ECE590-03
Enterprise Storage Architecture

Fall 2016

.~* CLOUD *~.

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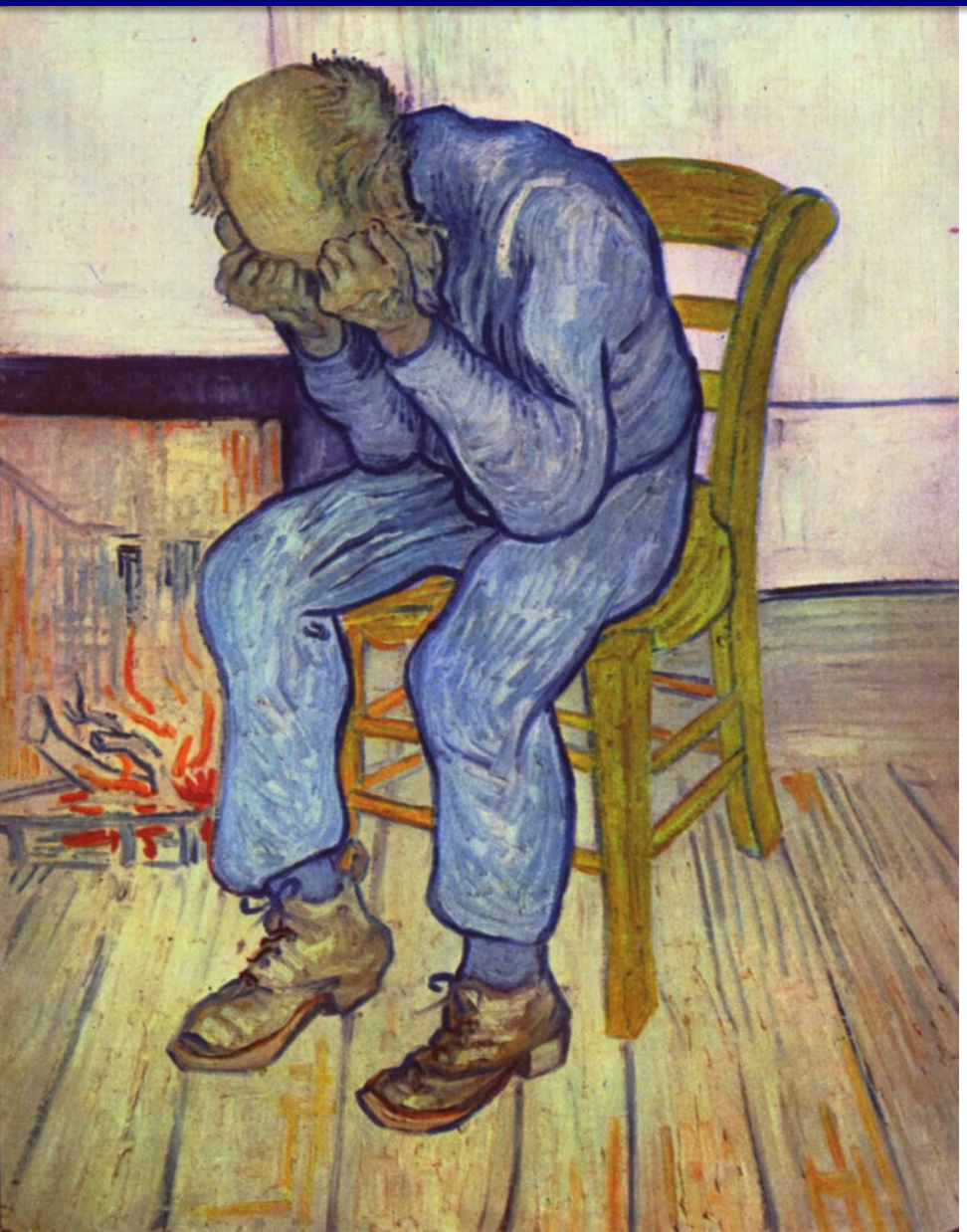
Includes material adapted from the course "Information Storage and Management v2" (module 13), published by EMC corporation.

Meta-notes

Notes I've added to the EMC stuff will appear in boxes like this one.

CLOUD



- What is it?
  - Most overused and abused buzzword of the 21st century.

Cloud

- What is it?
  - It's when you borrow a computer over a network.
  - That's all.

- Lots of ways to "borrow".
- Lots of kinds of "computer".
- Lots of kinds of "network".

- Marking nonsense was so bad the National Institute of Standards and Technology (NIST) produced a definition which most people go by now

Why do cloud stuff?

- So you don't have to buy the stuff.
  - Save time and up-front costs.
- So you don't have to maintain the stuff.
  - Avoid recurring effort and unpredictable expenses (or rather, pay to make them someone else's problem)
- So you can rent more stuff only when you need to.
  - The "Christmas season" effect – only rent servers to handle 100M hits/day when you actually might get 100M hits in a day.

Drivers for Cloud Computing

- Business requirements
  - Transformation of IT processes to achieve more with less
  - Better agility and higher availability at reduced expenditure
  - Reduced time-to-market
  - Accelerated pace of innovation
- IT challenges to meet business requirements are:
  - Serving customers worldwide round the clock, refreshing technology quickly, faster provisioning of IT resources – all at reduced cost
- These challenges are addressed with the emergence of cloud computing

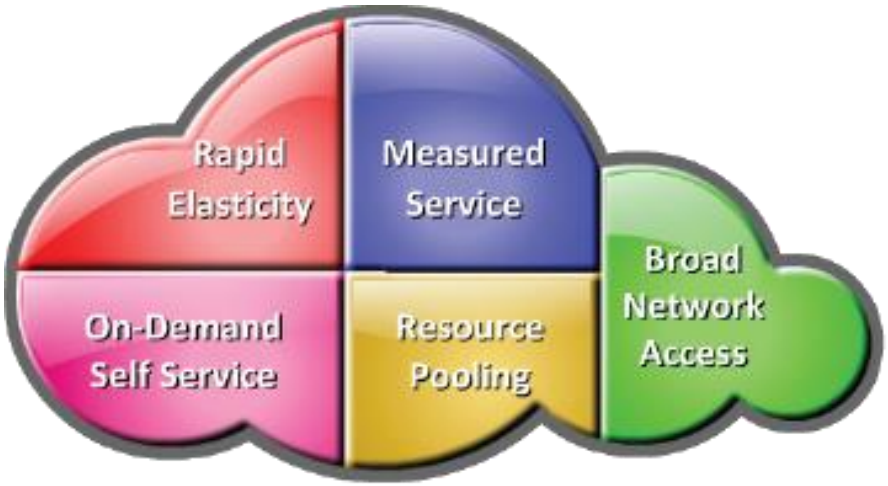
What is Cloud Computing?

