UE17MC602
Cloud Computing

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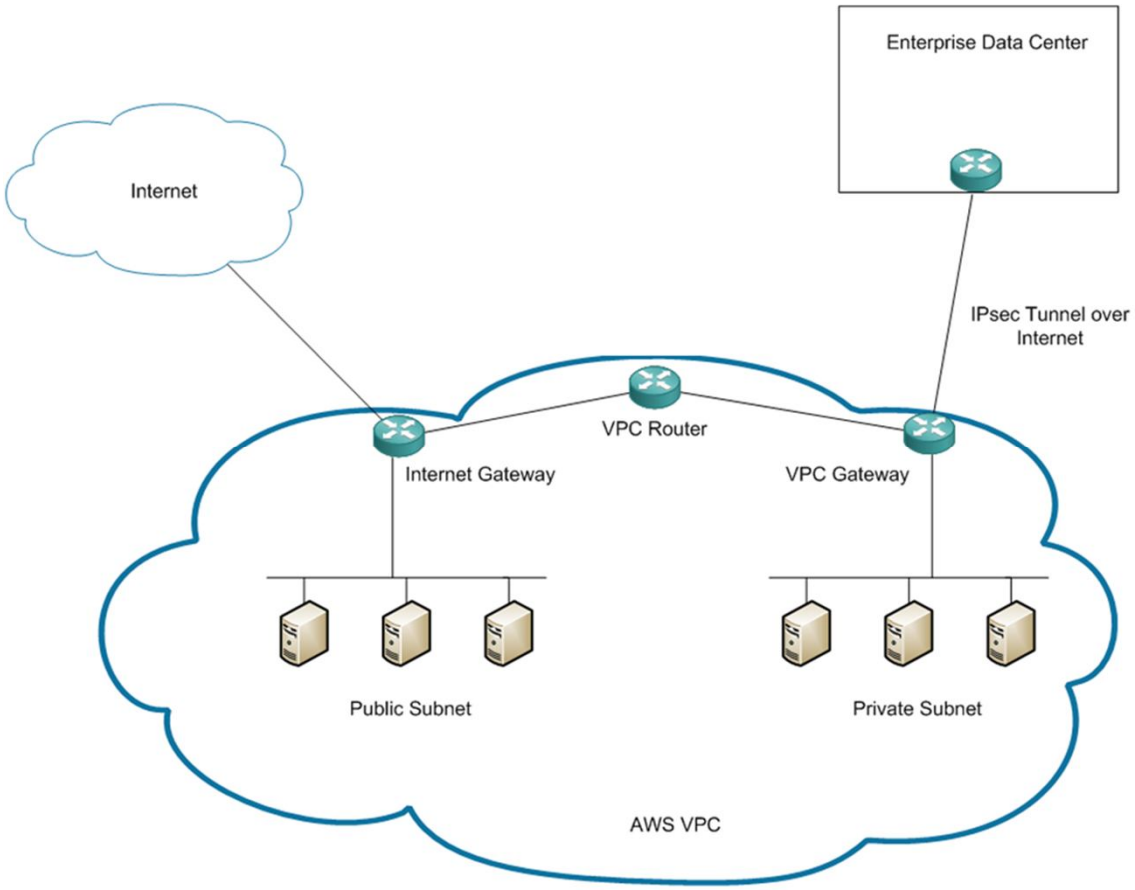
Questions

1. What Is Cloud Computing?
2. What are the facilities provided by the cloud?
3. What are the benefits of Cloud Computing?
4. Identify and explain different evaluation of web.
5. How semantic web and informatic explosion works?
6. Differentiate and describe Web 2.0 and Web 3.0.
7. What are the aspects of future evaluation?
8. Describe different characteristics of Cloud with example.
9. Explain virtualization concept and types with example.
10. How virtualization and cloud computing is related?
11. What is Hypervisor? Explain use of each types.
12. Explain cloud deployment model with example.
13. Explain different service models with example.
14. Name few market players and services provides in Cloud.

