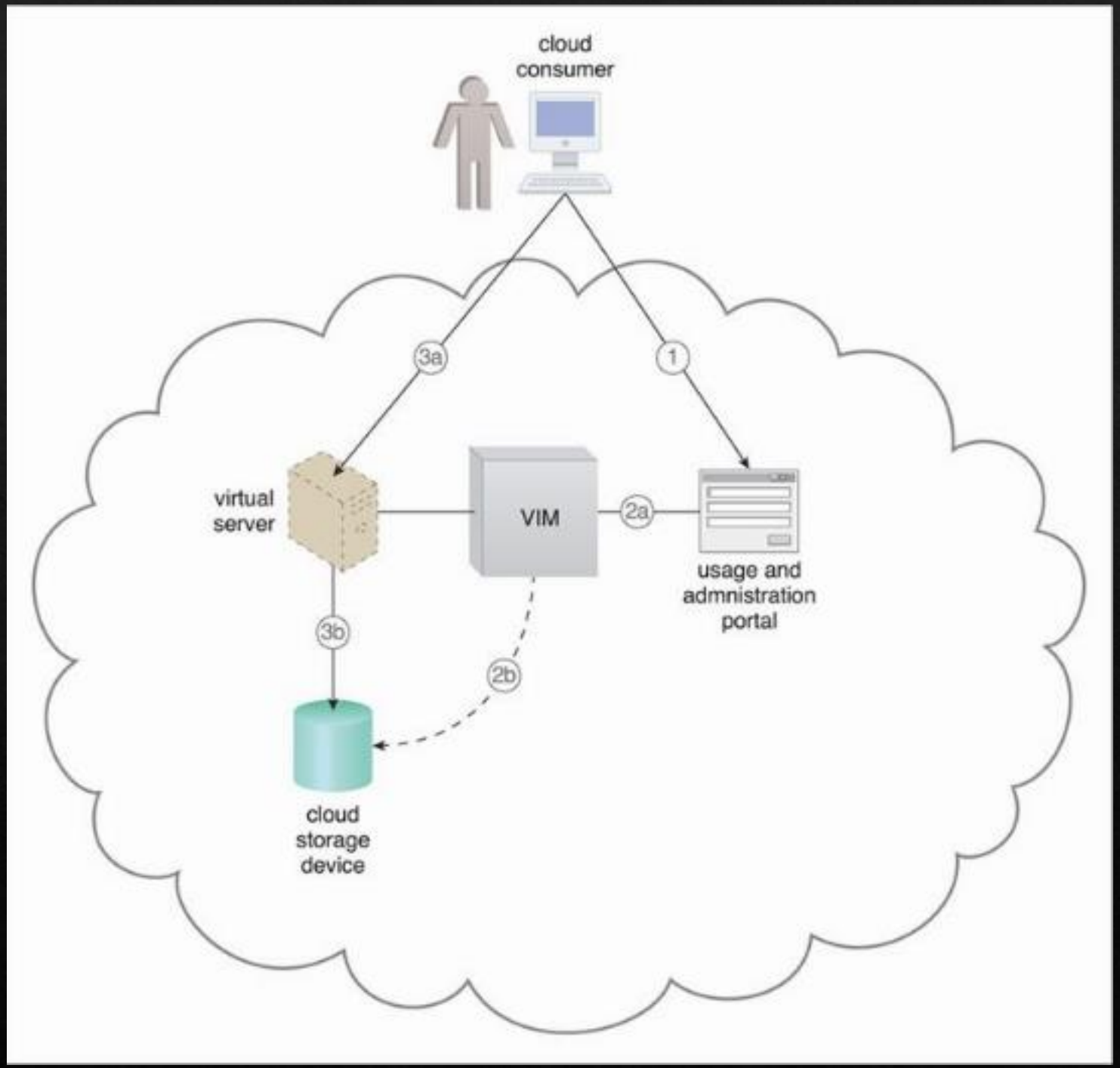
- Network Storage Interfaces – Most legacy network storage falls under this category, e.g., SCSI for storage blocks, NFS for network storage.
  - Storage processing levels and thresholds for file allocation are usually determined by the file system itself (tend to be suboptimal)
- Object Storage Interfaces - Various types of data can be referenced and stored as Web resources. This is referred to as object storage.
  - REST protocol, Web service-based cloud services as examples

Technical Interfaces to Storage (2)

- Database Storage Interfaces – support a query language in addition to basic storage operations.
  - Relational Data Storage – relies on table to organize similar data into rows and columns. Use of the industry standard Structured Query Language (SQL). Examples include IBM DB2, Oracle database, Microsoft SQL and MySQL.
    - Complex relational database designs can imposes higher processing overhead and latency
  - Non-relational Data Storage – aims at reducing processing overhead of relational databases.
    - Drawback – tend to not support relational database functions such as transactions or joins.


Non-Relational
Relational
Analytic
Hadoop
Horton
Cloudera
MapR
Zettaset
Hadapt
Teradata Aster
IBM InfoSphere
HP Vertica
Infobright
ParAccel
Calpont
VectorWise
EMC Greenplum
SAP Hana
SAP Sybase IQ
Oracle Times-Ten
Operational
InterSystems
Progress
Objectivity
Versant
Spark
Oracle
IBM DB2
SQLSrvr
JustOneDB
Document
Lotus Notes
MarkLogic
McObject
MySQL
Ingress
PostgreSQL
Sybase ASE
EnterpriseDB
NoSQL
CouchDB
MongoDB
RavenDB
'Data as a Service'
App Engine
SimpleDB
Cloudant
NewSQL
Amazon RDS
SQL Azure
Database.com
Xeround
FathomDB
HandlerSocket
Akiban
MySQL Cluster
Clustrix
Drizzle
GenieDB
ScalArc
NimbusDB
Key Value
Couchbase
Riak
Redis
Casasandra
Membrian
Voldemort
BerkeleyDB
Big Tables
HyperTable
HBase
Graph
FlockDB
InfiniteGraph
Neo4j
AllegroGraph
SchoonerSQL
Tokutek
Continuent
Translattice
ScaleBase
CodeFutures
VoltDB


cloud
consumer
3
1
proprietary
cloud storage
administration UI
cloud
storage device
(object-based)
2
cloud
storage
software
usage and
administration
portal
virtual
storage
virtualization
platform
physical
storage

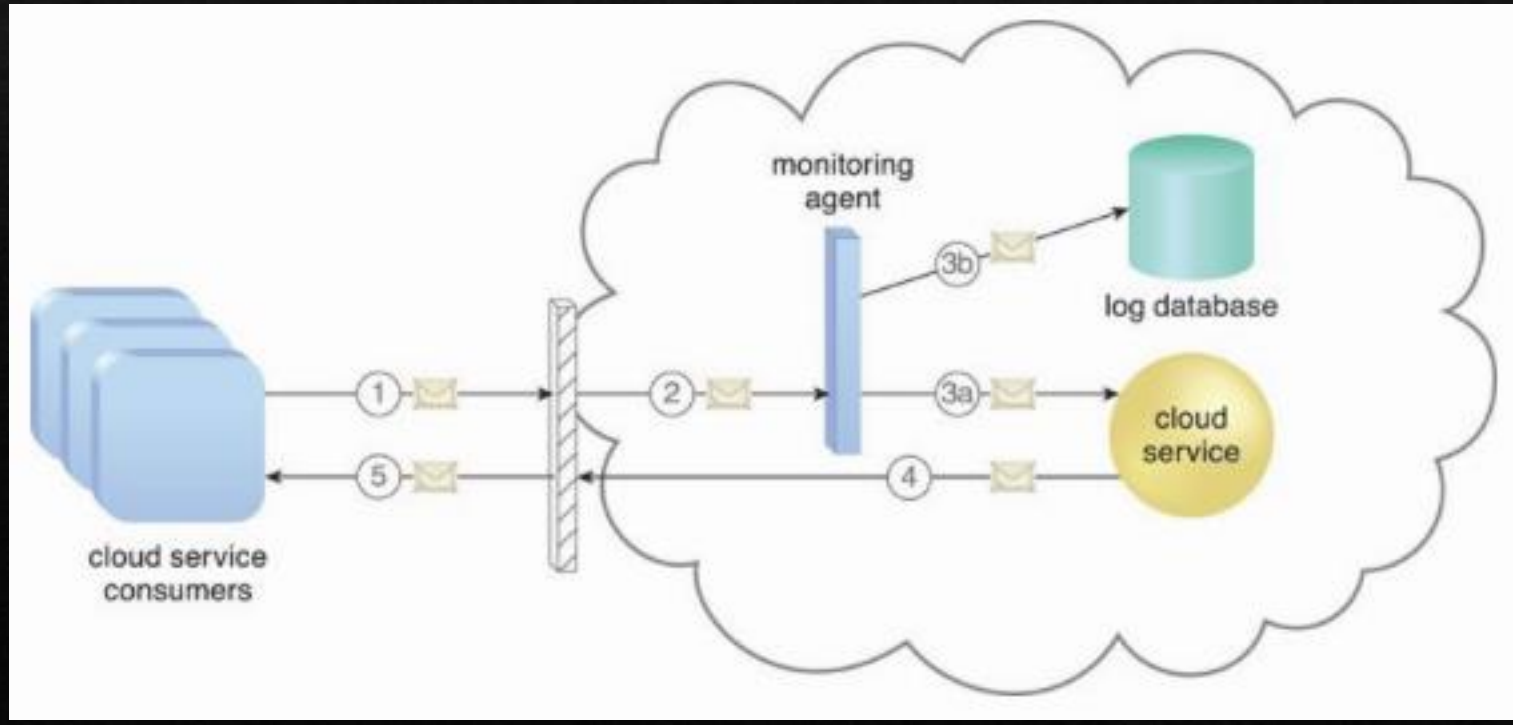

cloud
consumer
3a
1
virtual
server
VIM
2a
usage and
admnistration
portal
3b
2b
cloud
storage
device

Cloud Usage Monitor Mechanism

- A lightweight and autonomous software program responsible for collecting and processing IT resource usage data.
- Metrics – amount of data, number of transactions, usage time, etc.
- Three common agent-based implementation formats:
  - Monitoring agent
  - Resource agent
  - Polling agent

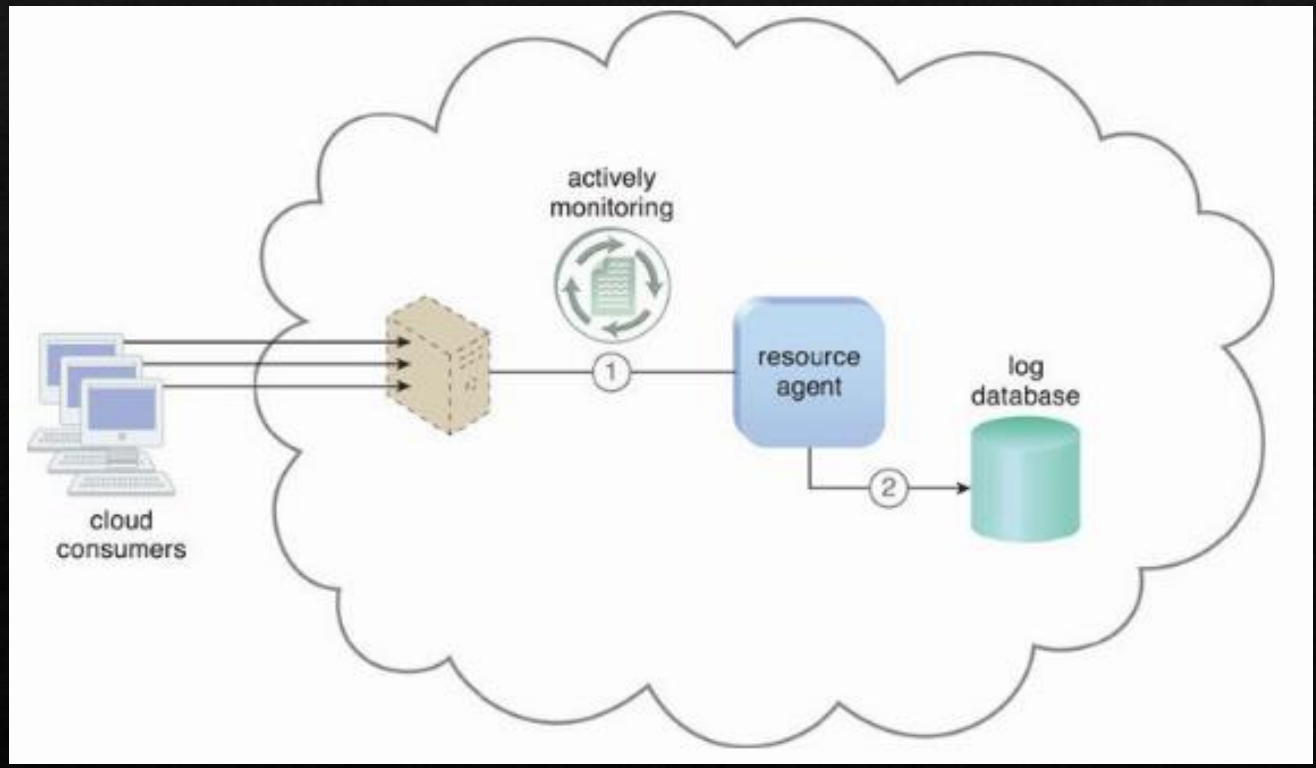
Monitoring Agent

- A service agent existing along communication paths, monitoring and analyzing data flows.
- Measure network traffic and message metrics.



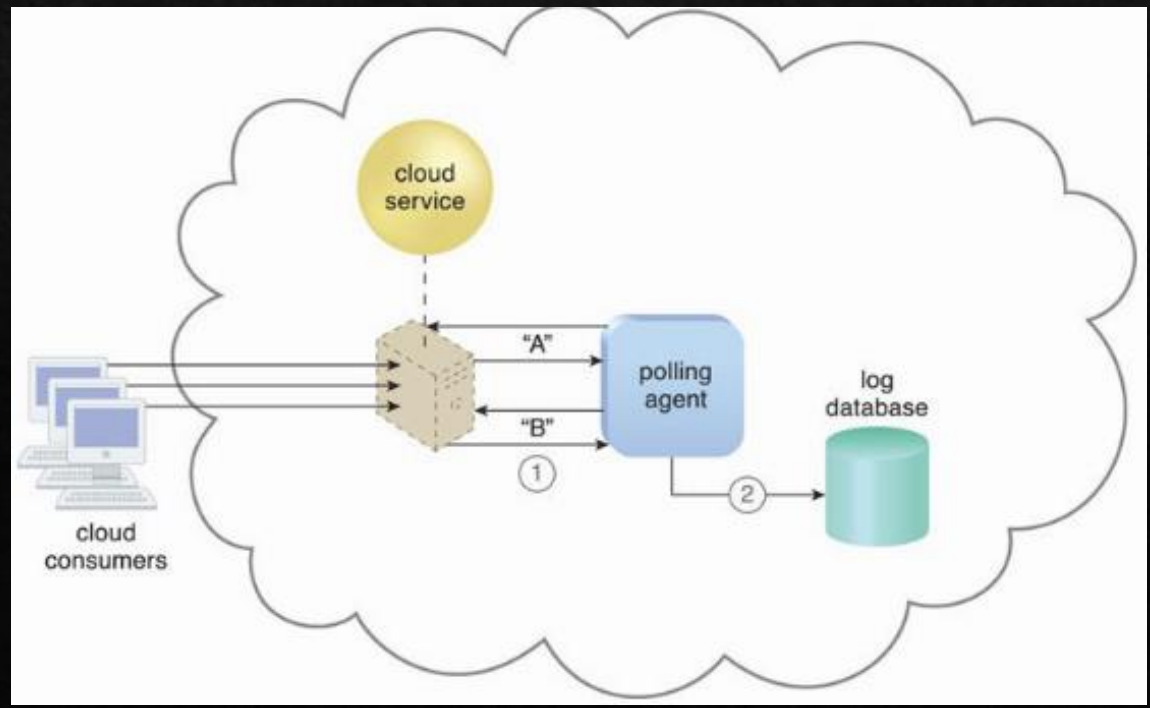
Resource Agent

- Even-driven agent monitoring resource usage based on pre-defined, observable at the resource software level such as initiating, suspending, resuming and vertical scaling.



Polling Agent

- A processing module that collects cloud service usage data by polling IT resources.
- Commonly used to periodically monitor IT resource status, such as uptime and downtime.



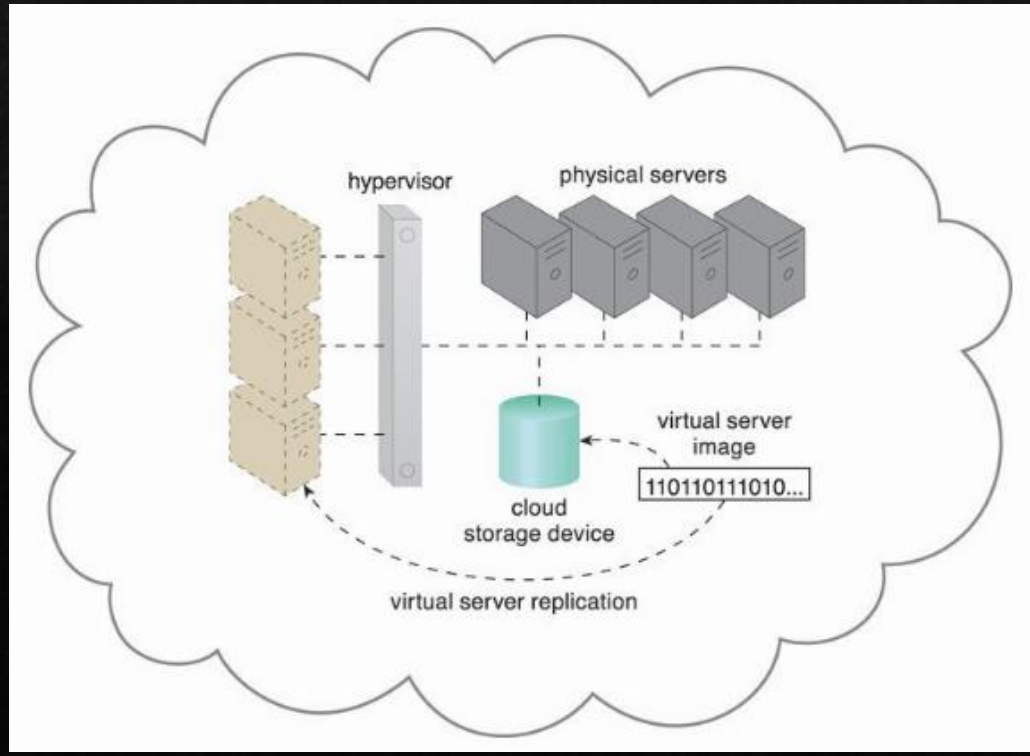
Case Study (DTGOV) Continued

- Needs to define a model that allows virtual servers of varying performance levels to be leased and billed hourly.
- Each resource usage event that is generated by VIM contains the following data:
  - Event Type (starting, started, scaled, stopping, stopped), VM Type – pre-defined VM configurations, VM ID, Cloud Consumer ID, Timestamp.
  - Usage measurements – for every VM, a measurement period (in a scale of minute usage).
  - VM can be started, scaled and stopped multiple times (e.g., started and scaled, or scaled and scaled).