Cloud Computing

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

– NIST

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



On-demand Self-service

- Enables consumers to unilaterally provision computing capabilities (examples: server time and storage capacity) as needed automatically
- Consumers view service catalogue via a Web-based user interface and use it to request for a service

Translation:

Press button → Receive resource

Broad Network Access

- Computing capabilities are available over the network
- Computing capabilities are accessed from a broad range of client platforms such as:
  - Desktop computer
  - Laptop
  - Tablet
  - Mobile device

Translation:

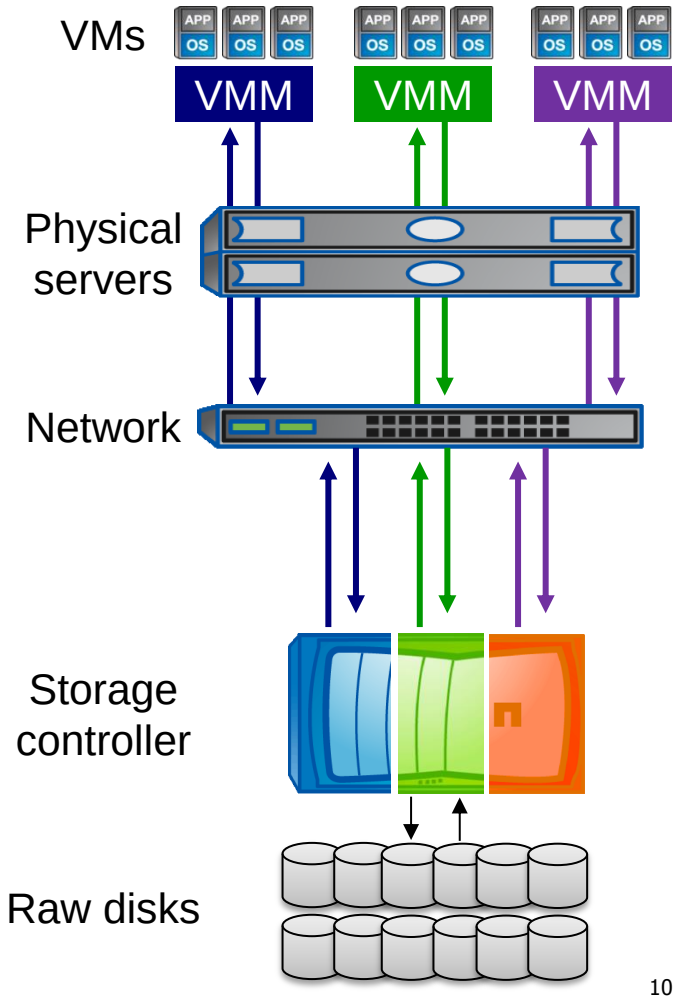
Leasing a physical server doesn't count.

Resource Pooling

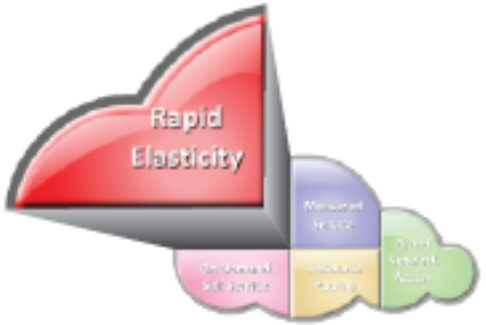
- Provider's computing resources are pooled to serve multiple consumers using a multitenant model
- Resources are assigned from the pool according to consumer demand
- Consumers have no control or knowledge over the exact location of the provided resources

“Resource pooling”?

- What are some architectures/technologies that pool resources?
  - RAID array and LVM pools raw disks
  - NAS/SAN in general pools storage
  - Server virtualization pools compute
  - End-to-end virtual environment pools them all at once!



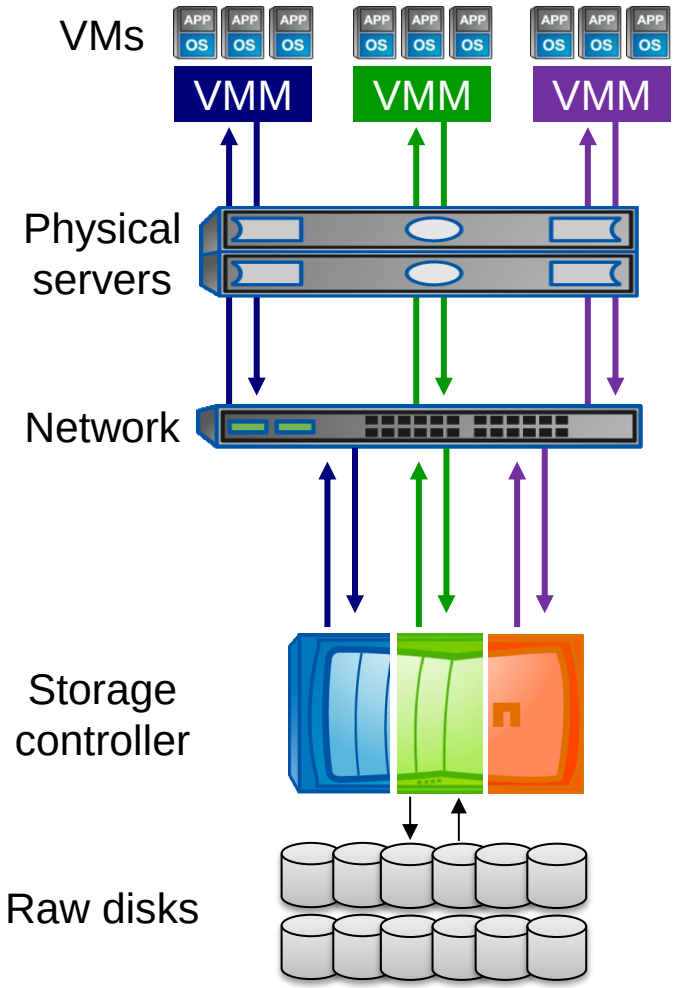
Rapid Elasticity



- Computing capabilities can be elastically provisioned and released
- Computing capabilities are scaled rapidly, commensurate with consumer's demand
  - Provides a sense of unlimited scalability