15. Explain Cloud Architecture with a neat diagram.
16. Describe the merits and demerits of using different business driver in cloud.
17. What are the technological challenges faced by cloud computing? Explain.
18. Describe multitenancy with an example.
19. Cloud application design principles in detail.
20. Following cloud application architectures
    A. Spark-based Architecture
    B. Lamda Architecture
    C. Kappa architecture
    D. Machine pipelining

- **Why the Name Cloud?**
- The term “Cloud” came from a network design that was used by network engineers to represent the location of various network devices and their inter-connection. The shape of this network design was like a cloud.



- **Cloud Gaming**
- Cloud gaming is an online game distribution.
- The most common methods of cloud gaming currently are video (or pixel) streaming and file streaming.
  - Cloud gaming, also in some cases called "**gaming on demand**
  - **E.g.** http://www.pubgonthecloud.com/,

    Play Station Now-PS4 , GeForce, Vortex, Paperspace
- **Everyday** life activities such as
  - Banking, Email, Media Streaming, and Ecommerce all use the Cloud.
- On the Business side, Applications, Infrastructure, Storage, Sales/CRM use **Cloud** services

- **What Is Cloud Computing?**
- *Cloud computing* is the on-demand delivery of IT resources and applications via the Internet with ***pay-as-you-go*** pricing.
- Whether you run applications that share photos to millions of mobile users or deliver services that support the critical operations of your business, the cloud provides rapid access to flexible and low-cost IT **resources**.
- With cloud computing, you don't need to make large **up-front investments** in hardware and spend a lot of time managing that hardware.
- Instead, you can provision exactly the **right type and size** of computing resources you need to power your newest bright idea or operate your IT department.
- With cloud computing, you can access as many resources as you need, almost instantly, and only pay for what you use.

Why Cloud?

- A Business Case of e-commerce industry
  - Amazon needs 1000 more servers during Diwali to accommodate high number of users visiting the website and after that period it does not need those servers.
- **Solution**
  - Cloud is the solution with dynamic ways to scale up and scale down the services when required
  - Cloud computing means data is stored at a remote place and is synchronized with other web information

Example

- Whenever you travel through a bus or train, you take a ticket for your destination and hold back to your seat till you reach your destination.

- Likewise other passengers also takes ticket and travel in the same bus with you and it hardly bothers you where they go.

- When your stop comes you get off the bus thanking the driver. Cloud computing is just like that bus, carrying data and information for different users and allows to use its service with minimal cost.

- **Advantages**
- In its simplest form, cloud computing provides an easy way to access **servers, storage, databases**, and a broad set of **application services** over the Internet.
- Cloud computing providers the own and maintain the network-connected hardware required for these application services, while you provision and use what you need for your workloads.
- a revolutionary shift in how technology
- how organizations budget and pay for technology services.
- To reconfigure the computing environment quickly to adapt to changing business requirements can optimize spending.
- Capacity can be automatically scaled up or down to meet fluctuating usage patterns.

- Services can be temporarily taken offline or shut down permanently as business demands dictate.
- In addition, with pay-per-use billing, AWS Cloud services become an operational expense instead of a capital expense.
- While each organization experiences a unique journey to the cloud with numerous **benefits**.

FIGURE 1.1 Six advantages of cloud computing

Six advantages of cloud computing

- **Variable vs. Capital Expense:** The ability to *trade capital expense for variable operational expense*. Instead of having to invest heavily in data centers and servers before knowing how you're going to use them.
- **Economies of Scale:** The *organizations benefit from massive economies of scale*. By using cloud computing, you can achieve a lower variable cost than you would get on your own. Thousands of customers use which translates into lower prices.
- **Stop Guessing Capacity:** The Company often end up either sitting on expensive idle resources or dealing with limited capacity. With cloud computing, organizations can *stop guessing about capacity requirements* for the infrastructure necessary to meet their business needs by scale-up or scale-down the resources.