$$U_{\text{total\_VM\_type\_j}} = \sum_{t_{start}}^{t_{end}} T_{cycle_i}$$

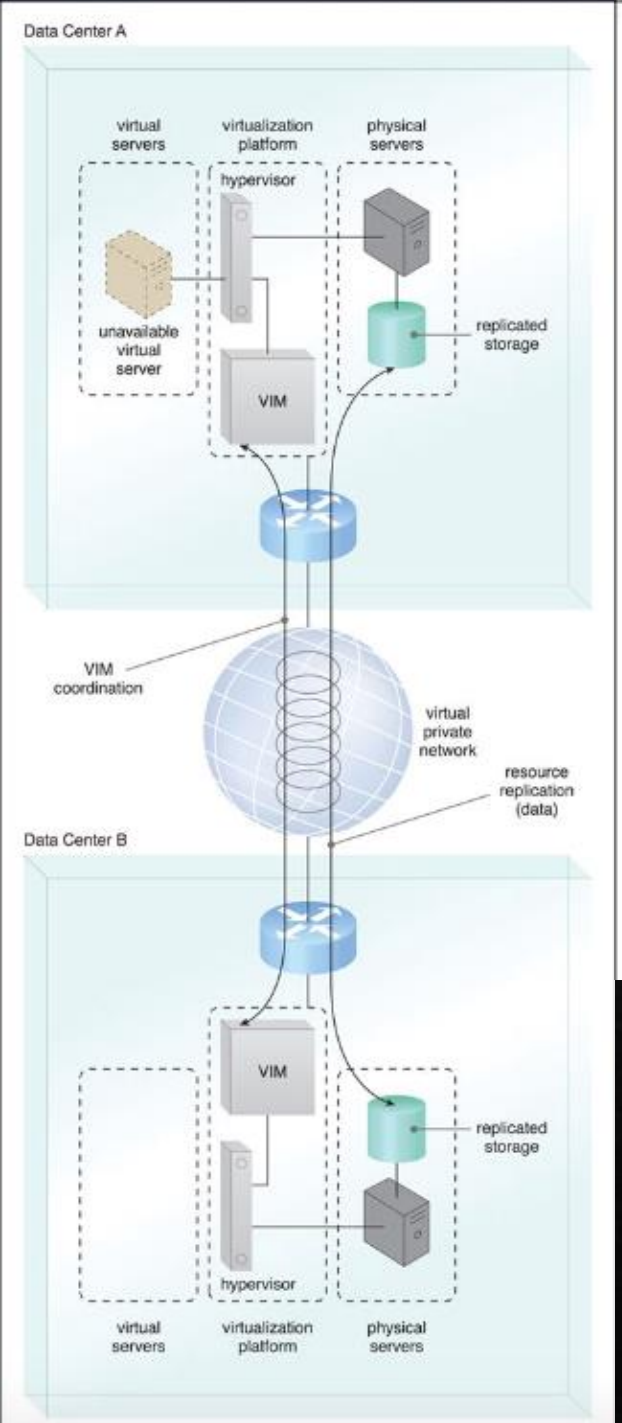
Resource Replication

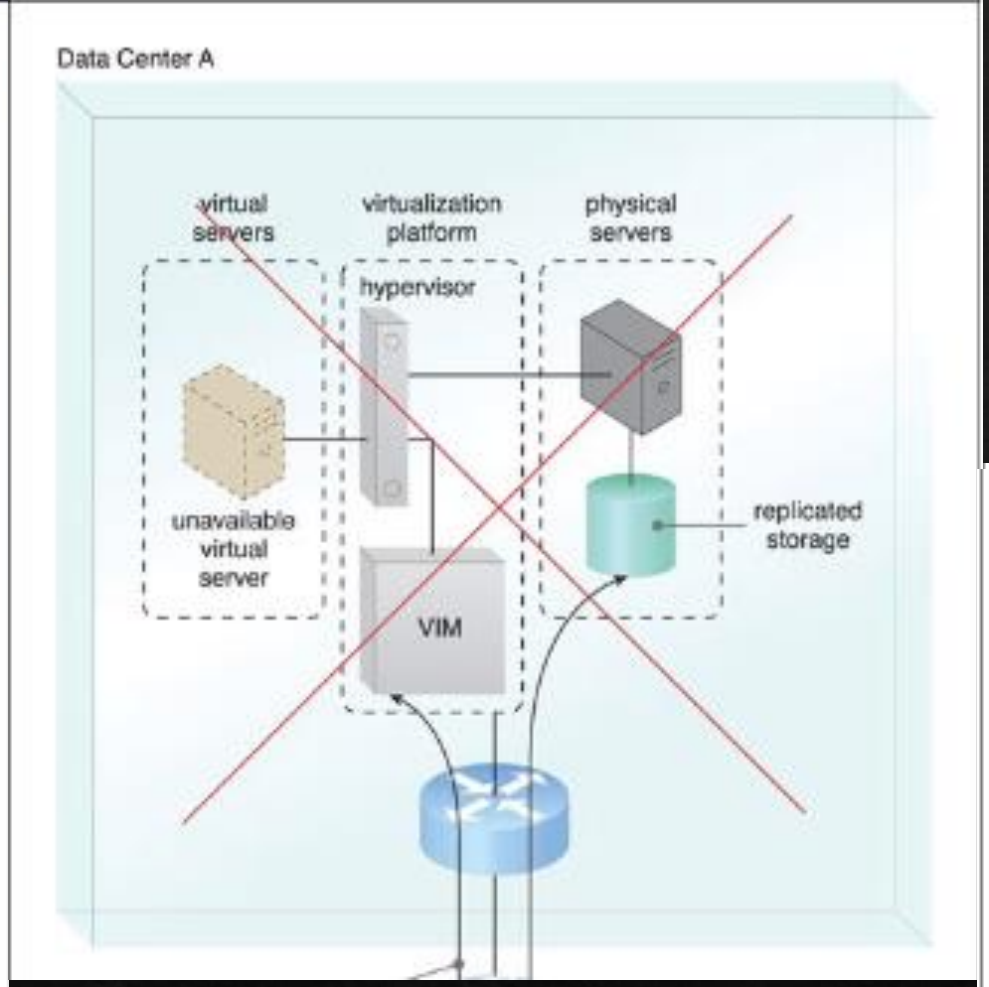
- The creation of multiple instances of the same IT resource.
- Replication is typically performed when an IT resource's availability and performance need to be enhanced.

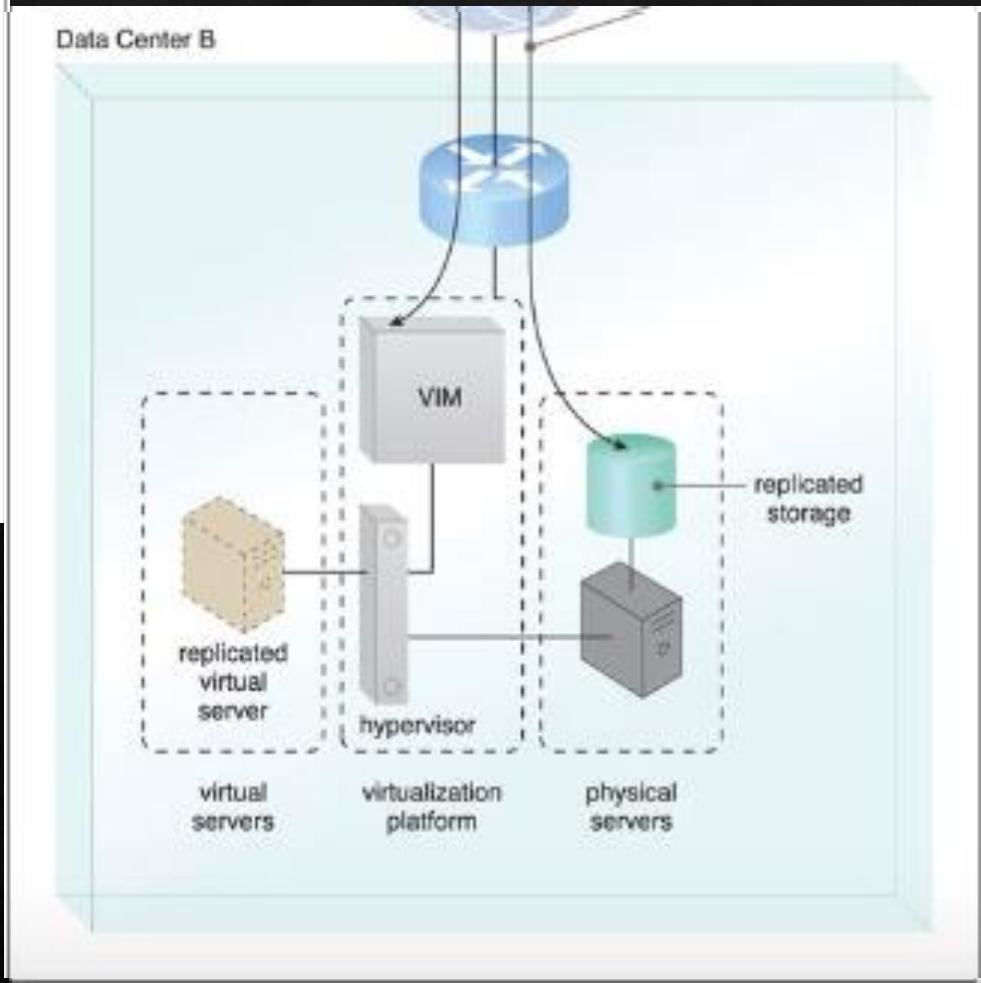


Case Study (DTGOV) Continued.

- A set of high-availability virtual servers that can be automatically relocated to physical servers running in different data centers in response to severe failure conditions.

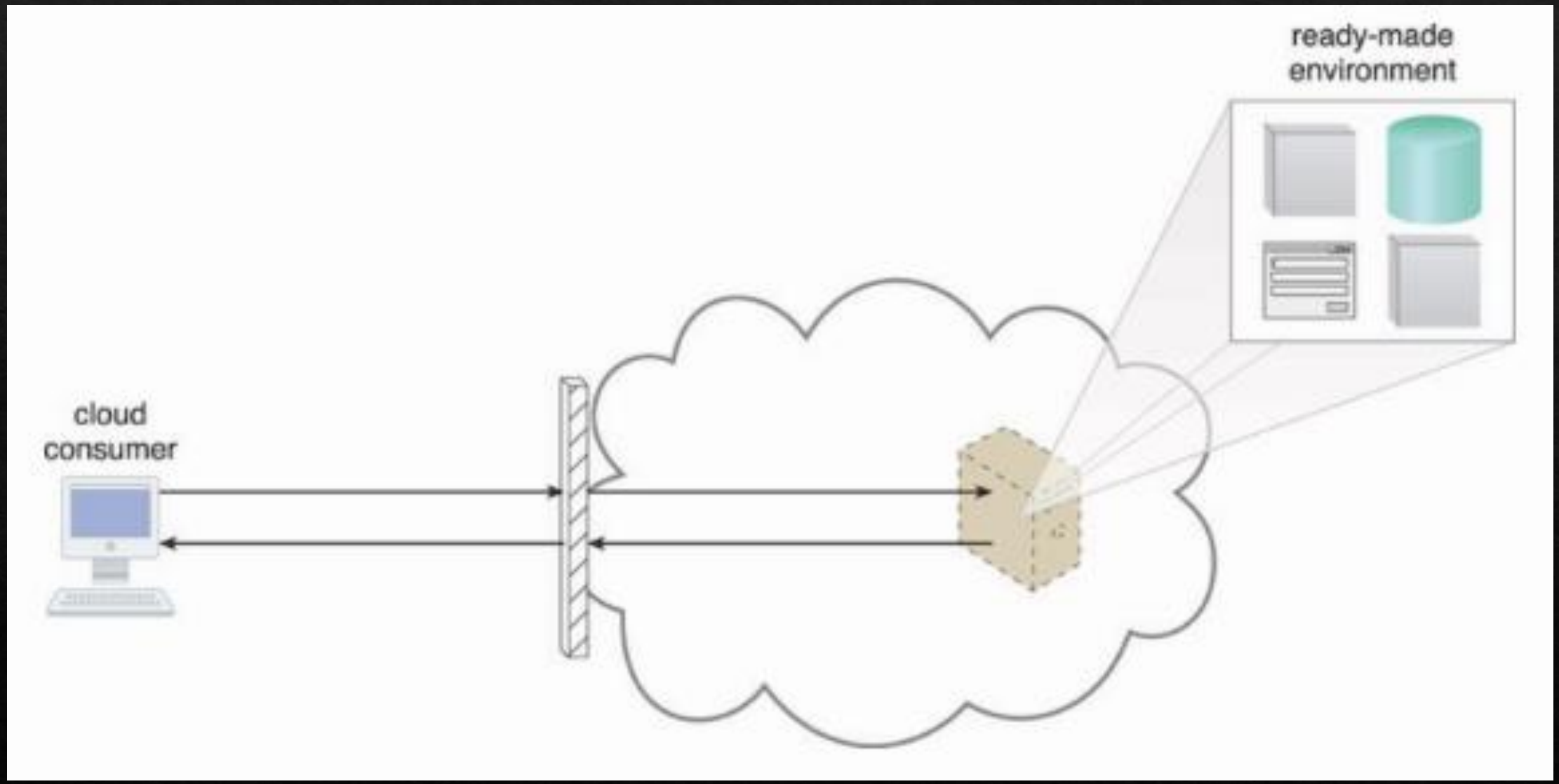

Data Center A
virtual servers
virtualization platform
physical servers
hypervisor
unavailable virtual server
replicated storage
VIM
VIM coordination
virtual private network
resource replication (data)
Data Center B
VIM
replicated storage
hypervisor
virtual servers
virtualization platform
physical servers

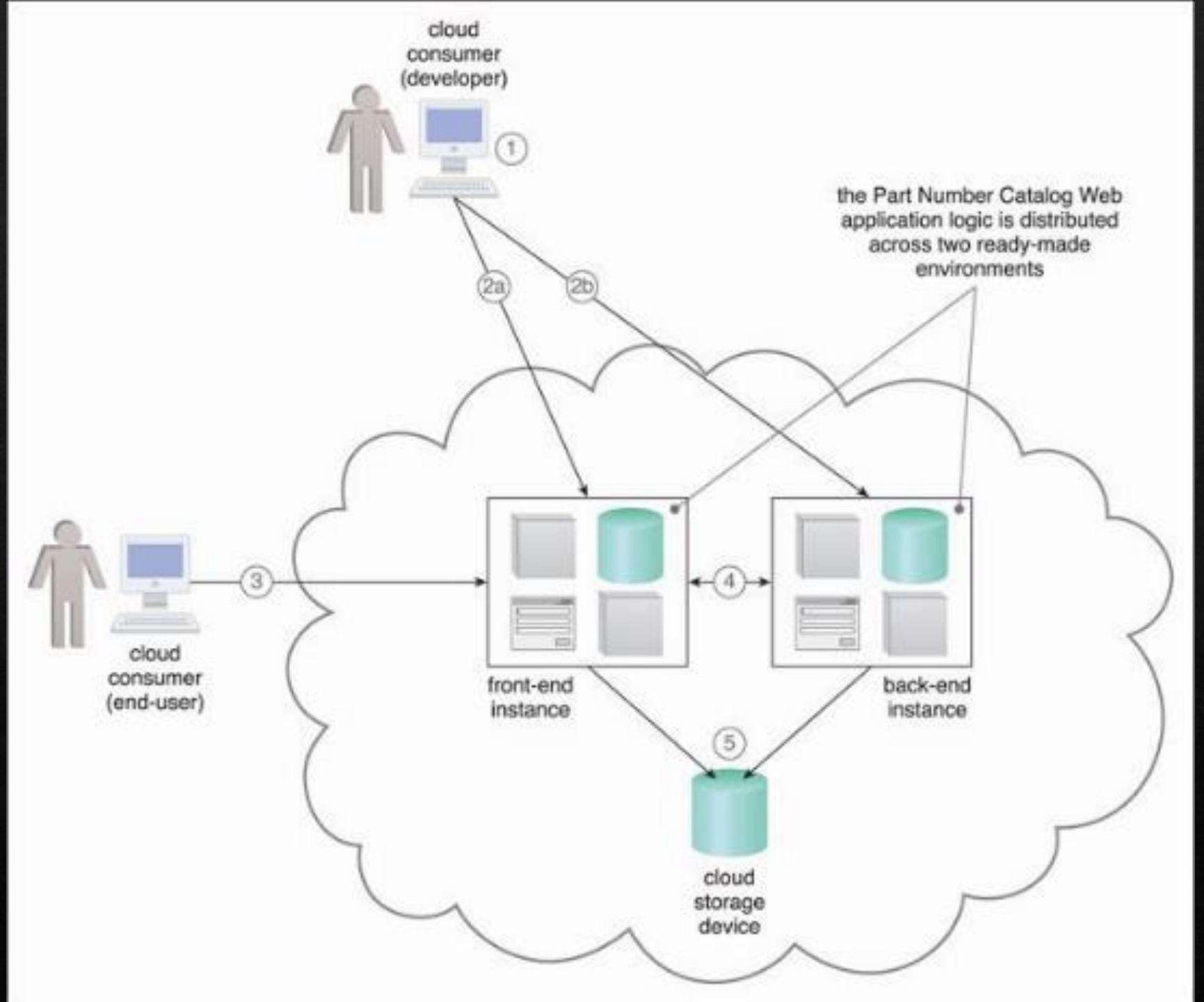

Data Center A
virtual servers
virtualization platform
physical servers
hypervisor
unavailable virtual server
replicated storage
VIM


Data Center B
VIM
replicated storage
replicated virtual server
hypervisor
virtual servers
virtualization platform
physical servers

Ready-Made Environment

- A defining component of the PaaS cloud delivery model that represents a pre-defined, cloud-based platform comprised of a set of already installed IT resources,
  - ready to be used and
  - customized by a cloud consumer.
- Typically equipped with Software Development Kit (SDK)


ready-made
environment
cloud
consumer


cloud
consumer
(developer)
1
the Part Number Catalog Web
application logic is distributed
across two ready-made
environments
2a
2b
3
4
5
cloud
consumer
(end-user)
front-end
instance
back-end
instance
cloud
storage
device

Cloud Computing Mechanisms

Special Cloud Mechanisms

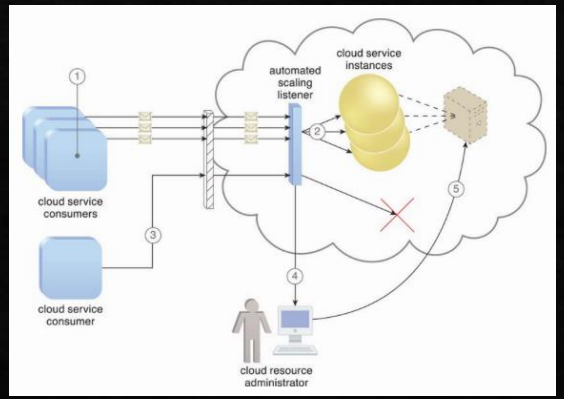
Specialized mechanisms in support of one or more cloud characteristics.

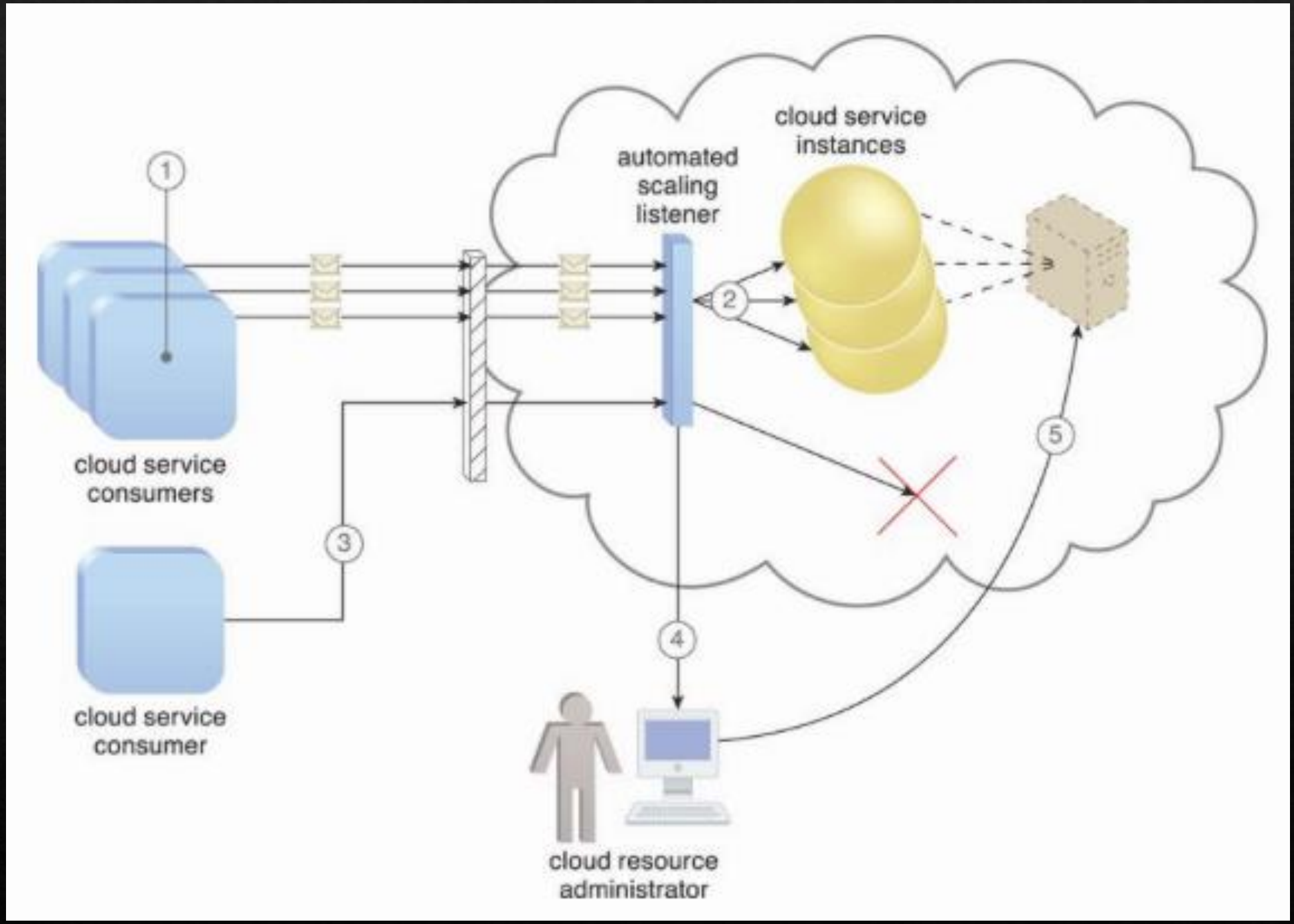
- Automatic Scaling Listener
- Load Balancer
- Pay-per-use Monitor
- Audit Monitor
- Failover Systems
- Hypervisor
- Resource Cluster
- Multi-Device Broker
- State Management Database

Automatic Scaling Listener

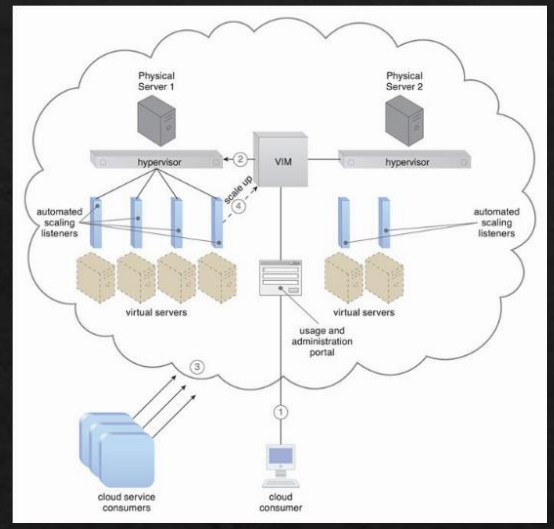
- This mechanism is a service agent that monitors and tracks communications between cloud service consumers and cloud services for dynamic scaling purposes.
- Typically placed near a firewall (or at hypervisor) tracking workload (processing requests) status.
- What does it do in general?

- Automatically scaling IT resources out or in based on parameters previously defined by the cloud consumer (commonly referred to as auto-scaling).
- Automatic notification of the cloud consumer when workloads exceed current thresholds or fall below allocated resources.
- This way, the cloud consumer can choose to adjust its current IT resource allocation.