Rapid elasticity

- How can we scale each layer of this stack?



Measured Service

- Cloud computing provides a metering system that continuously monitors resource consumption and generates reports
  - Helps to control and optimize resource use
  - Helps to generate billing and chargeback reports

Translation:

We watch what you use and, if this is a pay-for-use cloud, charge you for it.

Benefits of Cloud Computing

Benefits	Description
Reduced IT cost	• Reduces the up-front capital expenditure (CAPEX)
Business agility	• Provides the ability to deploy new resources quickly • Enables businesses to reduce time-to-market
Flexible scaling	• 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
High availability	• Ensures resource availability at varying levels, depending on consumer's policy and priority

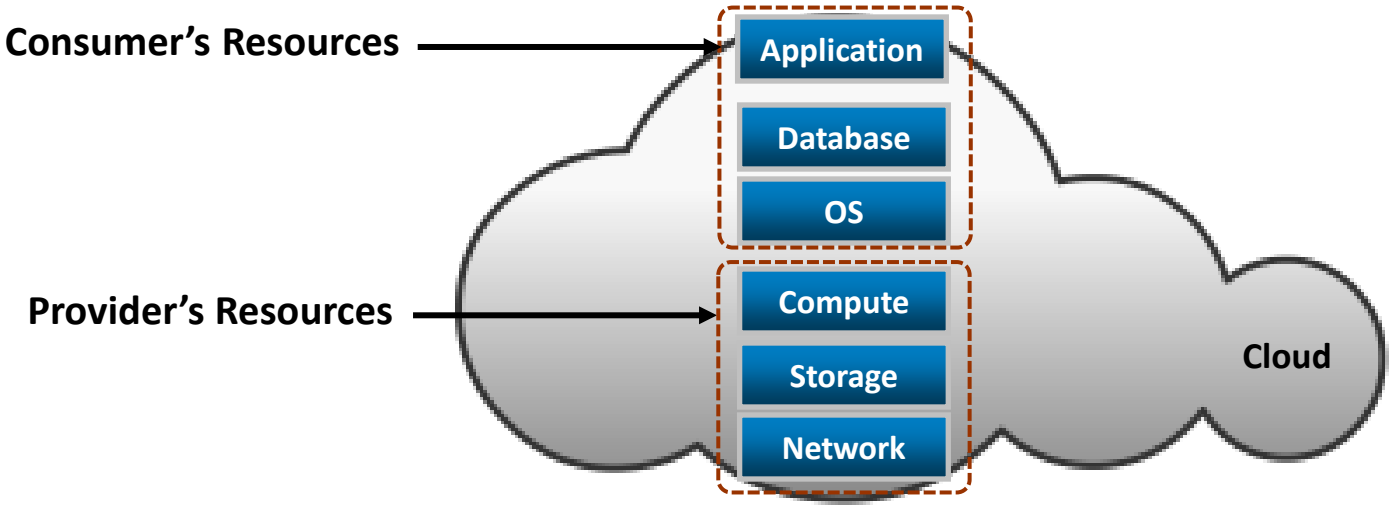
Cloud Service Models

- Infrastructure-as-a-Service (IaaS)
- Platform-as-a-Service (PaaS)
- Software-as-a-Service (SaaS)

- Storage-as-a-Service (StaaS)
- Tons of other stuff -as-a-Service (XaaS)

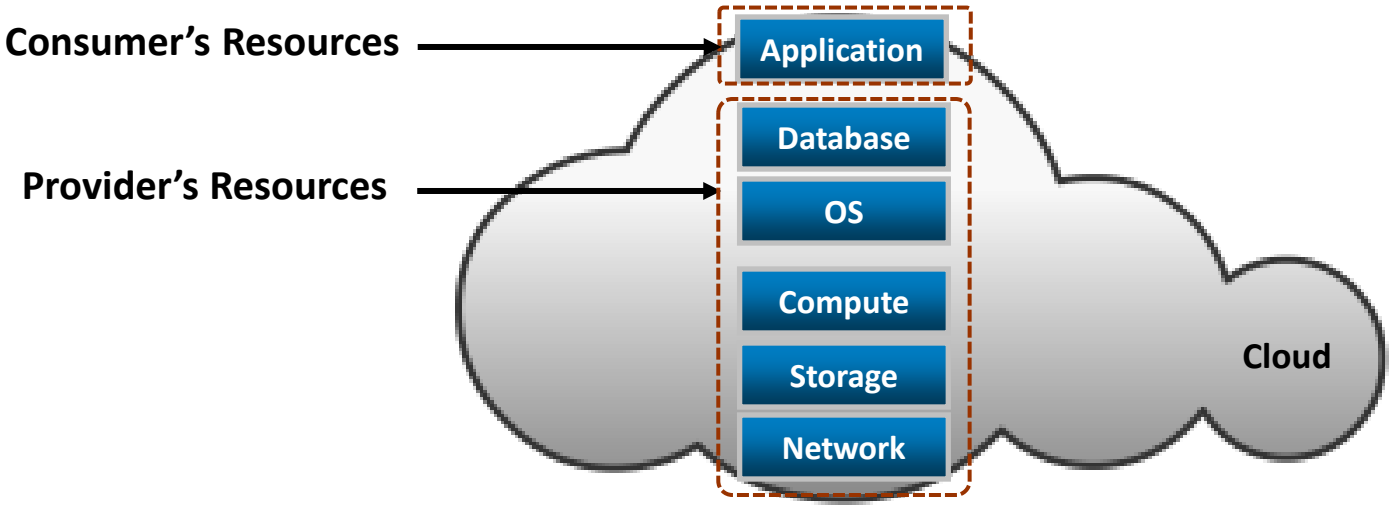
Infrastructure-as-a-Service

- Consumers deploy their software, including OS and application on provider's infrastructure
  - Computing resources such as processing power, memory, storage, and networking components are offered as service
  - Example: Amazon Elastic Compute Cloud
- Consumers have control over the OSs and deployed applications