- **Increase Speed and Agility:** In Cloud Computing New IT resources allows organizations to reduce the time it takes to make those resources available to developers from weeks to just minutes. This results in a dramatic *increase in speed and agility* for the organization.
- **Focus on Business Differentiators:** Cloud computing allows organizations to focus on their business priorities, instead of on the heavy lifting of racking, stacking, and powering servers. Organization can *stop spending money on running and maintaining data centers*.
- **Go Global in Minutes:** The ability to *go global in minutes*. Organizations can easily deploy their applications to multiple locations around the world with just a few clicks and satisfy customer needs.

Course Outline

Credits: 04	Contact Hours:56		Autonomy Course
Type of learning:	Apply based	40-50% practice sessions	Remaining Concept Learning
Evaluation Pattern			
	Components	CBT	Practical	Scale to
ISA:60	T1	20	20	20
	T2	10	30	20
	Assignment			10
	Deployment			10
ESA:40	Theory		40	15
	Exercise based Evaluation		60	25

Agenda

- Unit 1 - **Introduction**
- Unit 2 - **IaaS**
- Unit 3 - **PaaS**
- Unit 4 **- SaaS**
- Unit-5 –**Cloud for latest technologies**

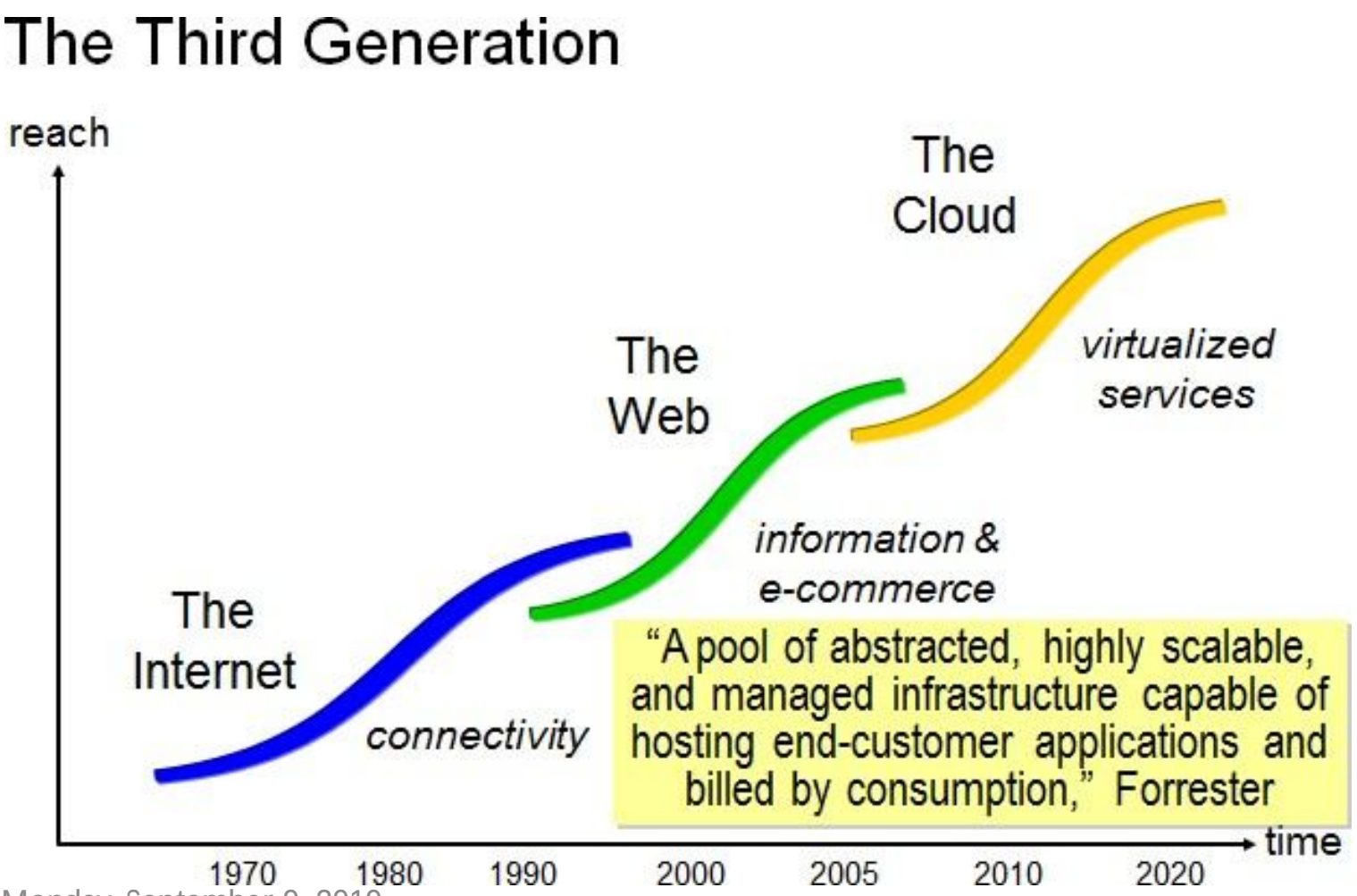
Reading Resources

- Text Books
  - Dinkar Sitaram & Geetha Manjunath, Moving to the cloud, Elsevier Publications, 2011. [Unit 1,2,3,4,5 Chapter 1 -4 , Chapter 7-9]
  - "AWS Certified Solutions Architect **Official Study Guide**", Joe Baron, Hisham Baz, John Wiley & Sons, Reprint 2017.
  - Aurobindo Sarkar & Amit shah, Learning AWS, Packtpublishing, second edition, 2018. [Unit 1 - Chapter 1]
- References
  - Srinivasan A & Suresh J, Cloud Computing: A PracticalApproach for Learning and Implementation, Pearson Education, 2014.

Unit 1

- Agenda
  - Evolution of the web
  - Cloud Computing
  - Cloud Deployment models
  - Business drivers for cloud computing
  - Cloud technologies – Service Models
  - Designing Multi-tenancy
  - Design principles
  - Emerging cloud based application architectures
  - Lab: Setting up your AWS account.

Where are we now?




websites
conventional
forums
content-providers
familiar
hierarchically-arranged
first-generation
programming-expertise
text-based
read
information
small-group
archived-listservs
common-entry
web
Web1.0
obtain
browse
directed