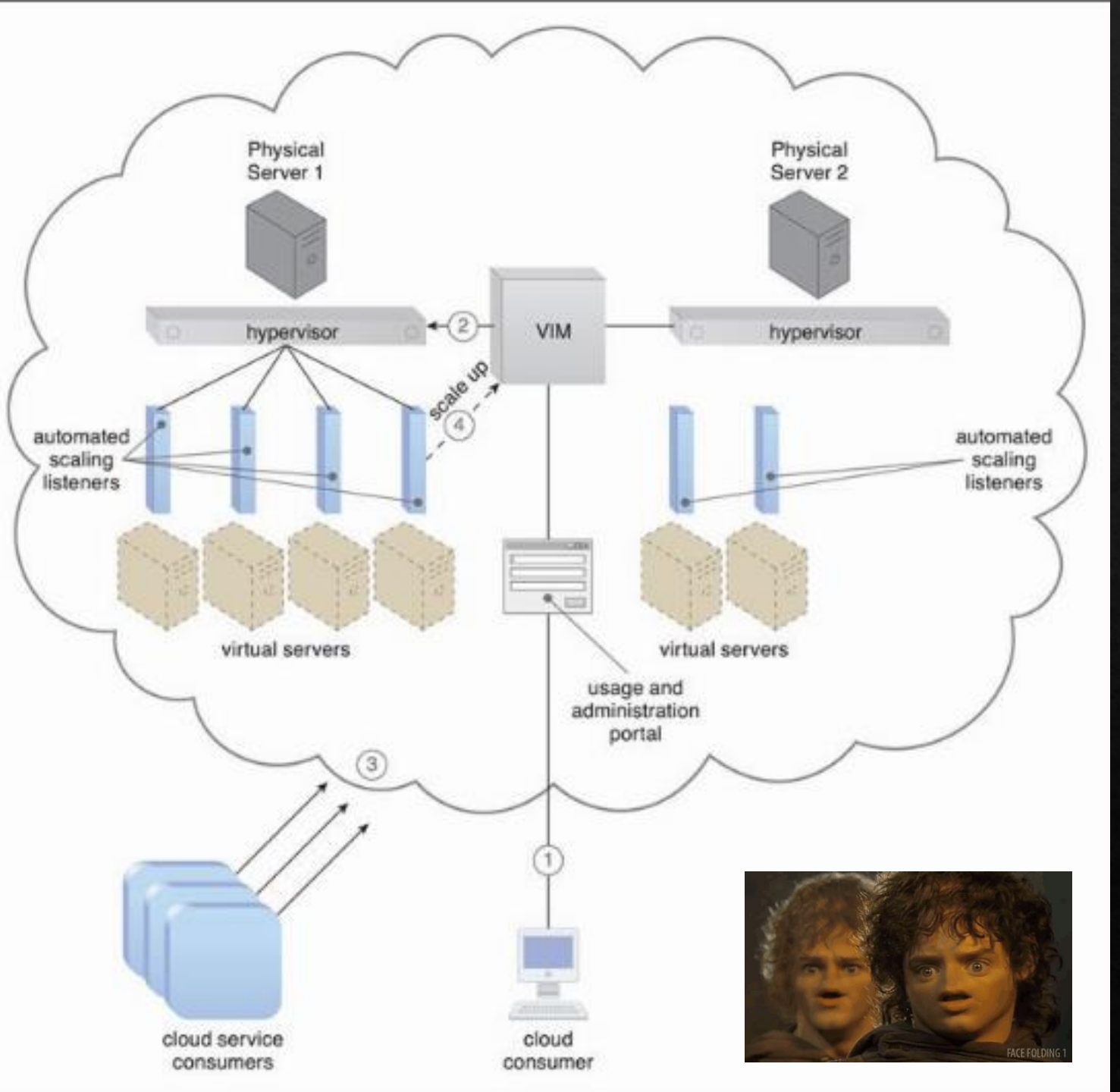



cloud service instances
automated scaling listener
1
2
3
4
5
cloud service consumers
cloud service consumer
cloud resource administrator

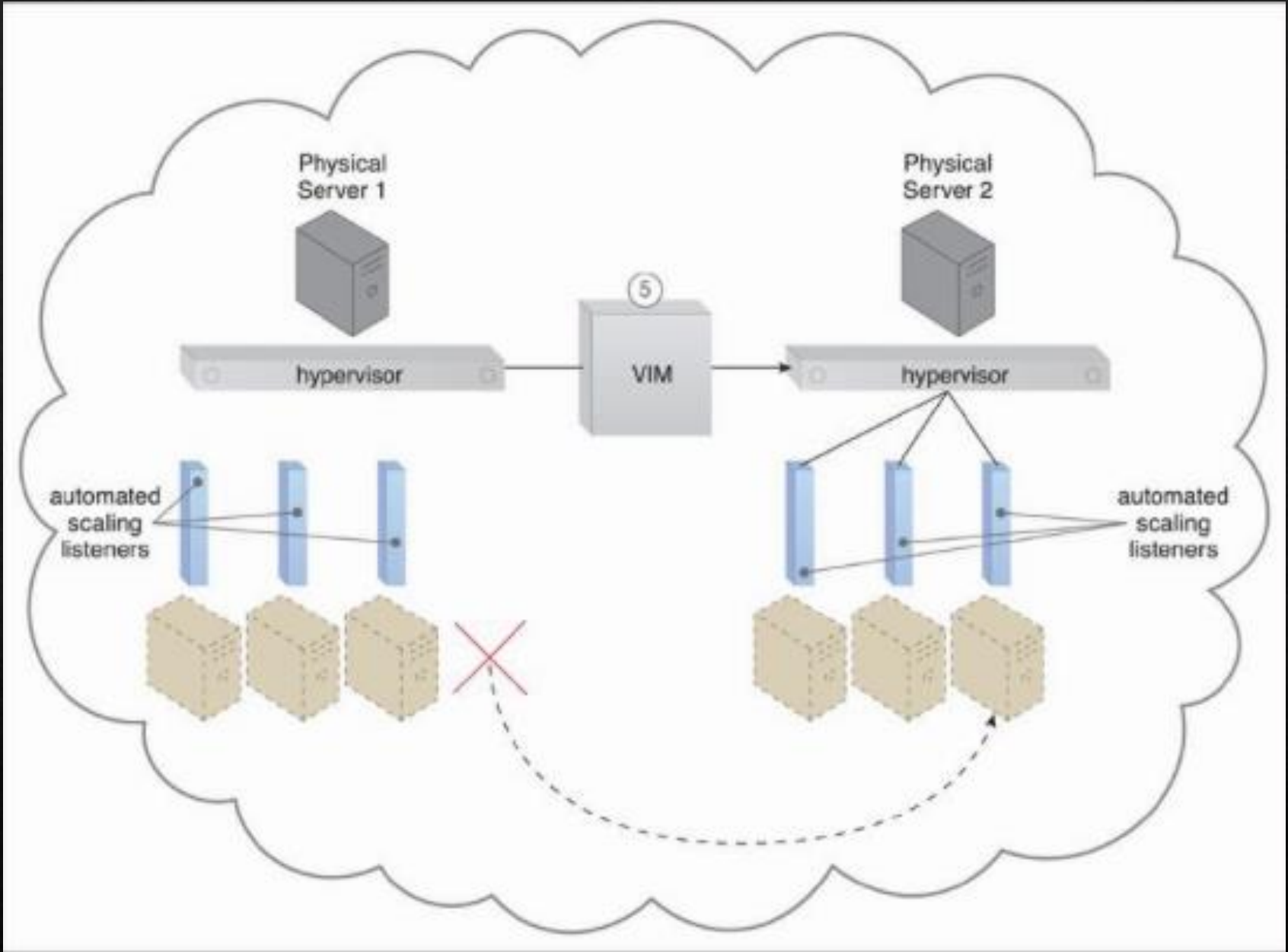
Case Study (DTGOV)



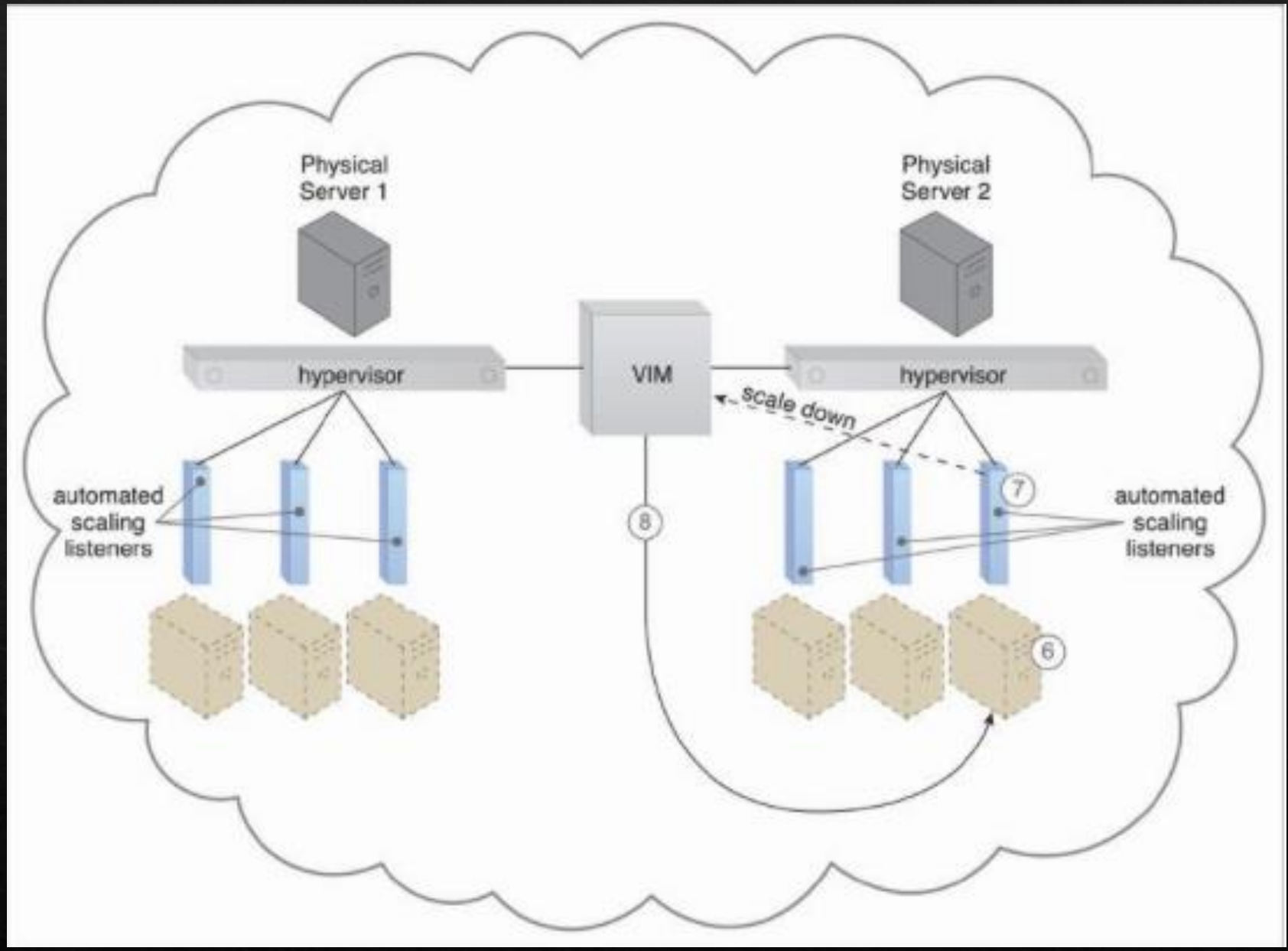
- DTGOV's physical servers vertically scale virtual server instances, starting with the smallest VM configuration
  - (1 virtual processor core, 4 GB of virtual RAM) to the largest (128 virtual processor cores, 512 GB of virtual RAM).
- Scale-Down – VM resides in the same physical server while being scaled down.
- Scale-Up – capacity is doubled. VIM may live migrate VM to other servers (a current one is overcommitted.)
- Auto-scaling settings controlled by cloud consumers determine the runtime behavior of automated scaling listener agents.


Physical Server 1
Physical Server 2
hypervisor
VIM
hypervisor
2
scale up
4
automated scaling listeners
automated scaling listeners
virtual servers
virtual servers
usage and administration portal
3
1
cloud service consumers
cloud consumer

FACE FOLDING 1



- Physical server 1 is overcommitted. VIM live migrates scaled-up VM to the physical server 2.



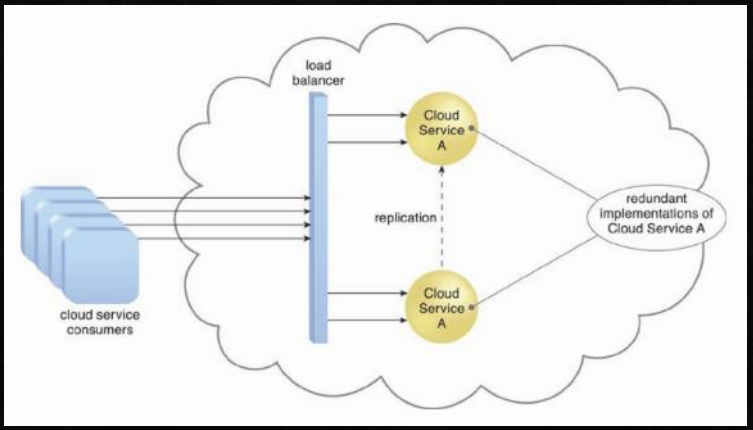
- Usage remains 15% below the capacity, scaled-down.

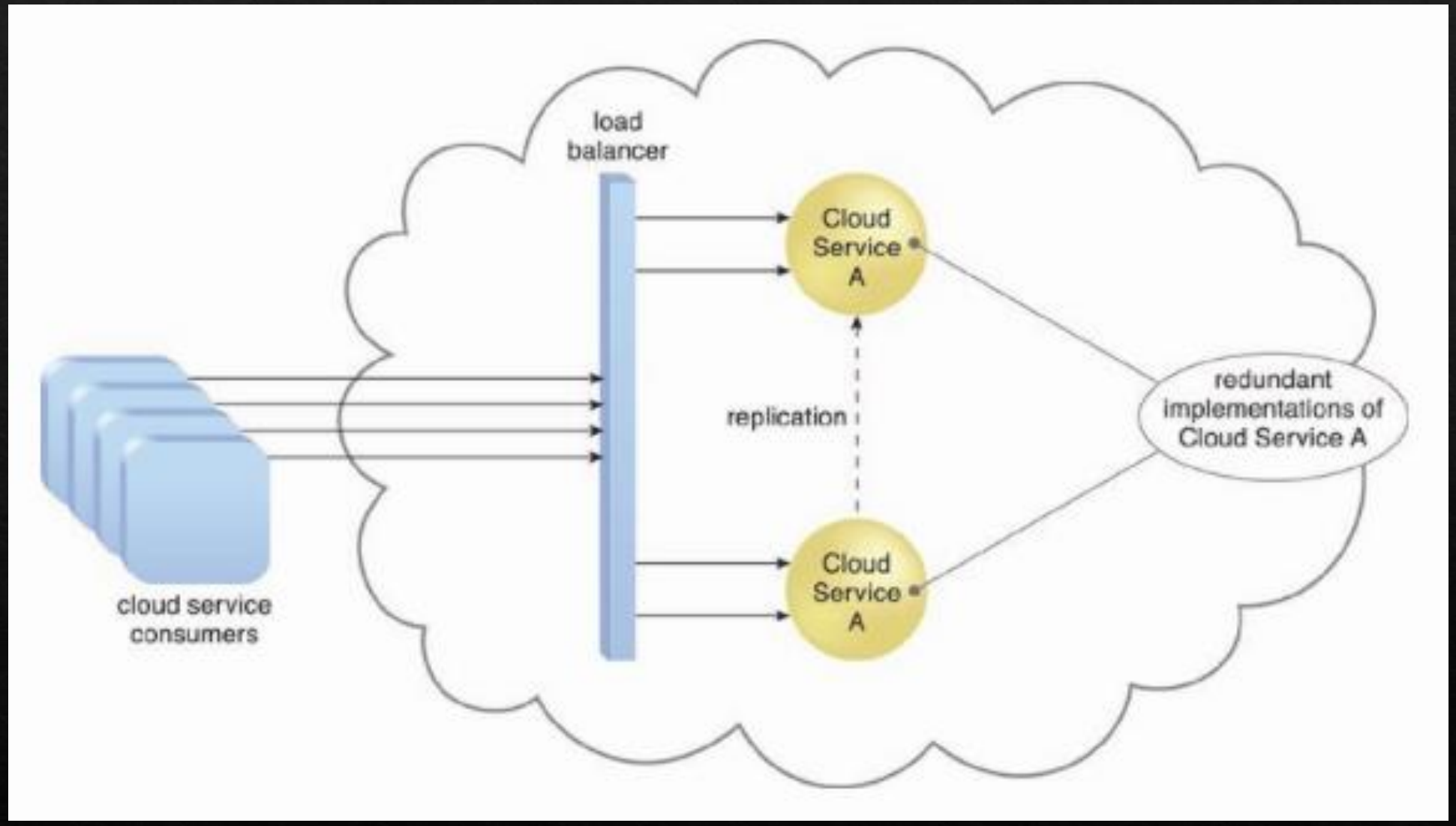
Load Balancer

- A common approach to horizontal scaling is to balance a workload across two or more IT resources to increase performance and capacity beyond what a single IT resource can provide.
- The load balancer mechanism is a runtime agent with logic fundamentally based on this premise.

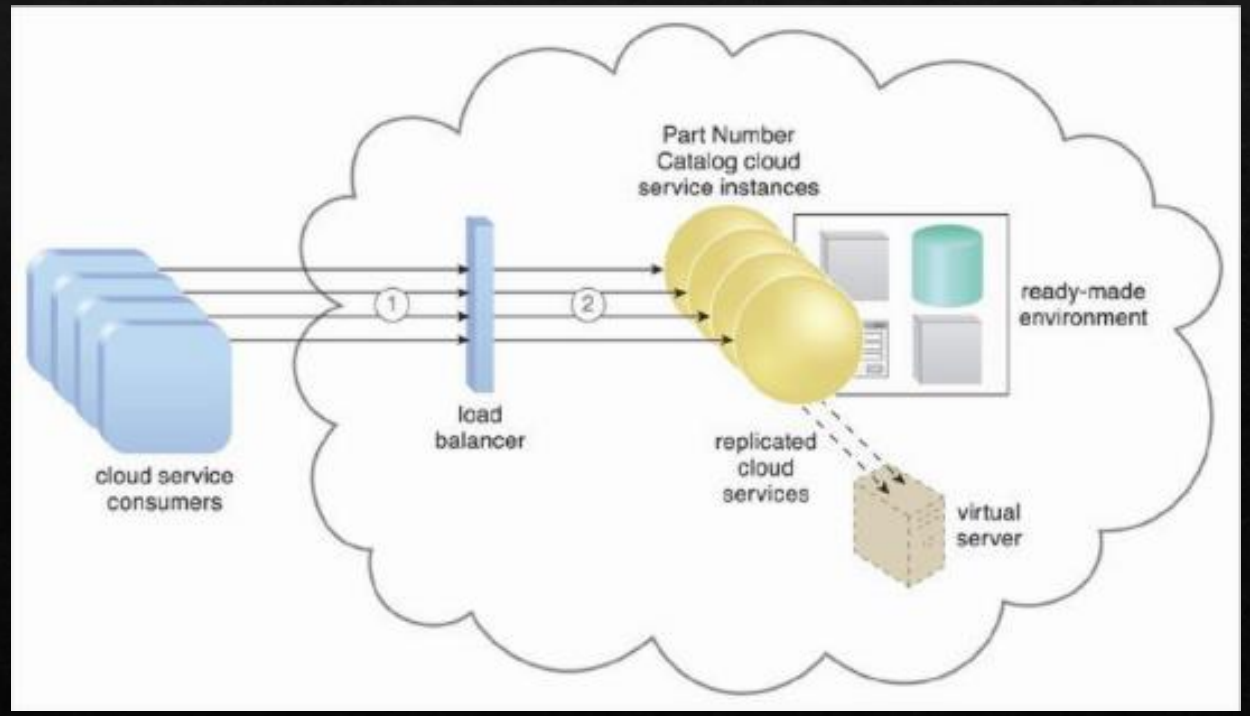
Load Balancer Functionalities

- **Asymmetric Distribution** – larger workloads are issued to IT resources with higher processing capacities.
- **Workload Prioritization** – workloads are scheduled, queued, discarded, and distributed workloads according to their priority levels.
- **Content-Aware Distribution** – requests are distributed to different IT resources as dictated by the request content.