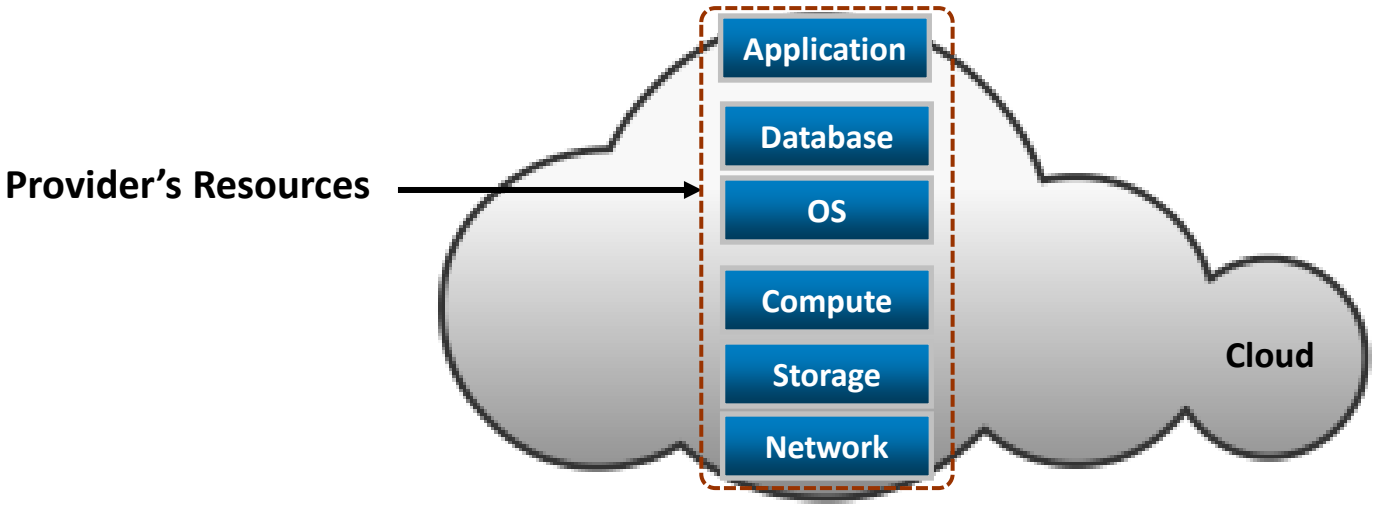
Platform-as-a-Service

- Consumers deploy consumer-created or acquired applications onto provider's computing platform
  - Computing platform is offered as a service
  - Example: Google App Engine and Microsoft Windows Azure Platform
- Consumer has control over deployed applications



Software-as-a-Service

- Consumers use provider's applications running on the cloud infrastructure
  - Applications are offered as a service
  - Examples: EMC Mozy and Salesforce.com
- Service providers exclusively manage computing infrastructure and software to support services



Storage as a Service

- Several delivery models:

- "Comes with storage" model: the storage you get is the virtual disk attached to your VM (cheap)
- NAS-type: Can request file-oriented space.
  - Example: Amazon Elastic File System (which is just NFS for money)
- SAN-type: Can request block-oriented space.
  - Example: Amazon Elastic Block System (attaches to VM as virtual disk)
  - Example: Traditional SAN LUNs
- Object storage: A simplified storage interface
  - Example: Amazon S3
  - Need to zoom in...

Object storage

- Insight: if we drop traditional POSIX file interface (open/close/seek/read/write), can make a cheaper/faster/simpler file system

- Simpler verbs: GET and PUT
  - GET: Read the whole thing
  - PUT: Write the whole thing
- Intentionally omitted verbs: SEEK, MODIFY, etc.

- Example: Amazon S3
  - GET/PUT stuff to URLs
  - All storage details behind that hidden from user
  - Cloud provider can migrate/replicate data and redesign back end
  - No changes means no consistency issues!

