ITCS443 Parallel and Distributed Systems

Cloud Computing and Virtualization

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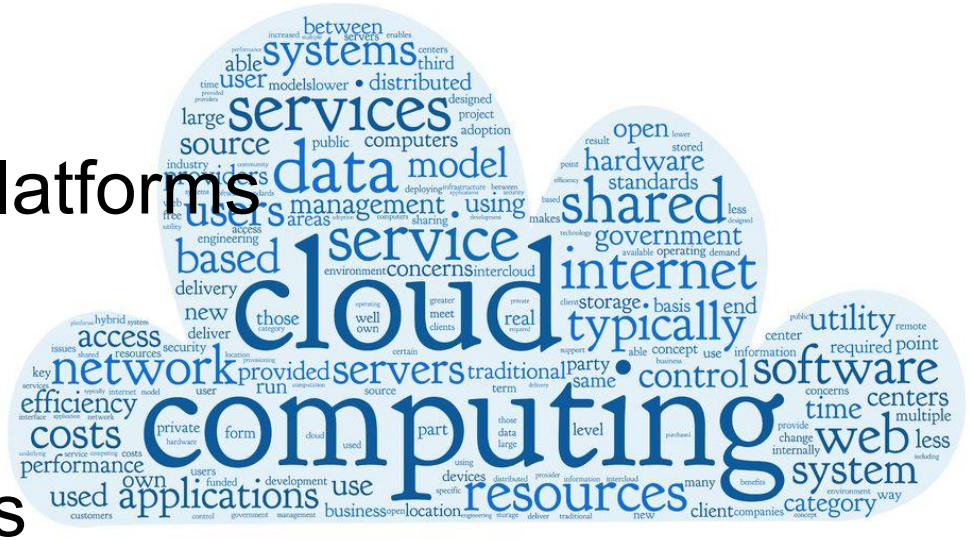
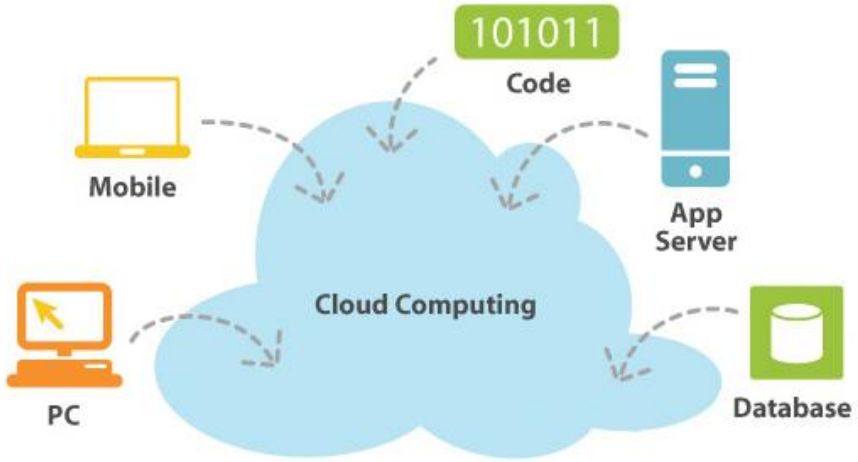
Semester 1/2019

Outline

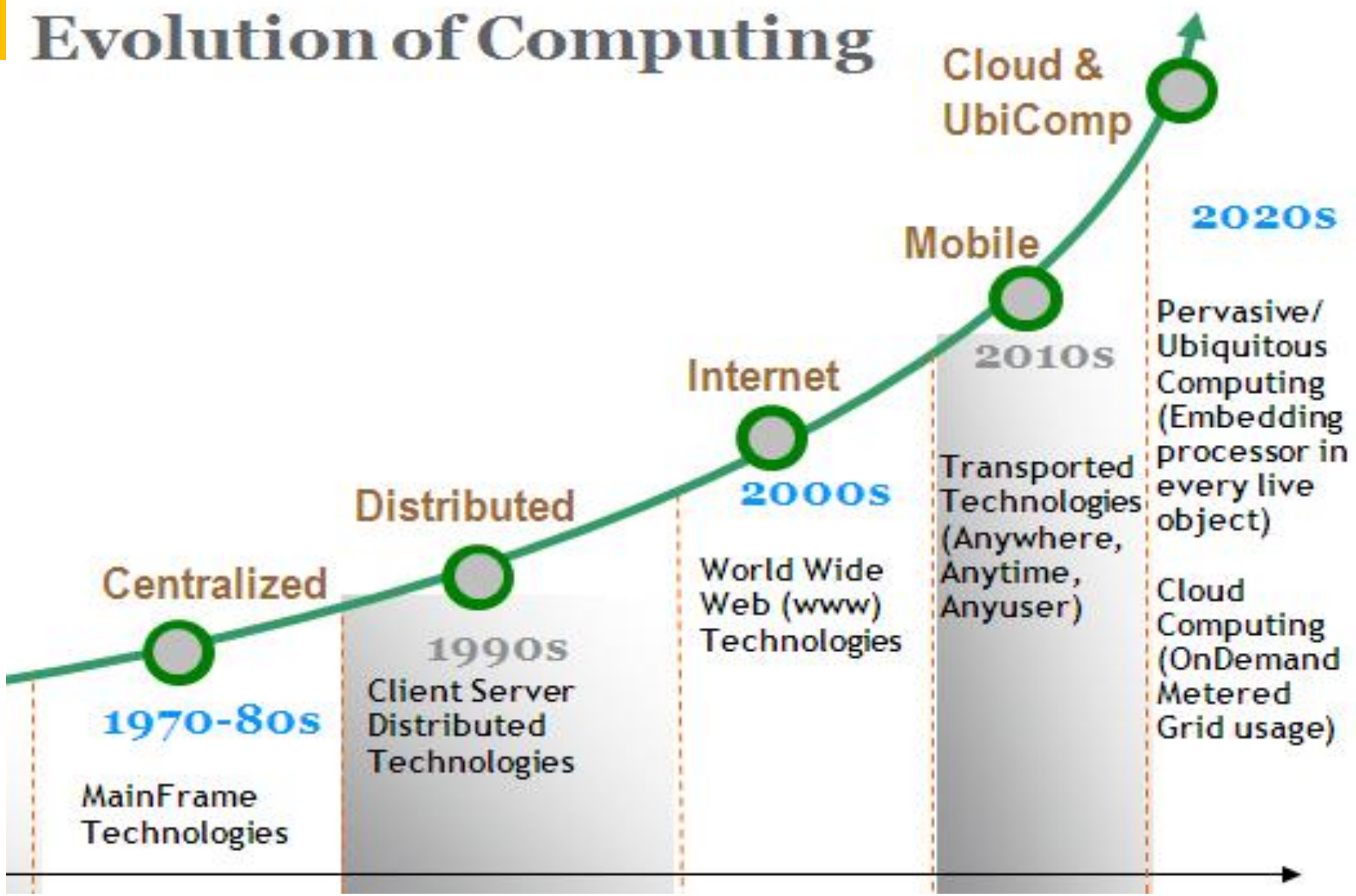
- Evolution of Computing Platforms
- NIST Cloud Framework
- Cloud Service Models
- Cloud Deployment Models
- Scaling
- Multitenant Technology
- Roles in Cloud
- Cloud Adoption Model
- Virtualization Concepts





Evolution of Computing Platforms

Evolution of Computing Platforms



Latest Evolution

Cloud Computing

Big Data

Machine Intelligence

Internet of Things

Mobile Computing

Social Networks

Internet of Things

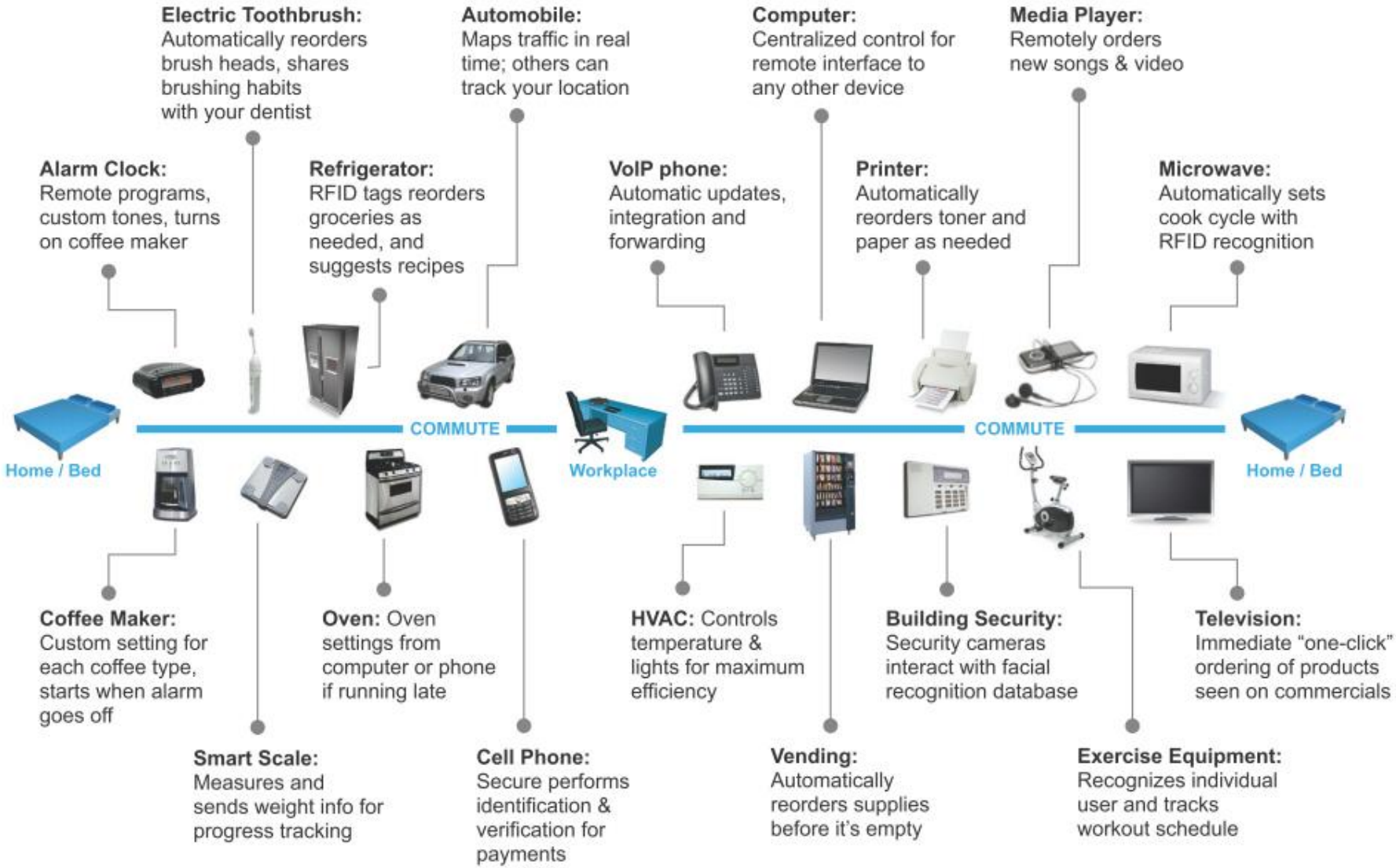
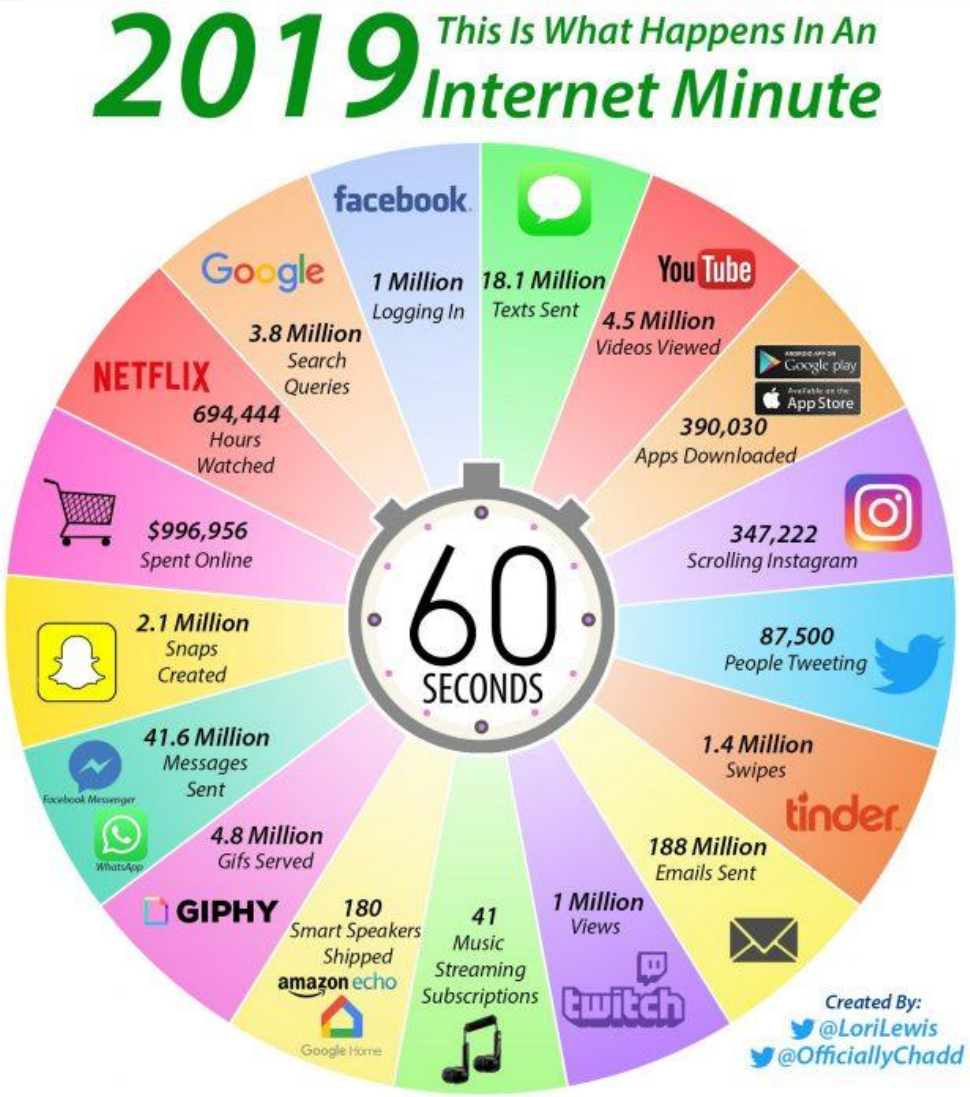


Figure 3. The Internet of Things

Big Data: From Biology to Astronomy

Data are created every minute!