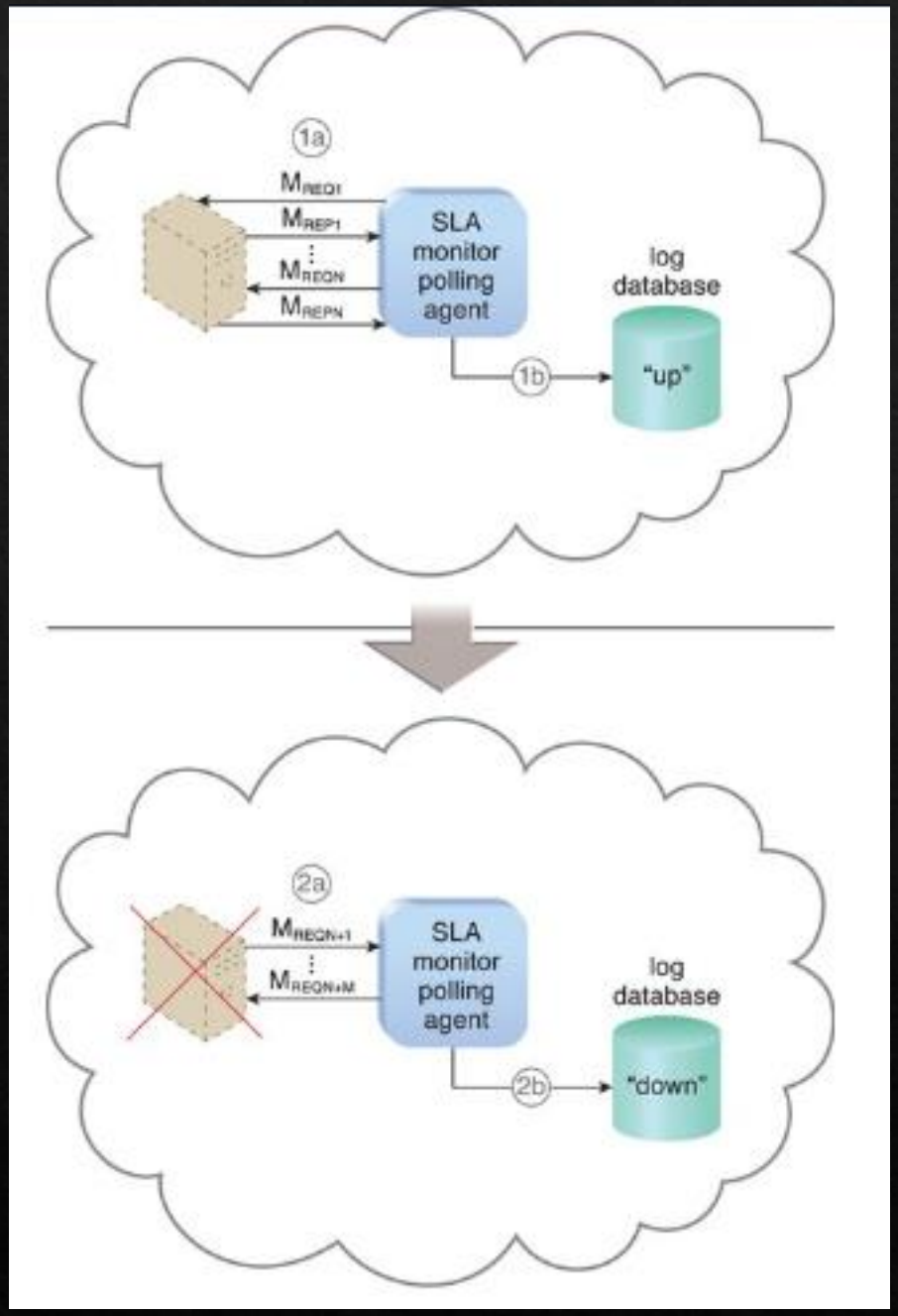

load
balancer
Cloud
Service
A
replication
Cloud
Service
A
redundant
implementations of
Cloud Service A
cloud service
consumers

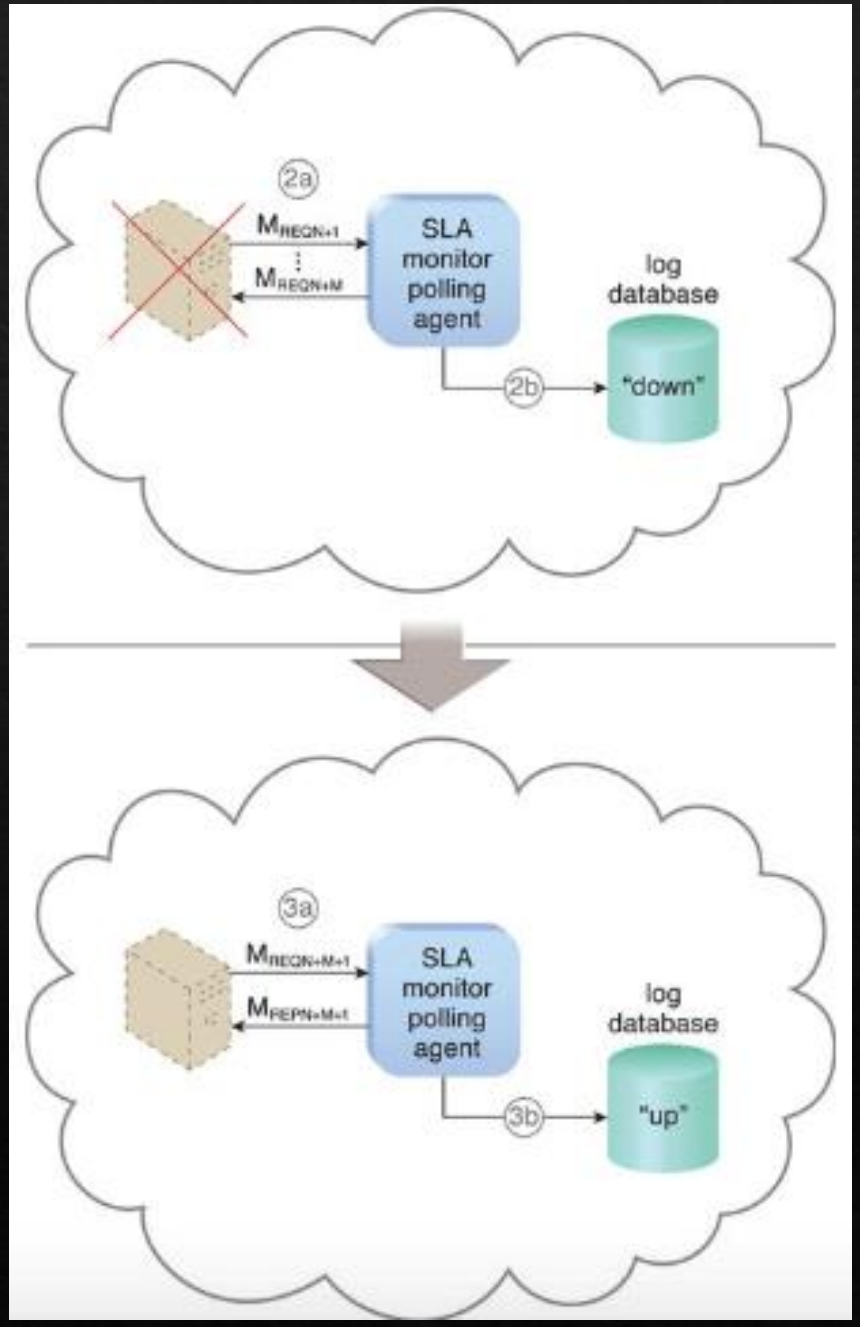
- A load balancer is programmed or configured with a set of performance and QoS rules and parameters with the general objectives of optimizing IT resource usage, avoiding overloads, and maximizing throughput.
- The load balancer mechanisms can exist as a:
  - multi-layer network switch
  - dedicated hardware appliance
  - dedicated software-based system (common in server operating systems)
  - service agent (usually controlled by cloud management software)

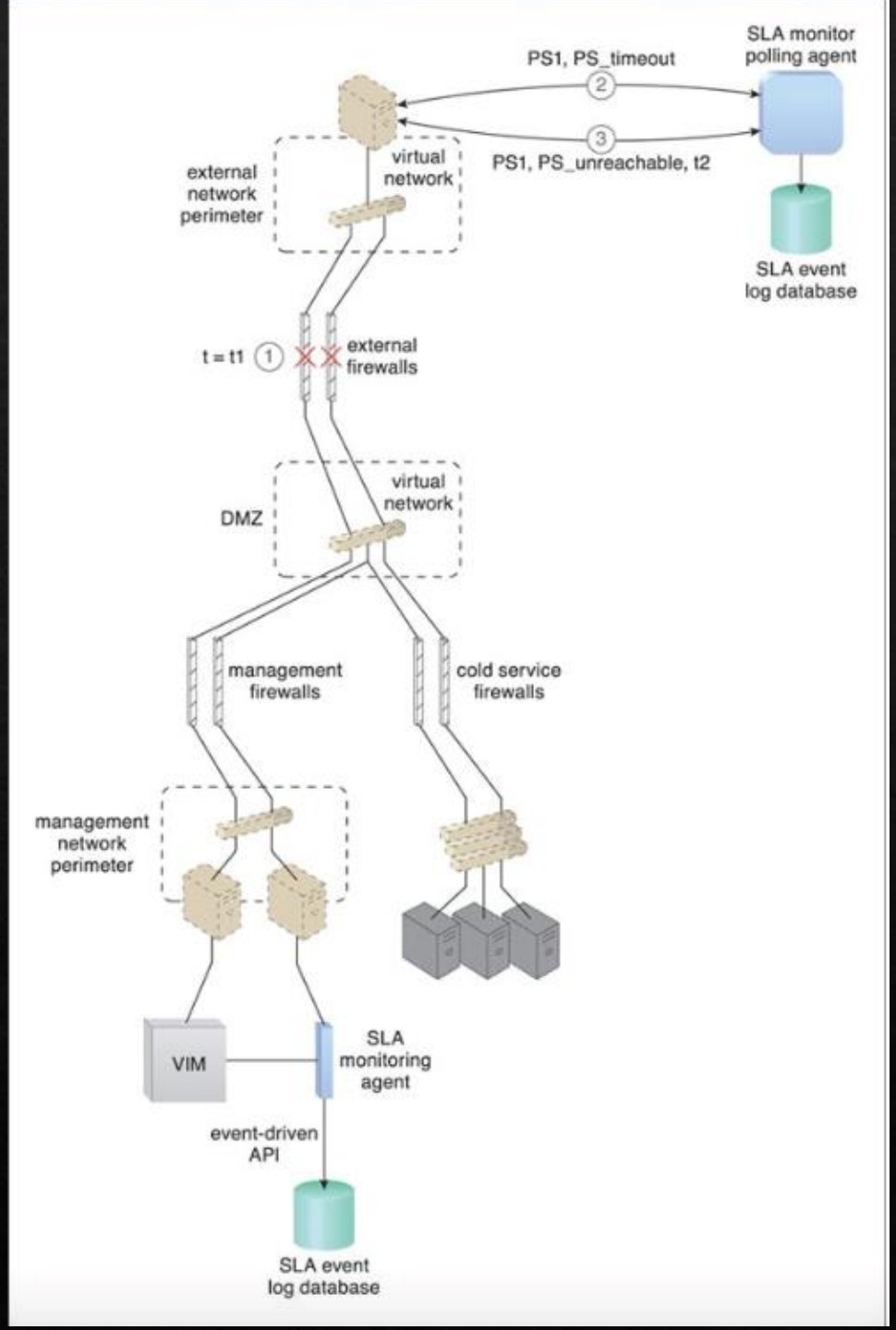


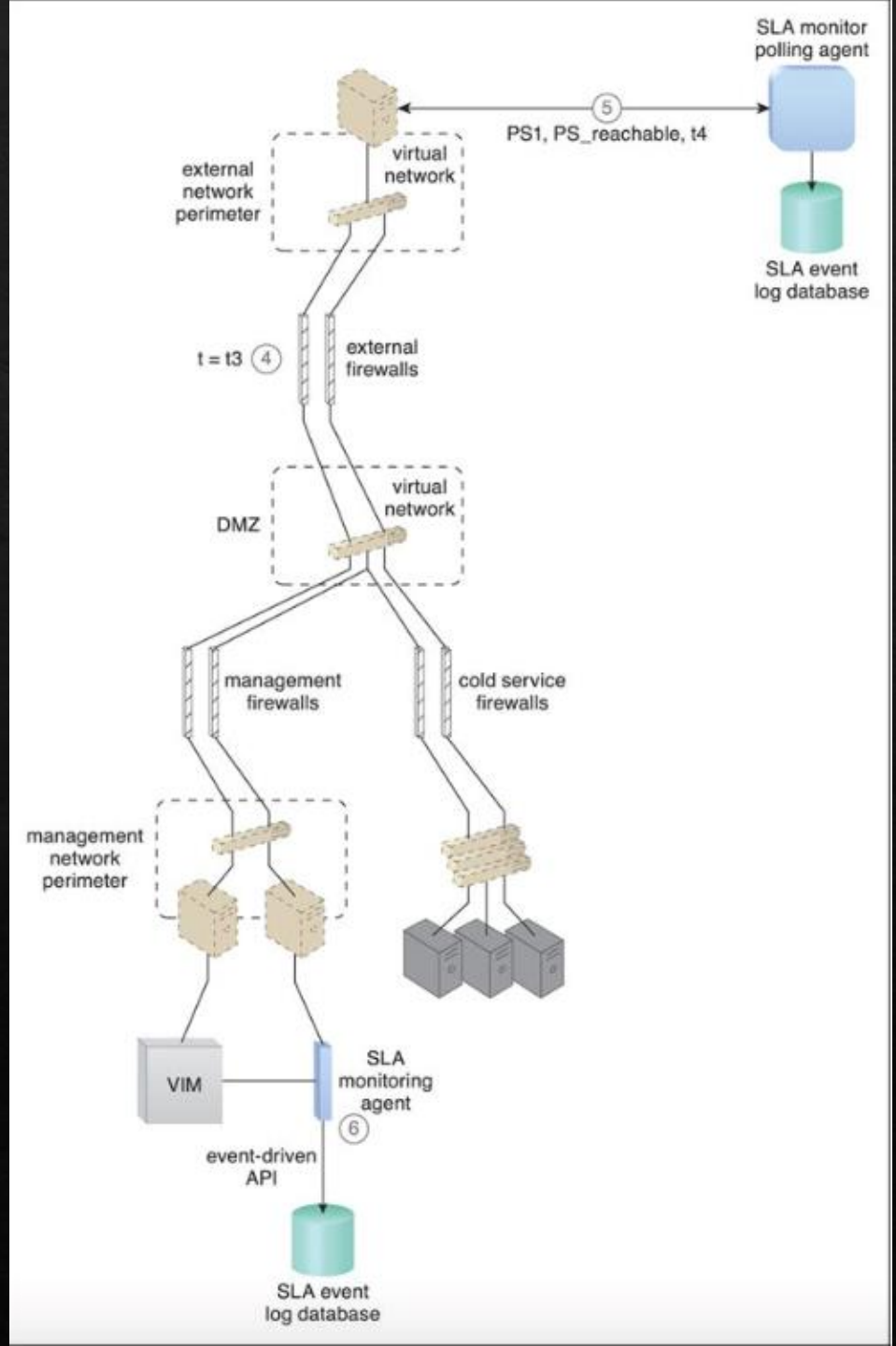
SLA Monitor

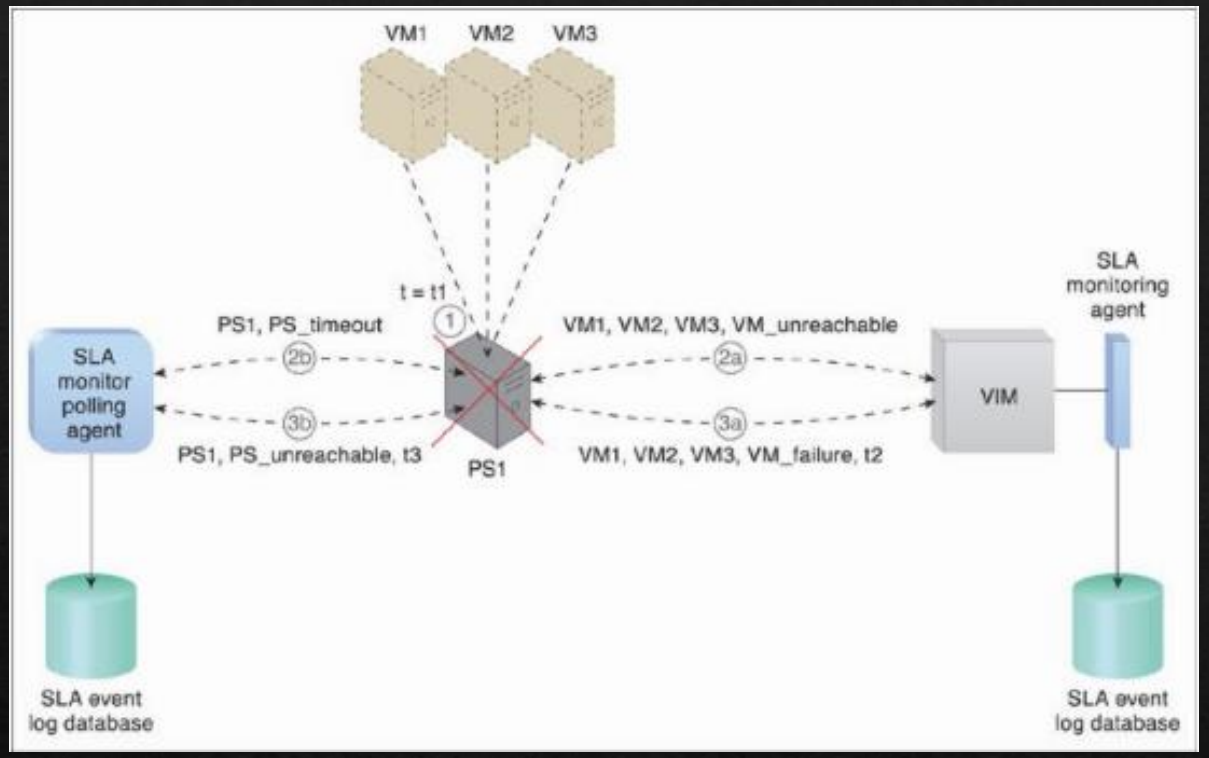
- To specifically observe the runtime performance of cloud services to ensure that they are fulfilling the contractual QoS requirements that are published in SLAs.

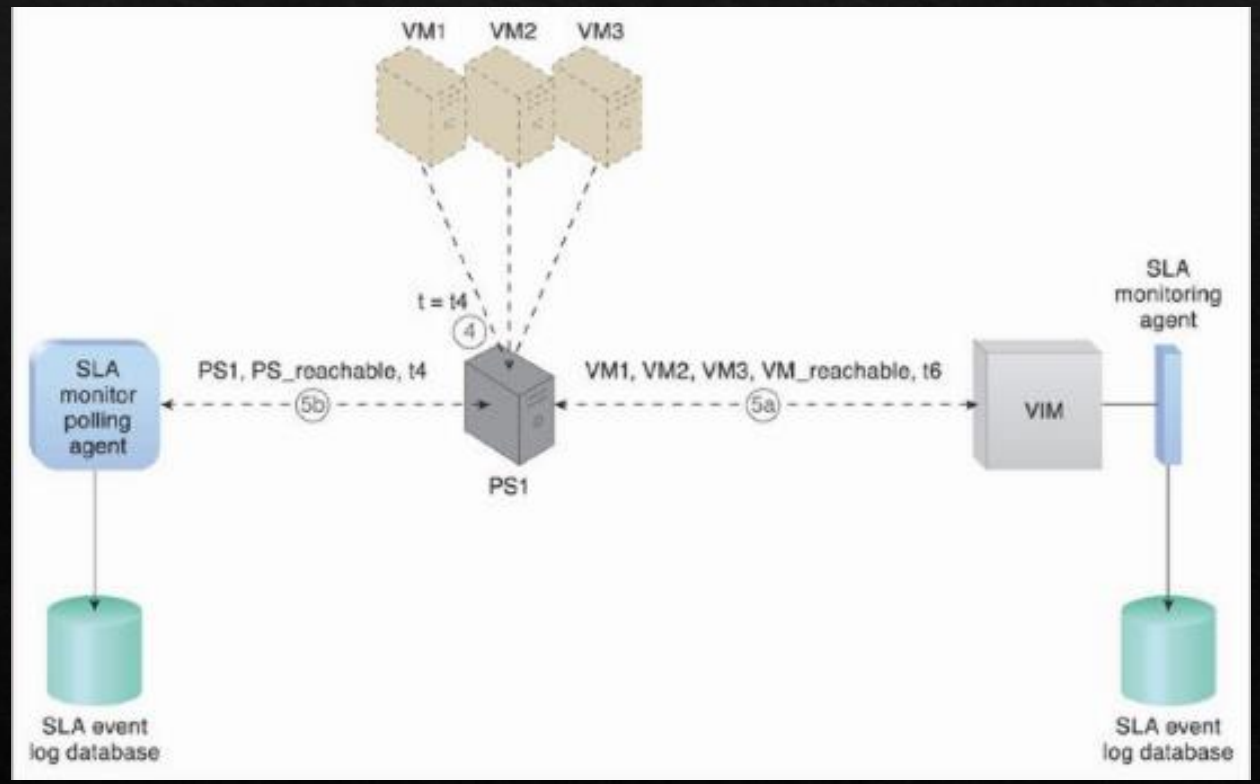

1a
M_{REQ1}
M_{REP1}
M_{REQN}
M_{REPN}
SLA monitor polling agent
log database
1b
"up"
2a
M_{REQN+1}
M_{REQN+M}
SLA monitor polling agent
log database
2b
"down"


2a
M_{REQN+1}
M_{REQN+M}
SLA monitor polling agent
log database
2b
"down"
3a
$M_{REQN+M+1}$
$M_{REPN+M+1}$
SLA monitor polling agent
log database
3b
"up"


SLA monitor
polling agent
PS1, PS_timeout
2
3
PS1, PS_unreachable, t2
external
network
perimeter
virtual
network
SLA event
log database
t = t1
1
external
firewalls
DMZ
virtual
network
management
firewalls
cold service
firewalls
management
network
perimeter
VIM
SLA
monitoring
agent
event-driven
API
SLA event
log database