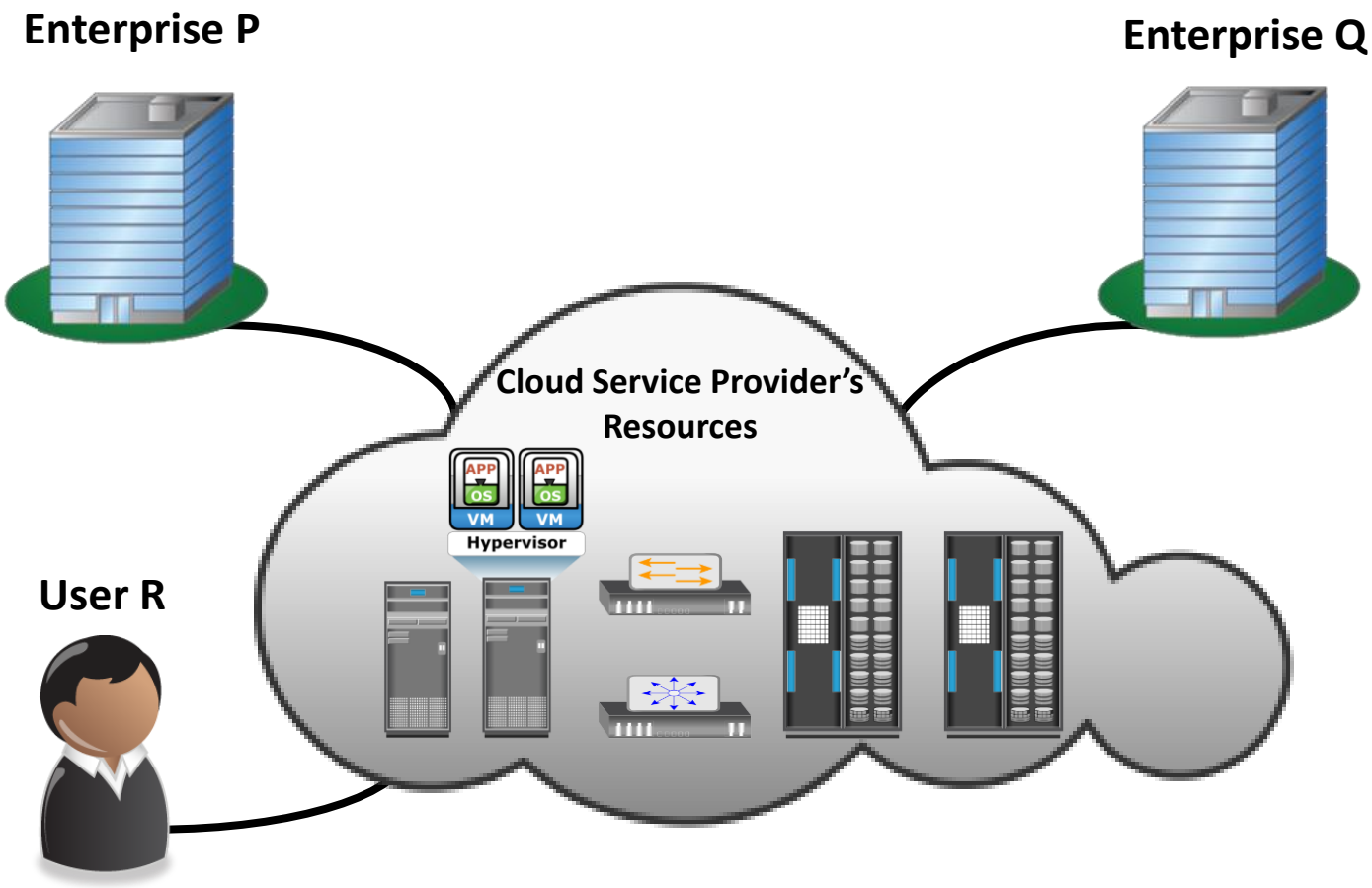
Cloud Deployment Models

- Public
- Private
- Community
- Hybrid

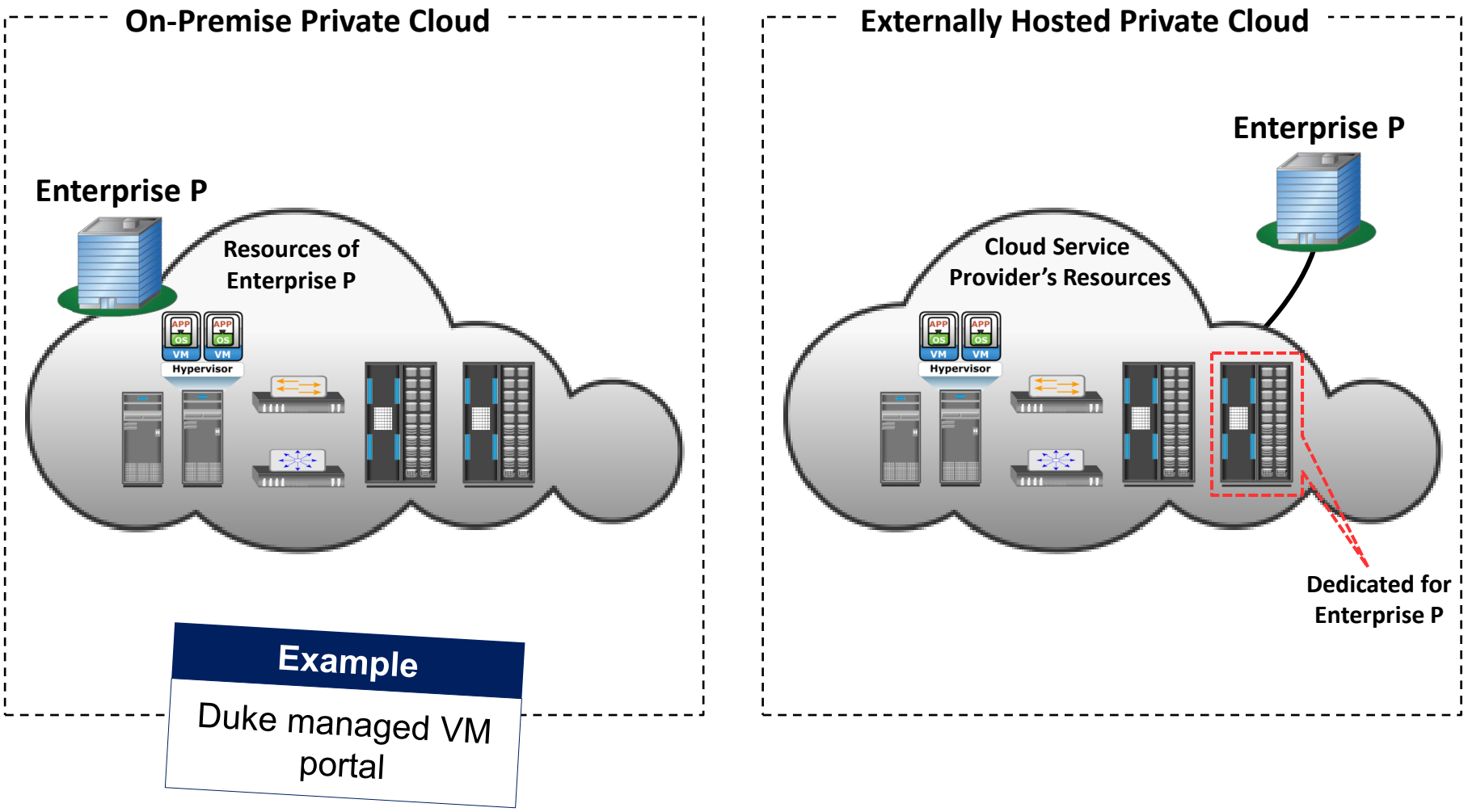
Public Cloud

Example

Amazon AWS, Microsoft Azure, etc.