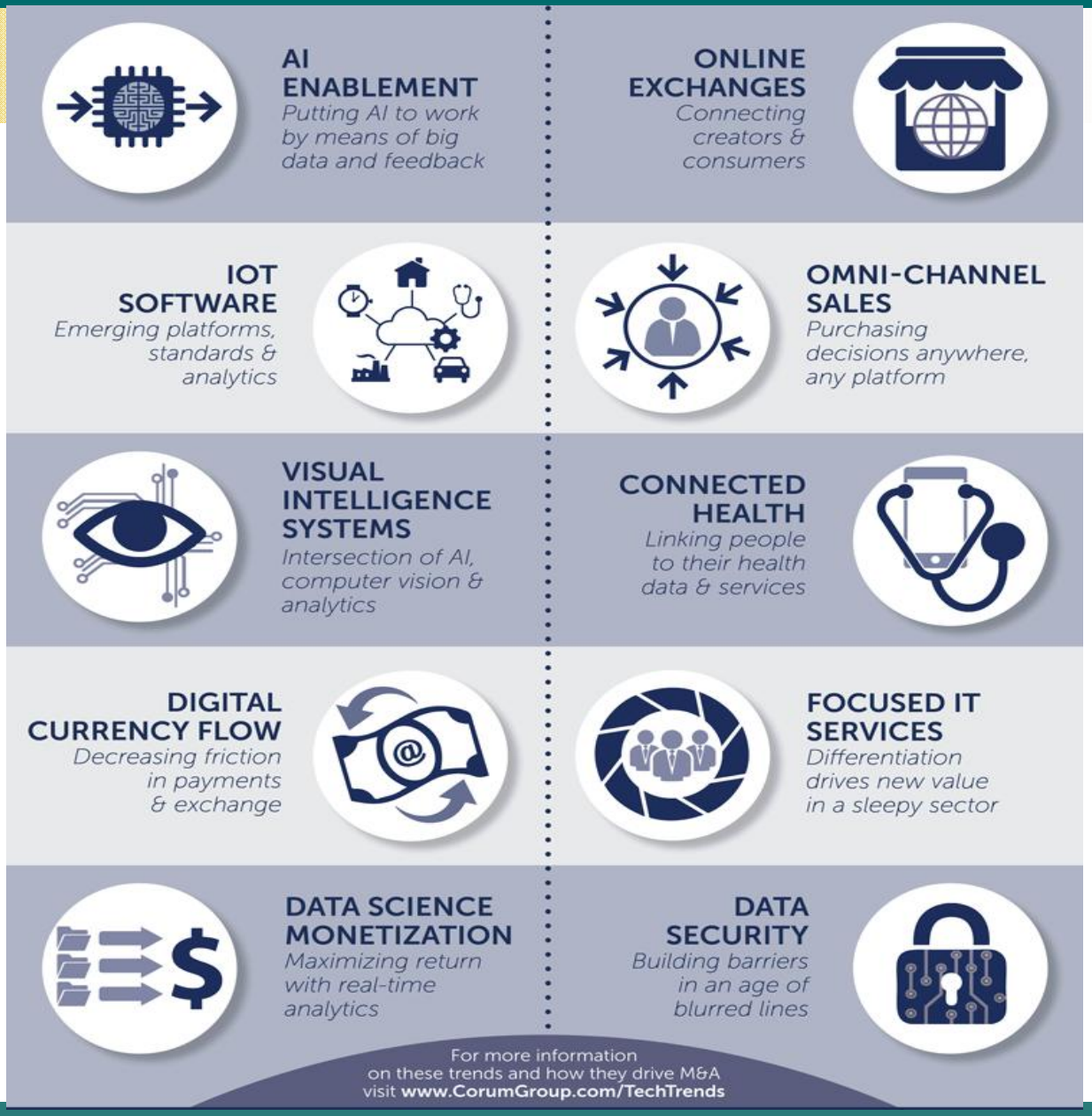


Top 10 Technology Trends 2019

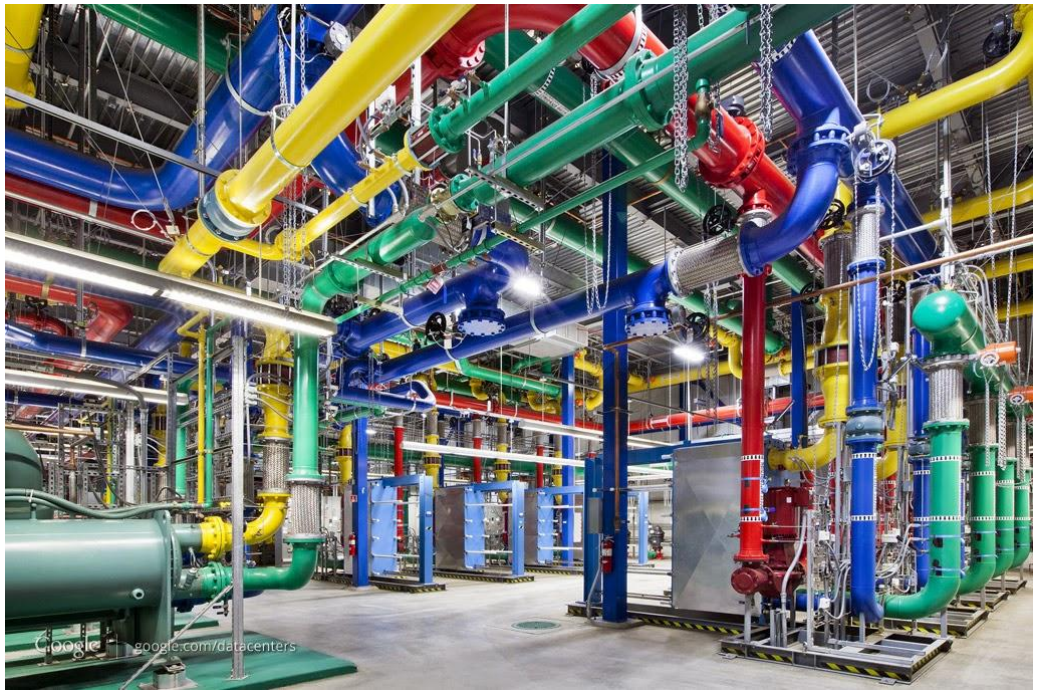
Gartner

Corum Top Ten Disruptive Technology Trends

2018

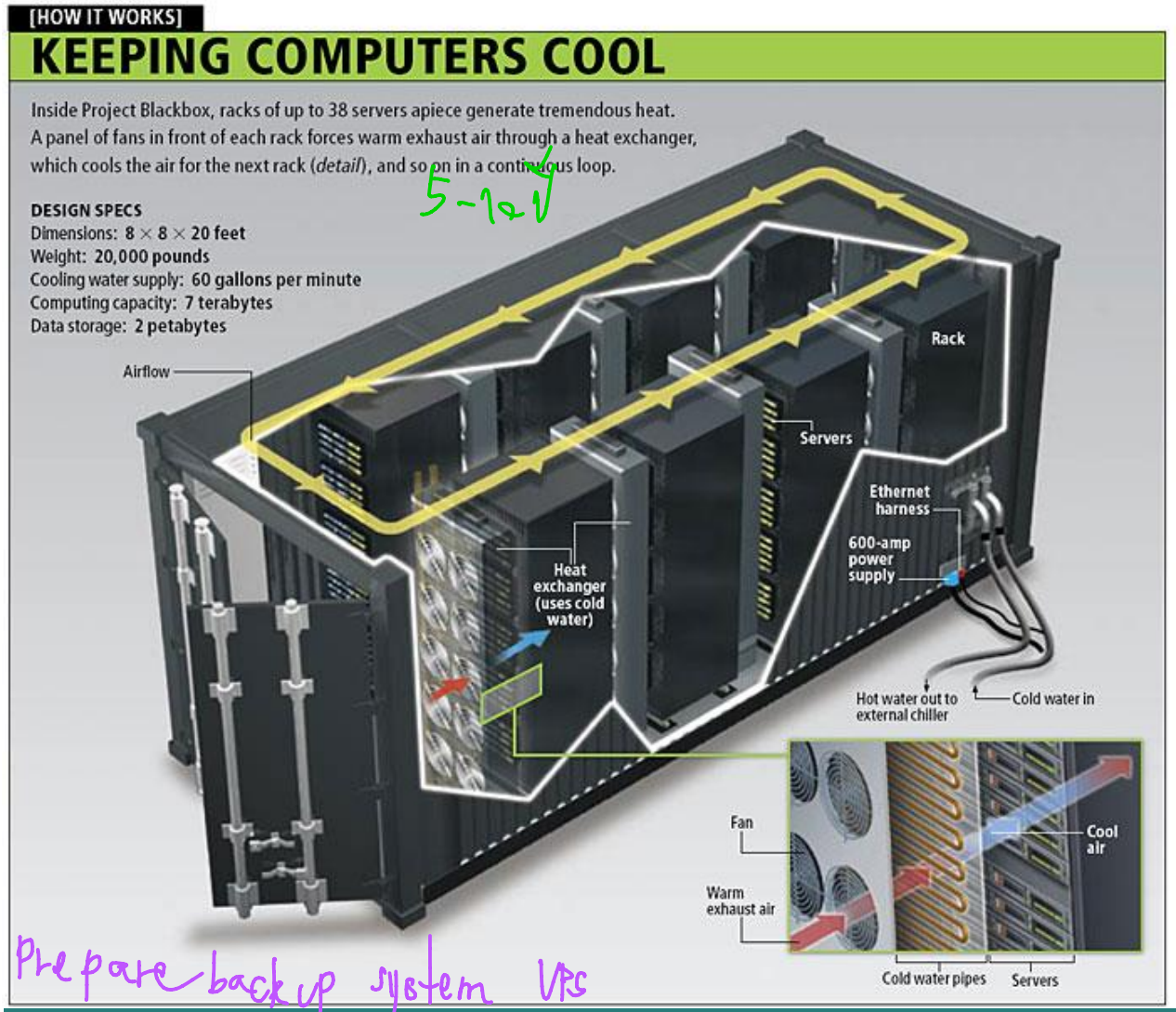


Data Centers



Building a Data Center

Sun's Modular Data Center: Project Blackbox

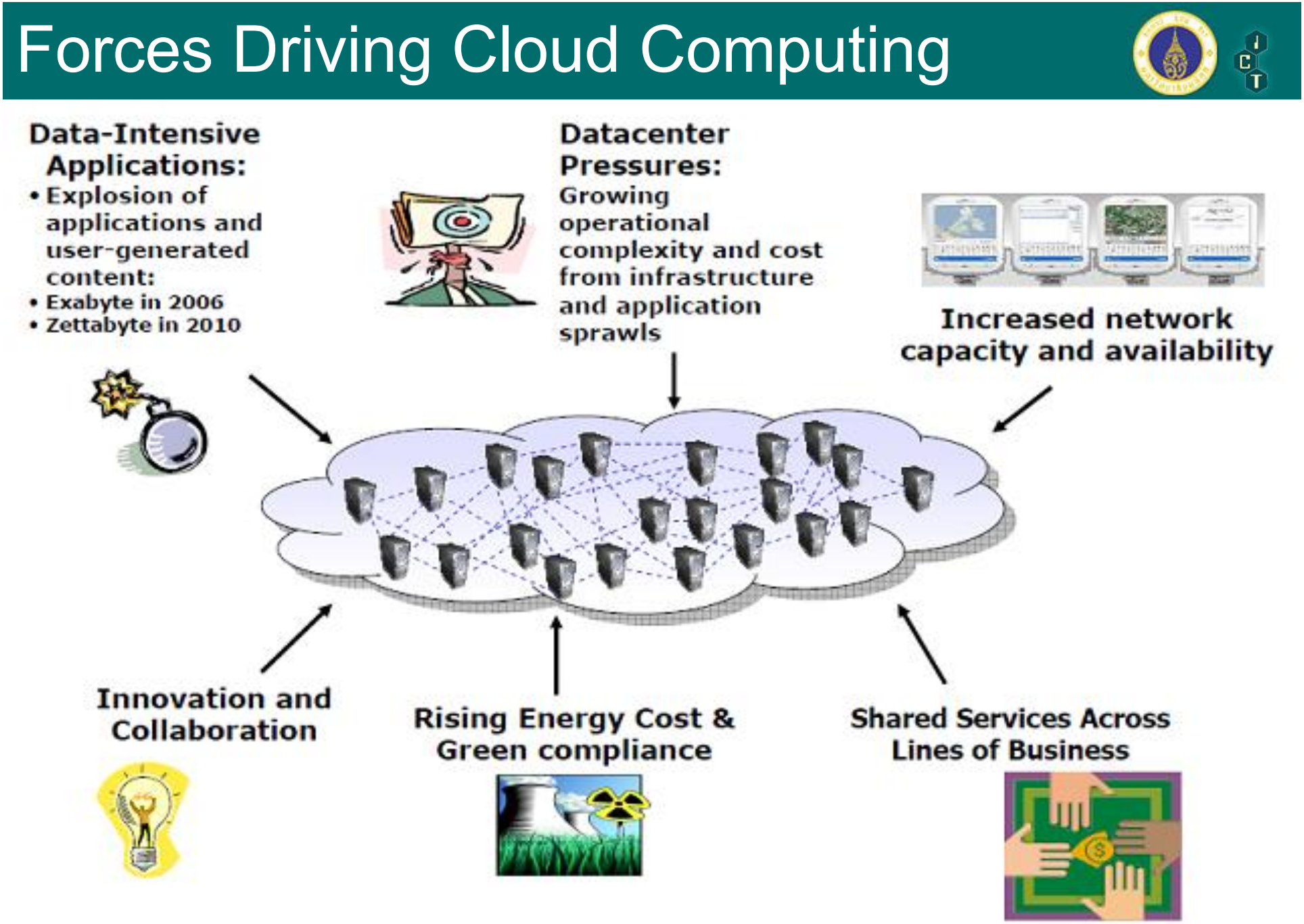


How Large of a Data Center?

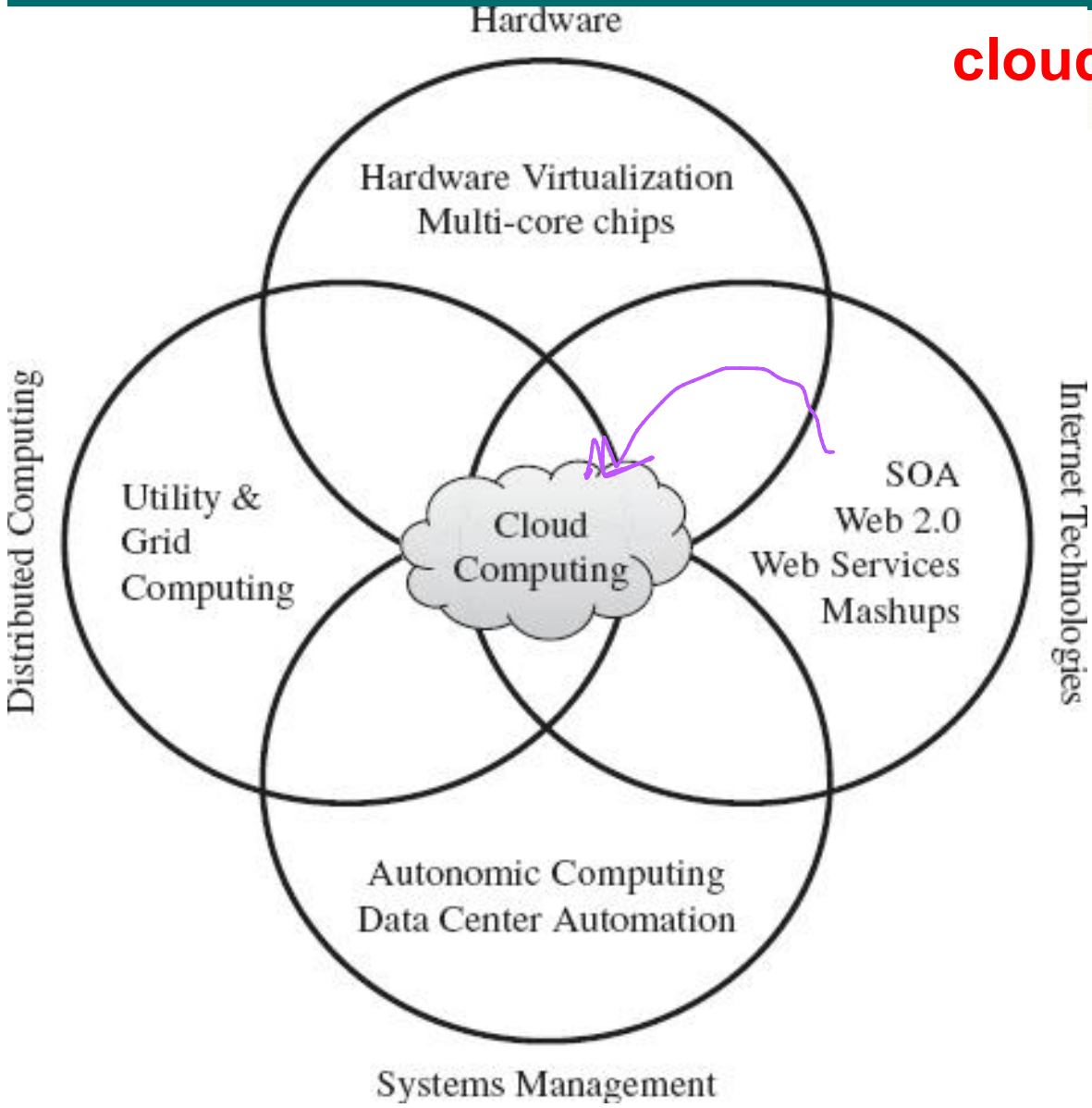
Facts and Stats of World's largest data centers

- Google 16 data centers: 9 in U.S., 1 in South America, 4 in Europe and 2 in Asia with about 2.5 million servers
- Facebook:
  - 1.13 billion daily active users (as of September 2016)
  - 60,000 servers (2010)
  - Own about $3.63 billion in "network equipment" (end of 2015)
- Amazon:
  - Amazon has 11 cloud regions
  - **1.5 million servers** in 7 locations
- Microsoft:
  - 1 billion users and 1,000,000 servers
  - Microsoft has 17 regions.
- Rackspace Hosting has 100,000 servers across 6 data centers.

Forces Driving Cloud Computing



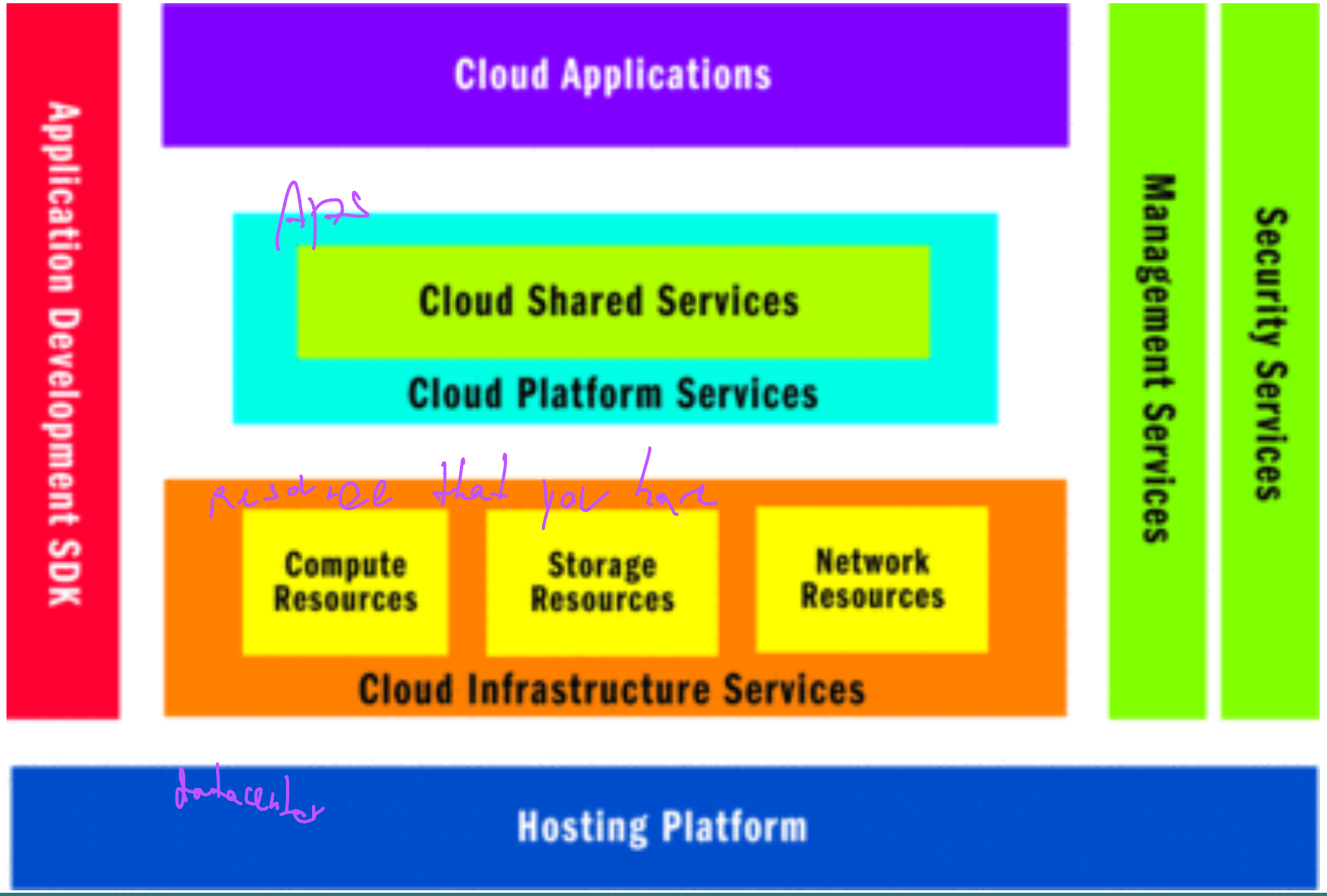
What Technologies Leads to Clouds



cloud-enabling technologies

- Broadband Networks
- Internet Architecture
- Data Center Technology
- Virtualization Technology
- Web Technology
- Multitenant Technology
- Service Technology

Cloud Computing Platform



Cloud Services

Cloud Services

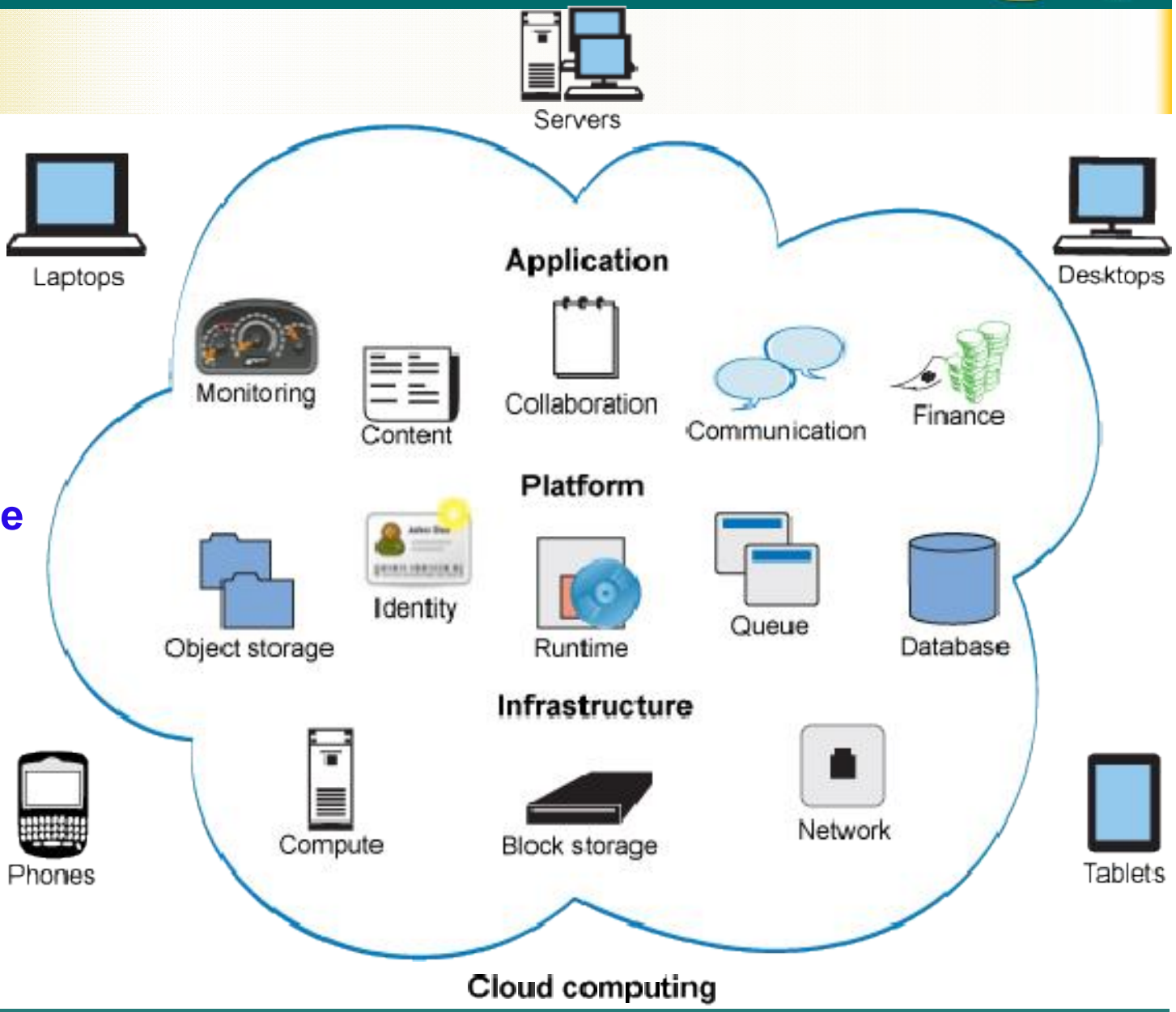
Service Catalogs

Self-service provisioning

A Big Picture of Cloud

Goals

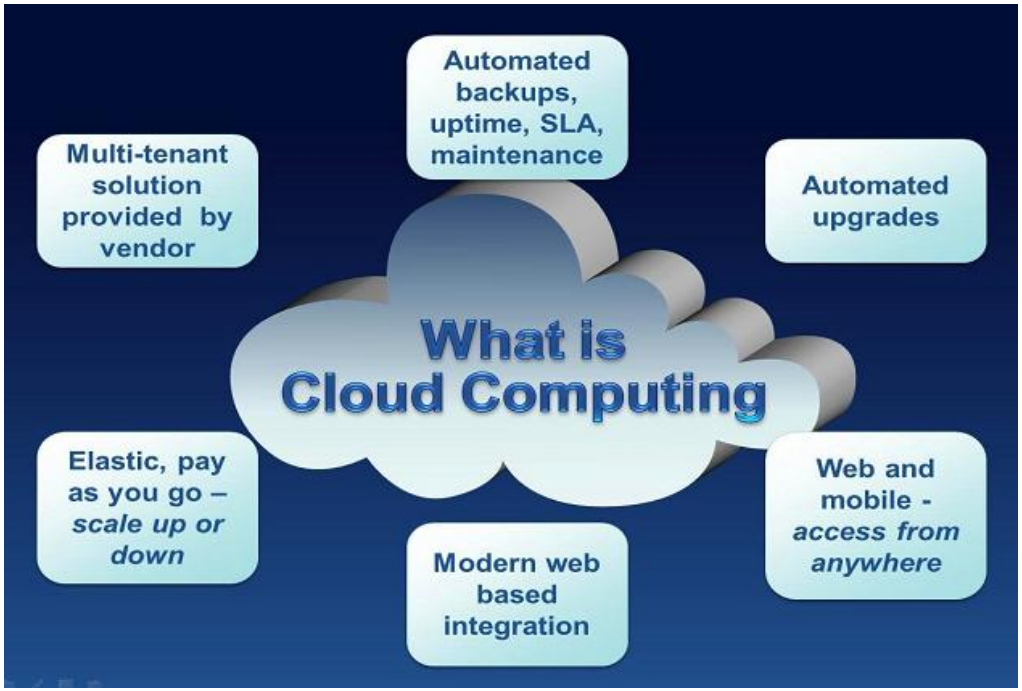
- **Always online**
- **Anywhere, any time, any device**
- **Unlimited resources**