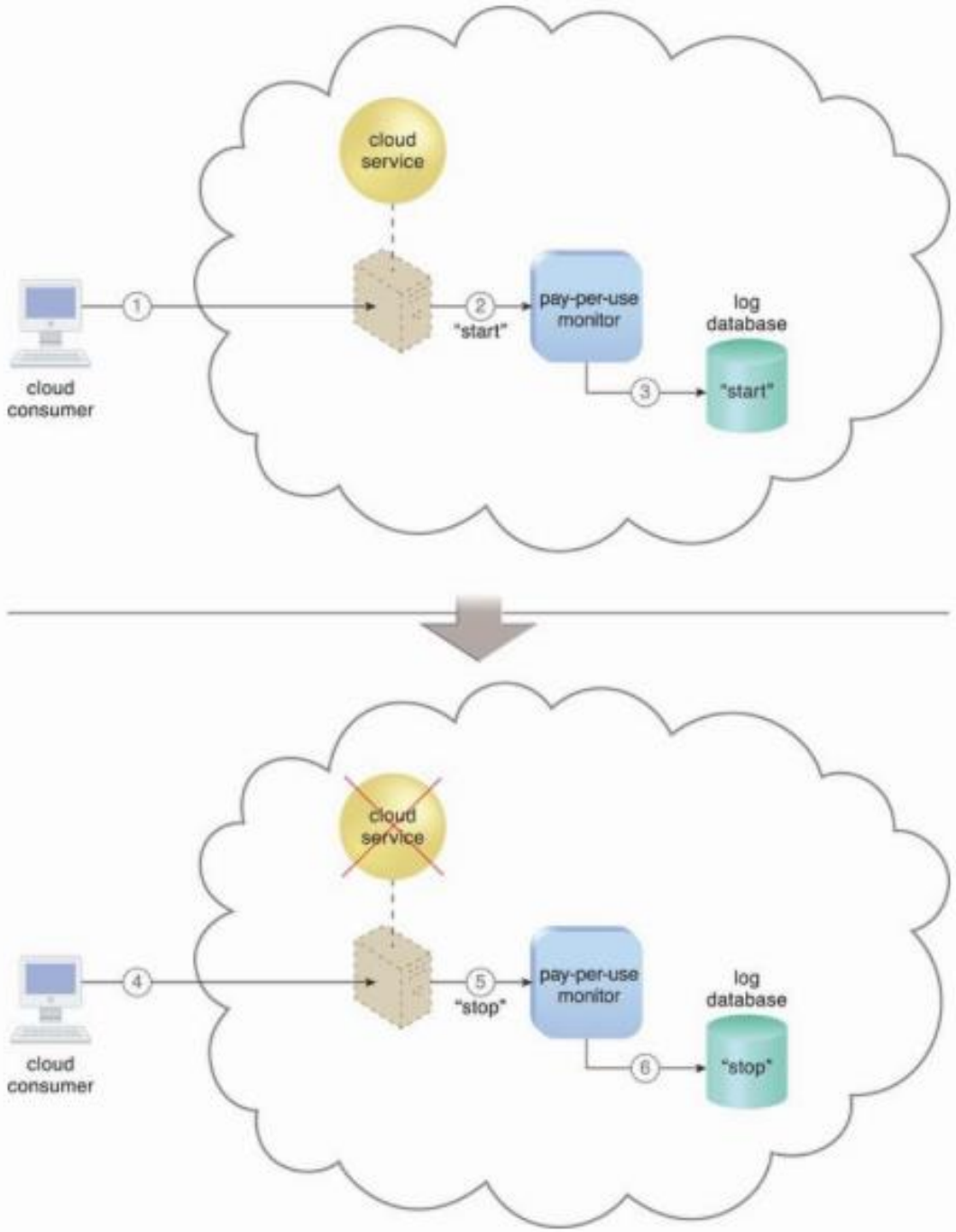

SLA monitor
polling agent
5
PS1, PS_reachable, t4
external
network
perimeter
virtual
network
SLA event
log database
t = t3
4
external
firewalls
DMZ
virtual
network
management
firewalls
cold service
firewalls
management
network
perimeter
VIM
SLA
monitoring
agent
6
event-driven
API
SLA event
log database


VM1
VM2
VM3
t = t1
1
PS1, PS_timeout
2b
VM1, VM2, VM3, VM_unreachable
2a
SLA monitor polling agent
VIM
SLA monitoring agent
3b
PS1, PS_unreachable, t3
PS1
VM1, VM2, VM3, VM_failure, t2
3a
SLA event log database
SLA event log database

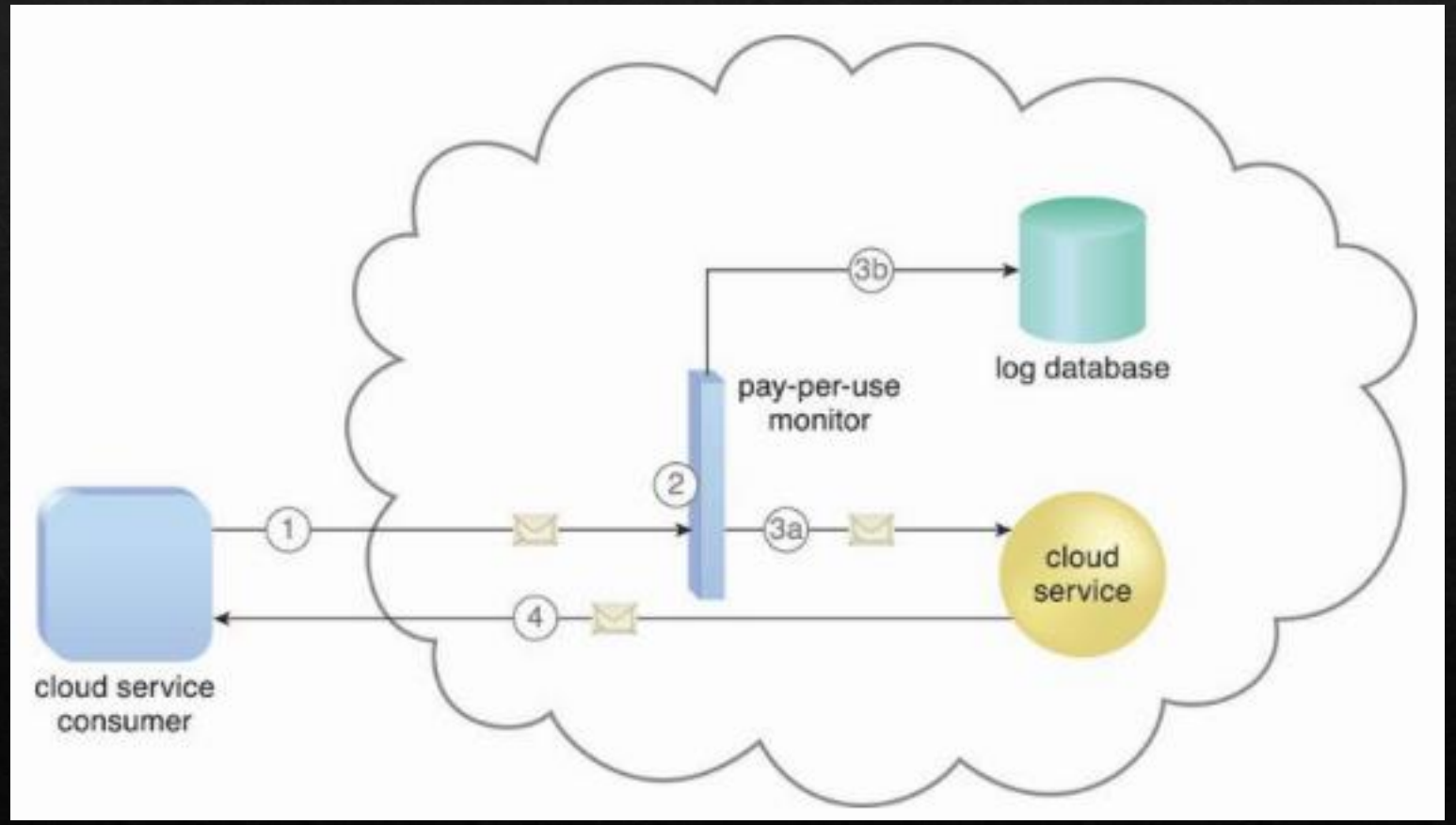

VM1
VM2
VM3
t = t4
4
SLA monitoring agent
SLA monitor polling agent
PS1, PS_reachable, t4
5b
VM1, VM2, VM3, VM_reachable, t6
5a
VIM
PS1
SLA event log database
SLA event log database

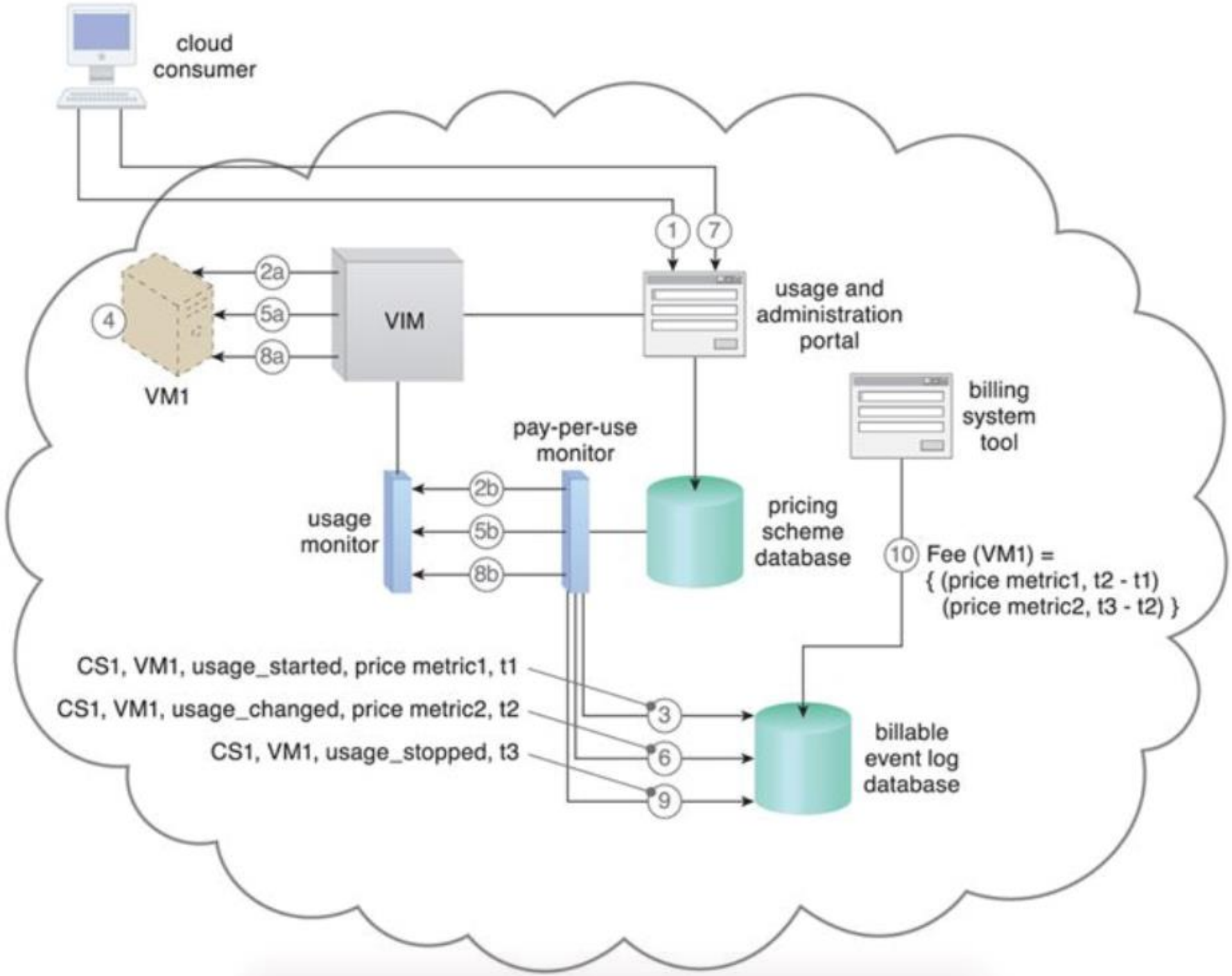
Pay-per-use Monitor

- The pay-per-use monitor mechanism measures cloud-based IT resource usage in accordance with predefined pricing parameters and generates usage logs for fee calculations and billing purposes.
- Some typical monitoring variables are:
  - request/response message quantity
  - transmitted data volume
  - bandwidth consumption
  - time duration



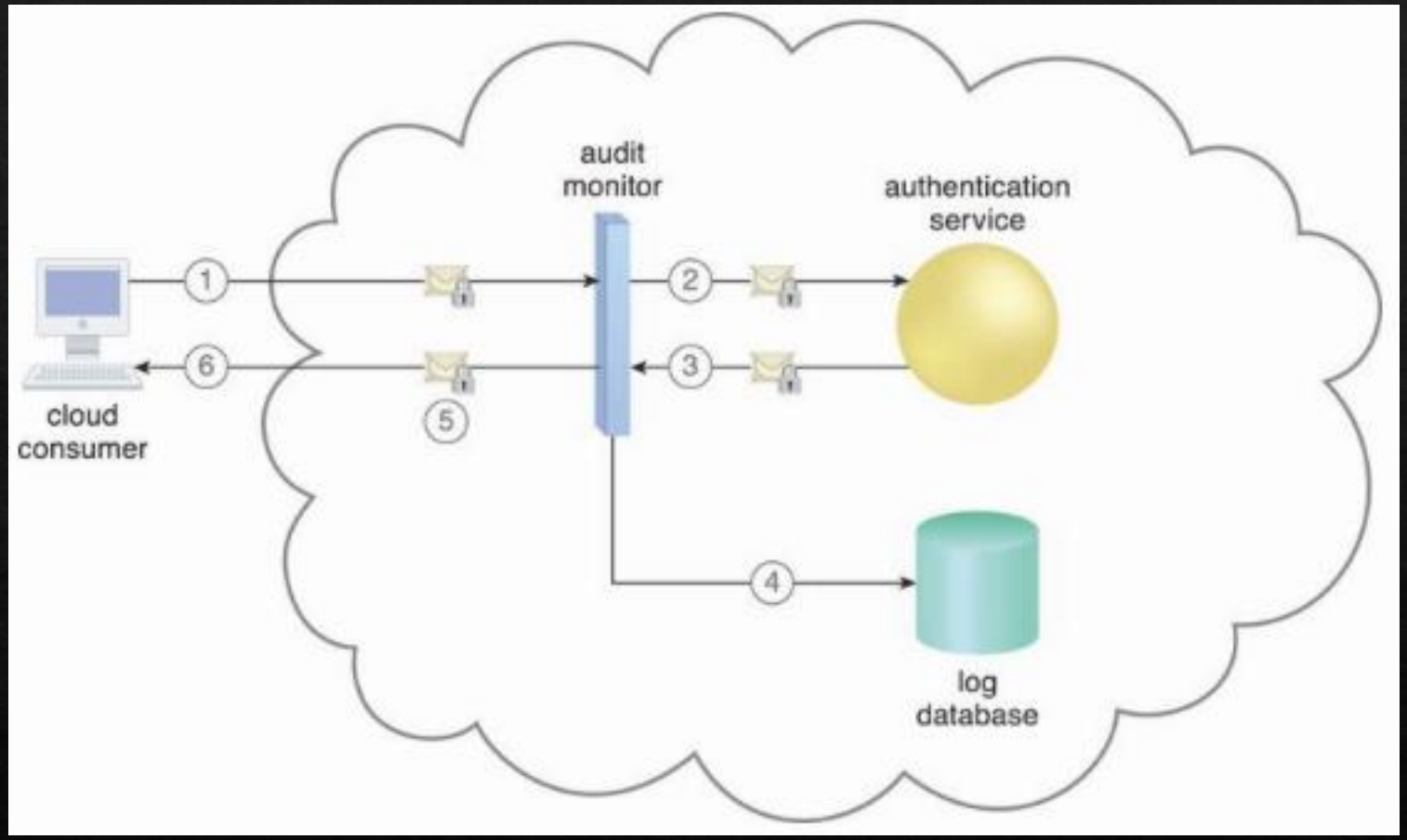
- Monitor based on service request.

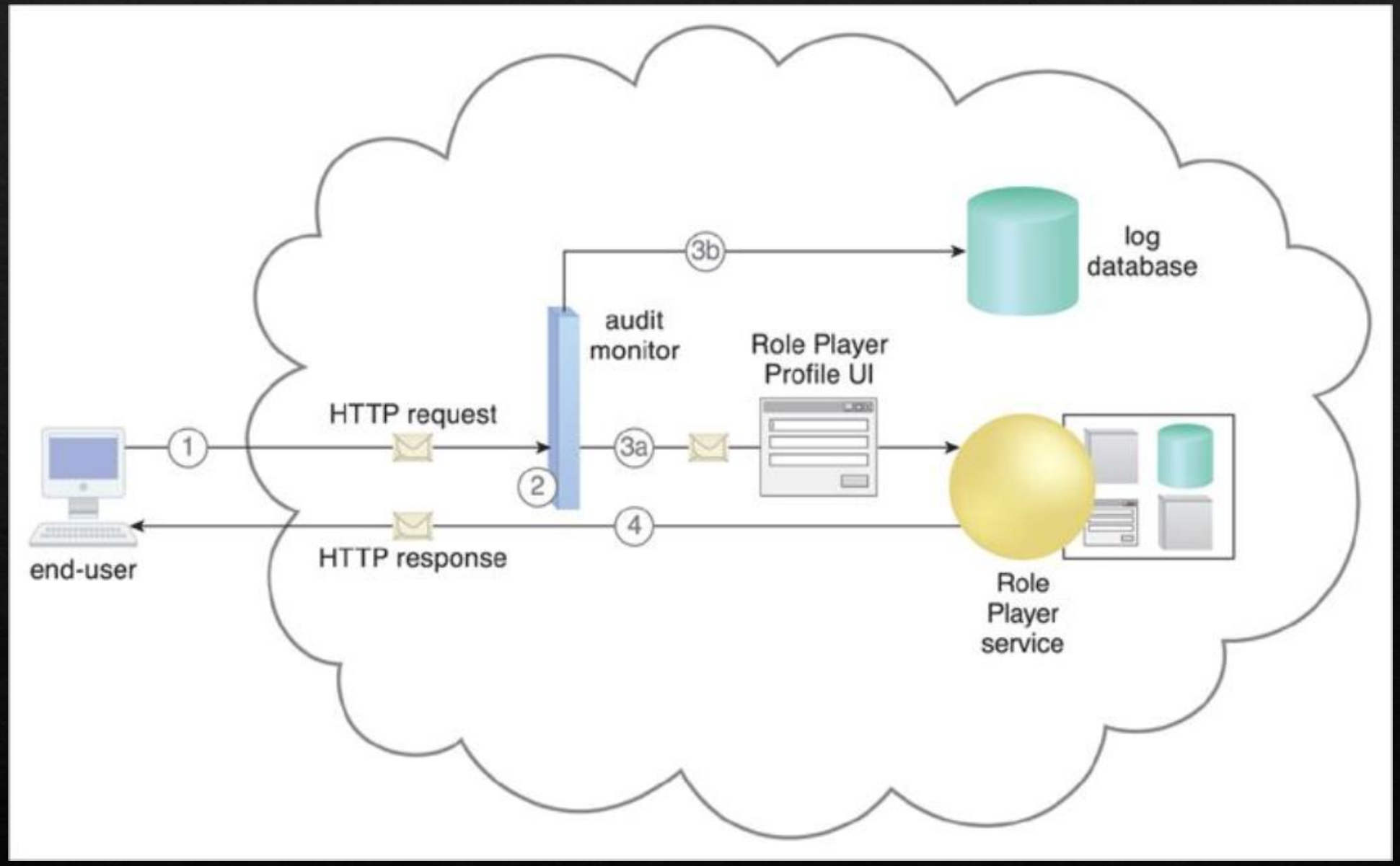



cloud consumer
1
7
2a
5a
8a
4
VIM
VM1
usage and administration portal
billing system tool
pay-per-use monitor
2b
5b
8b
usage monitor
pricing scheme database
10
Fee (VM1) =
{ (price metric1, t2 - t1)
(price metric2, t3 - t2) }
CS1, VM1, usage_started, price metric1, t1
CS1, VM1, usage_changed, price metric2, t2
CS1, VM1, usage_stopped, t3
3
6
9
billable event log database

Audit Monitor

- The audit monitor mechanism is used to collect audit tracking data for networks and IT resources in support of (or dictated by) regulatory and contractual obligations.
- For example, data related to login (whether successful or failed logins, number of attempts, credentials, etc.)