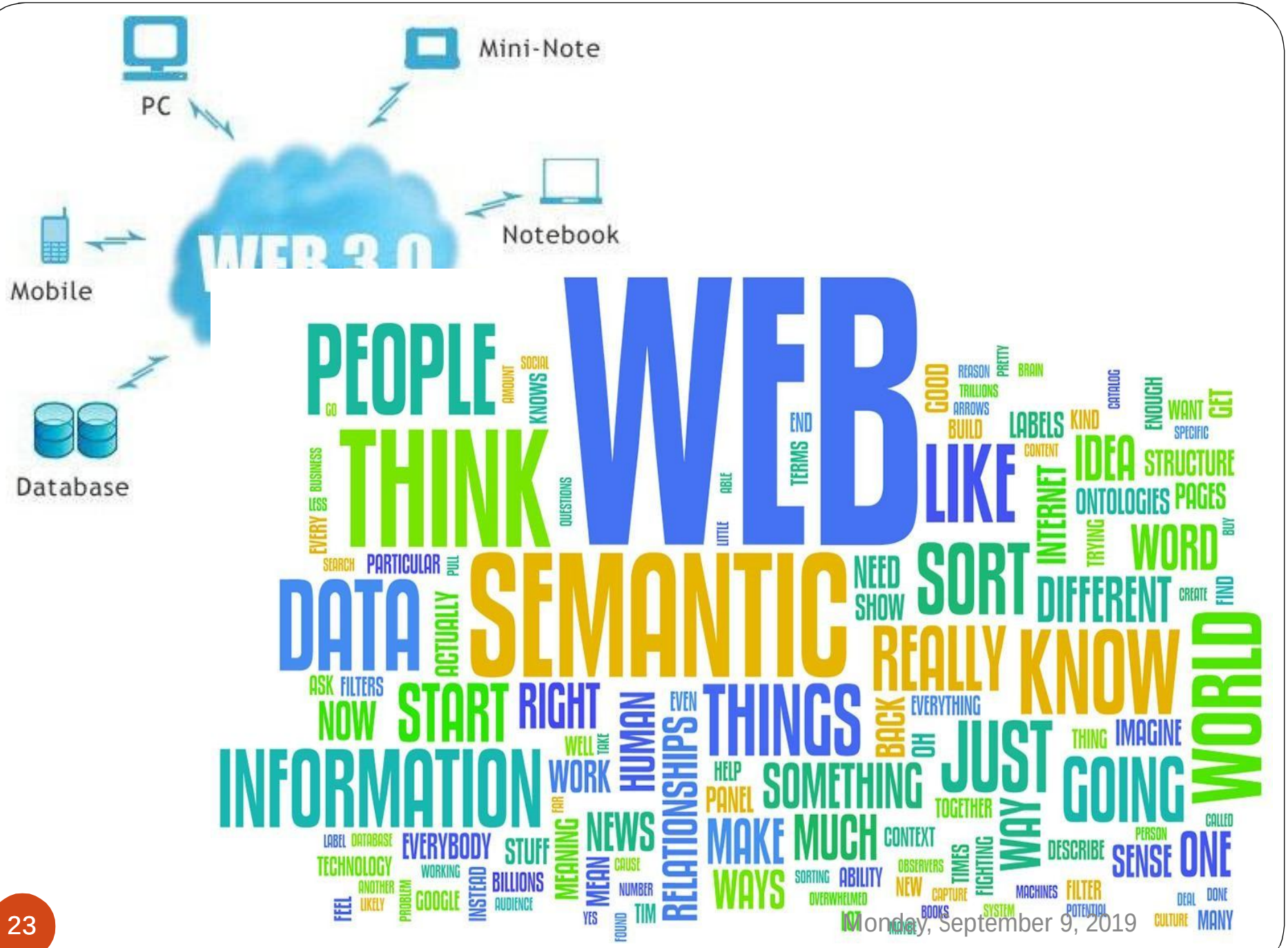
Evolution of the Web

- **Internet based computing** – 1990s – web 1.0
  - Displays information
  - Just a gigantic (huge) library
  - Read only
- **Web 2.0 and Social networking**
  - 2000s – rapid growth – Digital reality
  - Applications that allowed users to upload information to the web – user generated content
  - It looks like a Virtual world
  - Read and write – reviews, tags, ratings, annotations and blogs
  - Bcoz of this, Data is exploding – Hence Mining was ultimately required


INTERNET
COMMUNITIES
CREATIVITY
BLOGS
WWW
PRIVACY
WEB 2.0
NETWORK
WIKIS
VIDEO SHARING
INTERACTIVITY
SOCIAL NETWORKING
PARTICIPATION

- **Semantic Web - Web 3.0**
  - Information Explosion
    - Mobile devices made web accessible from anywhere, anytime and on any device
    - Google maps, location-based services, augmented reality applications….
    - Mobile devices are therefore computationally powerful having touch, accelerometer and other sensors
    - Mobile vendors are also providing cloud services (icloud, skydrive) to host app data and make available on multiple personal devices of the user.

- **Future Evaluation-** *aka the Cloud*
  - Cloud will continue to be a huge information source
  - Greater storage of personal data and profiles with immense interaction bring the digital world closer to the real world.
  - Mobility makes the Web available everywhere increasing intensity
  - Cloud platforms have already made it possible to harness large amounts of computing power to analyze large amounts of data.
  - The new applications will be accessible on multiple heterogeneous devices, including mobile devices