NIST Cloud Definition

Cloud computing is a *pay-per-use* model for enabling *ubiquitous, convenient, on-demand access* to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction

คลาวด์คอมพิวติ้งเป็นรูปแบบการจ่ายต่อการใช้งานสำหรับการใช้งานทั่วไป
การเข้าถึงที่สะดวกและตามต้องการไปยังพูลที่แบ่งใช้ของการกำหนดทรัพยากรการคำนวณที่สามารถจัดสรรได้อย่างรวดเร็วและเปิดตัวด้วยความพยายามในการจัดการขั้นต่ำหรือผู้ให้บริการปฏิสัมพันธ์



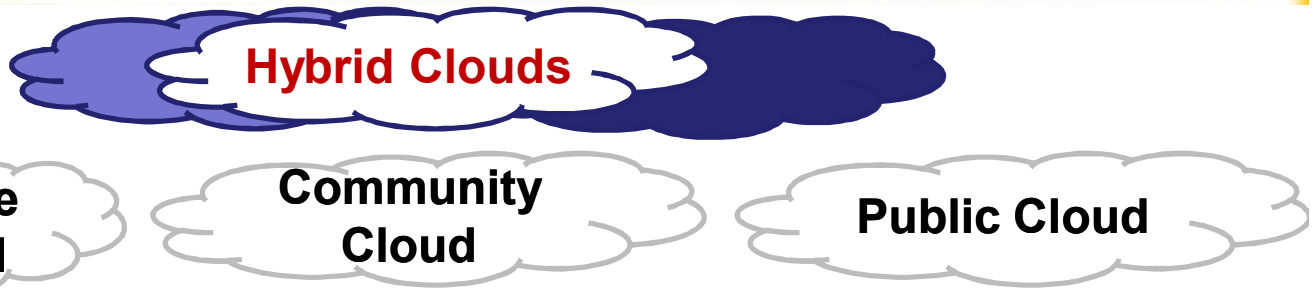
5 essential characteristics

3 service models

4 deployment models

National Institute of Standards and Technology (NIST)

NIST Cloud Framework



Deployment Models

Service Models

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

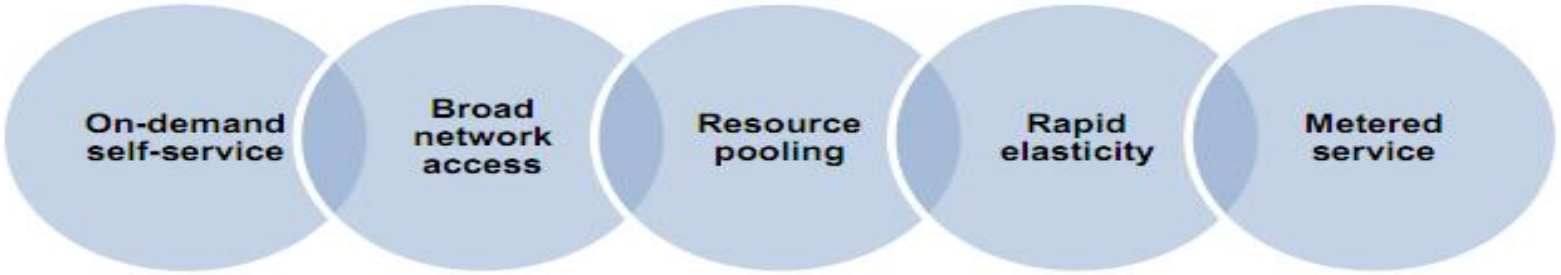
Essential Characteristics

- On Demand Self-Service
- Broadband Network Access
- Rapid Elasticity
- Resource Pooling
- Measured Services

Common Characteristics

- Massive Scale
- Resilient Computing
- Homogeneity
- Geographic Distribution
- Virtualization
- Service Orientation
- Low Cost Software
- Advanced Security

NIST Cloud Framework



5 Essential Cloud Characteristics	
On-demand self-services	Users can provision servers and networks with little human intervention get the server.
Broadband Network access	Any computing capabilities are available over the network, and can be accessed thru many different devices Just say what they want
Resource pooling	Multiple users can access clouds that serve other consumers according to demand. Location independence.
Elasticity	Automated ability of a cloud to transparently scale IT resources. Provisioning is rapid and scales out or based on needs
Metered services	Ability to keep track of the usage of its IT resources Just like utilities paid by hours or transactions

keep track of use, charge base on use

NIST Cloud Framework

Additional Cloud Characteristics	
Multi-tenancy migrate from server to . . .	• Enable an instance of the program to serve different consumers (tenants) whereby each is isolated from the others • Resource pooling allows cloud providers to pool large-scale IT resources to serve multiple cloud consumers
Resiliency	A form of failover that distributes redundant implementations of IT resources across physical locations

Clouds optimize resource usage and control it according to SLA (Service Level Agreement)

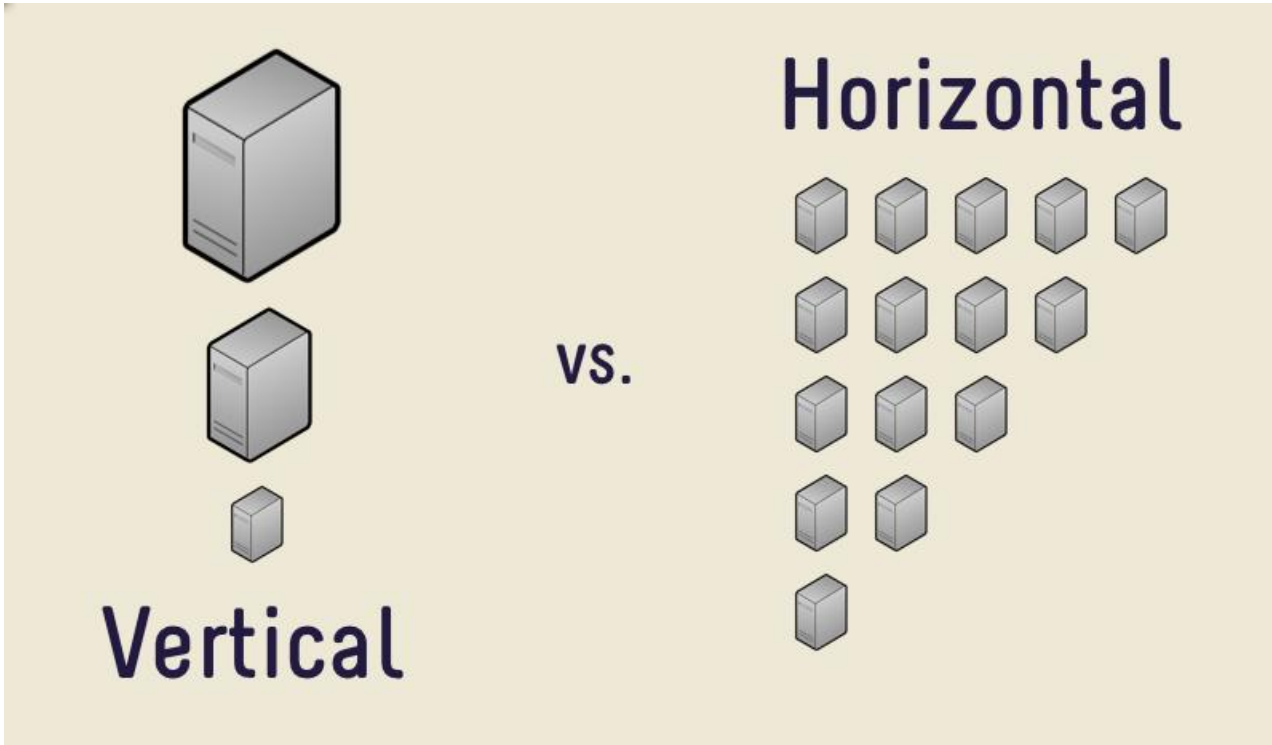
Vertical vs. Horizontal Scaling

Scale up/down vs. Scale out/in

Ability of IT resources to handle increased / decreased demands

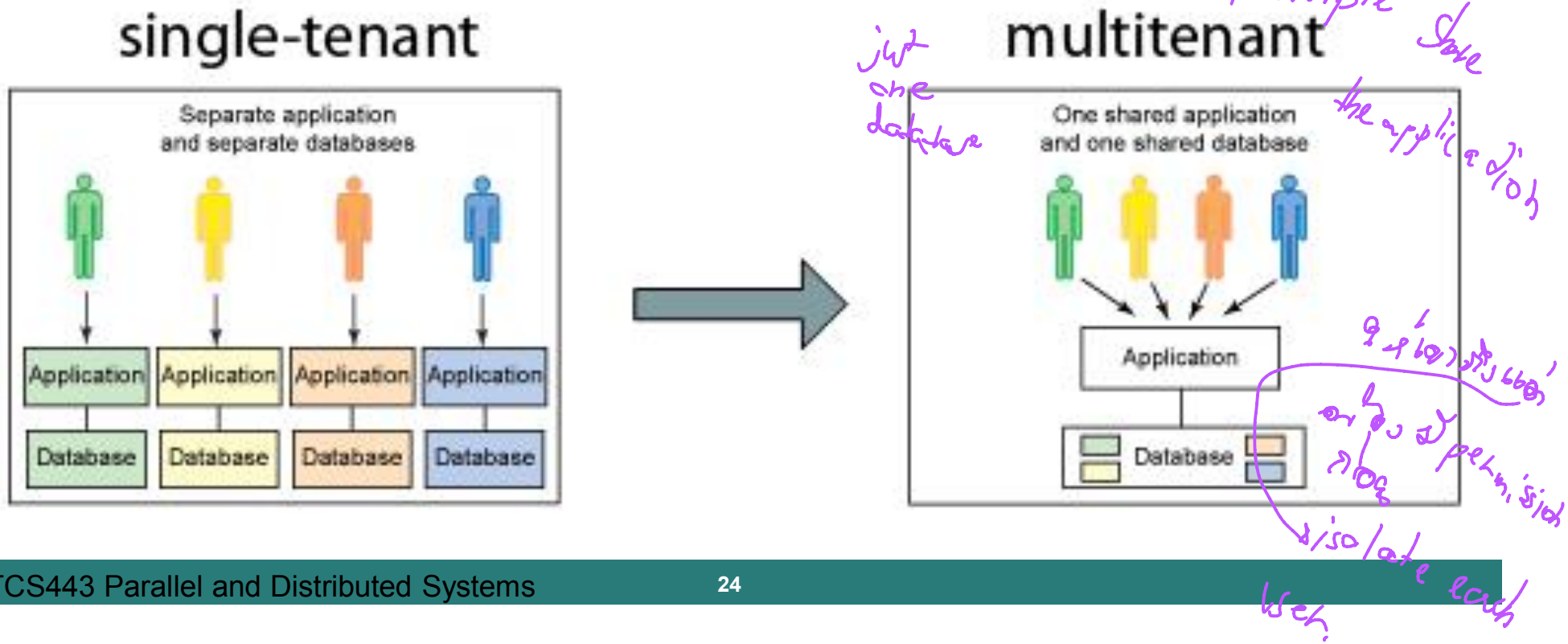
Horizontal Scaling: allocating or releasing IT resources of the same type

Vertical Scaling: replacing IT resources with higher or lower capacity



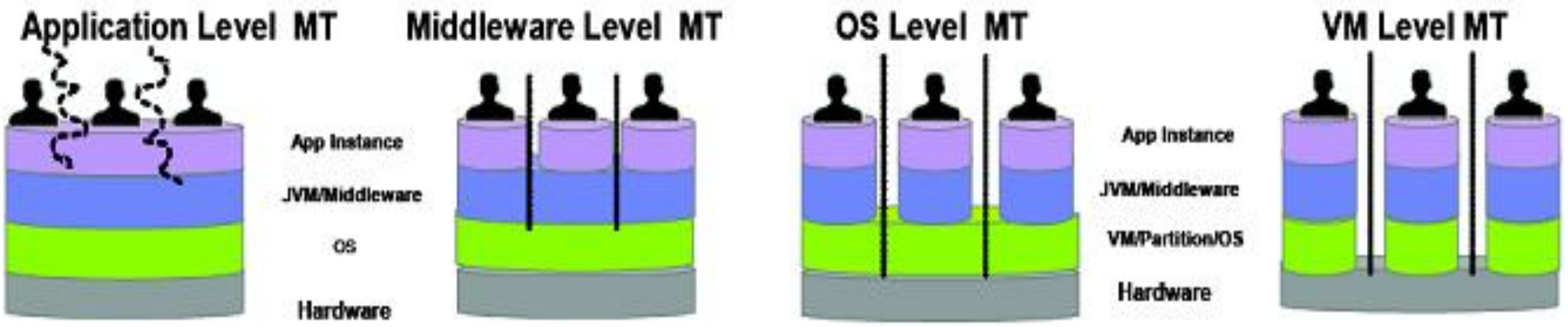
Multitenant Technology

- **Single-tenancy**: each customer has their own software instance
- **Multi-tenancy**: multiple customers (tenants) share the **same application**, running on the same OS, same hardware, with same data-storage mechanism
- **Benefits: isolation, cost saving, improved security**

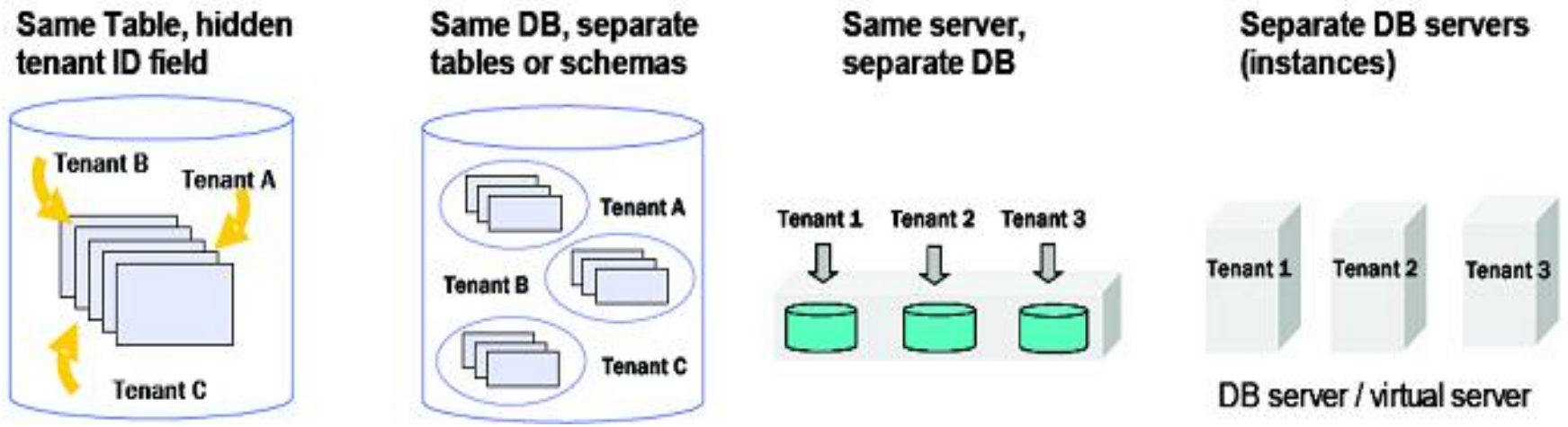


Multitenant Technology

Multi-tenancy at Different Levels



Example: Database Multi-tenancy



Cloud Service Models

SaaS

Use provider's applications over a network

PaaS

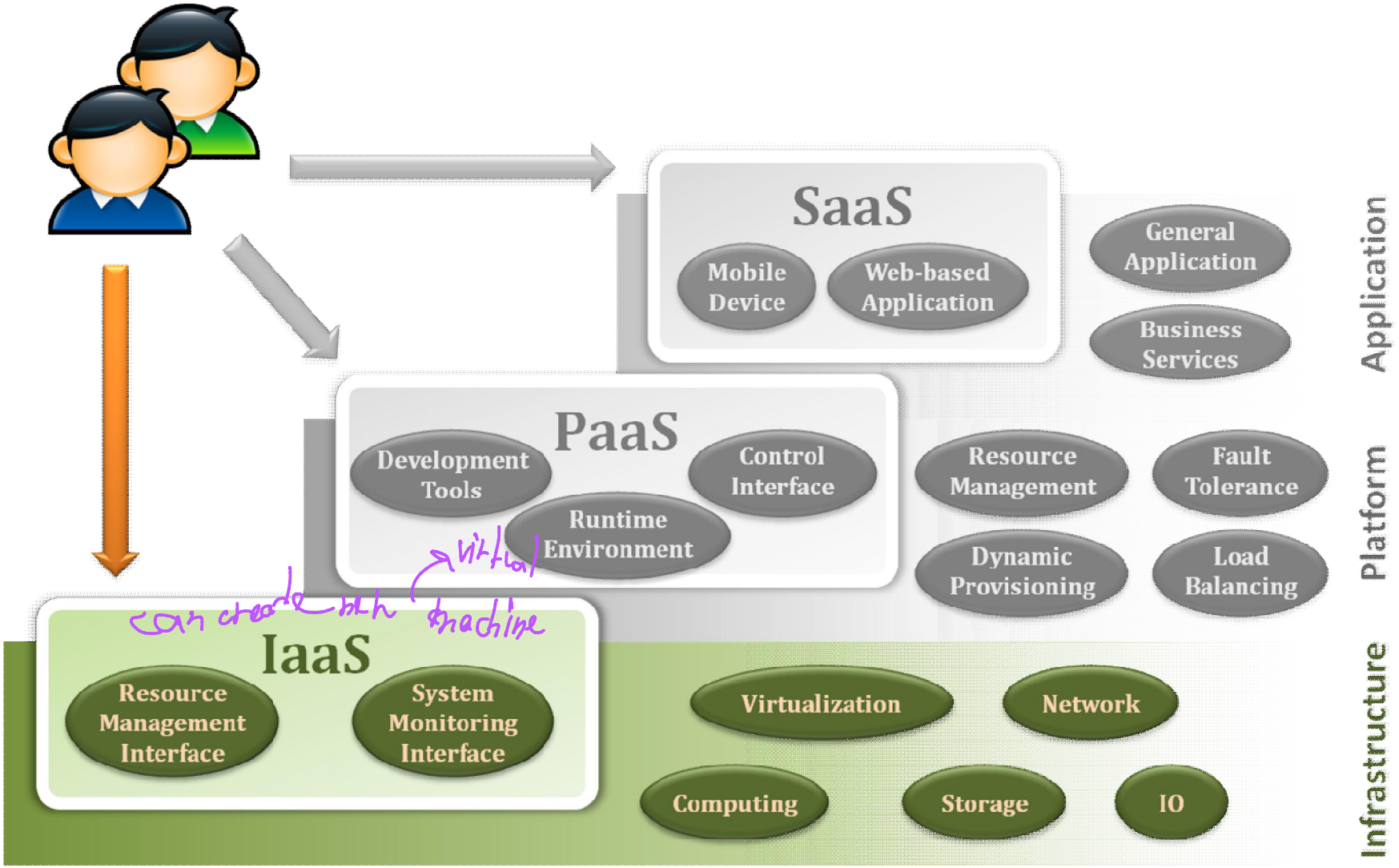
Deploy customer created applications to a cloud

IaaS

Rent processing, storage, network capacity, and other computing resources

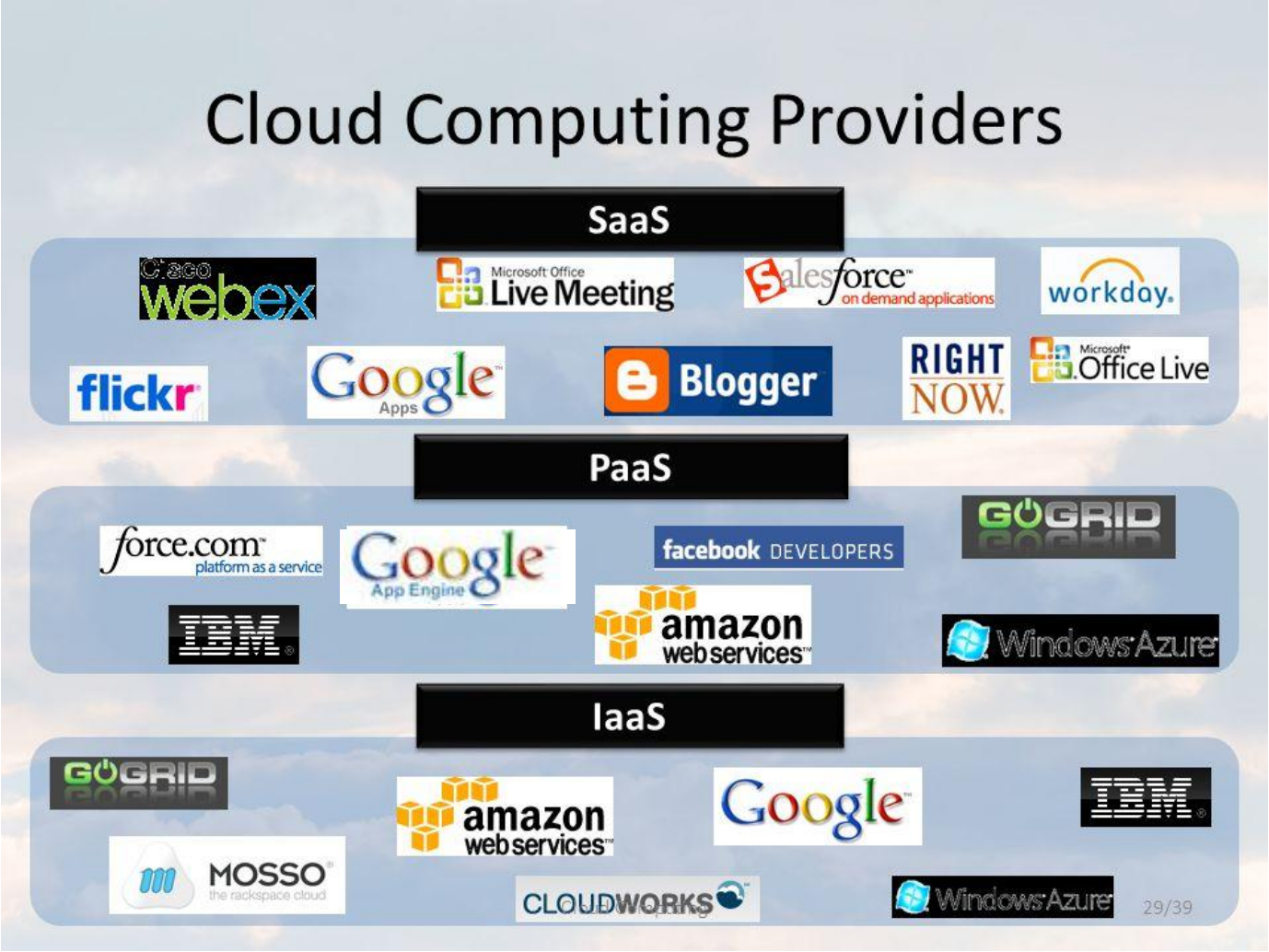
Cloud Service Models

Service Features



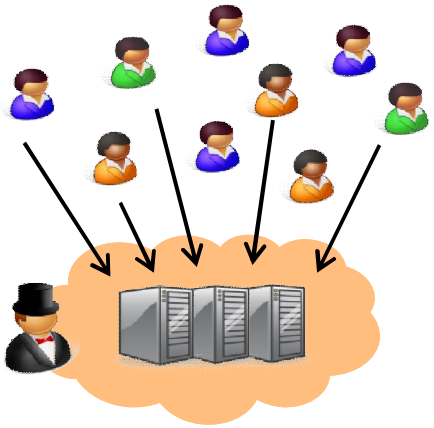
Cloud Service Models

Who are at which service?