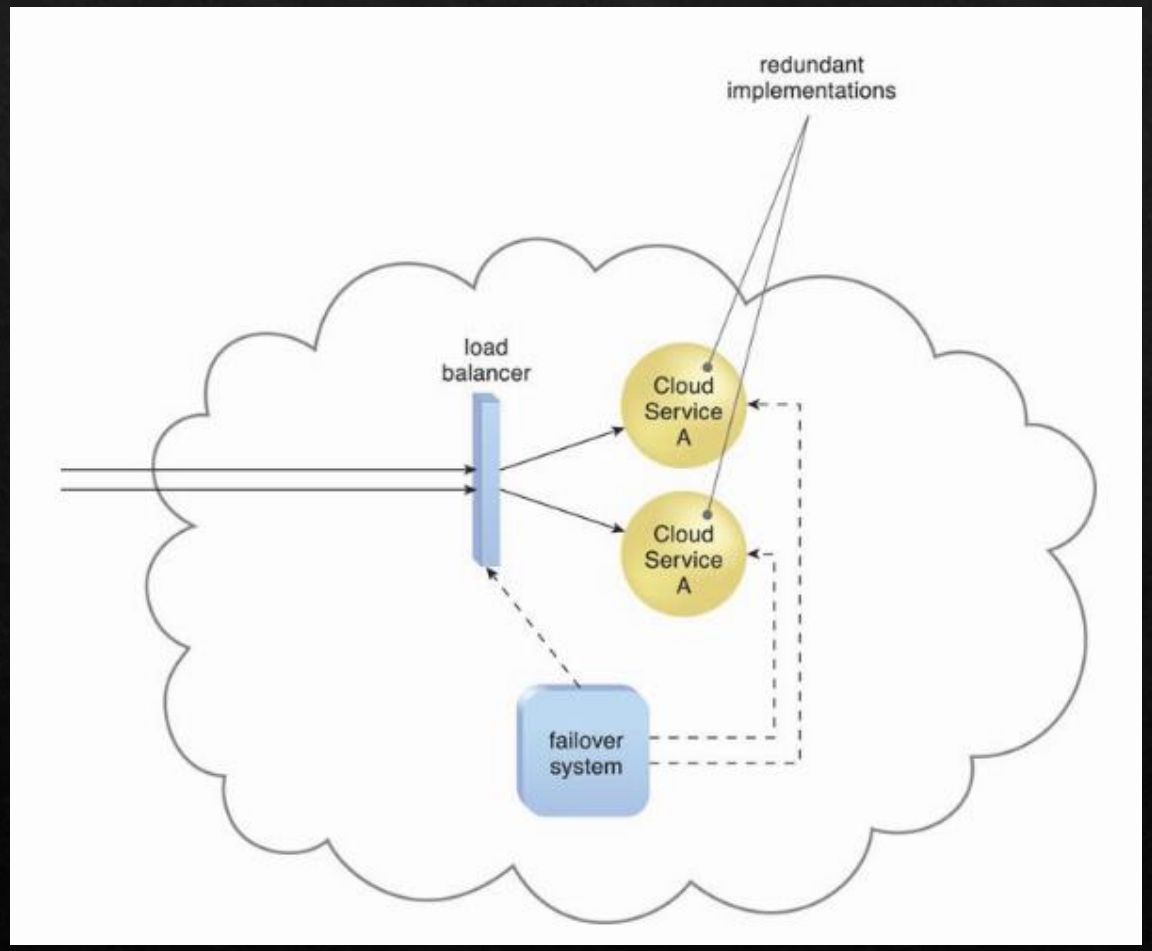

log
database
3b
audit
monitor
Role Player
Profile UI
HTTP request
1
2
3a
4
HTTP response
end-user
Role
Player
service

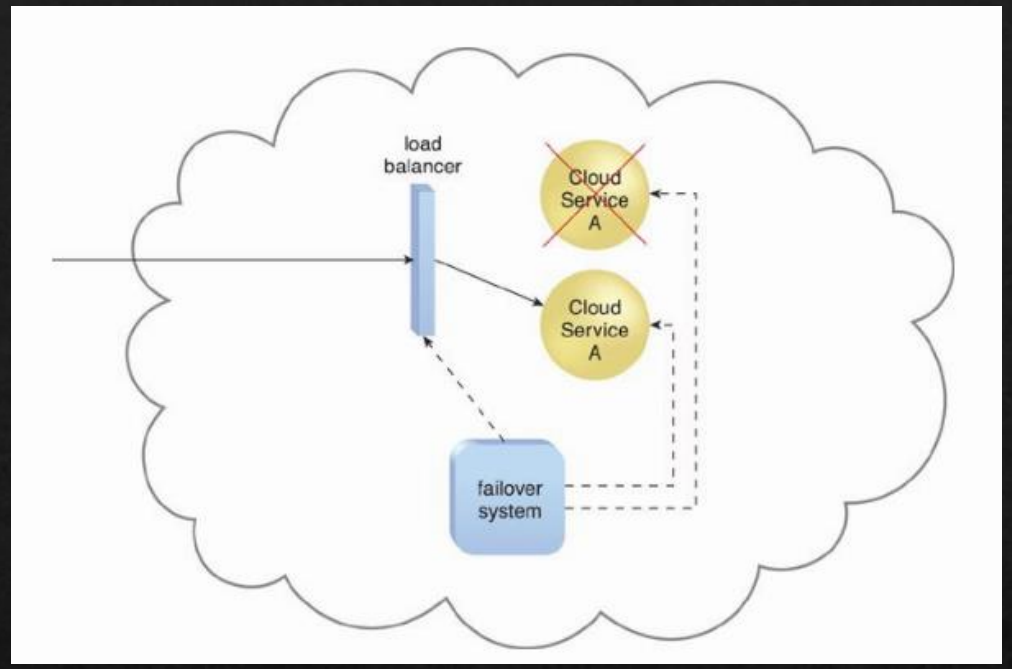
Failover System

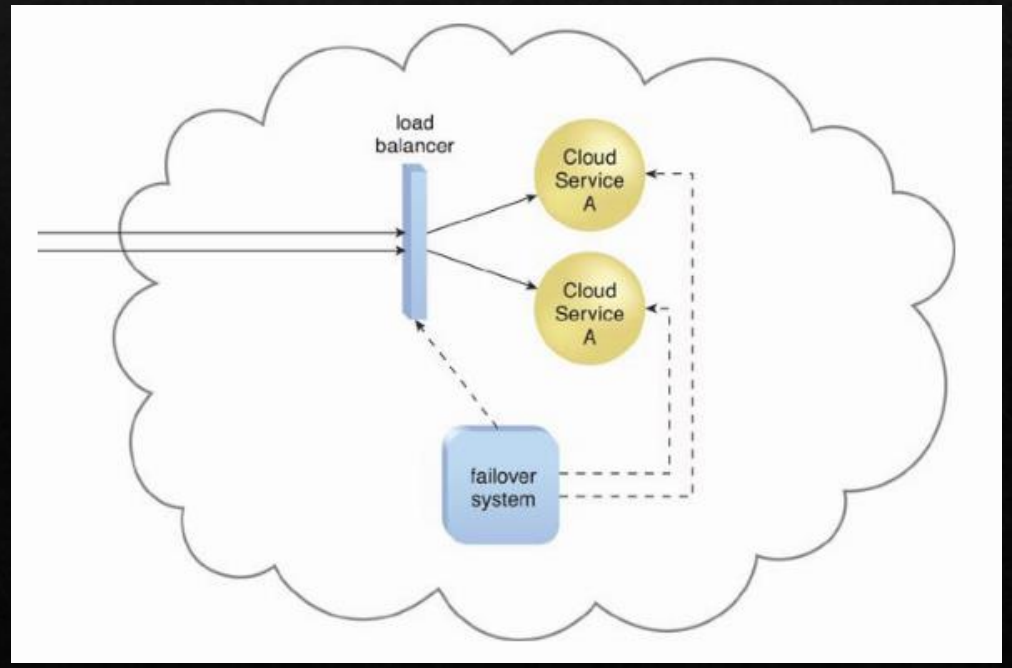
- A mechanism used to increase reliability and availability.
- To establish a clustering technology providing redundant implementations.
- A failover system is configured to automatically switch over to a redundant or standby IT resource instance whenever the currently active IT resource becomes unavailable.

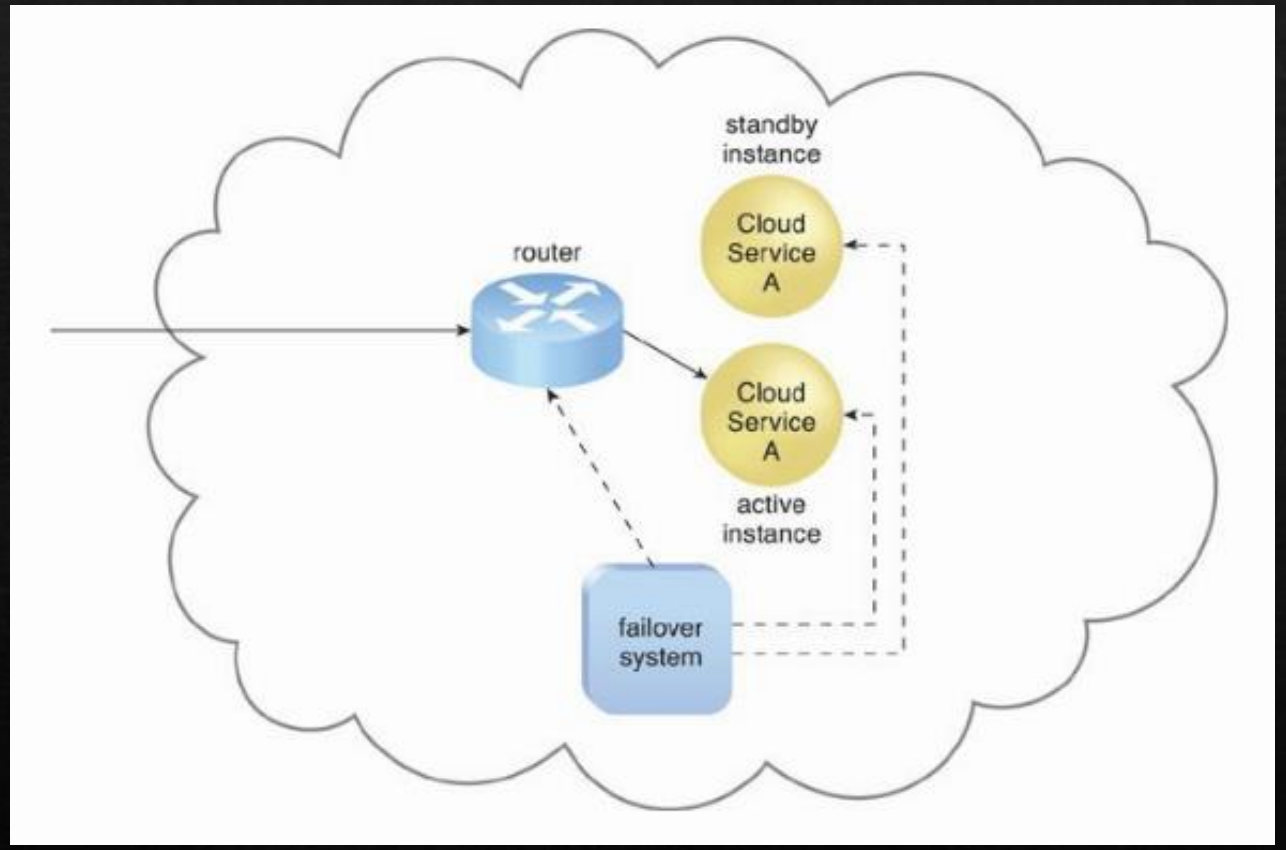
Failover System Configurations

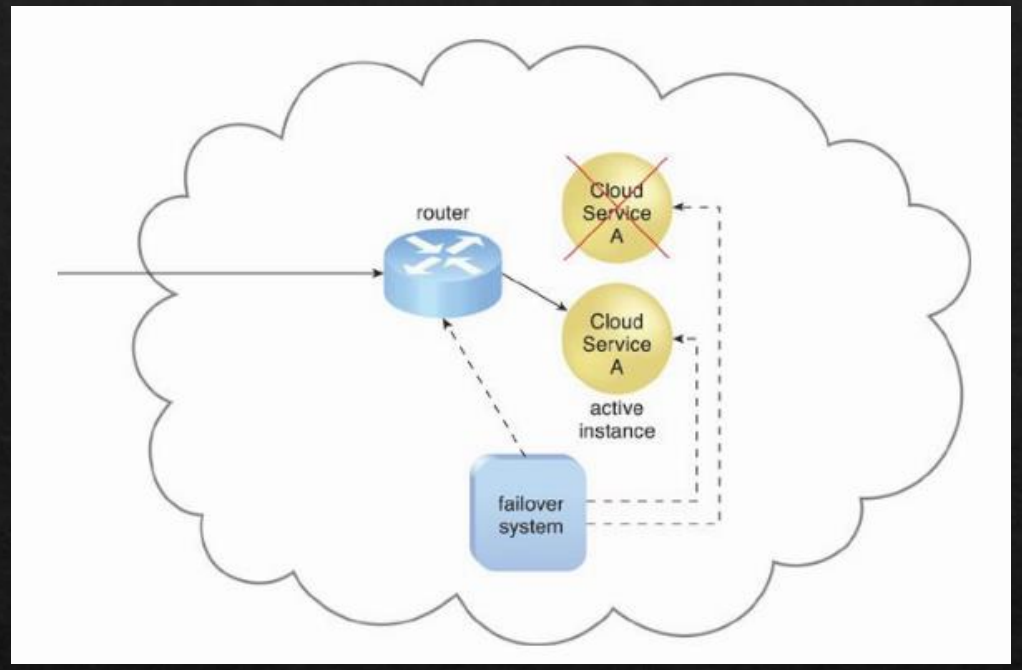
- Active-Active
  - Redundant implementations of the IT resource actively serve the workload synchronously. Load balancing among active instances is required
- Active-Passive
  - A standby or inactive implementation is activated to take over the processing from the IT resource that becomes unavailable, and the corresponding workload is redirected to the instance taking over the operation.

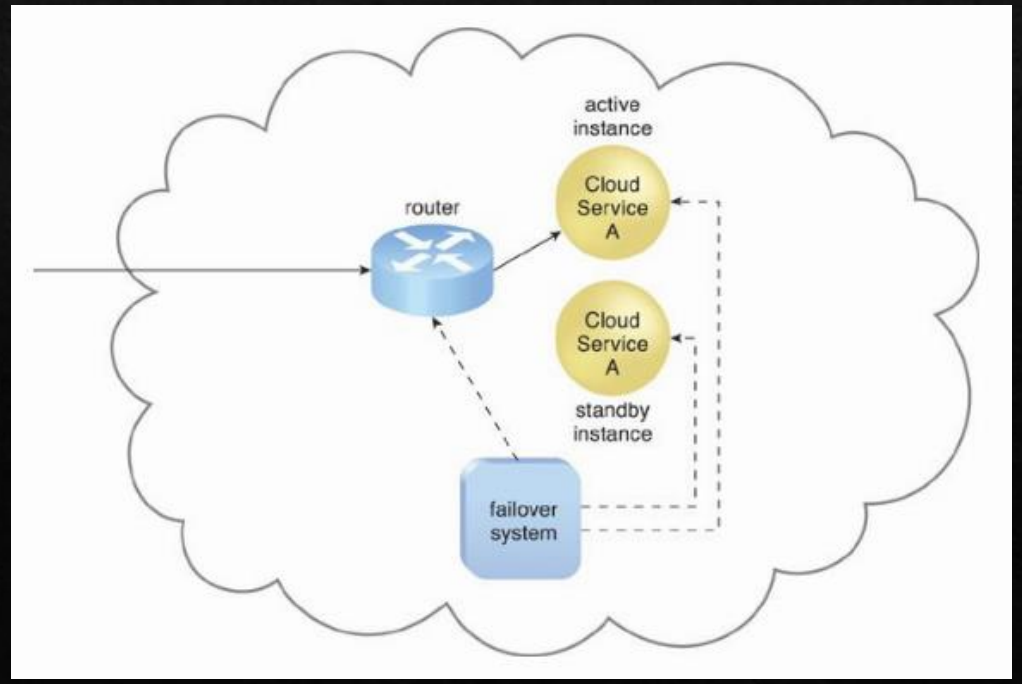

redundant
implementations
load
balancer
Cloud
Service
A
Cloud
Service
A
failover
system


load
balancer
Cloud
Service
A
Cloud
Service
A
failover
system


load
balancer
Cloud
Service
A
Cloud
Service
A
failover
system

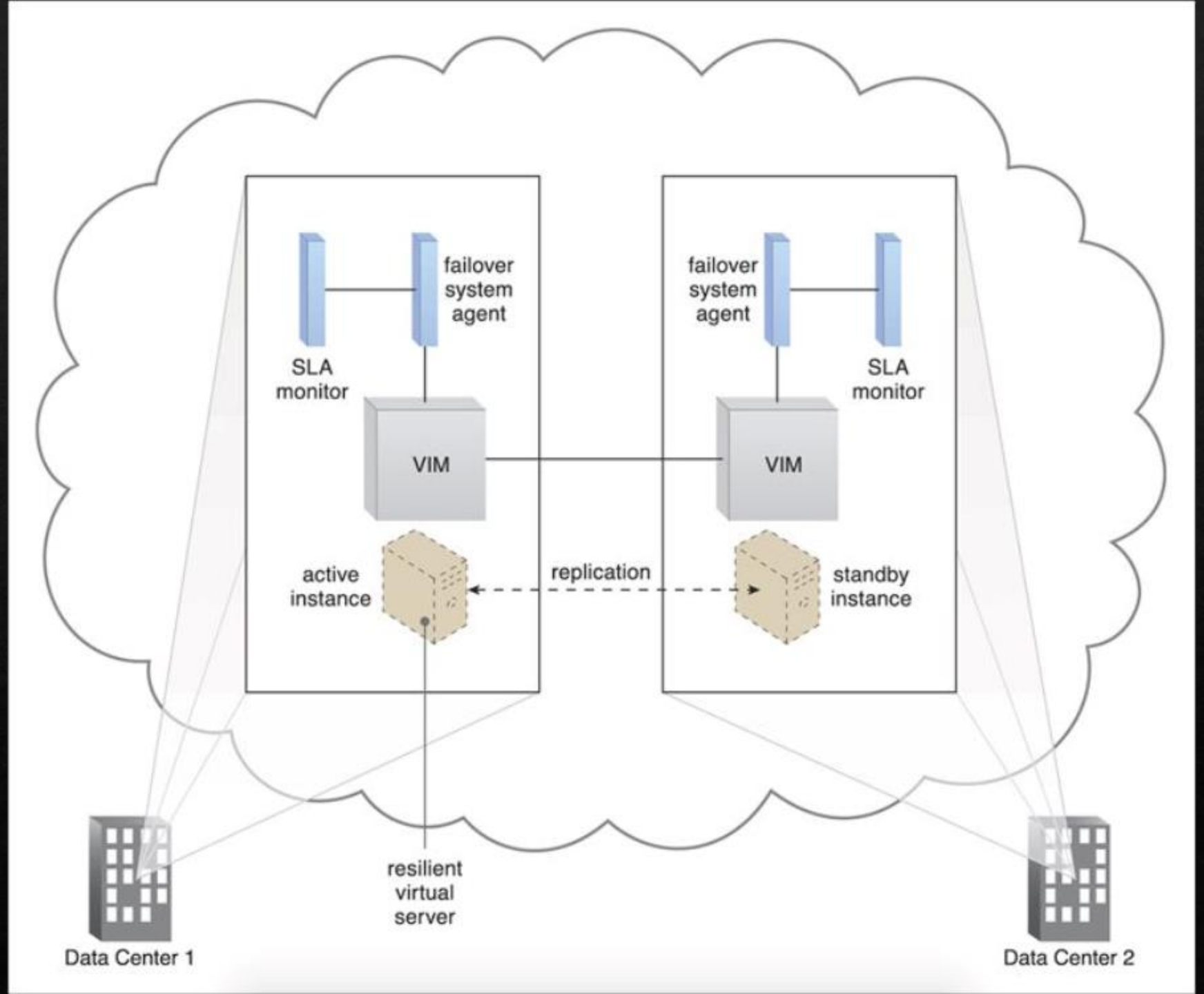

standby
instance
Cloud
Service
A
router
Cloud
Service
A
active
instance
failover
system

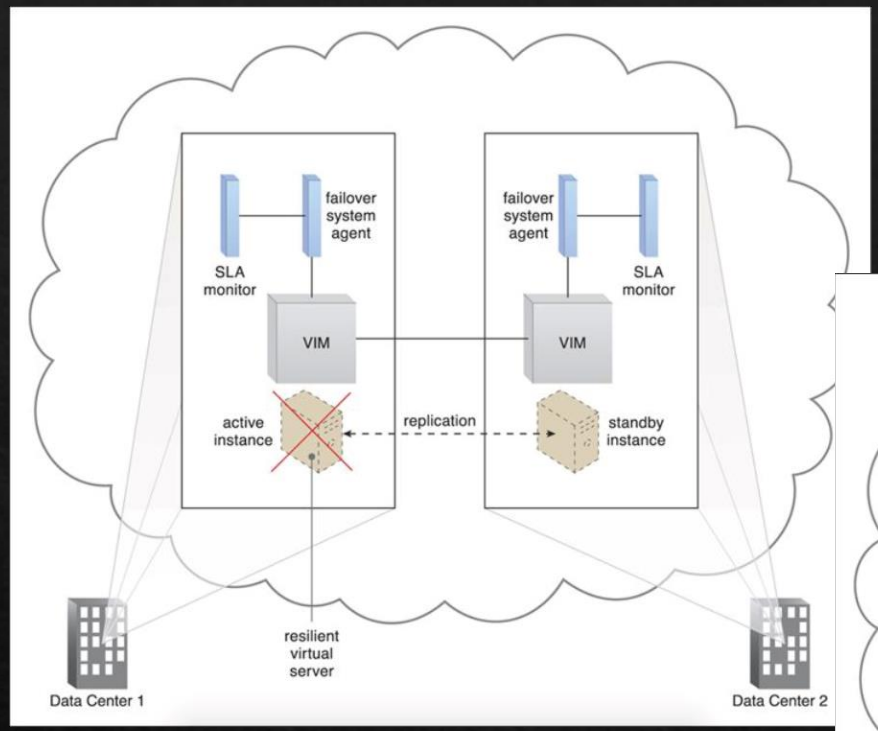

router
Cloud
Service
A
Cloud
Service
A
active
instance
failover
system

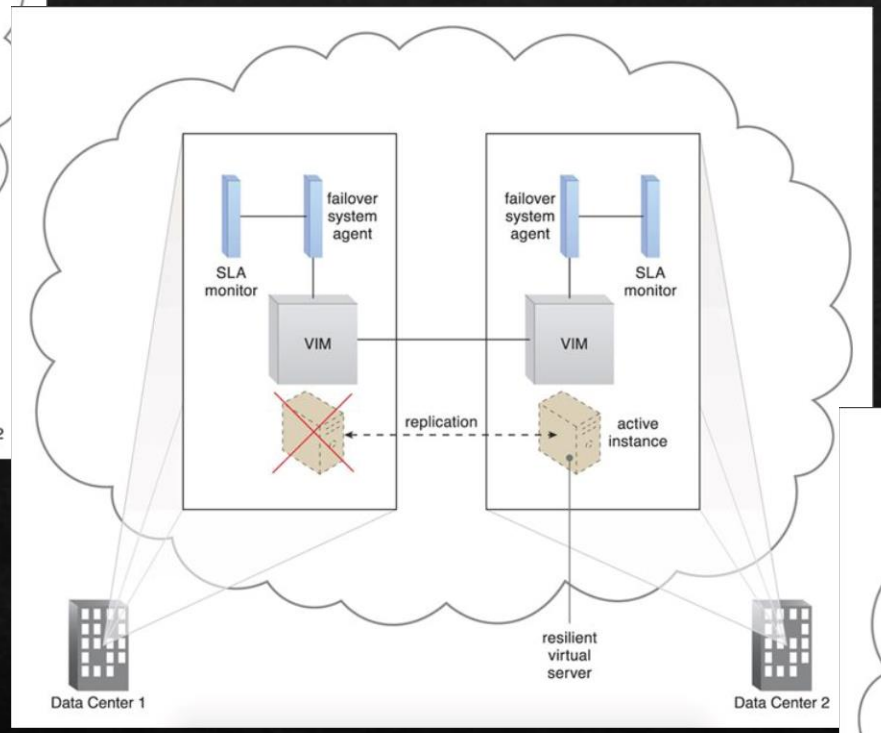

active
instance
router
Cloud
Service
A
Cloud
Service
A
standby
instance
failover
system