PC
Mini-Note
Notebook
Mobile
Database
WEB 3.0
WEB
SEMANTIC
PEOPLE
THINK
LIKE
DATA
INFORMATION
START
RIGHT
NOW
THINGS
REALLY
KNOW
SORT
DIFFERENT
WORLD
JUST
GOING
MAKE
MUCH
WAYS
SOMETHING
RELATIONSHIPS
HUMAN
WORK
NEWS
MEAN
MEANING
STUFF
EVERYBODY
TECHNOLOGY
GOOGLE
BILLIONS
INSTEAD
IDEA
STRUCTURE
ONTOLOGIES
PAGES
WORD
INTERNET
LABELS
NEED
SHOW
ONE
SENSE
DESCRIBE
IMAGINE
PARTICULAR
ACTUALLY
ASK
FILTERS
BACK
EVERYTHING
TOGETHER
PANEL
HELP
CONTEXT
TIMES
FIGHTING
MACHINES
FILTER
MANY
ENOUGH
WANT
GET
BUILD
GOOD
KIND
CREATE
FIND
TRYING
BUY
SEARCH
PULL
EVERY
BUSINESS
LESS
QUESTIONS
ABLE
LITTLE
TERMS
END
SOCIAL
KNOWS
AMOUNT
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PRETTY
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TRILLIONS
ARROWS
CATALOG
SPECIFIC
CONTENT
THING
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EVEN
FAR
LABEL
DATABASE
FEEL
ANOTHER
LIKELY
PROBLEM
WORKING
INSTEAD
AUDIENCE
CAUSE
NUMBER
TIM
YES
FOUND
SORTING
ABILITY
OBSERVERS
NEW
OVERWHELMED
CAPTURE
BOOKS
SYSTEM
POTENTIAL
DEAL
DONE
CULTURE
PERSON
CALLED

Scenario: Web 3.0 (Cheshire Constabulary)

- A recent report states that by use of face recognition software to analyze photos, one can discover the name, birthday, and other personal information about people from Facebook. E.g. grocery stores- CCTV
- Customer data that can be analyzed to derive great insights into the buying behavior, buying pattern and even methods to counteract competitors
- Businesses can use the location of people, together with personal information, to better serve customers, as certain mobile devices keep detailed logs of the location of their users.
- Due to all these reasons and more, the next generation Web, Web 3.0, has been humorously called "**Cyberspace looks at You"**

Web 2.0 vs Web 3.0

Feature	Web 2.0	Web 3.0
Communication	Interaction	Engaged / Invested
Information	Dynamic	Portable and personal
Focus	Community	Individual
Personal Interest	Blogs / wikis / social media	Livestreams
Content	Sharing	Exhibition
Interaction	Interacts with web applications	Interacts with smart applications
Searching	Keywords / tags	Context / relevance
Advertising	Interactive	Behavioural
Technologies	Flash, Java, XML	RDF, RDFS, OWL RDF – resource description framework OWL – ontology web language

In short

- Web 1.0 – sharing of information – one way
- Web 2.0 – interaction – two way
- Web 3.0 – Intelligent and omnipresent (widespread) – three way (web server interacts intelligently)

Current/Future Evolution

- More sophisticated applications that can analyse the data stored in the cloud
- More intelligent and rich user interactive applications is quite possible
- The user should not bother about the infrastructure, platform, libraries and application deployment
- It should be automated and abstracted
- Business can leverage cloud computing is through the **wisdom of crowds** for better decision making

E,g. - The Hollywood Stock Exchange (**HSX**) is an online game that is a good example of crowd wisdom

Why Cloud?