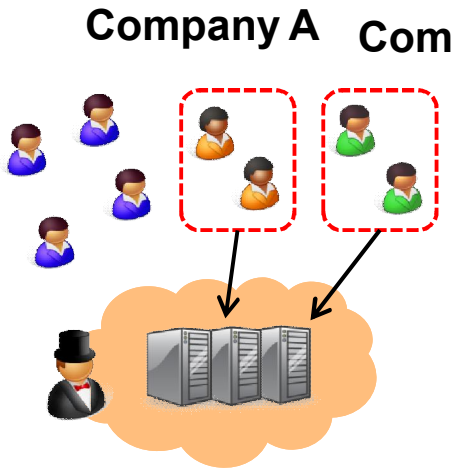


Cloud Deployment Models

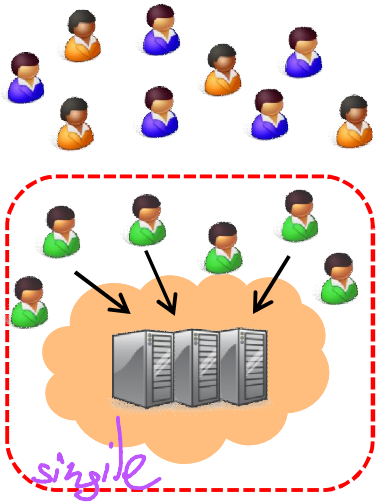
Who is a customer of the cloud?



Public



Community



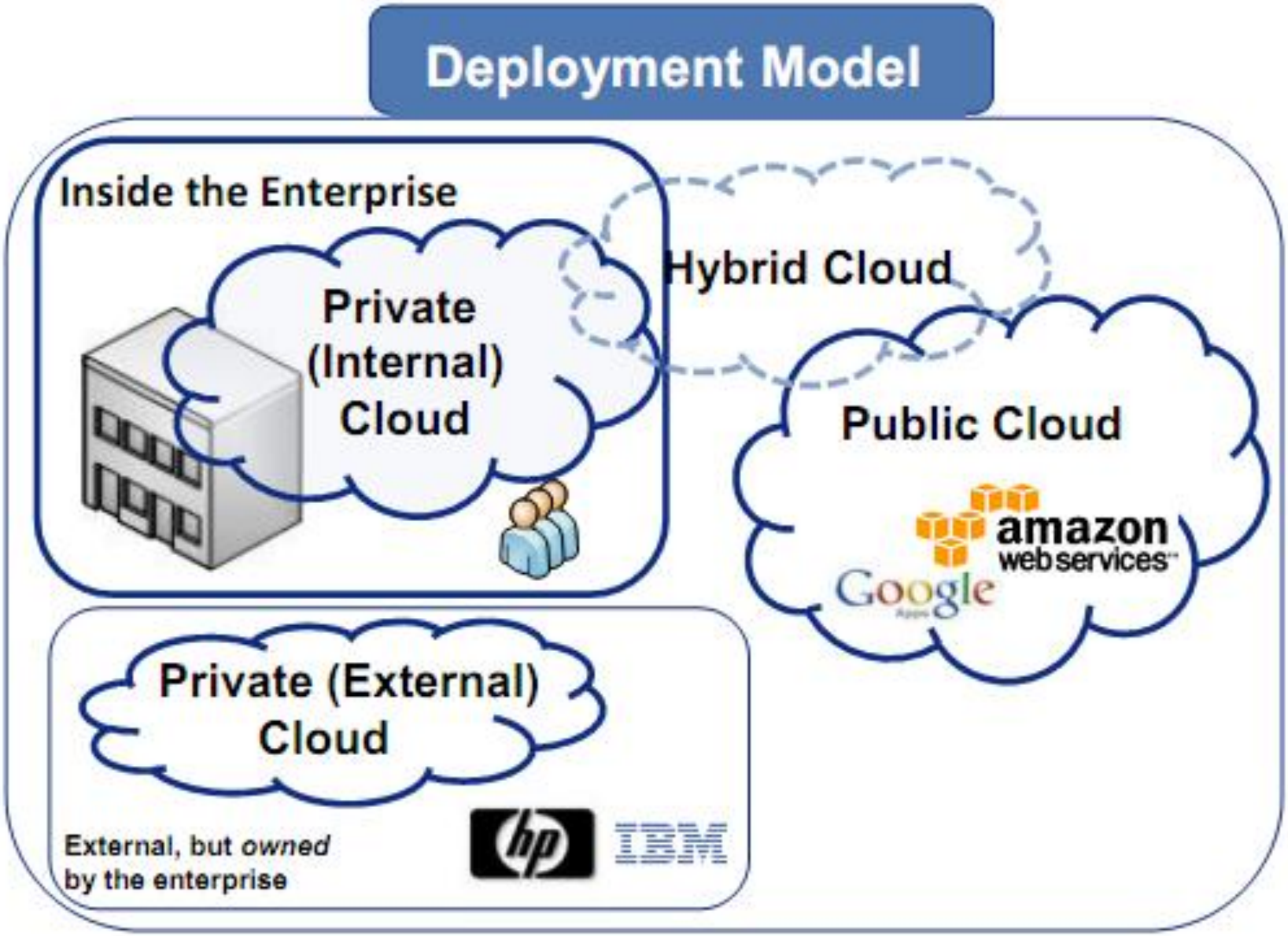
Private

Public cloud: Amazon, Microsoft, Google, IBM

Community cloud: Shared by several similar organizations

Private cloud: Shared within a single organization

Cloud Deployment Models

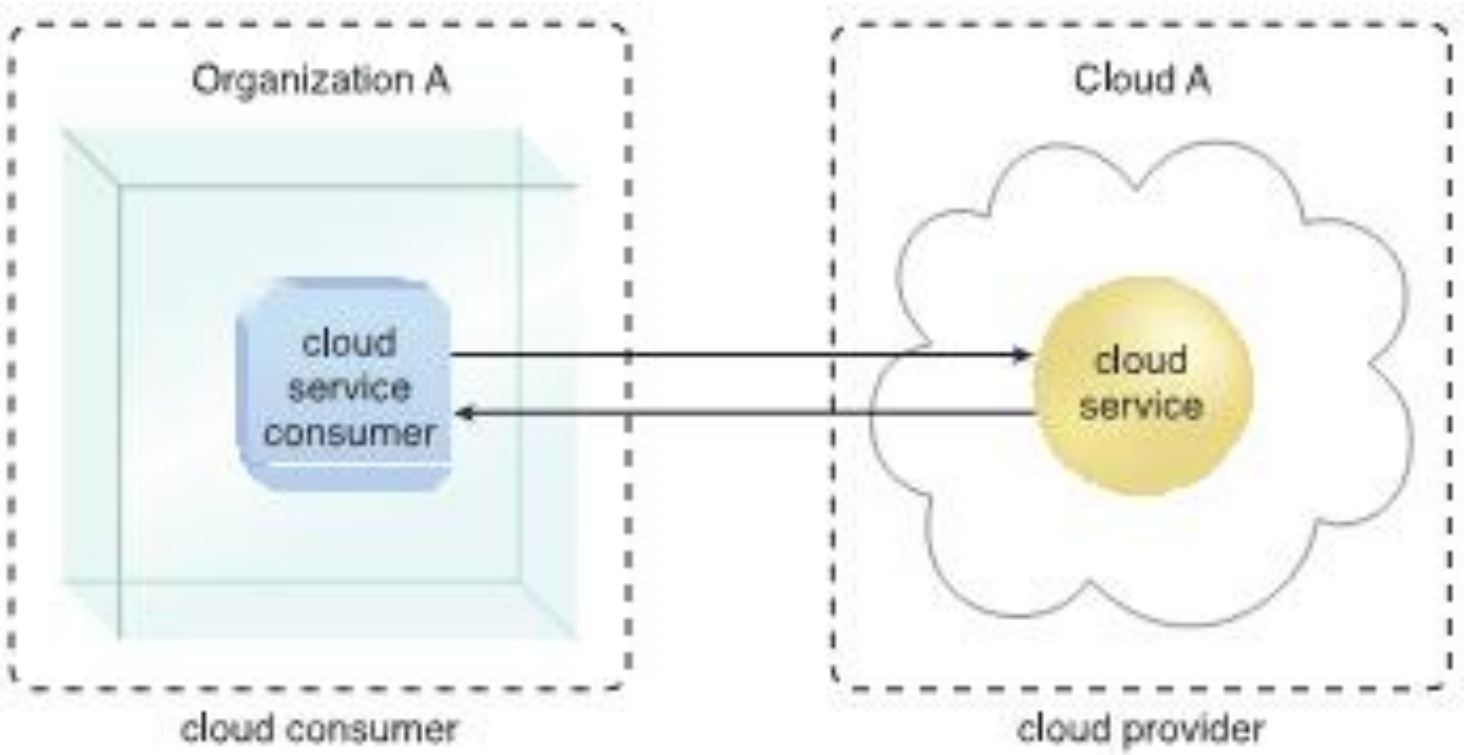


Roles in Cloud

Cloud Provider vs. Cloud Consumer

Cloud provider provides cloud-based IT resources

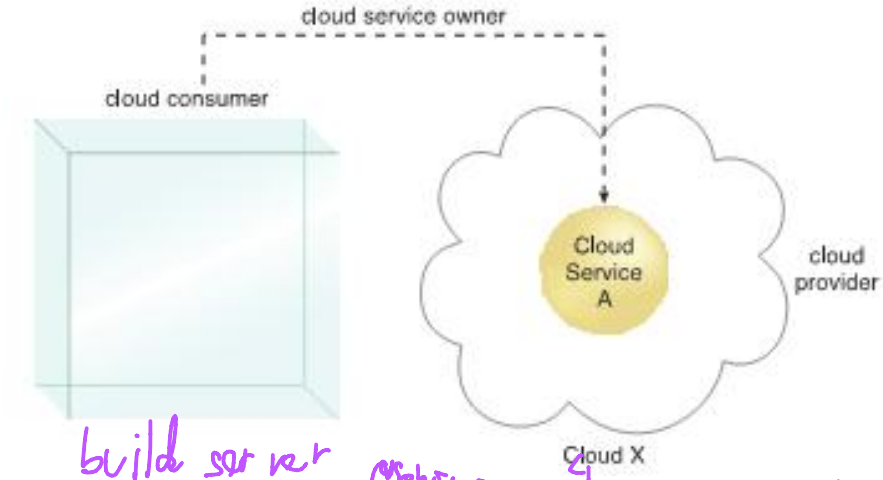
Cloud consumer uses IT resources made available by cloud providers

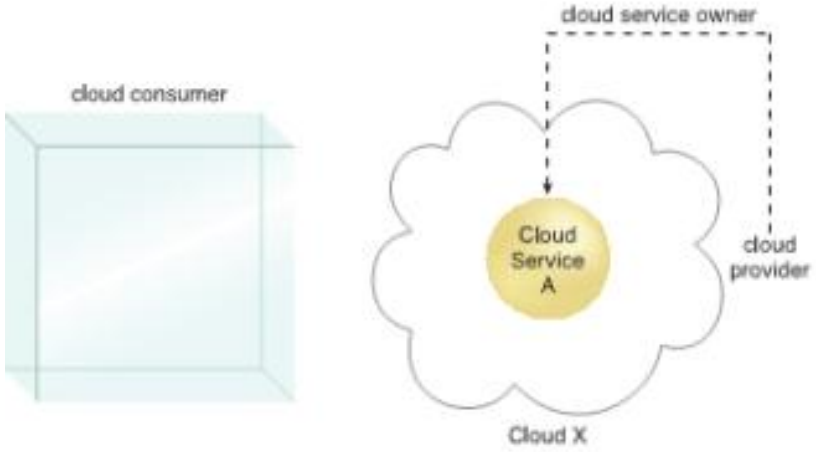


Roles in Cloud

Cloud Service Owner

A person/organization who legally owns a cloud service





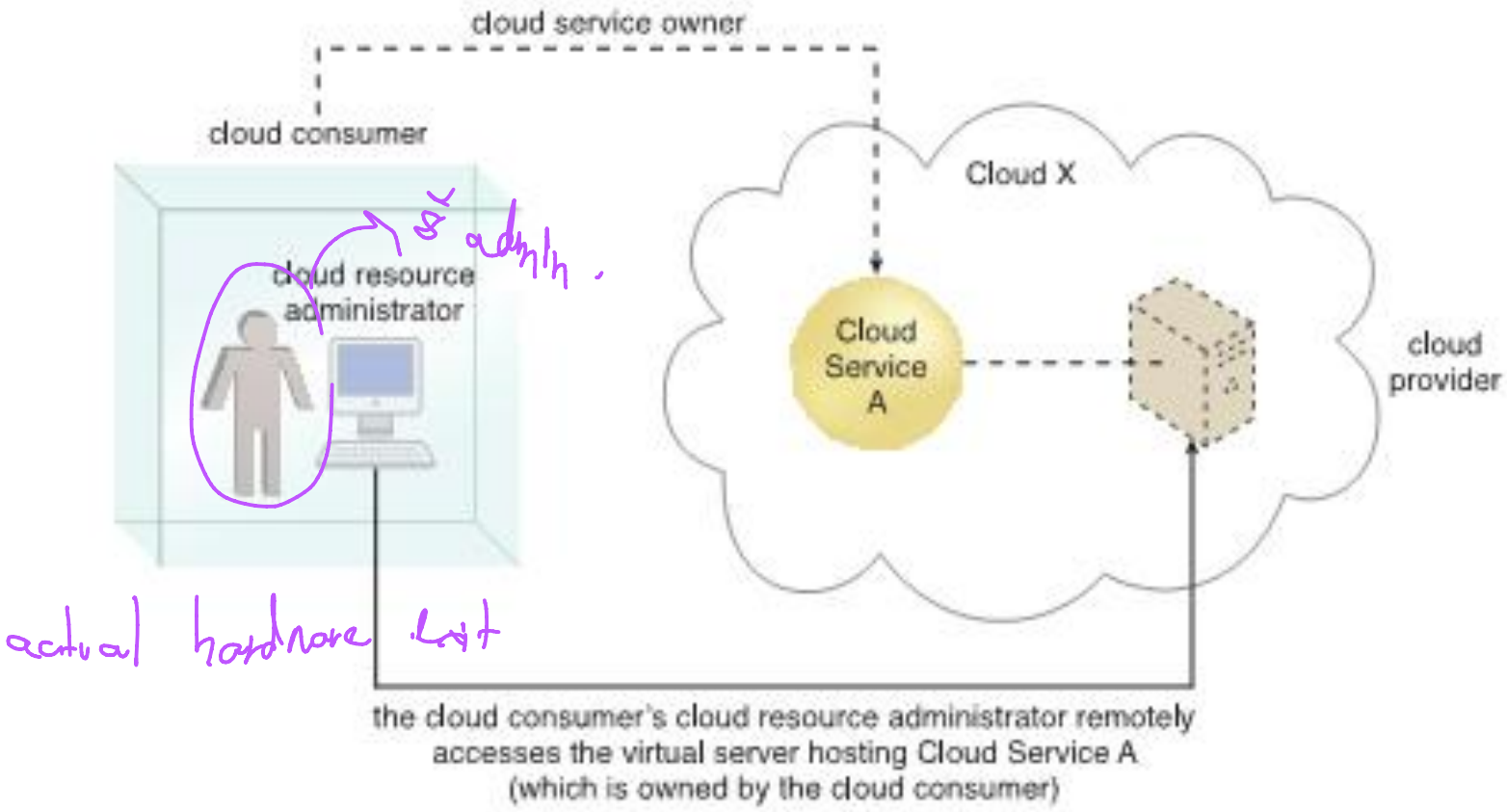
A cloud consumer can be a cloud service owner when it deploys its own service in a cloud

A cloud provider becomes a cloud service owner if it deploys its own cloud service, typically for other cloud consumers to use

Roles in Cloud

Cloud Resource Administrator

A person or organization responsible for administering a cloud-based IT resource (including cloud services)

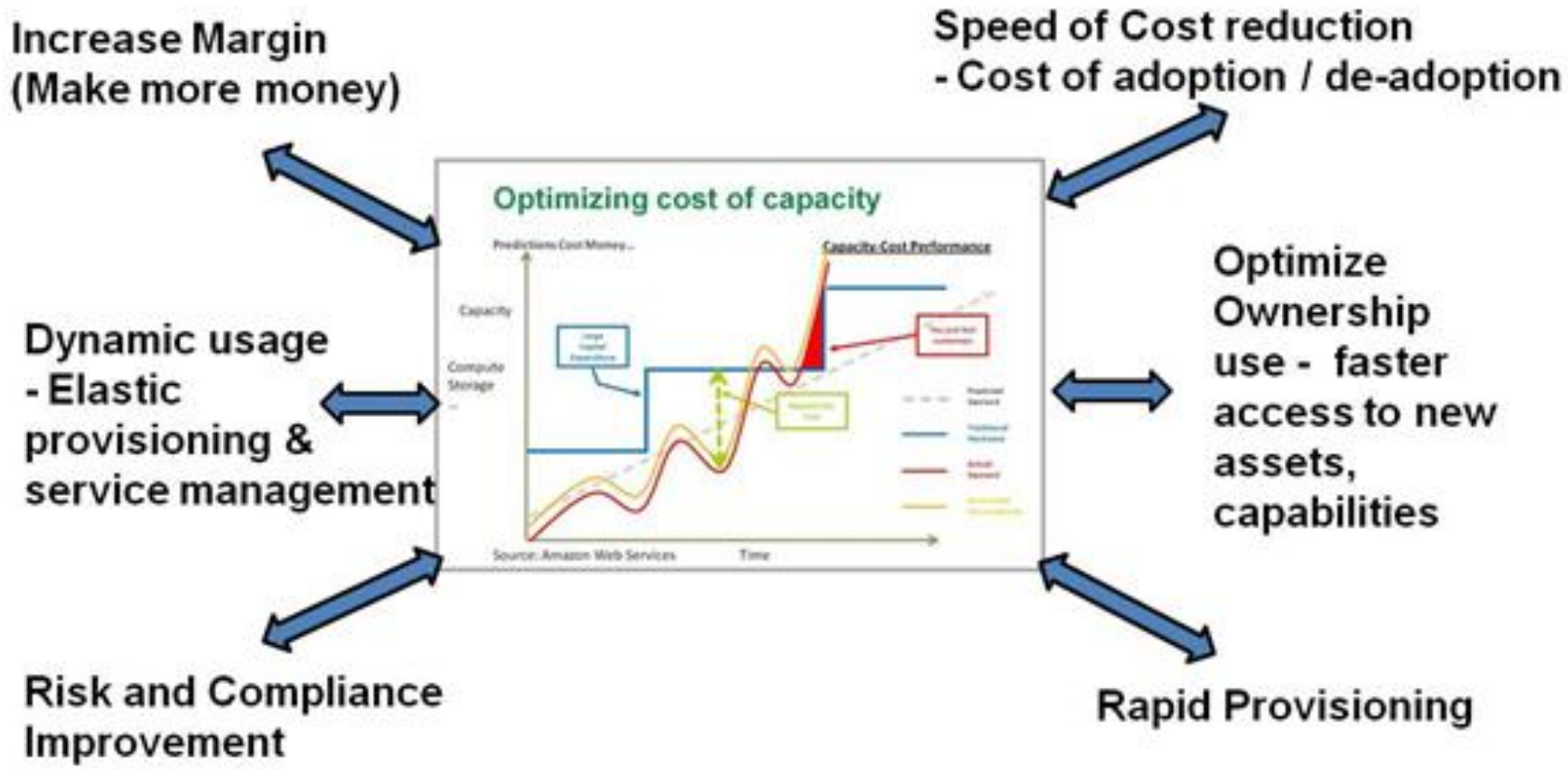


Cloud Market Share

https://www.forbes.com/sites/louiscolumbus/2018/01/07/83-of-enterprise-workloads-will-be-in-the-cloud-by-2020/

Cloud Capacity and Utilization

Motivation



Top Cloud Applications

Which applications moved to Cloud

Top services or applications moving to the cloud:*

Small business

1. Storage (40%)
2. Conferencing & collaboration (37%)
3. Messaging (36%)

Medium business

1. Storage (35%)
2. Messaging (33%)
3. Office & productivity suites (32%)

Large business

1. Conferencing & collaboration (40%)
2. Storage/business process apps (35%)
3. Messaging/ compute power (34%)

Federal govt.