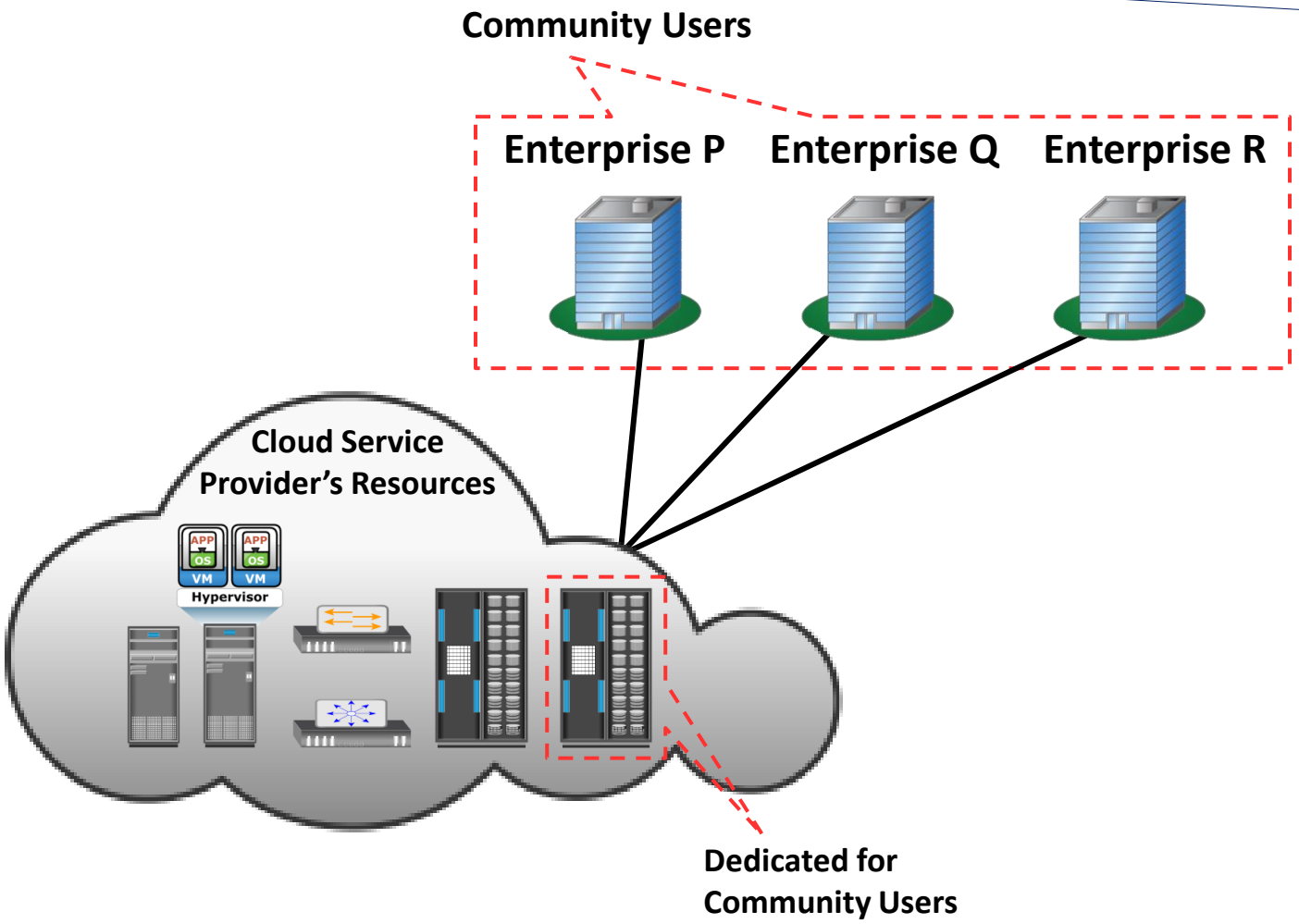
Private Cloud



Community Cloud

Example

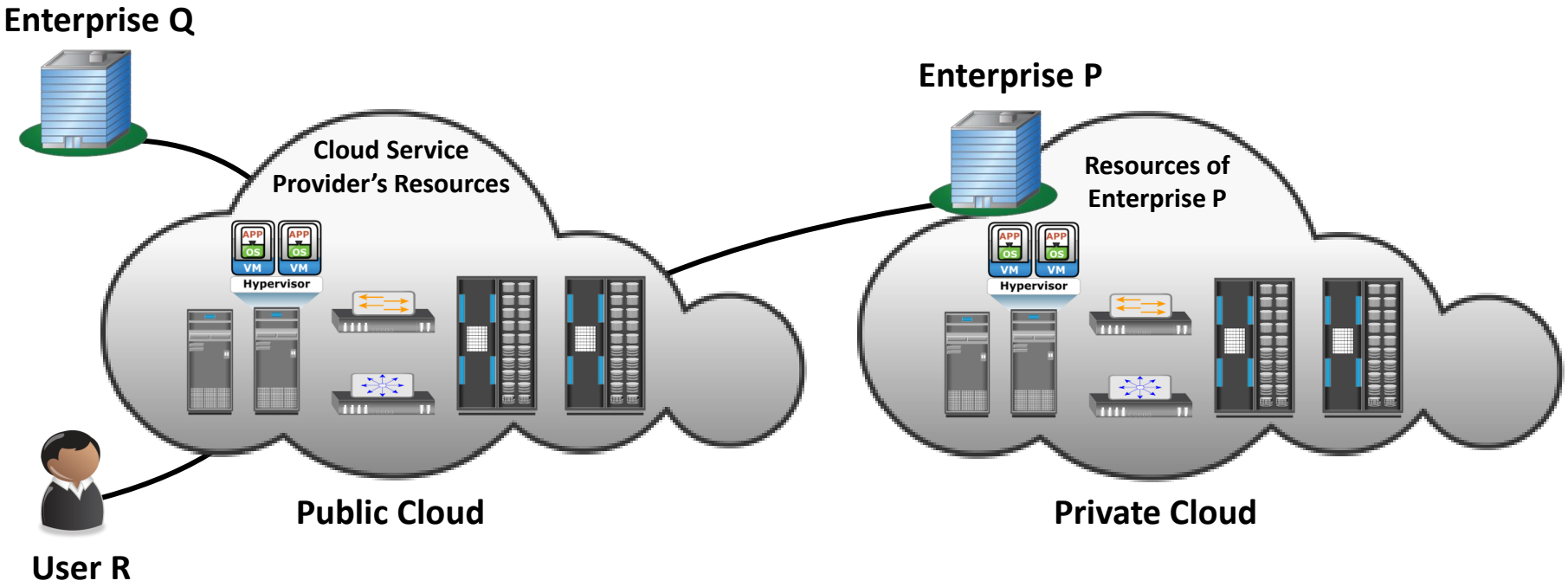
I was going to reference one of the academic shared compute clusters that were popular a while ago, but it seems like Amazon ate all of them.