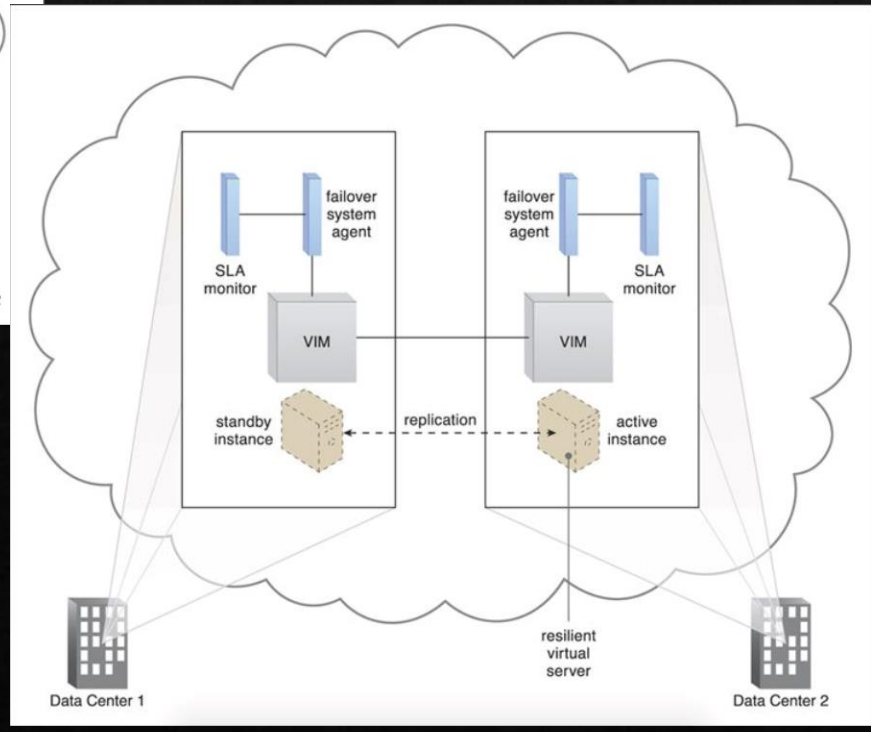
Case Study (DTGOV)

- DTGOV creates a resilient virtual server to support the allocation of virtual server instances that are hosting critical applications
  - which are being replicated in multiple data centers.
- The replicated resilient virtual server has an associated active-passive failover system.
- Its network traffic flow can be switched between the IT resource instances that are residing at different data centers, if the active instance were to fail.


failover system agent
SLA monitor
VIM
active instance
replication
failover system agent
SLA monitor
VIM
standby instance
resilient virtual server
Data Center 1
Data Center 2

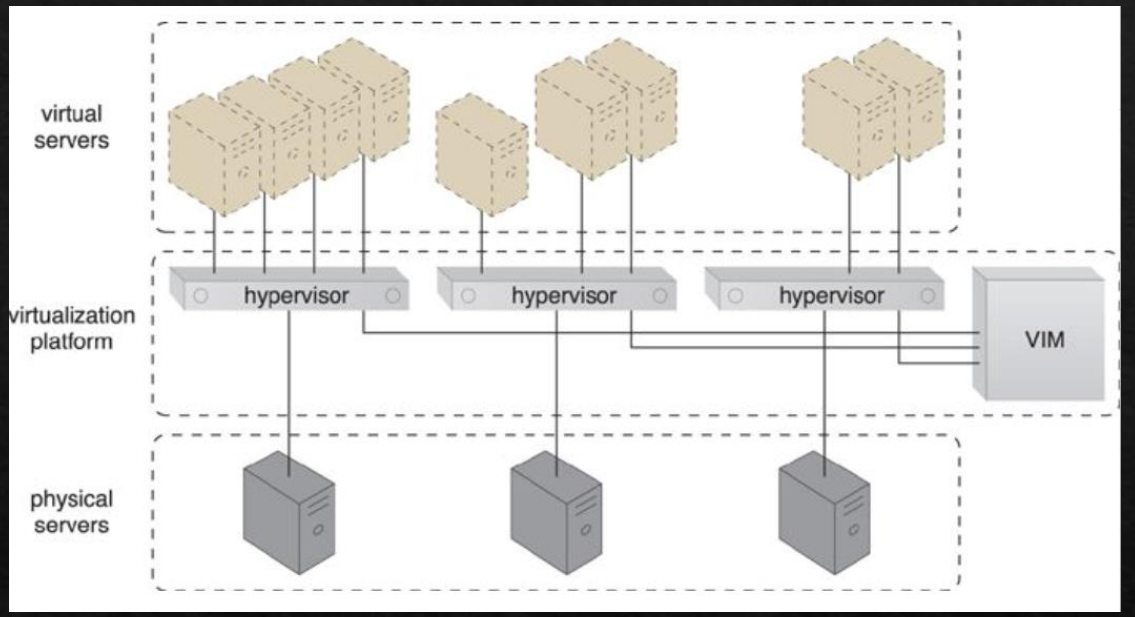

failover system agent
SLA monitor
VIM
failover system agent
SLA monitor
VIM
active instance
replication
standby instance
resilient virtual server
Data Center 1
Data Center 2


failover system agent
SLA monitor
VIM
failover system agent
SLA monitor
VIM
replication
active instance
resilient virtual server
Data Center 1
Data Center 2


failover system agent
SLA monitor
VIM
failover system agent
SLA monitor
VIM
standby instance
replication
active instance
resilient virtual server
Data Center 1
Data Center 2

Hypervisor

- A fundamental part of virtualization infrastructure that is primarily used to generate virtual server instances of a physical server.
- A hypervisor is generally limited to one physical server and can therefore only create virtual images of that server.
- A hypervisor has limited virtual server management features, such as increasing the virtual server's capacity or shutting it down.
- The VIM provides a range of features for administering multiple hypervisors across physical servers.

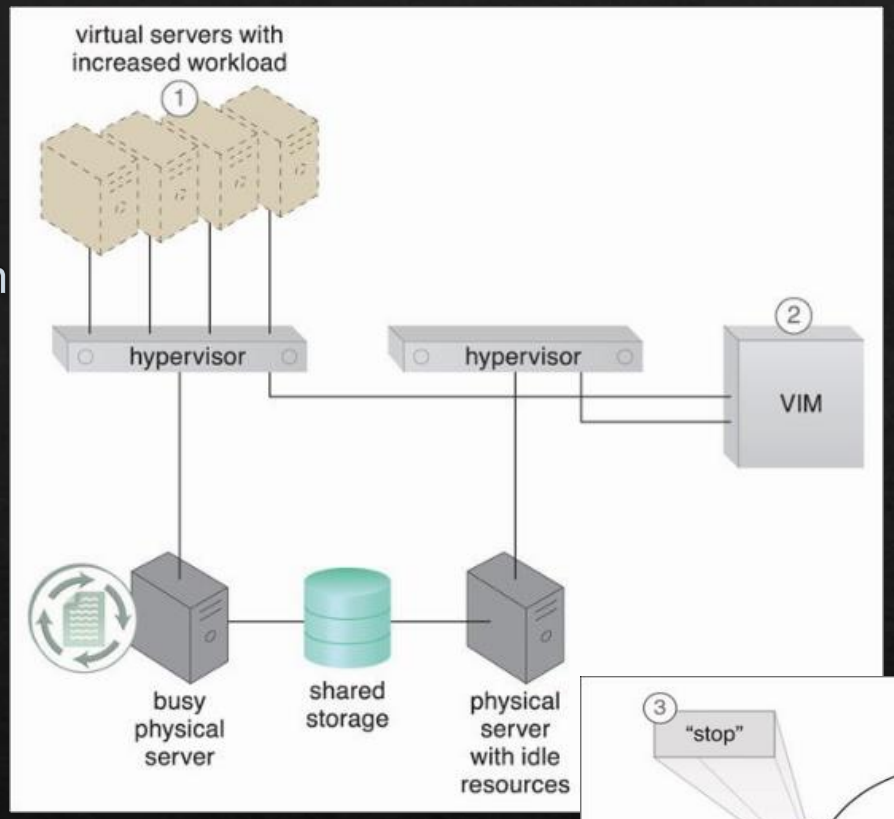


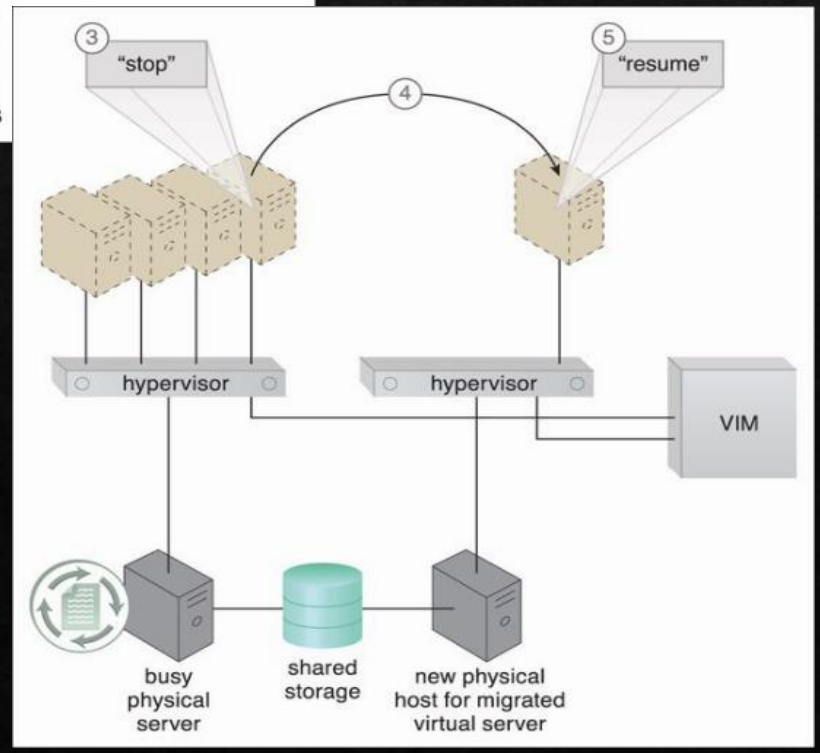
Hypervisor (2)

- Hypervisor software can be installed directly in bare-metal servers and provides features for
  - controlling,
  - sharing and
  - scheduling the usage of hardware resources.

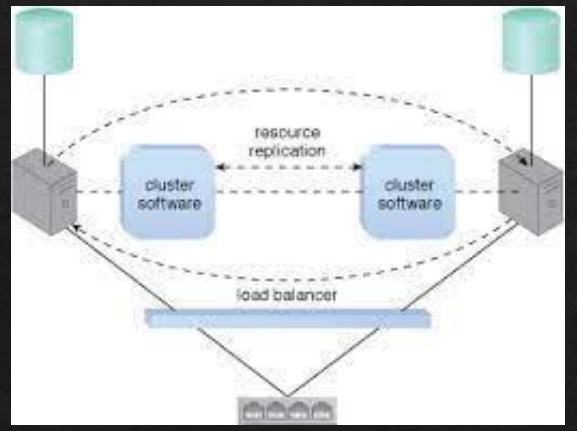
Case Study (DTGOV)

- DTGOV has established a virtualization platform in which the same hypervisor software product is running on all physical servers.
- The VIM coordinates the hardware resources in each data center so that virtual server instances can be created from the most expedient underlying physical server.
- As a result, cloud consumers are able to lease virtual servers with auto-scaling features.
- In order to offer flexible configurations, the DTGOV virtualization platform provides live VM migration of virtual servers among physical servers inside the same data center.





Resource Cluster



- Cloud-based IT resources that are geographically diverse can be logically combined into groups to improve their allocation and use.
- The resource cluster mechanism is used to group multiple IT resource instances so that they can be operated as a single IT resource.
- This increases the combined computing capacity, load balancing, and availability of the clustered IT resources.

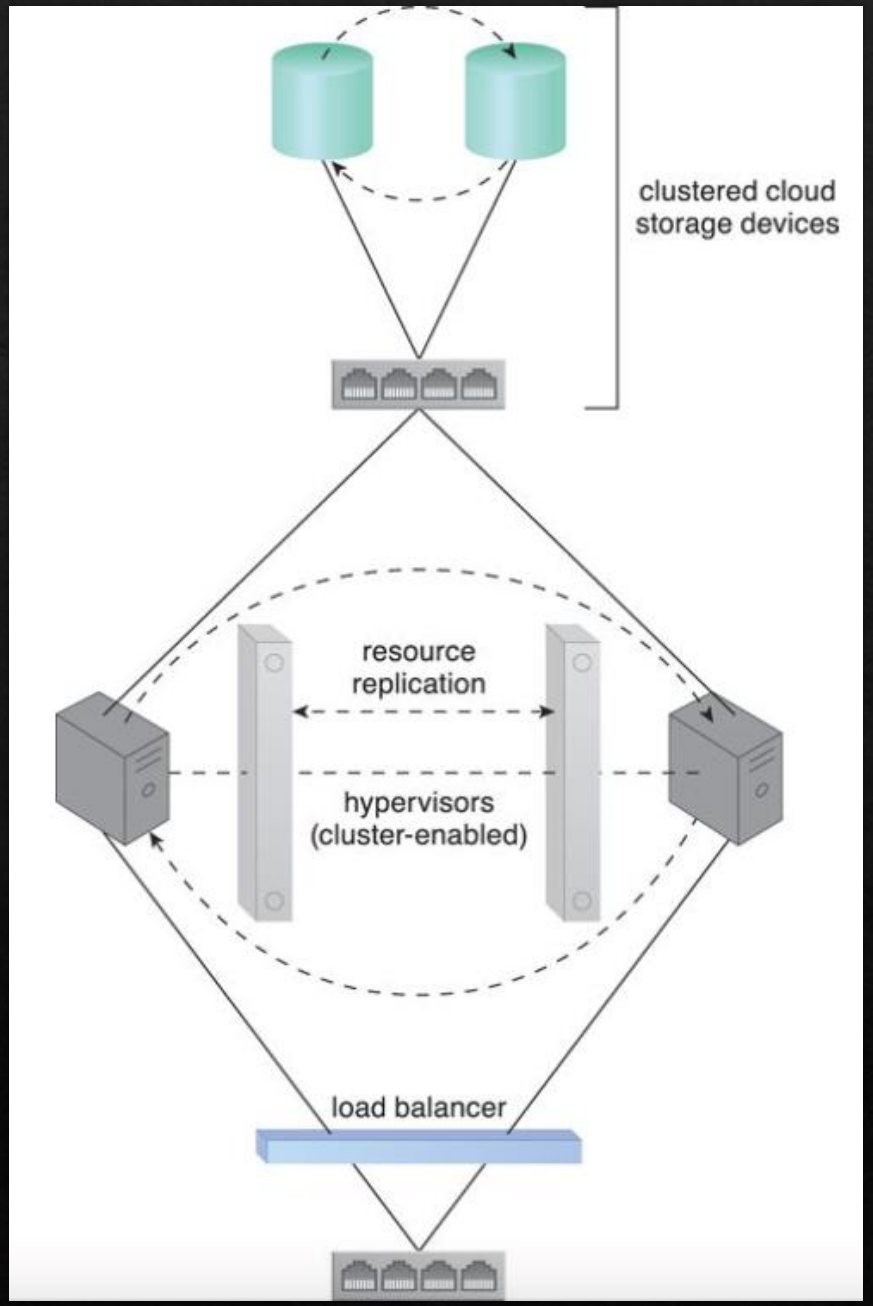
Resource Cluster (2)

- Resource cluster architectures rely on high-speed dedicated network connections, or cluster nodes, between IT resource instances to communicate about
  - workload distribution,
  - task scheduling,
  - data sharing, and
  - system synchronization.
- A cluster management platform that is running as distributed middleware in all of the cluster nodes is usually responsible for these activities.

Common Resource Cluster Types

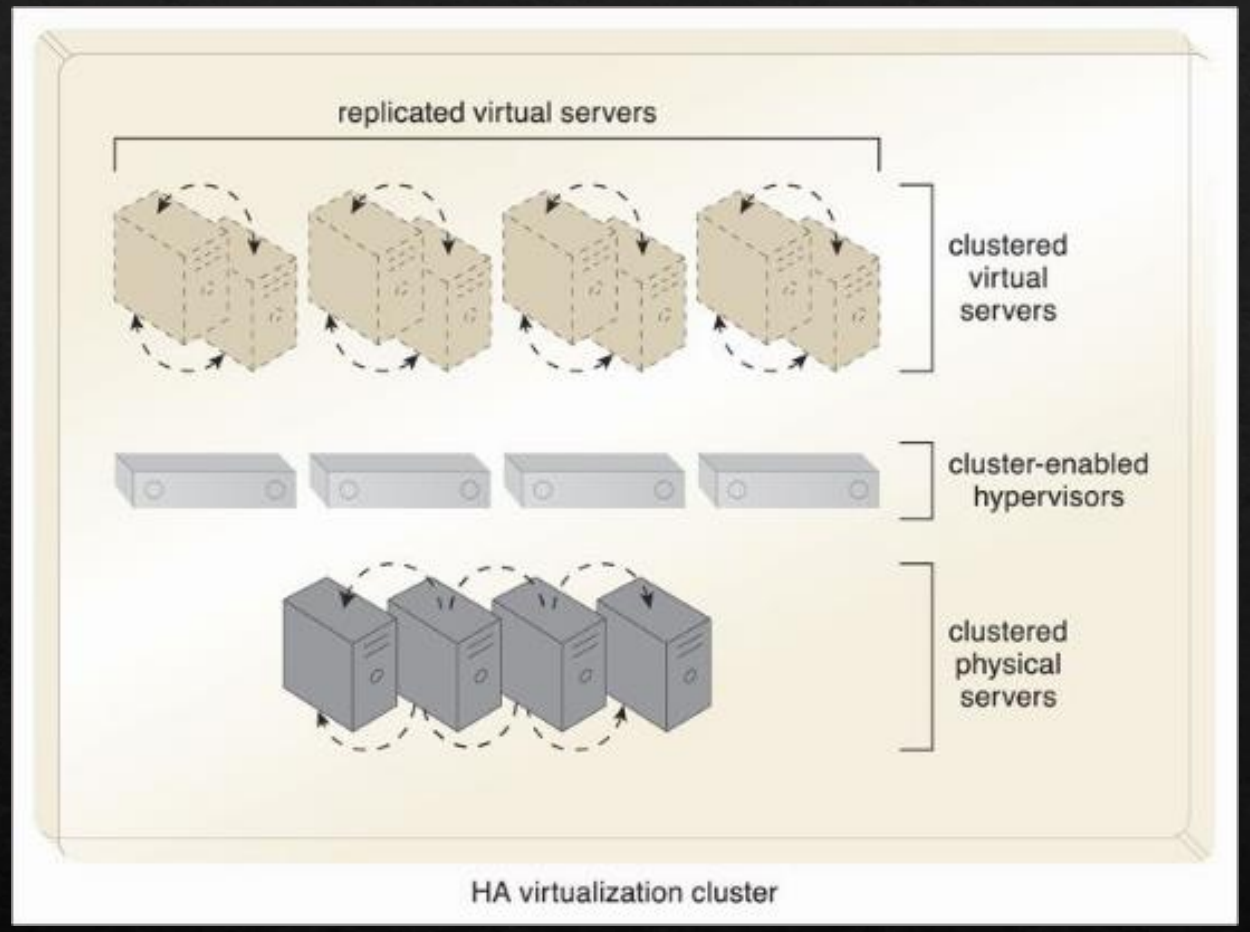
- Server Cluster – physical and virtual servers clustered to increase performance. Servers are able to live migrate from one to another.
- Database Cluster – designed to improve data availability.
- Large Dataset Cluster - data partitioning and distribution is implemented so that the target datasets can be efficiently partitioned without compromising data integrity or computing accuracy.