1. Conferencing & collaboration (39%)
2. Messaging (37%)
3. Business process apps (31%)

State/local govt.

1. Storage (19%)
2. Conferencing & collaboration (17%)
3. Messaging/business process apps/ compute power (15%)

Healthcare

1. Conferencing & collaboration (29%)
2. Compute power (26%)
3. Office & productivity suites (22%)

Higher education

1. Storage (31%)
2. Messaging/ conferencing & collaboration (29%)
3. Compute power (25%)

K-12

1. Storage (40%)
2. Conferencing & collaboration (36%)
3. Office & productivity suites (33%)

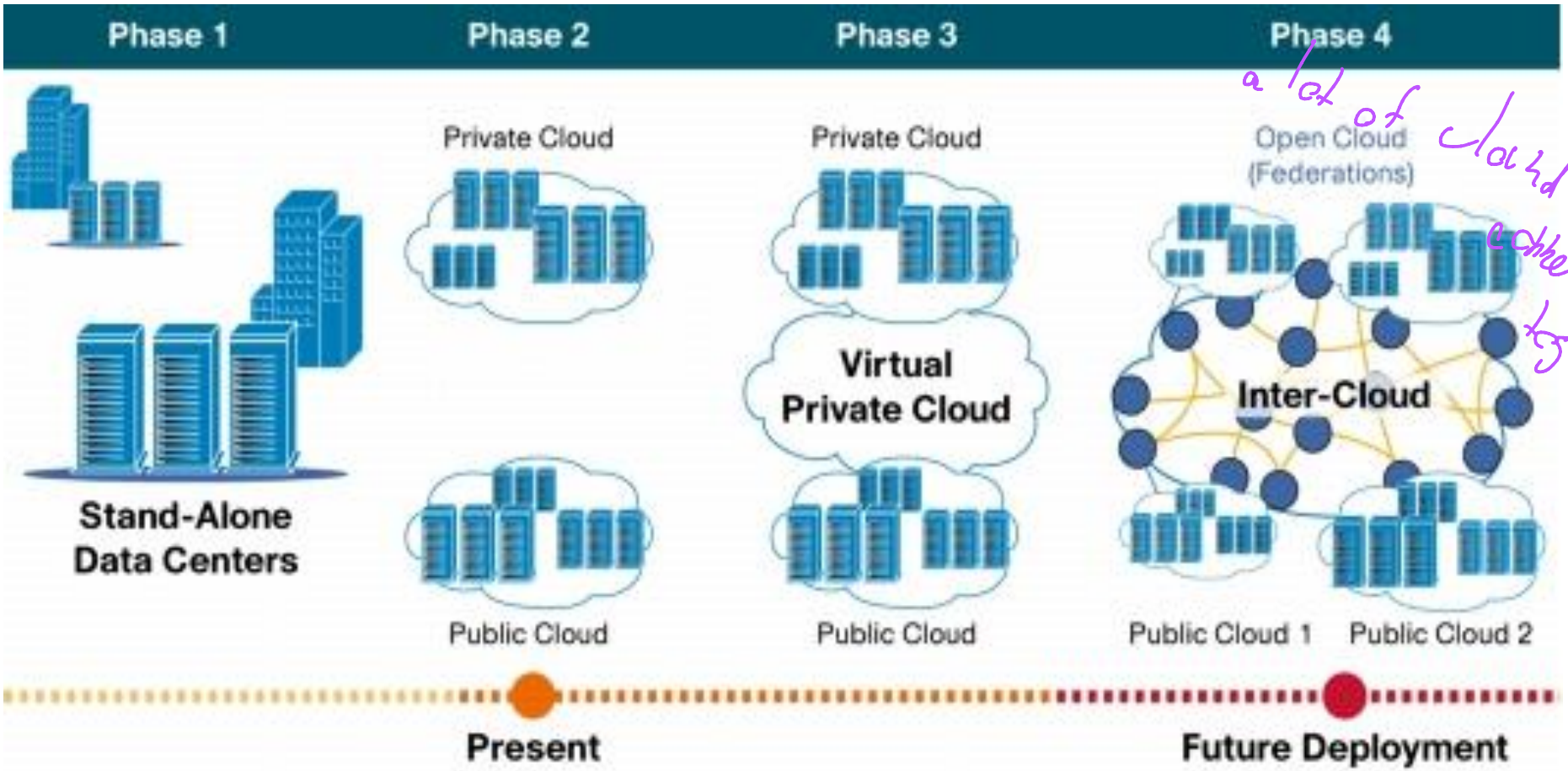
*Those who are migrating or have migrated

Most Used Enterprise Cloud Apps

MOST USED ENTERPRISE CLOUD APPS

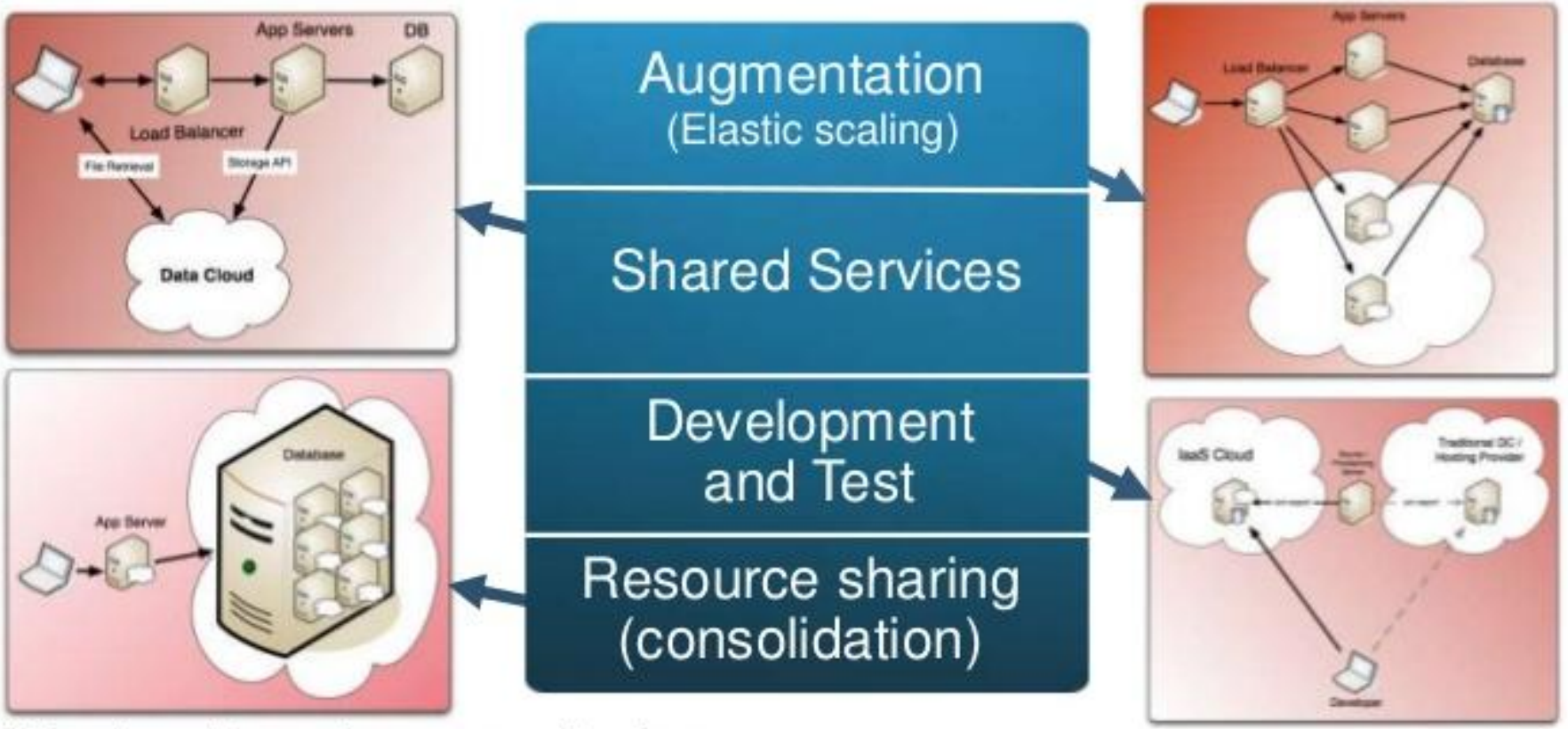
1. **Facebook** — Social
2. **Google Drive** — Cloud storage
3. **Google Gmail** — Webmail
4. **Twitter** — Social
5. **iCloud** — Cloud storage
6. **Google Docs** — Productivity
7. **YouTube** — Consumer
8. **LinkedIn** — Social
9. **Dropbox** — Cloud storage
10. **Microsoft OneDrive** — Cloud storage
11. **Salesforce** — Customer relationship management/sales force automation
12. **Cisco WebEx** — Collaboration
13. **Evernote** — Productivity
14. **RingCentral** — Telecom
15. **Okta** — Security

Cloud Adoption Model



Cloud Adoption Model

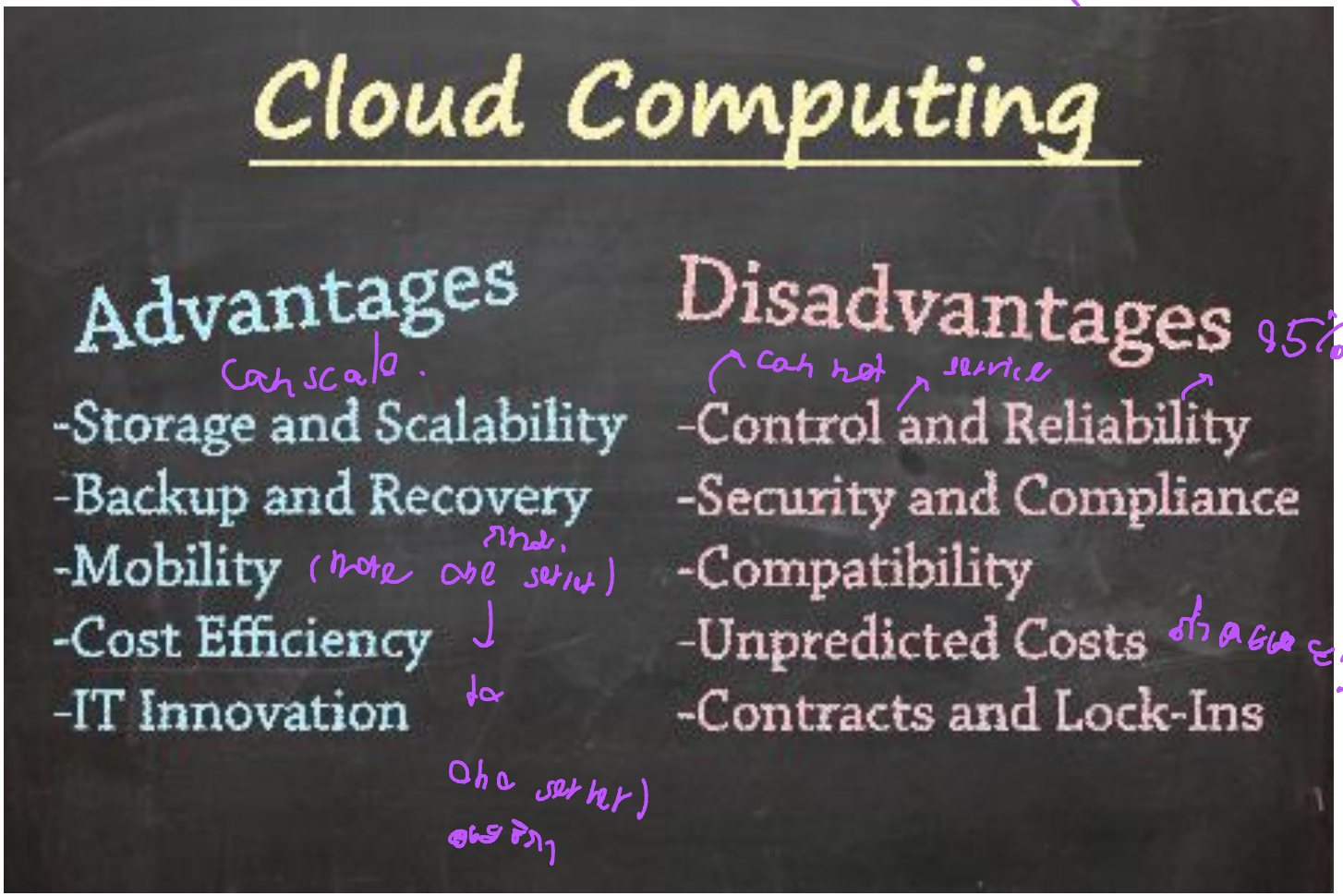
Starting with Common Use Cases



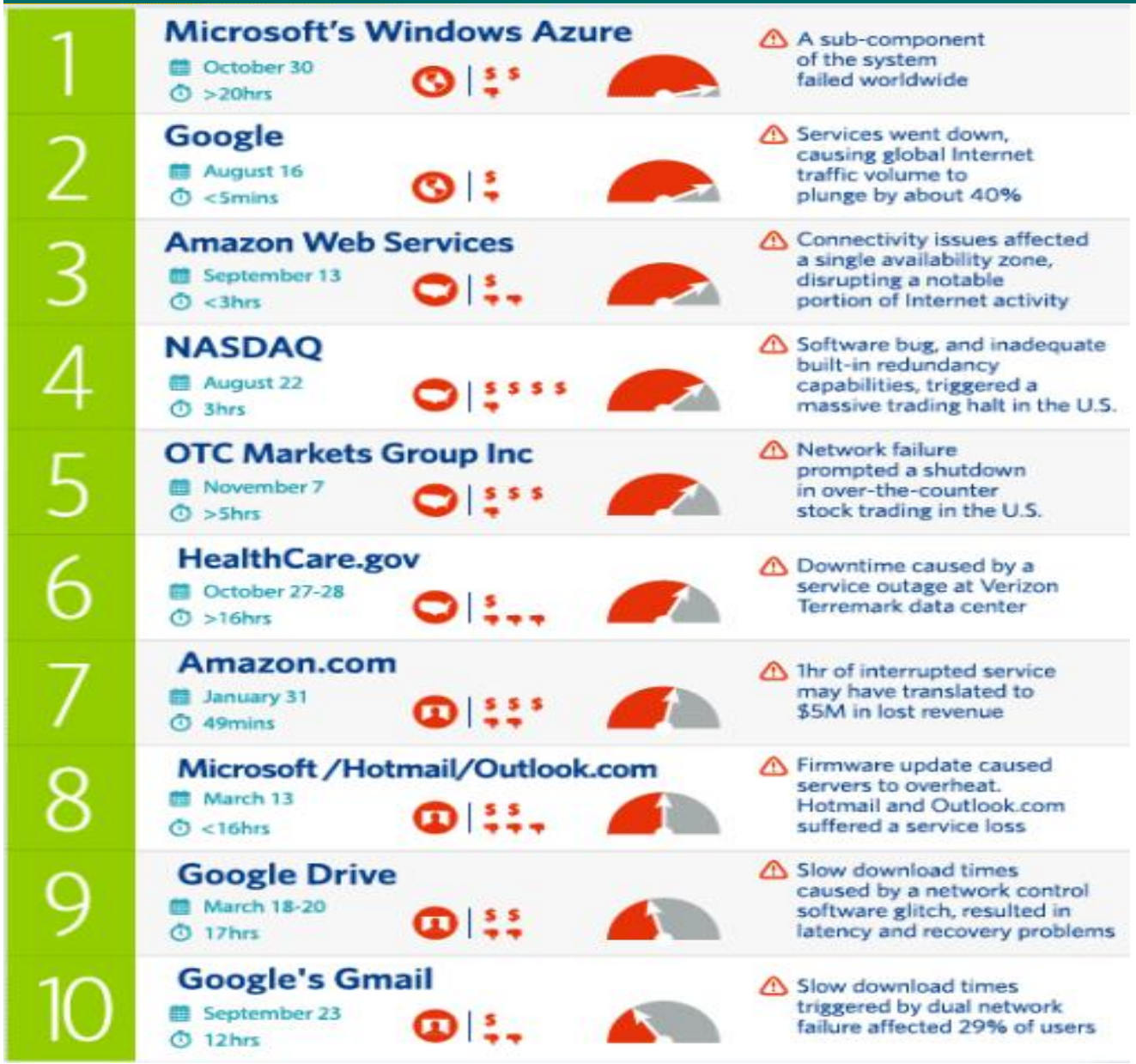
Most enterprises are trying

- **Shared development and test environments**
- **Hardware & Services consolidation**