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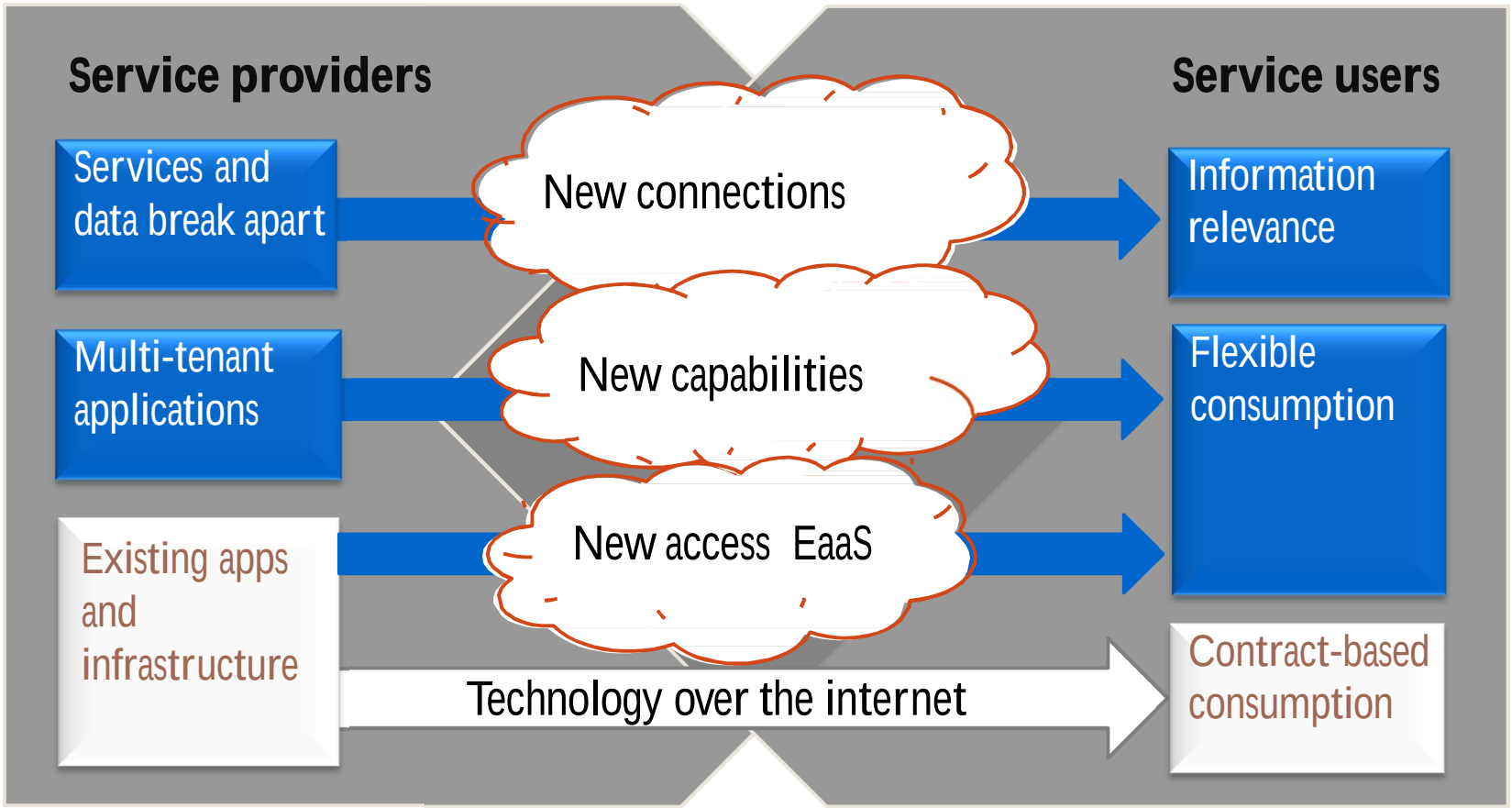
News

- **Prepping ForThe Inevitable MoveToThe Cloud**
- Venkat Malladi - Co-founder/CTO at Vymo. Former member of the Google Mobile team. Alum of BITS Pilani and Columbia University-May 18, 2018, 09:30am @ community voice, Forbes Technology council
- 50% of the global enterprises rely on cloud
- AI and machine learning will be the leading catalysts (67%) that will drive adoption of cloud technologies by the year 2020.
- 83% of the enterprise workload will be on the cloud by that same year, with 41% of the workload running on public cloud platforms (up from the current 31%).