Hybrid Cloud

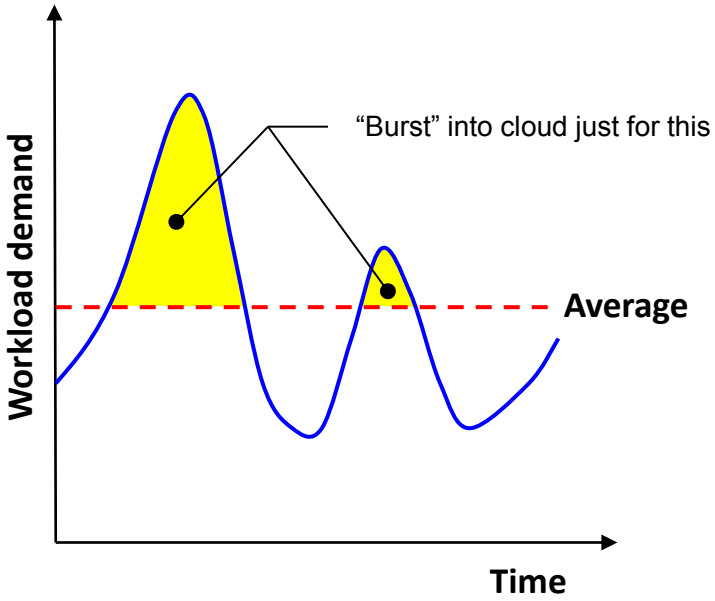
Example

Amazon Direct Connect to a hosted data center (e.g. Equinix)



Hybrid example with “bursting”

- Amazon has a program called Direct Connect
  - They have fast network lines at each Amazon AWS datacenter to nearby **colocation facilities**
    - **Colocation**: When you lease space for your server in someone else’s datacenter. (Colocation by itself isn’t considered ‘cloud’.)
  - You put up resources needed for your average workload
  - Run exclusively on your own gear most of the time
  - When demand grows past capacity, rent cloud services
  - Can start immediately; data comes from YOUR storage, not theirs
    - No migration



Side benefit to direct-connect to cloud

- If your storage is directly connected to cloud,
  you still own your data, but can benefit from cloud's compute

- Important for regulations or concerns of liability/privacy
  - Financial/medical generally can't use any public cloud otherwise
  - Legal discovery: want to know if your data is being inspected/subpoenaed by authorities (or the NSA without a warrant)

Cloud Challenges – Consumer's Perspective

- Security and regulation
  - Consumers are indecisive to transfer control of sensitive data
  - Regulation may prevent organizations to use cloud services
- Network latency
  - Real time applications may suffer due to network latency and limited bandwidth
- Supportability
  - Service provider might not support proprietary environments
  - Incompatible hypervisors could impact VM migration
- Vendor lock-in
  - Restricts consumers from changing their cloud service providers
  - Lack of standardization across cloud-based platforms

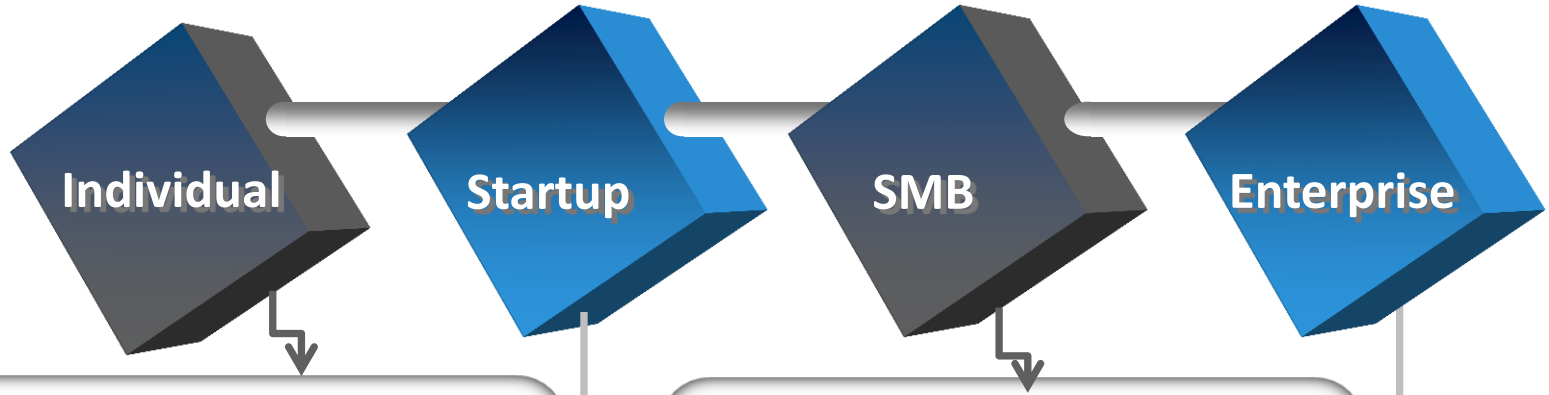
Cloud Challenges – Provider's Perspective

- Service warranty and service cost
  - Resources must be kept ready to meet unpredictable demand
  - Hefty penalty, if SLAs are not fulfilled
- Complexity in deploying vendor software in the cloud
  - Many vendors do not provide cloud-ready software licenses
  - Higher cost of cloud-ready software licenses
- No standard cloud access interface
  - Cloud consumers want open APIs
  - Need agreement among cloud providers for standardization

SLA = Service Level Agreement

Contract that says what you'll get (and the penalty the provider pays if you don't get it)

What Deployment Model Fits for You?