Cloud: Pros and Cons

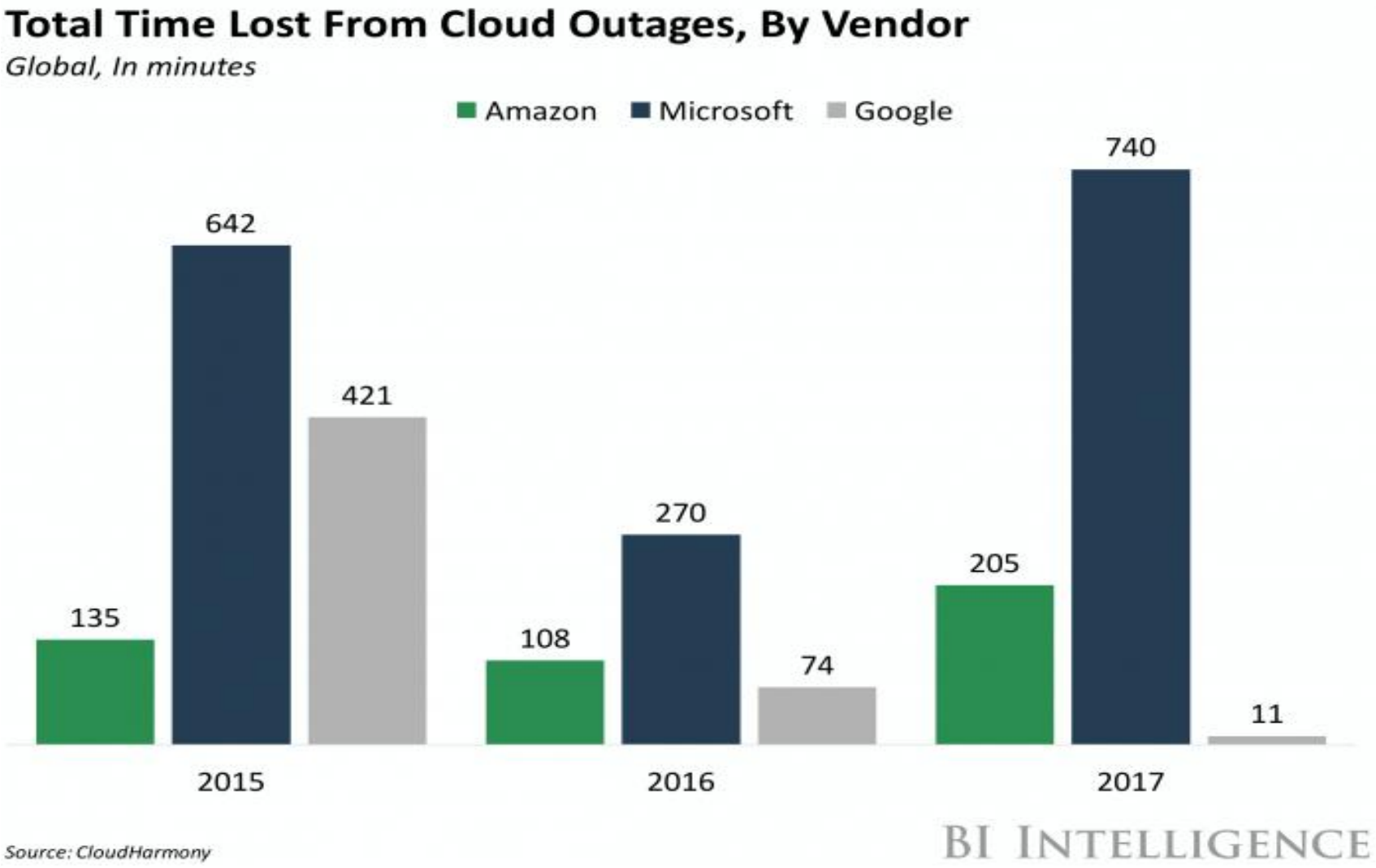


Cloud Downtime



Top Ten Cloud Computing Outages in 2013

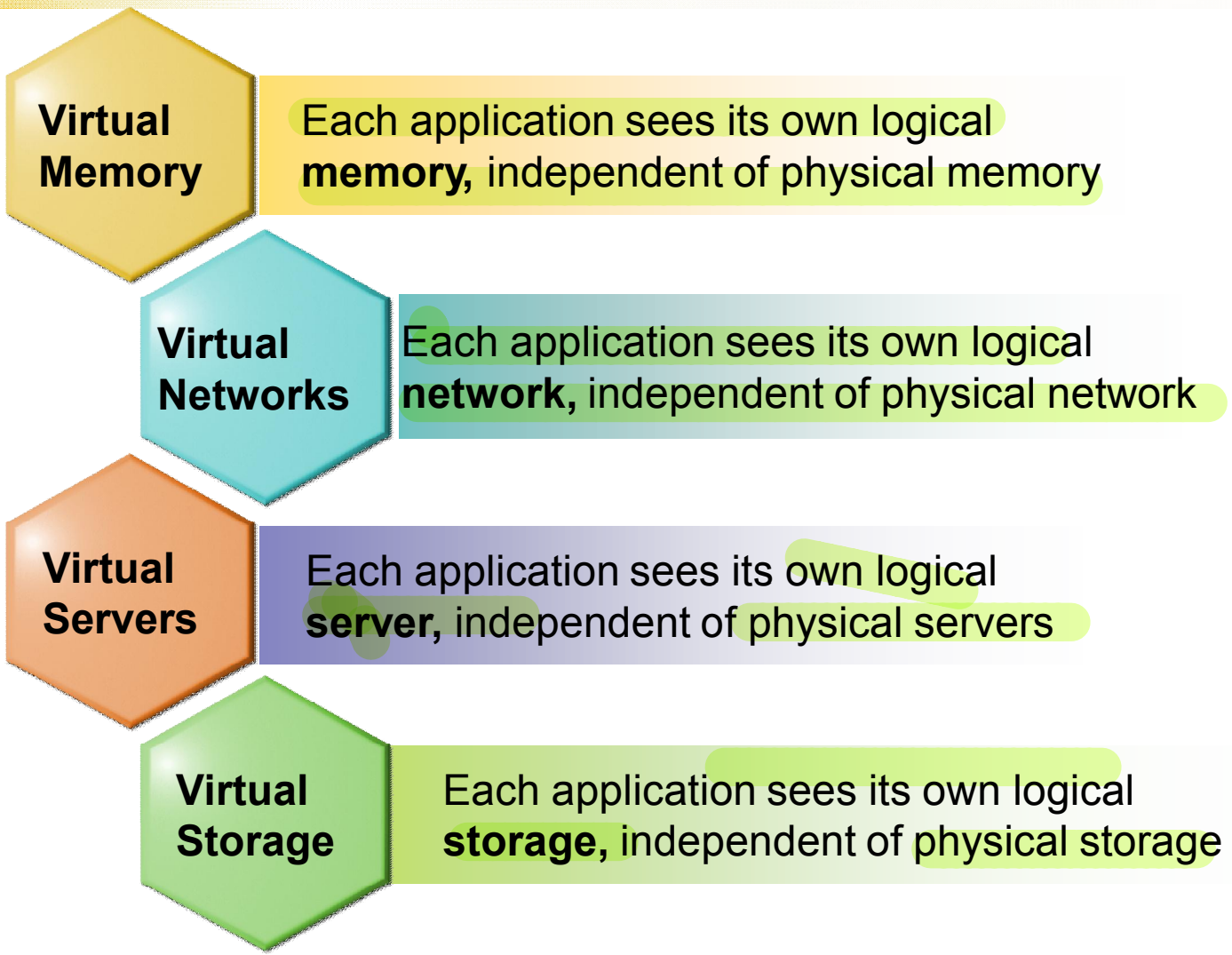
Cloud Downtime



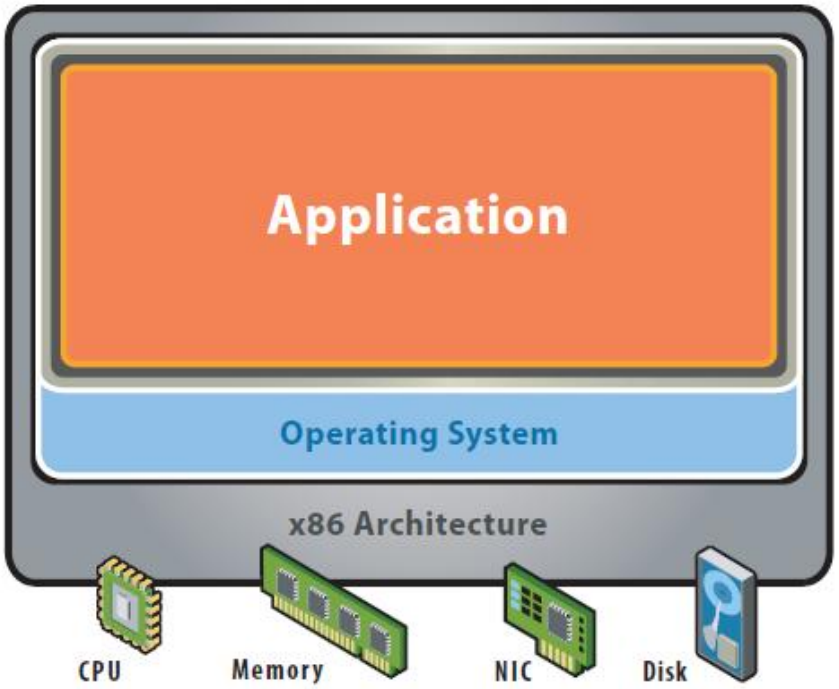
Sample SLAs

	Rackspace	Amazon
Uptime	100%	99.95%
Time-to-resolve	1 hour	Not specified
Timespan	Current period	"Service Year"
Credit back when failing to meet SLA	"Users receive 5% of the fees for each 30 minutes of network downtime, up to 100% of the fees"	"If the Annual Uptime Percentage for a customer drops below 99.95% for the *Service Year*, that customer is eligible to receive a Service Credit equal to 10% of their bill."

Virtualization Concepts



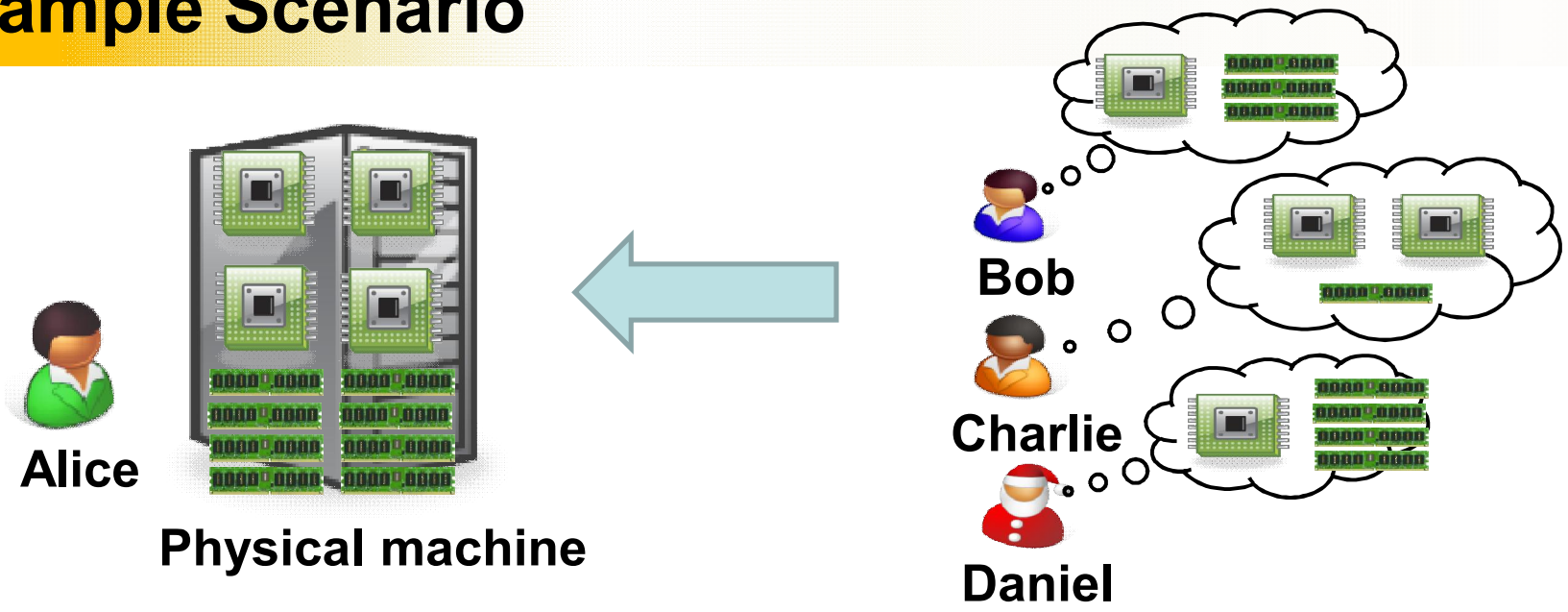
No Virtualized Server



- Single OS per machine
- Software and hardware tightly coupled
- Running multiple applications on same machine often creates conflict
- Inflexible and costly infrastructure

Server Virtualization

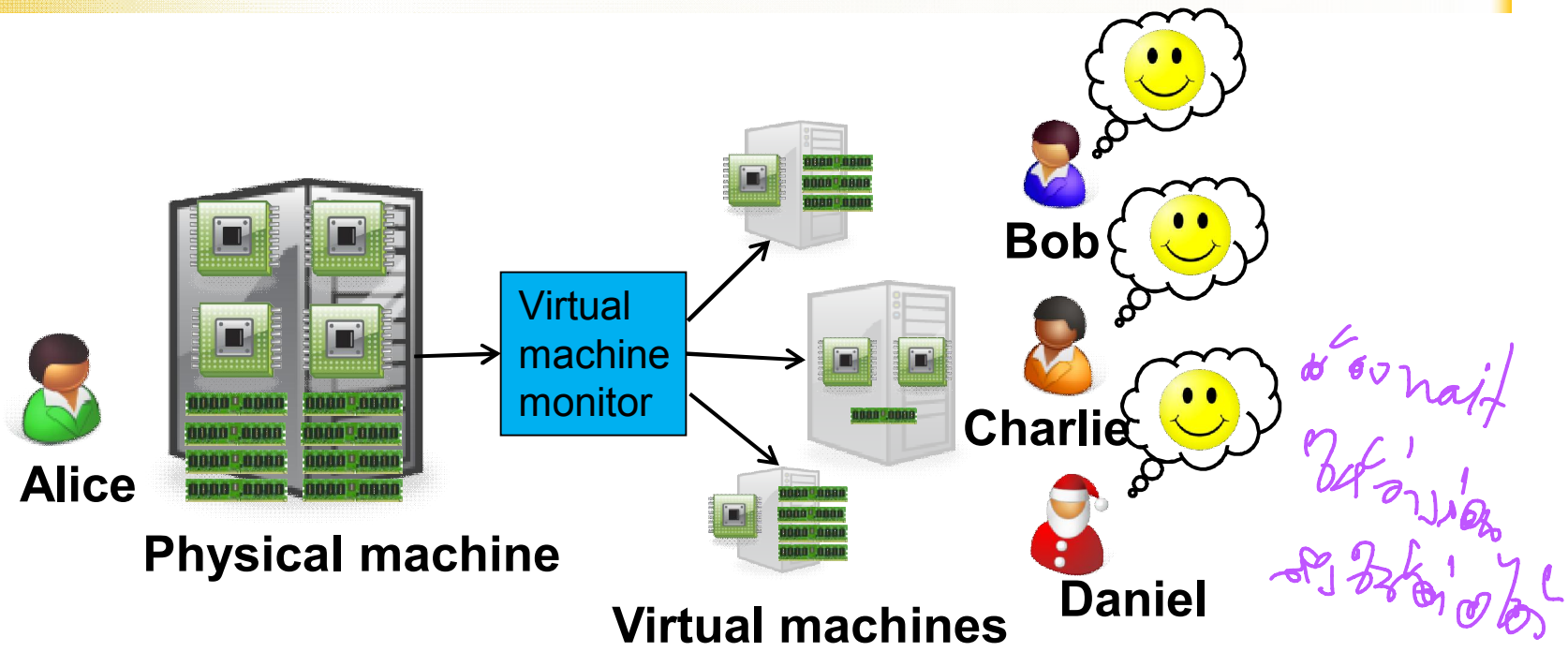
Sample Scenario



- Suppose Alice has a machine with 4 CPUs and 8 GB of memory, and three customers:
  - Bob wants a machine with 1 CPU and 3GB of memory
  - Charlie wants 2 CPUs and 1GB of memory
  - Daniel wants 1 CPU and 4GB of memory
- What should Alice do?

Server Virtualization

Sample Scenario



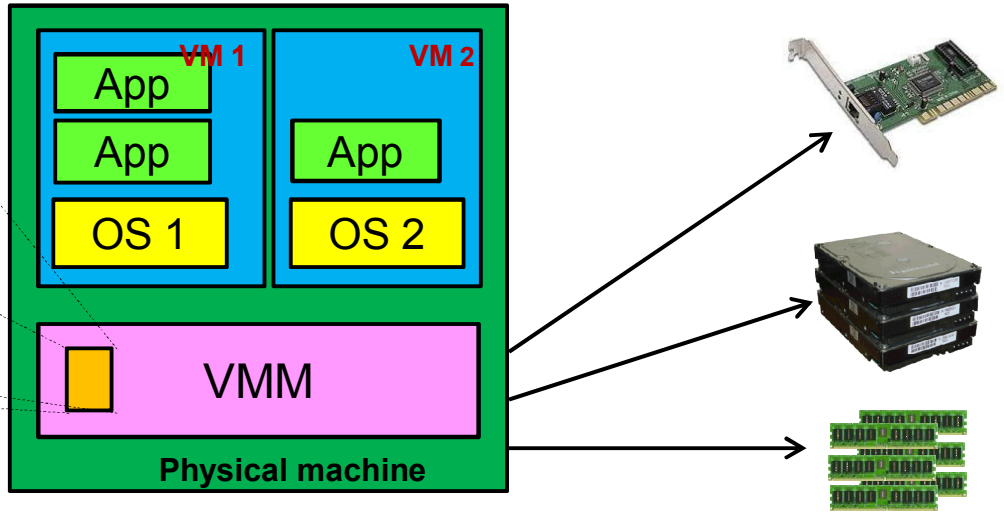
- Alice gives each customer a virtual machine (VM) with the requested resources
- From each customer's perspective, it appears as if they had a physical machine all by themselves (isolation)

Server Virtualization

Hypervisor (VMM)

VM	Virt	Phys
1	0-99	0-99
1	299-399	100-199
2	0-99	300-399
2	200-299	500-599
2	600-699	400-499

Translation table



split hardware to 2 parts

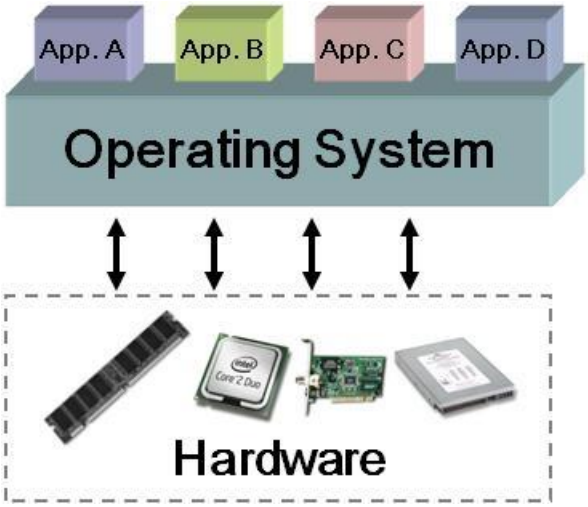
- Resources (CPU, memory, ...) are virtualized
- VMM ("Hypervisor") has translation table that maps each VM request for virtual to physical resources

help to map virtual and actual part.

Server Virtualization

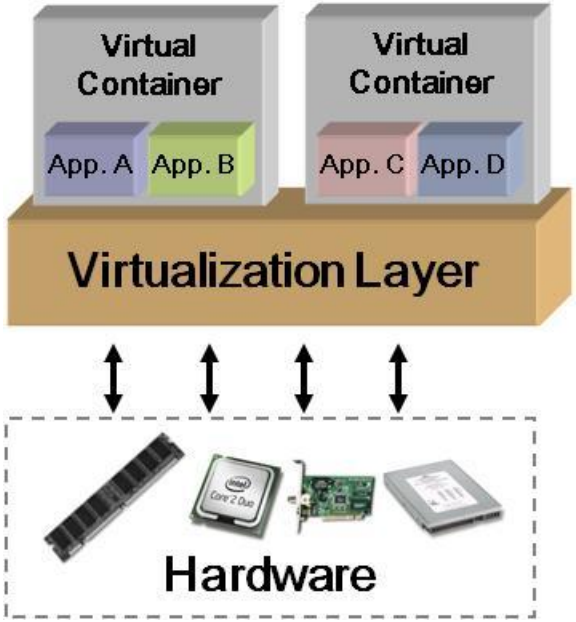
Non-Virtualized system

A single OS controls all hardware platform resources



Virtualized system

Multiple VMs on a single physical machine



Isolated VM

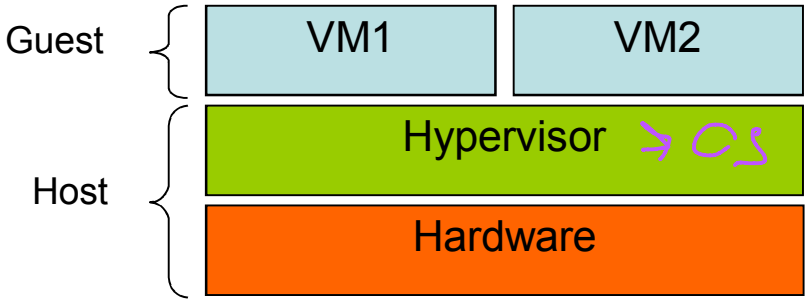
Hypervisor/ virtualization manager

to manage and monitor VMs

Server Virtualization

Two Hypervisor Types

bare-metal hypervisor



require some . . .