Load balancing and resource replication are implemented through a cluster-enabled hypervisor

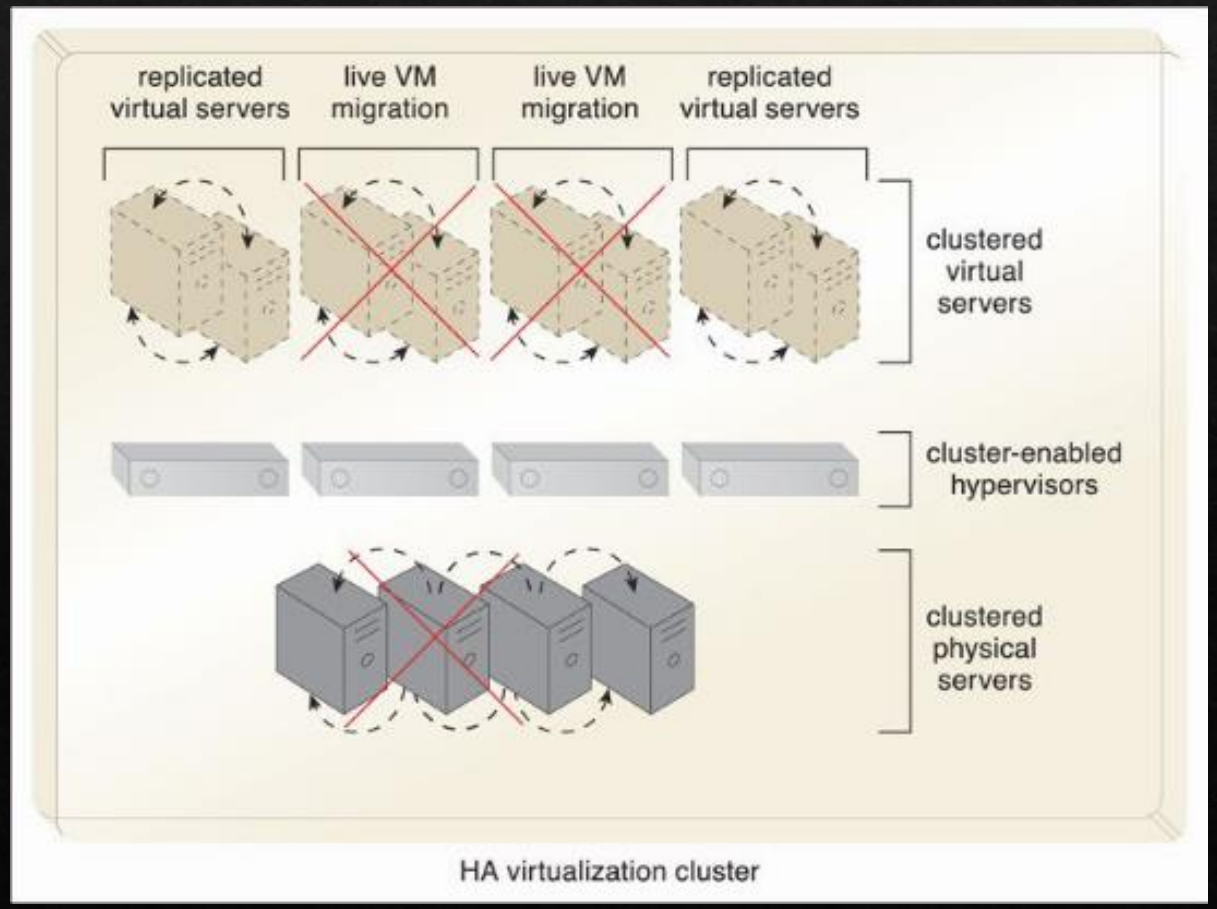


Two Basic Types of Resource Cluster

- **Load Balanced Cluster** – This resource cluster specializes in distributing workloads among cluster nodes to increase IT resource capacity while preserving the centralization of IT resource management.
- **HA Cluster** – A high-availability cluster maintains system availability in the event of multiple node failures, and has redundant implementations of most or all of the clustered IT resources. It implements a failover system mechanism that monitors failure conditions and automatically redirects the workload away from any failed nodes.



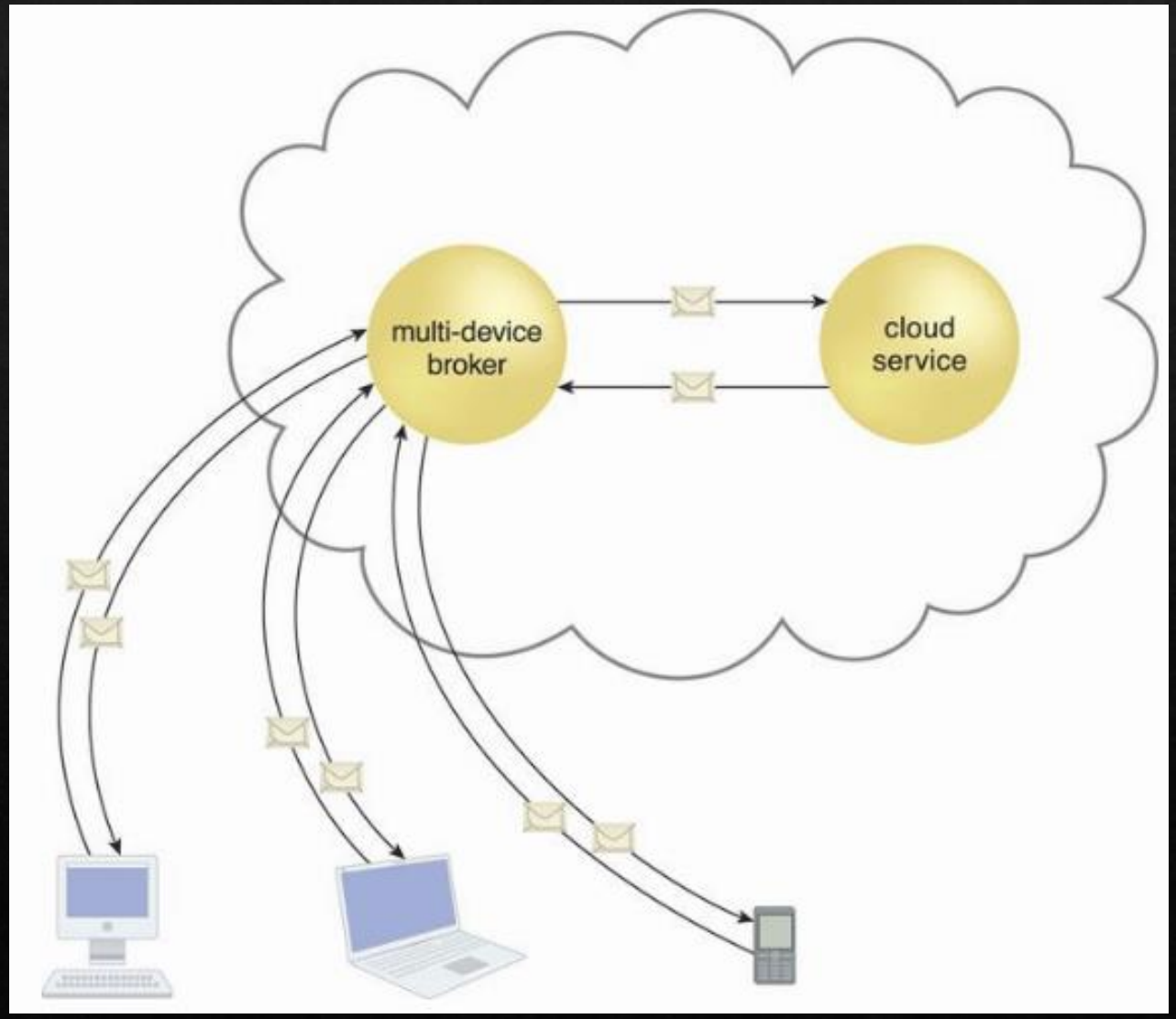
HA virtualization cluster



HA virtualization cluster

Multi-device Broker

- The multi-device broker mechanism is used to facilitate runtime data transformation so as to make a cloud service accessible to a wider range of cloud service consumer programs and devices.



- Multi-device brokers commonly exist as gateways or incorporate gateway components, such as:
  - XML Gateway – transmits and validates XML data
  - Cloud Storage Gateway – transforms cloud storage protocols and encodes storage devices to facilitate data transfer and storage
  - Mobile Device Gateway – transforms the communication protocols used by mobile devices into protocols that are compatible with a cloud service
- The levels at which transformation logic can be created include:
  - transport protocols
  - messaging protocols
  - storage device protocols
  - data schemas/data models

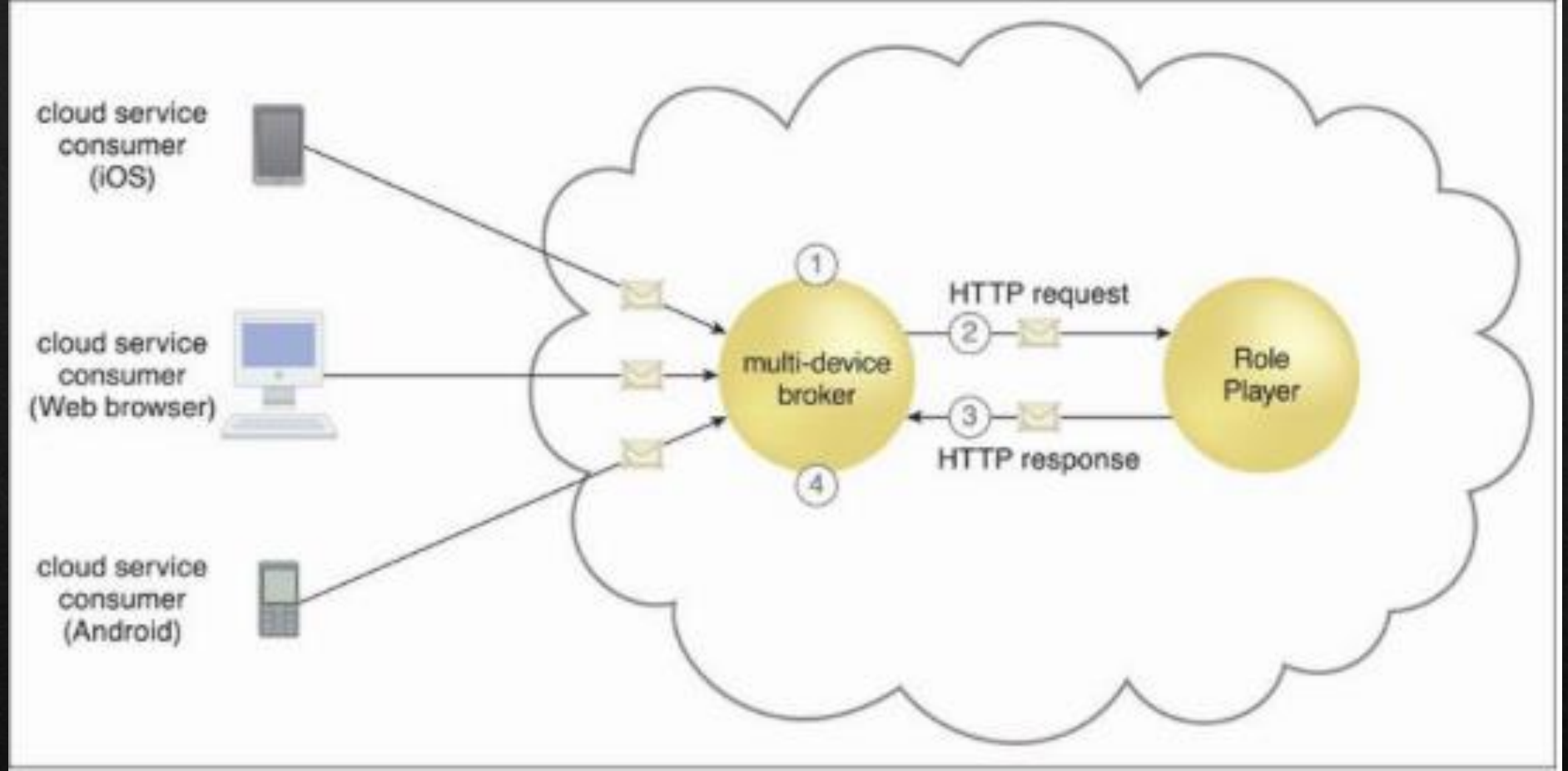
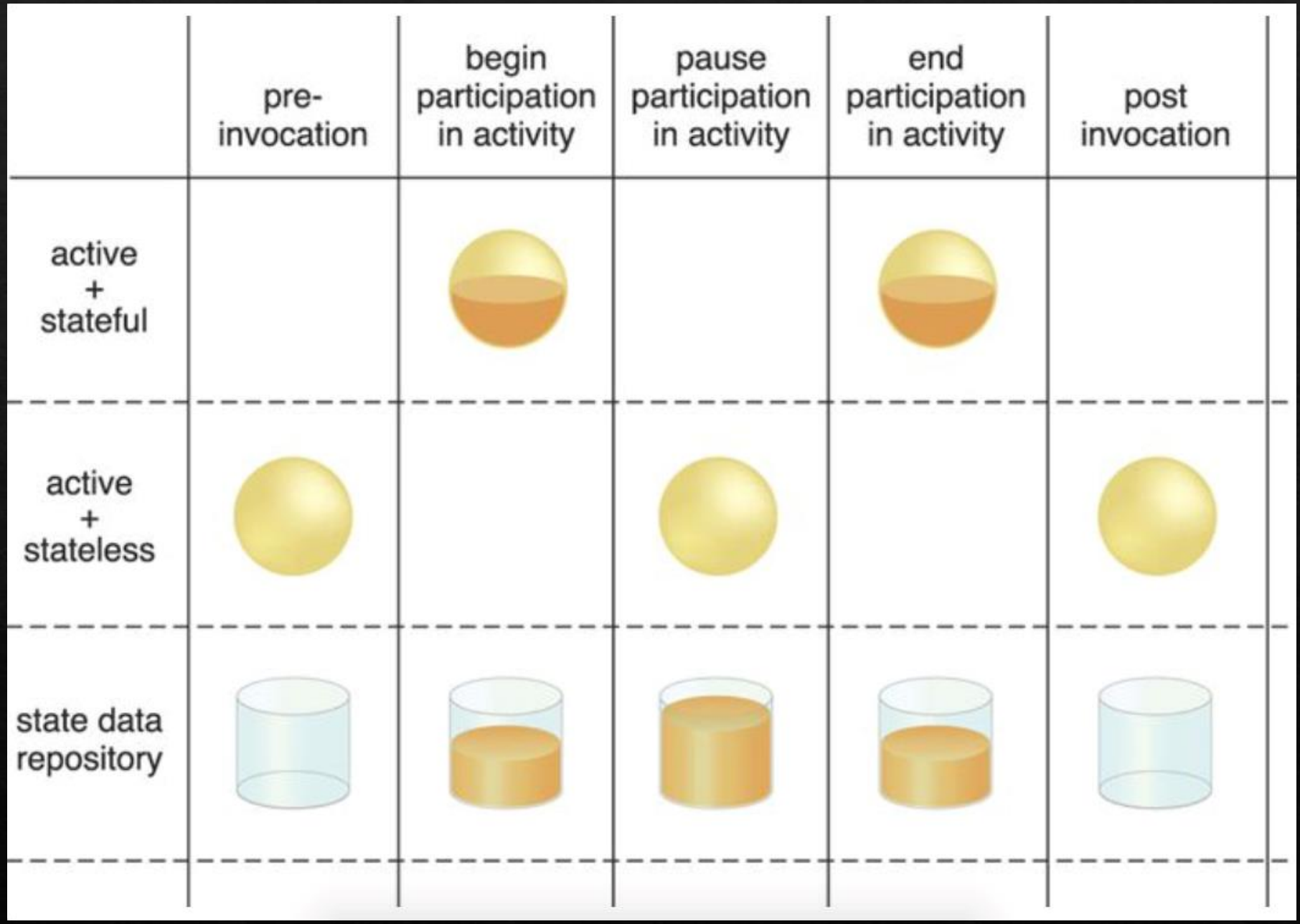
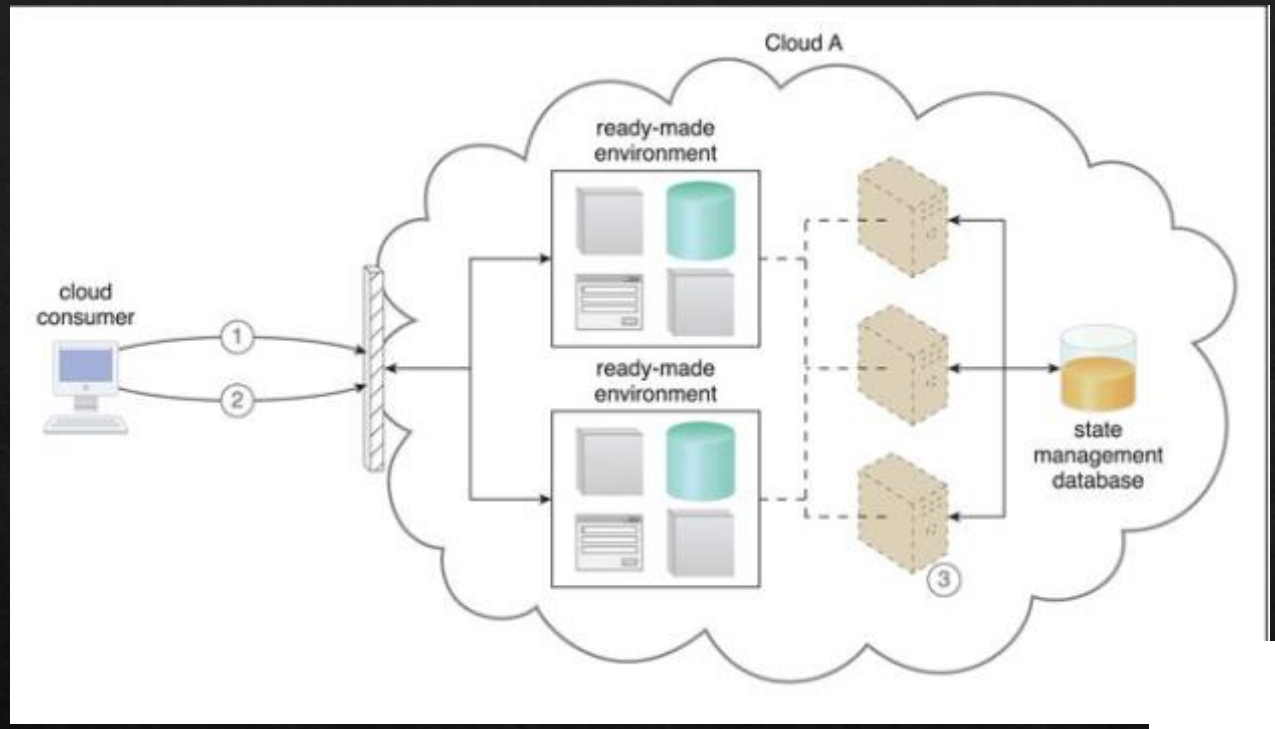


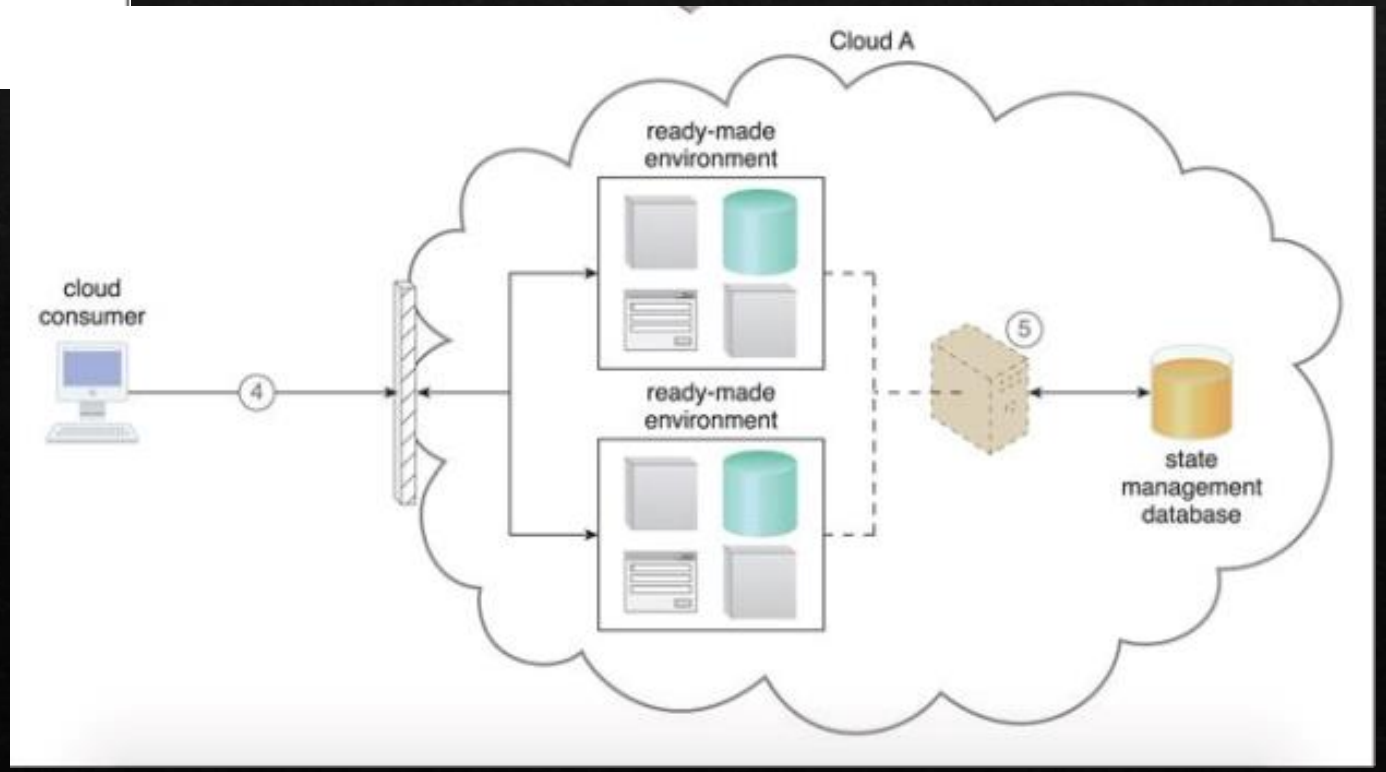
Figure 8.36. The multi-device broker intercepts incoming messages and detects the platform (Web browser, iOS, Android) of the source device (1). The multi-device broker transforms the message into the standard format required by the Innovartus cloud service (2). The cloud service processes the request and responds using the same standard format (3). The multi-device broker transforms the response message into the format required by the source device and delivers the message (4).

State Management Database

- A state management database is a storage device that is used to temporarily persist state data for software programs.
- As an alternative to caching state data in memory, software programs can off-load state data to the database in order to reduce the amount of runtime memory they consume
- By doing so, the software programs and the surrounding infrastructure are more scalable.
- State management databases are commonly used by cloud services, especially those involved in long-running runtime activities.


pre-
invocation
begin
participation
in activity
pause
participation
in activity
end
participation
in activity
post
invocation
active
+
stateful
active
+
stateless
state data
repository


Cloud A
ready-made environment
ready-made environment
cloud consumer
1
2
3
state management database


Cloud A
ready-made environment
ready-made environment
cloud consumer
4
5
state management database