Public cloud

- Convenience outweighs risk
- Low cost or free
- Ex: Picasa, Google apps

Hybrid cloud

- Tier 1 apps: private cloud
- Tier 2-4 apps (backup, archive, testing): public cloud

Public cloud

- Convenience outweighs risk

Private cloud

- Tier 2-4: private cloud
- Tier 1: may continue to run in a traditional data center environment

Brief sideline: CAPEX and OPEX

- CAPEX = Capital Expenditure
  - Big investments
  - E.g., buying land, constructing buildings, ordering IT gear, etc.
- OPEX = Operating Expenditure
  - Money paid over time (financial obligations)
  - E.g., payroll, electricity, lease payments

- On **high-risk** projects, want ways to turn CAPEX into OPEX
  - "This project might not work, so I don't want to buy a rack of gear to support it; better to lease gear or use cloud."
- On **low-risk** projects, want to invest CAPEX to stop unending OPEX payments
  - "The project was a success, and we'll be running this app for at least 10 years, it makes sense to buy servers/storage for it and stop paying a premium to the cloud provider to host it."

QoS Considerations

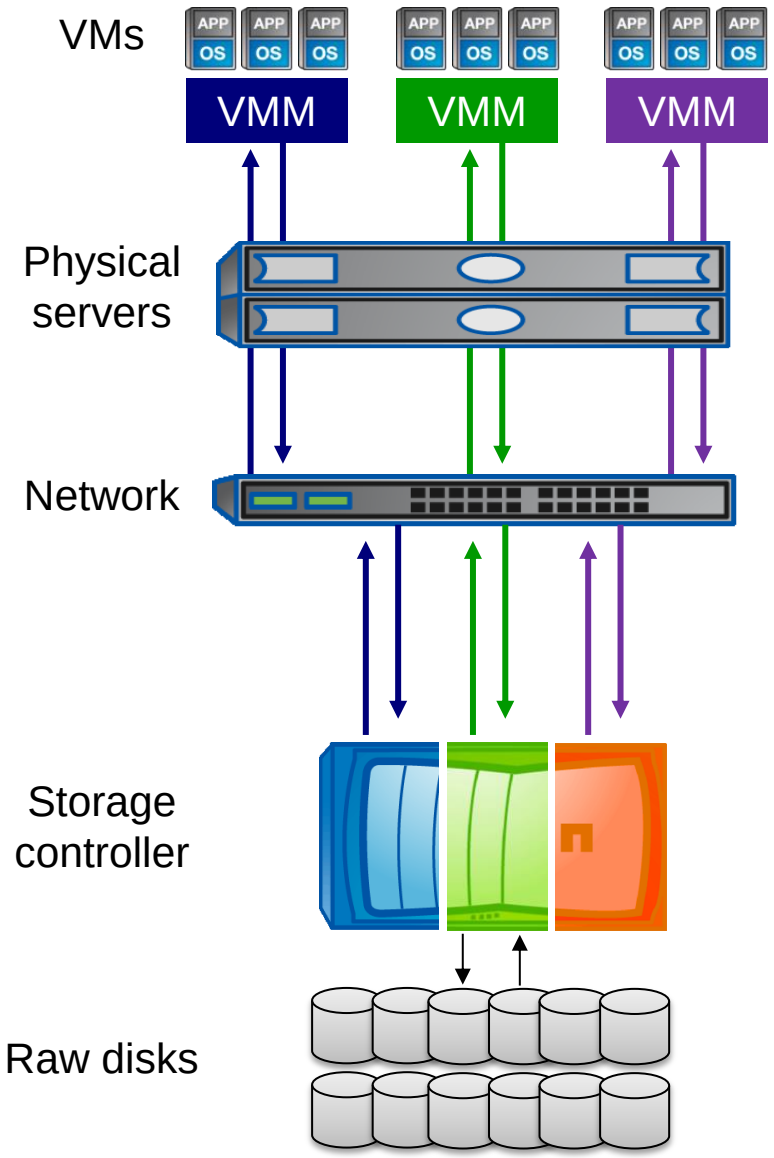
- Consumers should check whether the QoS attributes meet their requirements
- SLA is a contract between the cloud service provider and consumers that defines QoS attributes
  - Attributes examples: throughput, uptime, and so on

Quality of Service (QoS)

- As engineers, that previous slide is actually HUGE
- Want to set **performance guarantees and priorities**

- For CPU, prioritization/minimums are easy:
  - "If X is higher priority than Y and both X and Y are ready to run, run X"
  - "If X hasn't gotten it's minimum CPU time and X is ready to run, run X"
- For storage, it's hard; open field of research
- Challenges to storage QoS:
  - Allocation of cache?
  - Lots of implied reads/writes; how to prioritize?
    - Backup/replication IO
    - Journaling effects
  - Multiple metrics (IOPS for random, throughput for sequential)
    - If we guarantee a certain number of IOPS for a process, that could be most of our disk performance if we're doing random IO, or very little if we're doing sequential IO.

Multi-tenant virtual environments



Virtualize into VMs

Aggregate servers into hypervisor cluster

Virtualize with VLAN segmentation

Aggregate links with trunking

Virtualize management domains
(e.g. NetApp “Storage Virtual Machines”)

Virtualize into volumes

Aggregate with RAID/LVM