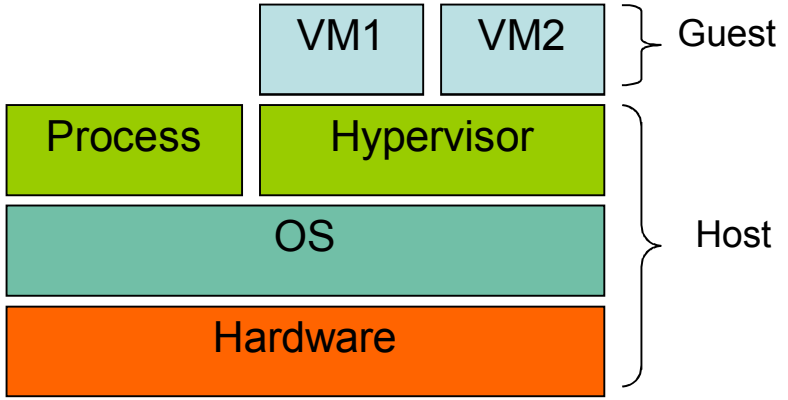
VMware ESX, Microsoft Hyper-V, Xen

Hypervisors run directly on the system hardware

- **More efficient and more secure**
- **Less hardware support**

less flexible.

hosted hypervisor



VMware Workstation, Microsoft Virtual PC, Oracle VirtualBox, QEMU, KVM

Hypervisors run on a host OS that provides I/O and memory management

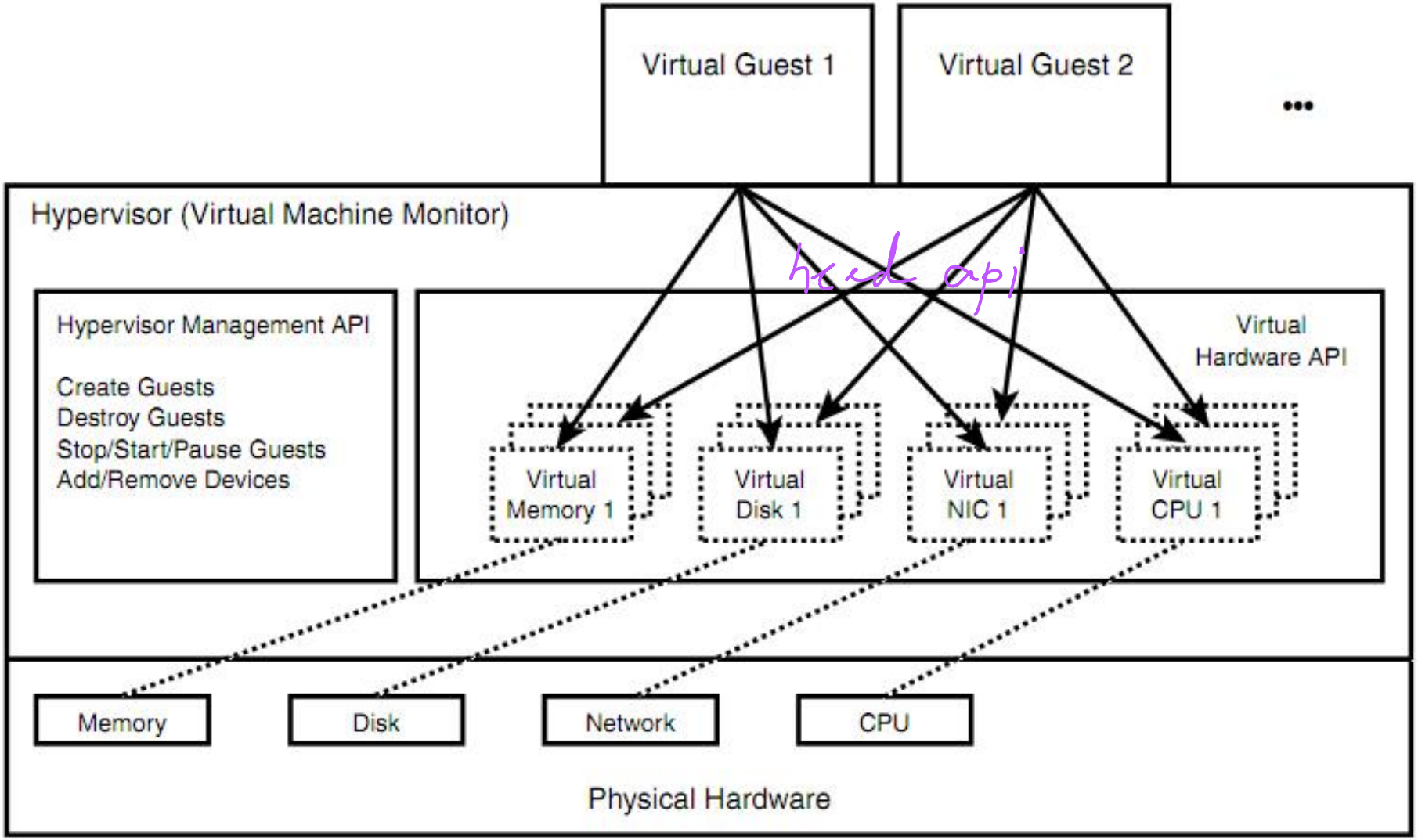
- **Easy to install and manage**
- **more overhead, less secure**

Server Virtualization Techniques

- *guest machine* is the virtual machine (VM)
- *Full virtualization* like ***VMWare***
  - Unmodified guest OS
  - Privileged instructions are translated into safe codes on the fly
  - Execution may slow
- *Para-virtualization* like ***Xen***
  - Modified guest OS and co-work with hypervisor
  - Any privileged instructions are replaced by hypervisor calls
- *Hardware-assisted virtualization (VT)* like ***KVM***
  - Unmodified guest OS
  - Require Intel VT-x or AMD-v support
  - Simplify VMM and give better performance

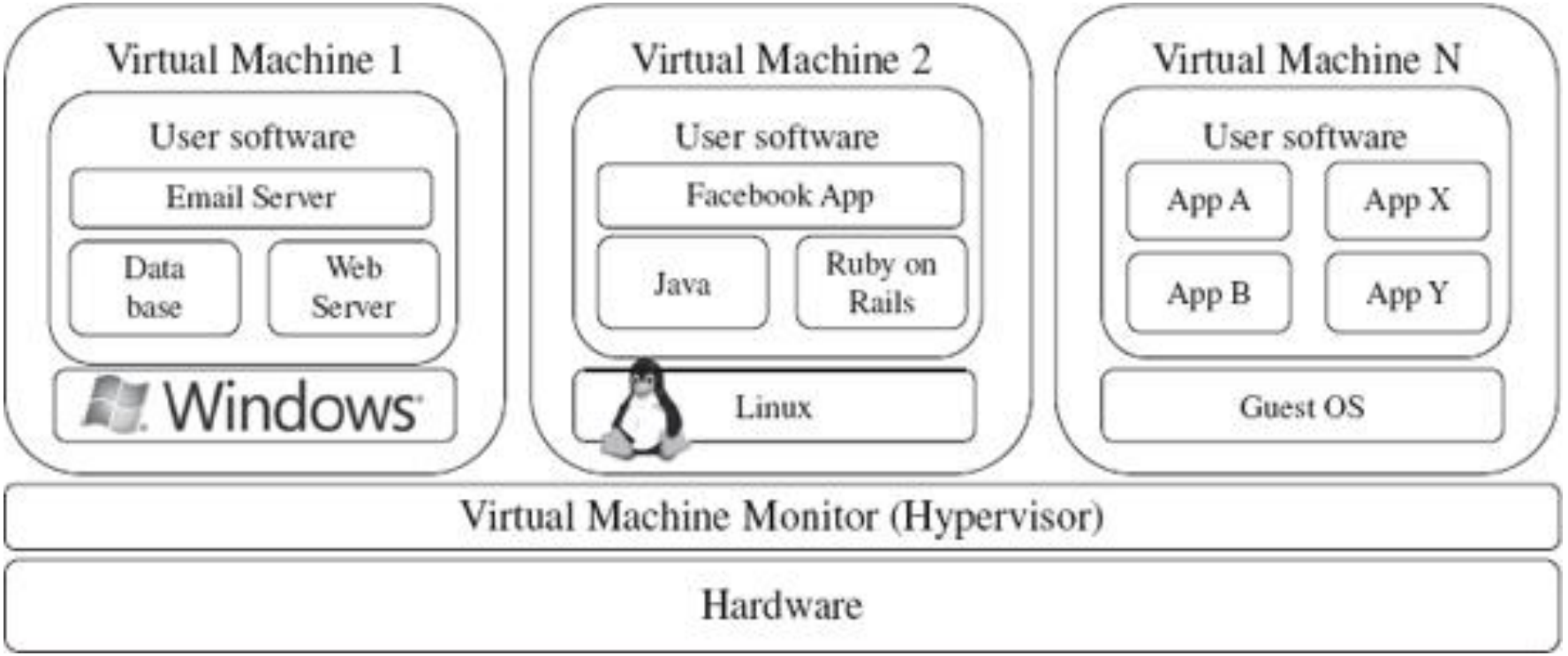
Server Virtualization

Hardware, Hypervisor and VM



Server Virtualization

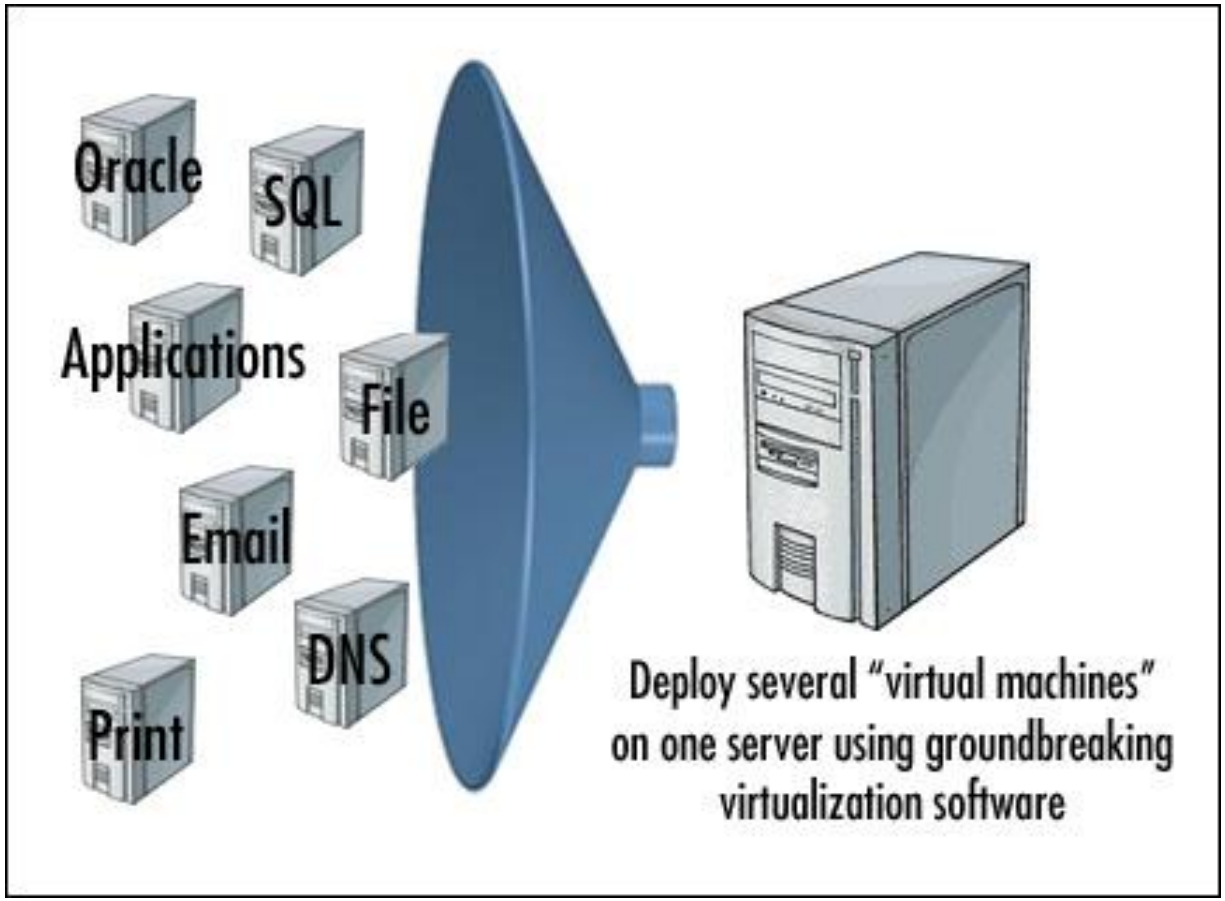
Guest Virtual Machines



Server Virtualization

Resource Consolidation

Run many logical (virtual) machines on the same physical machine and divide system resources between virtual machines



Server Virtualization

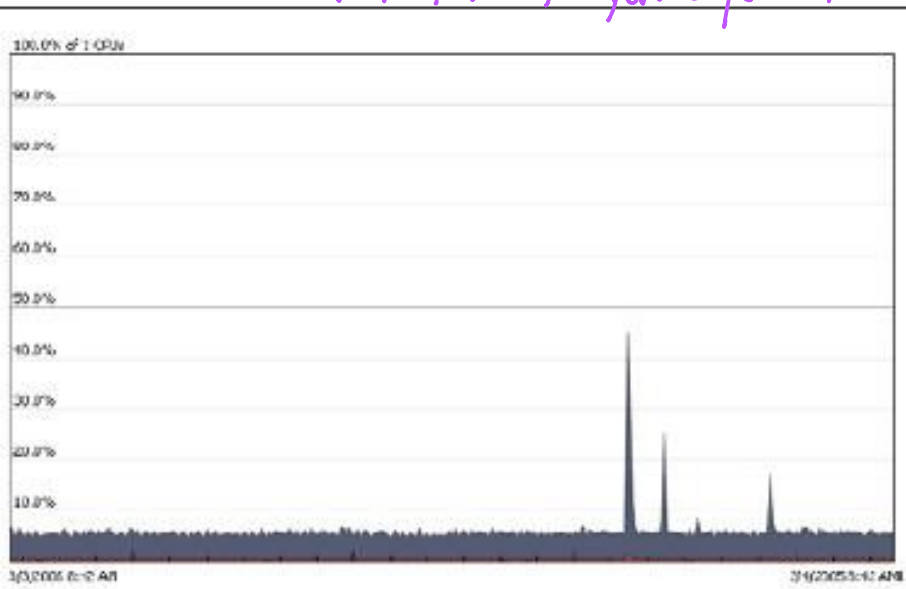
Higher Utilization การใช้งานที่สูงขึ้น

Consolidation of workloads from underutilized servers onto a single server to achieve higher utilization

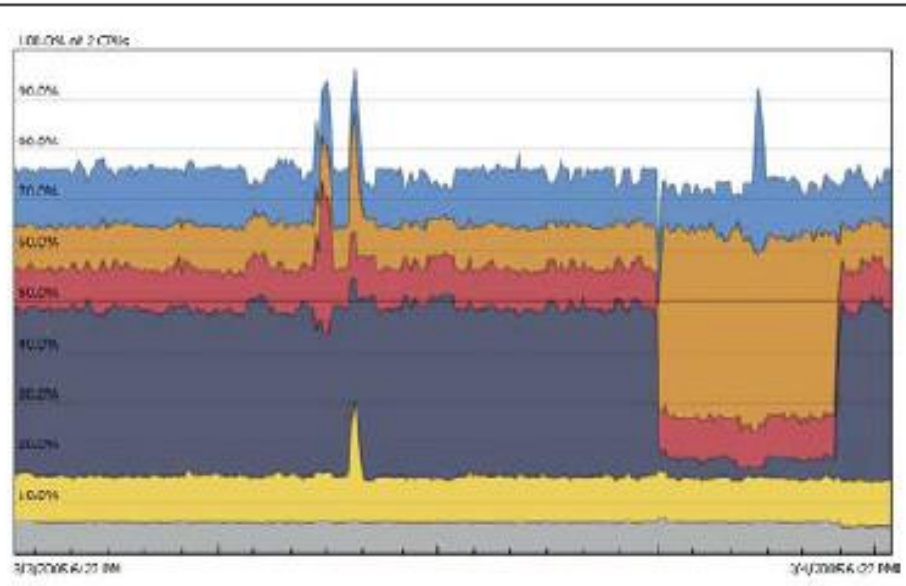
การรวมเวิร์กโหลดจากเซิร์ฟเวอร์ที่ใช้งานไม่ได้ไปยัง a เซิร์ฟเวอร์เดียวเพื่อให้เกิดการใช้ประโยชน์ที่สูงขึ้น

Can have virtization of systems.

Dedicated Server

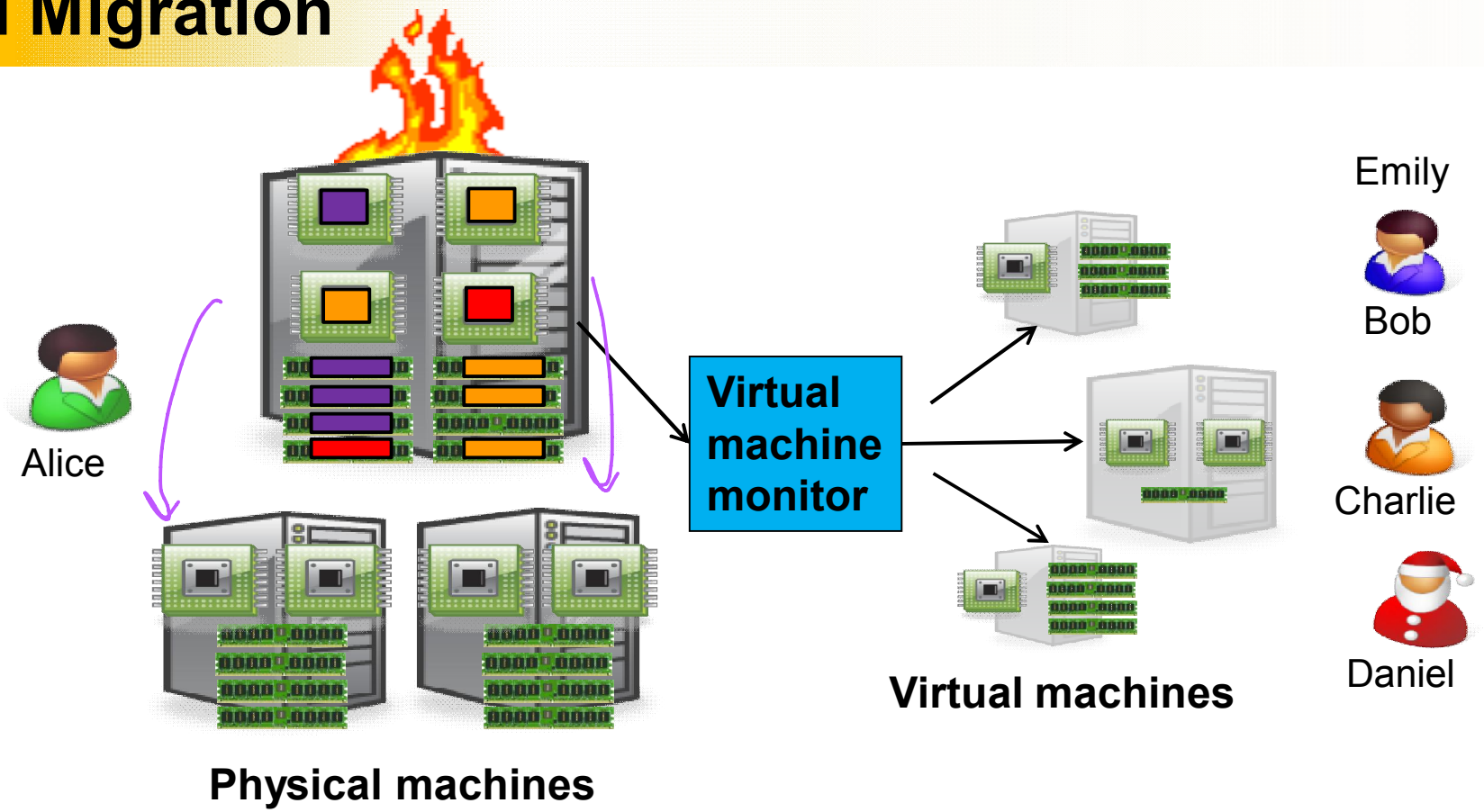


Virtualized Server



Server Virtualization

VM Migration

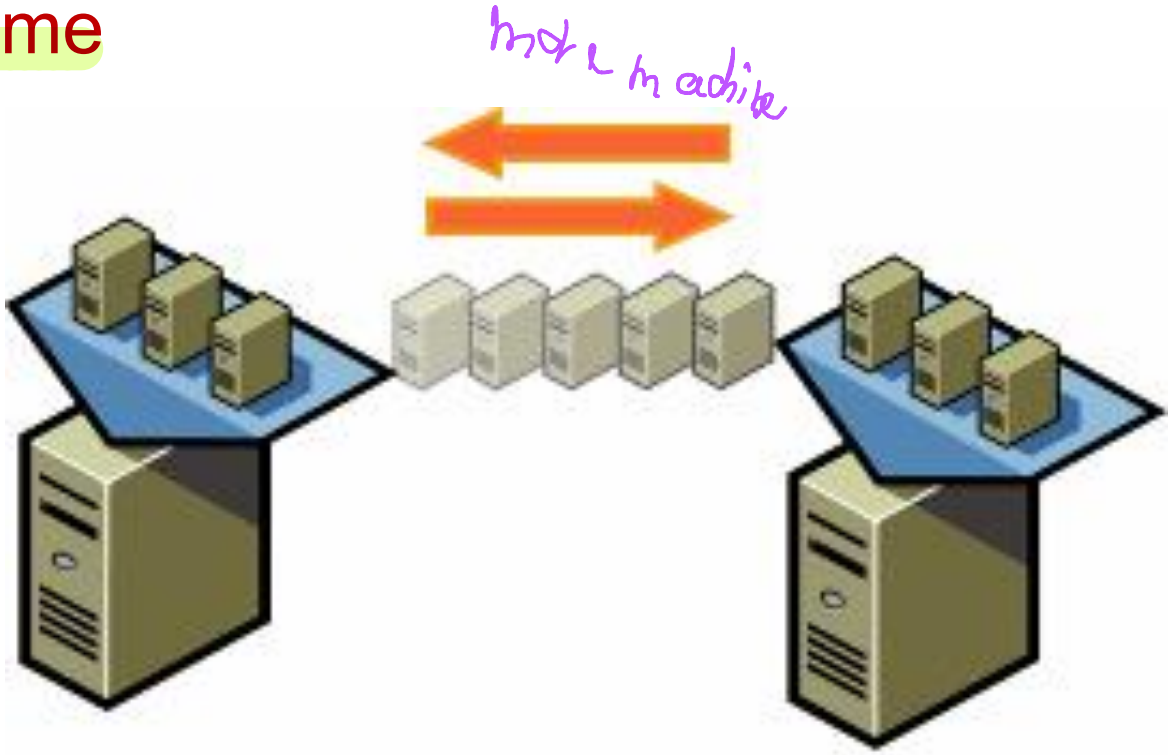


- What if the machine was shut down
- Alice can **migrate** a VM to another physical machine without any customer noticing

Server Virtualization

VM Migration

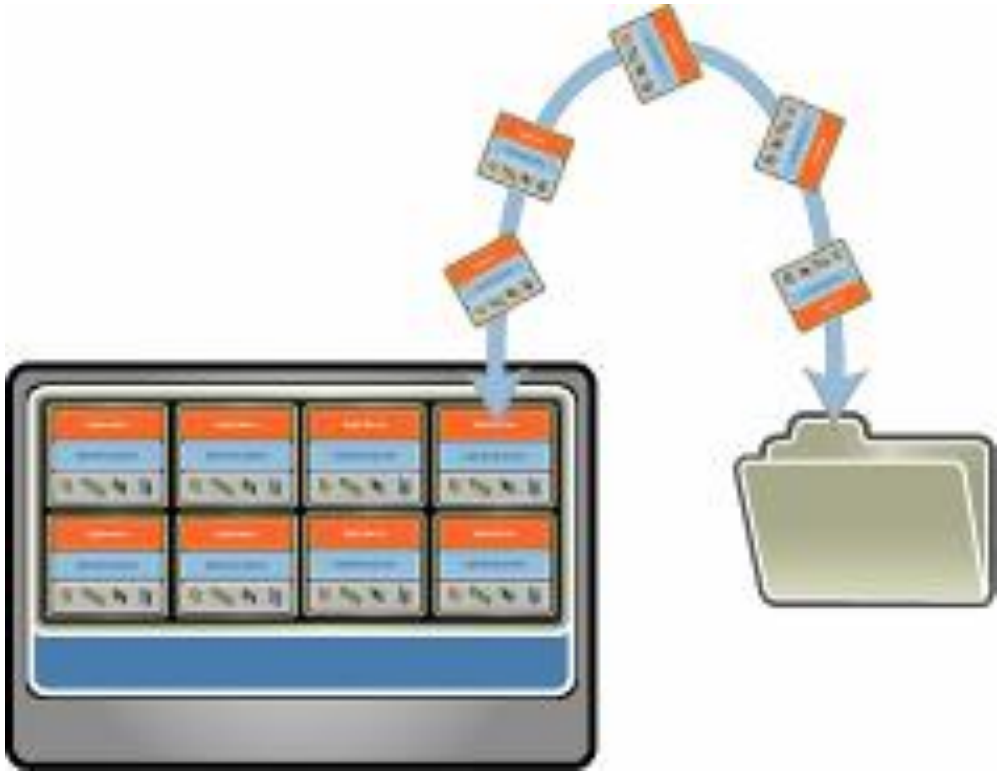
- Migrate a virtual machine to similar or different physical server
- Live migration of virtual machines with (almost) zero downtime



Server Virtualization

Snapshot as Backup

- Entire state of the virtual machine can be saved to files
- Move and copy virtual machines as easily as moving and copying files

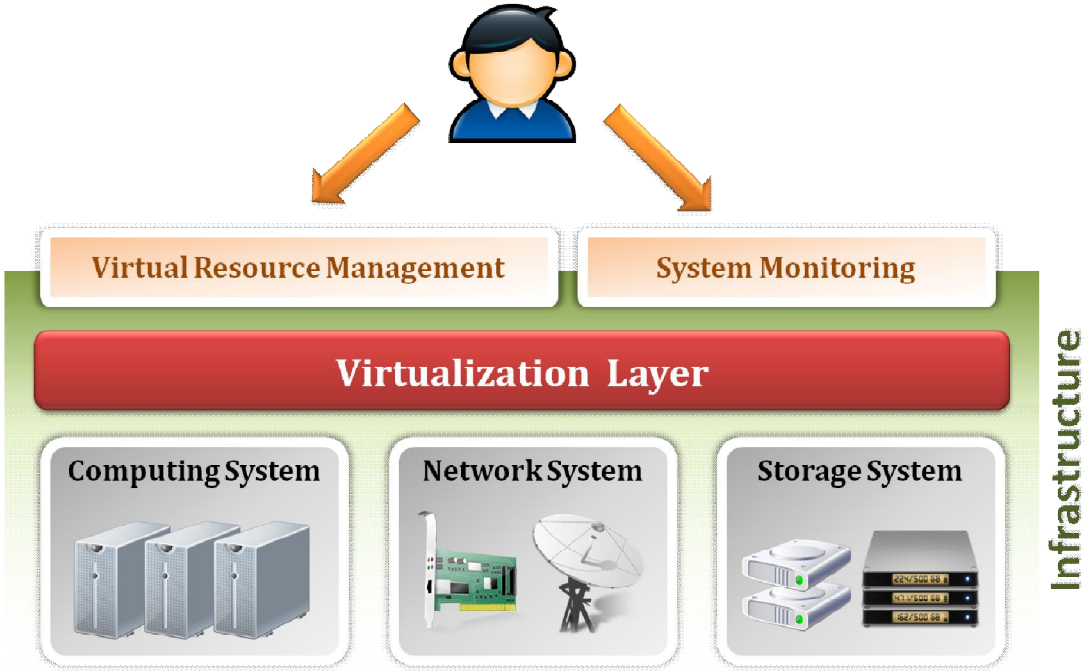


Server Virtualization

Summary

- **Virtualization** is an enabling technique to provide mapping of physical resources to multiple logical resources
- Virtual instances of IT resources: CPU, Memory, Network, Disk

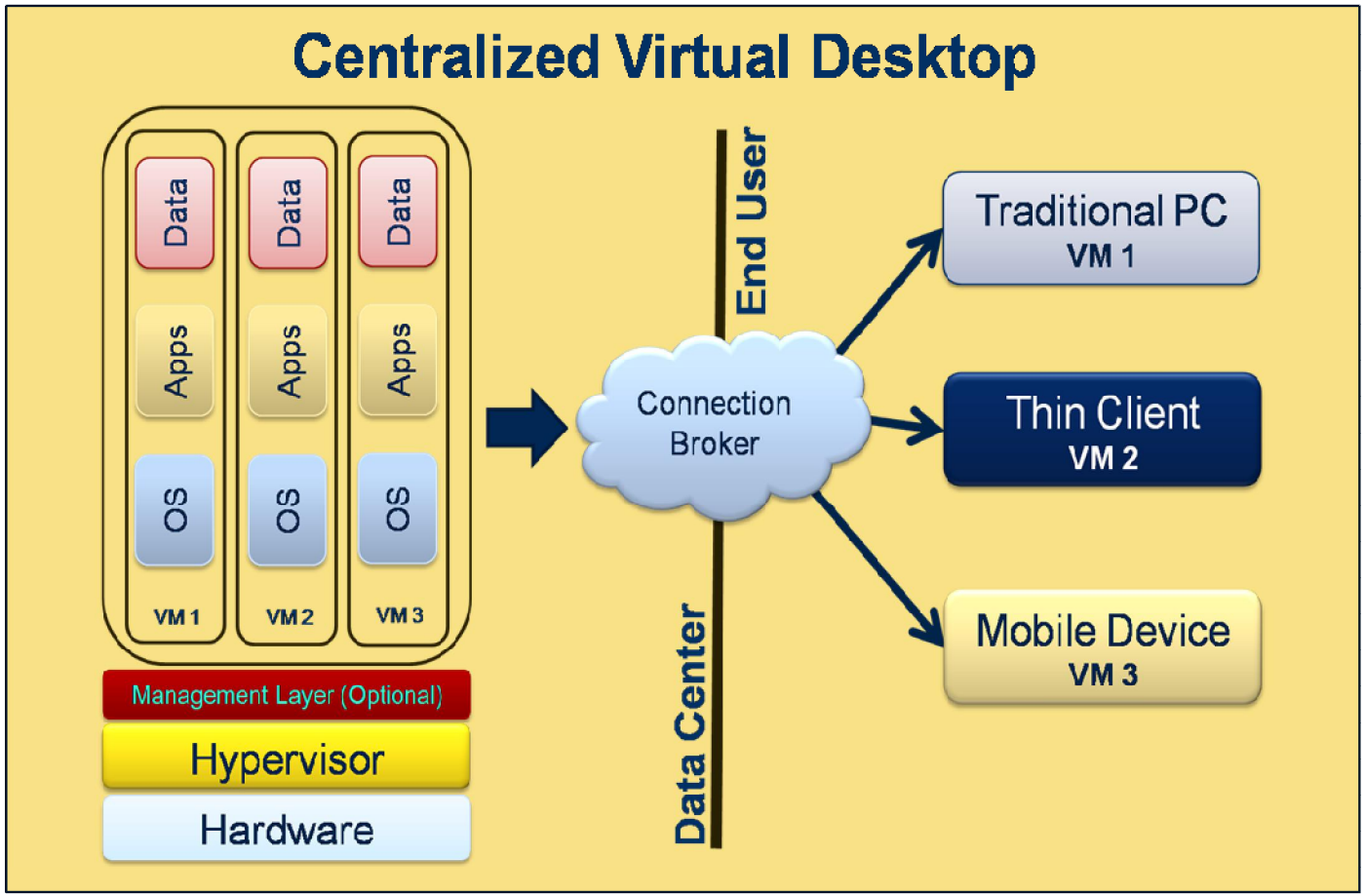
- **Isolate users from the underlying resources**
- **Isolate users from each other**
- **Isolate from fault and security**



Forms of Virtualization

Application Virtualization	• Application hosted in a datacenter and streamed to a desktop PC's • Ex: Citrix XenApp, Microsoft App Virtualization
Server Virtualization	• Hardware partitioning done on a server machines • Ex: VMware Server, VMware ESX, SUN xVM, Citrix Xen Server, etc
Desktop Virtualization	• Hardware partitioning performed on desktop machines • Ex: VMware workstations, Microsoft Virtual PC
Hosted Desktop Virtualization	• Desktop environment hosted in Datacenter & streamed to a thin client / PC. • Ex: VMware virtual Desktop Infrastructure (VDI), Microsoft Terminal Services
Operating System Virtualization	• The partitioning of system resources at the operating system level. • Ex: Parallels Virtuozzo, SUN Solaris Containers
Network Virtualization	• The logical segmentation of a physical network • Ex: VPN, VLAN
Storage Virtualization	• The pooling of multiple physical storage devices, often different types into a single logical device. • Ex: NAS gateway

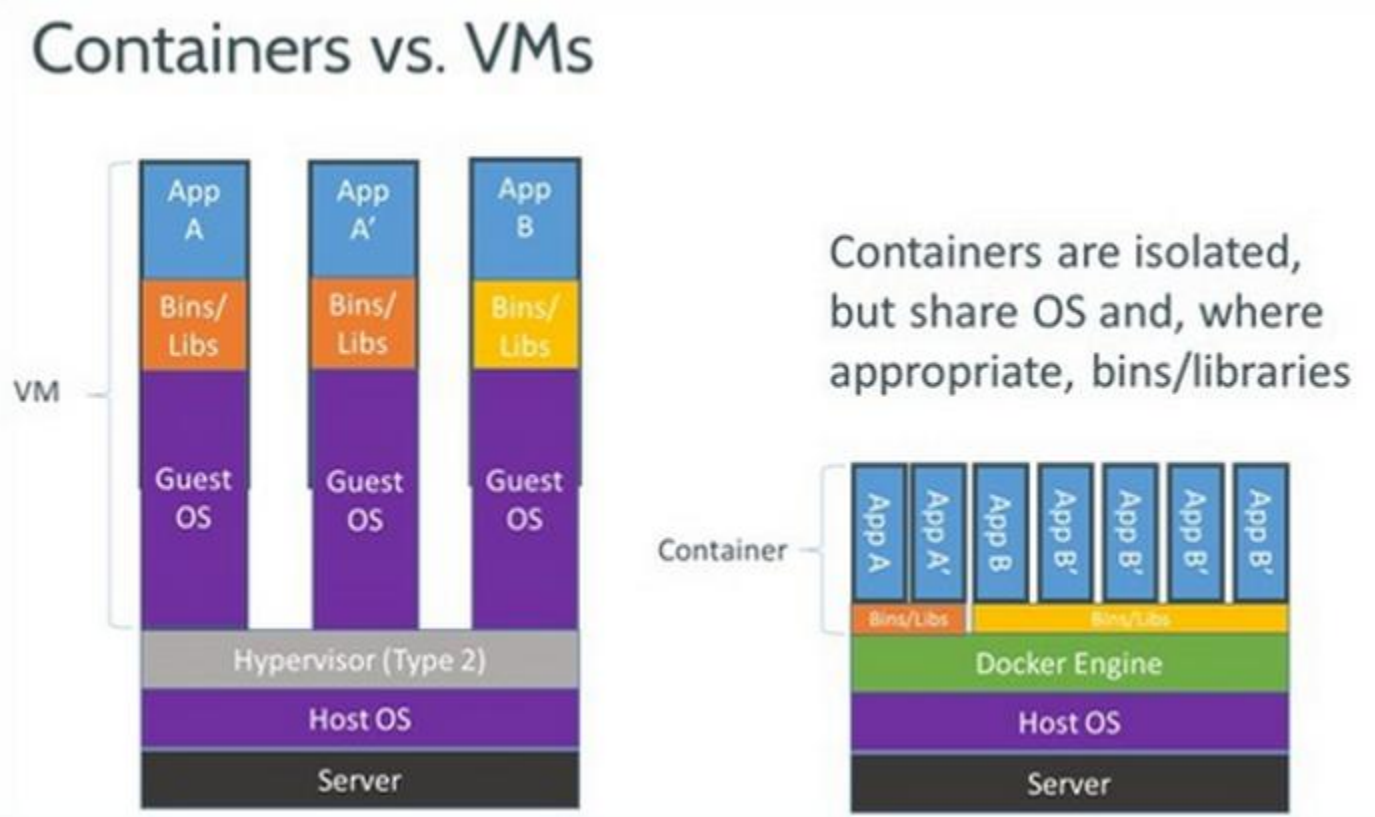
Desktop Virtualization



OS Virtualization

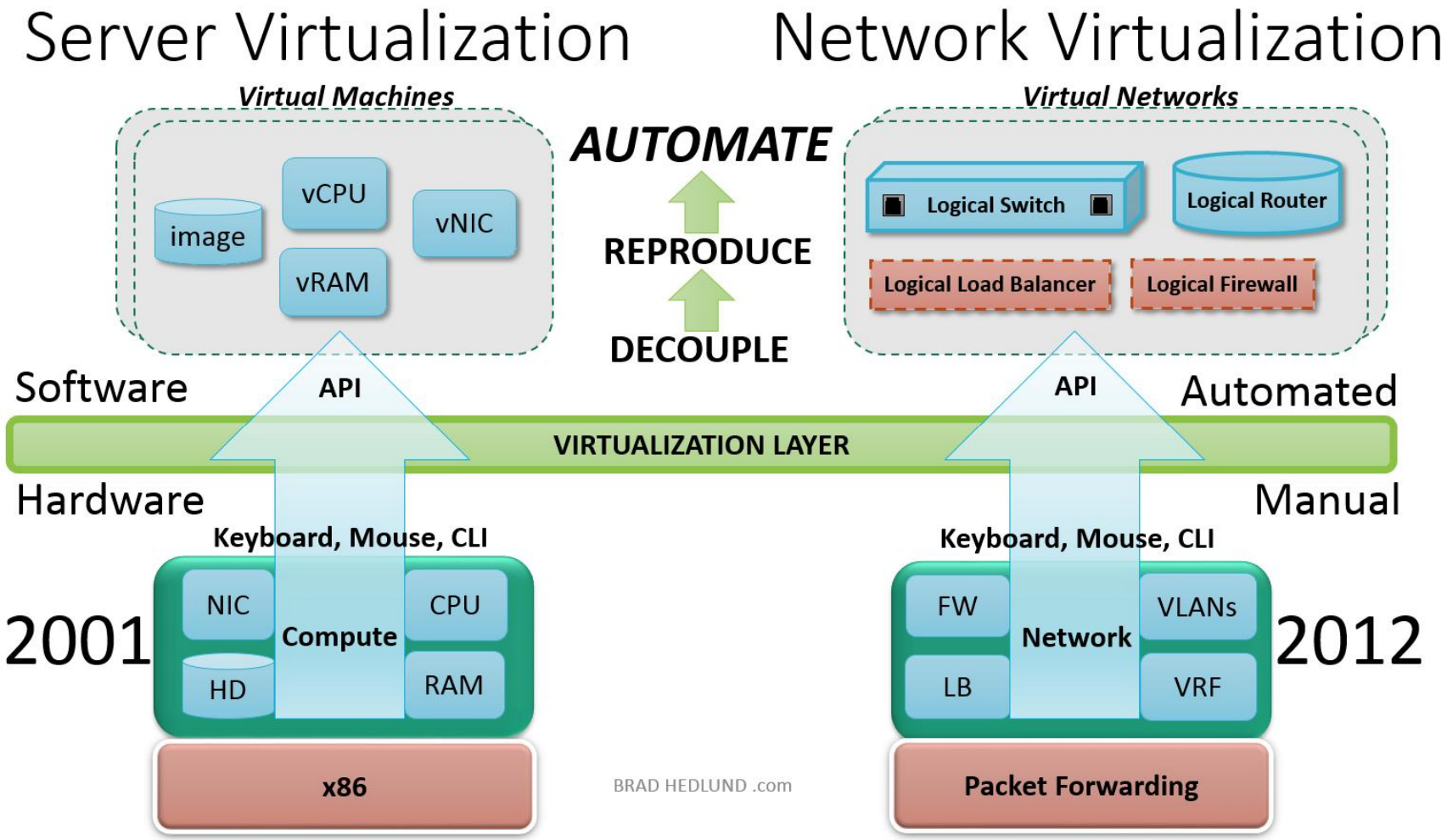
Container

- More light-weight than virtual machine
- Docker is popular



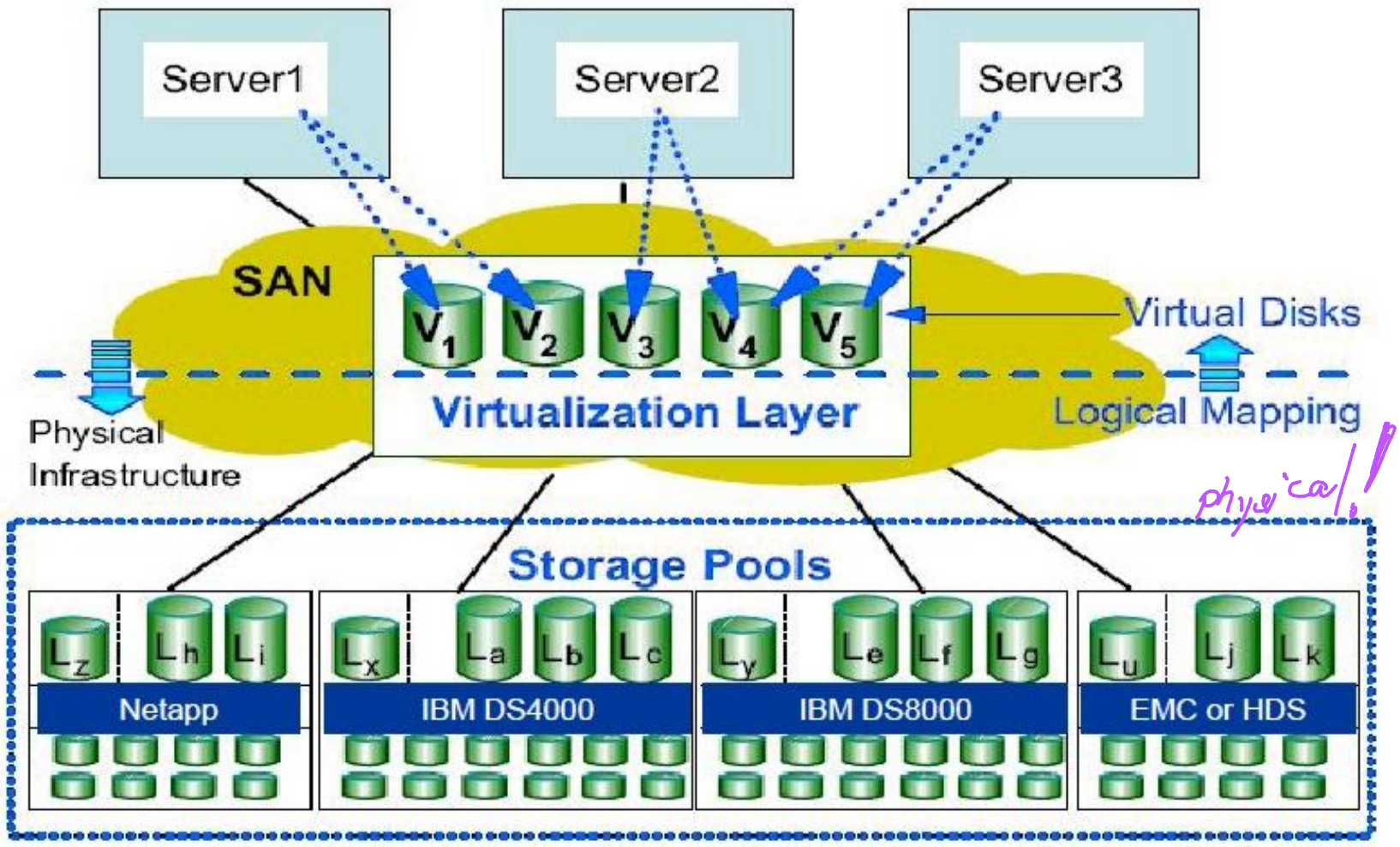
Network Virtualization

Virtual networks are placed on top of physical network elements



Storage Virtualization

Logical storage appears and behaves as physical storage directly connected to host, by combining multiple storage devices into a single storage pool



Virtualization in Cloud