“Facepalm”

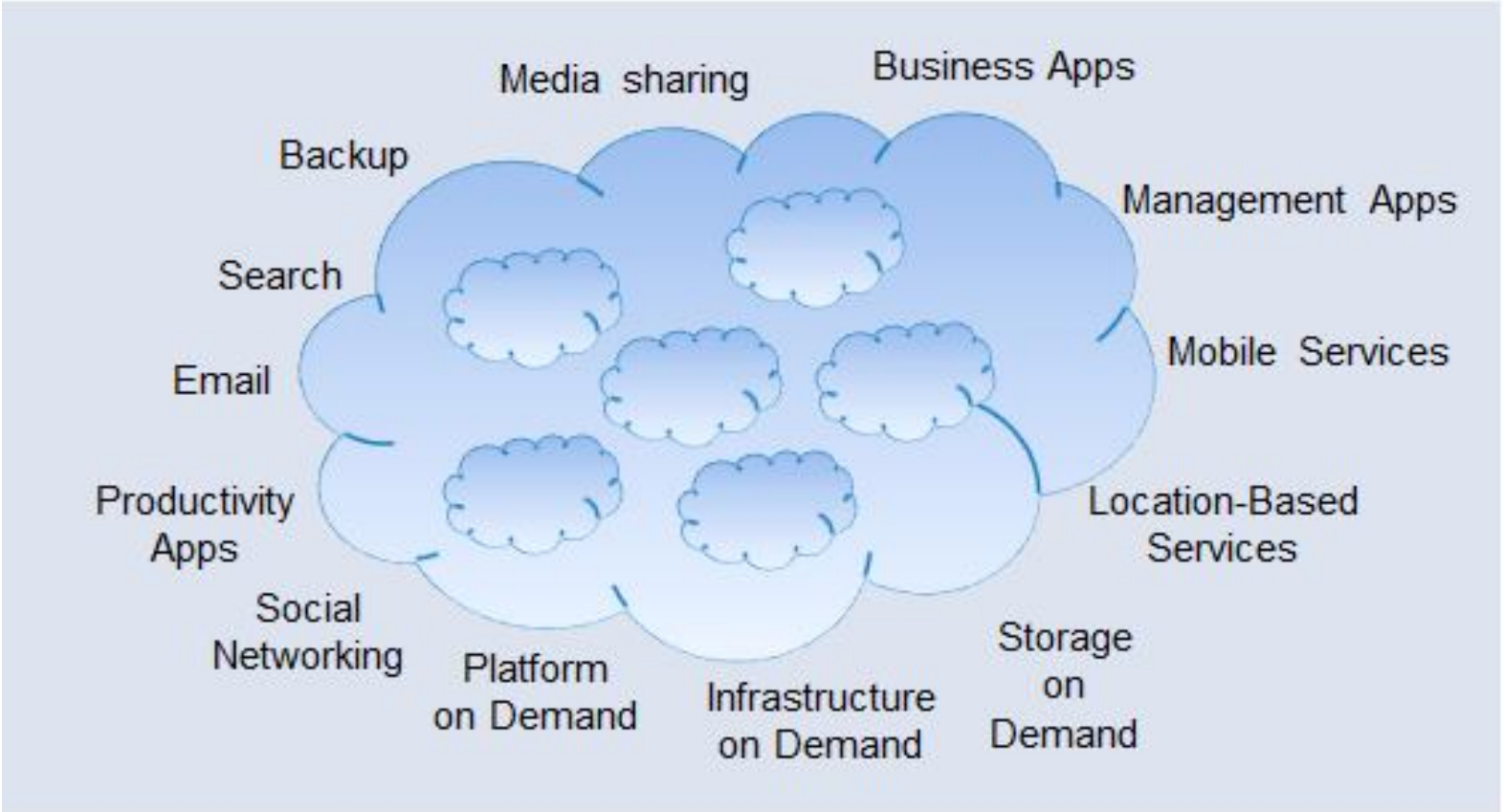
The cloud (r)evolution: solving problems that current technology models can't solve



What is Cloud Computing?

- Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort service provider interaction.
  - NIST- US National Institute of Standards and Technology

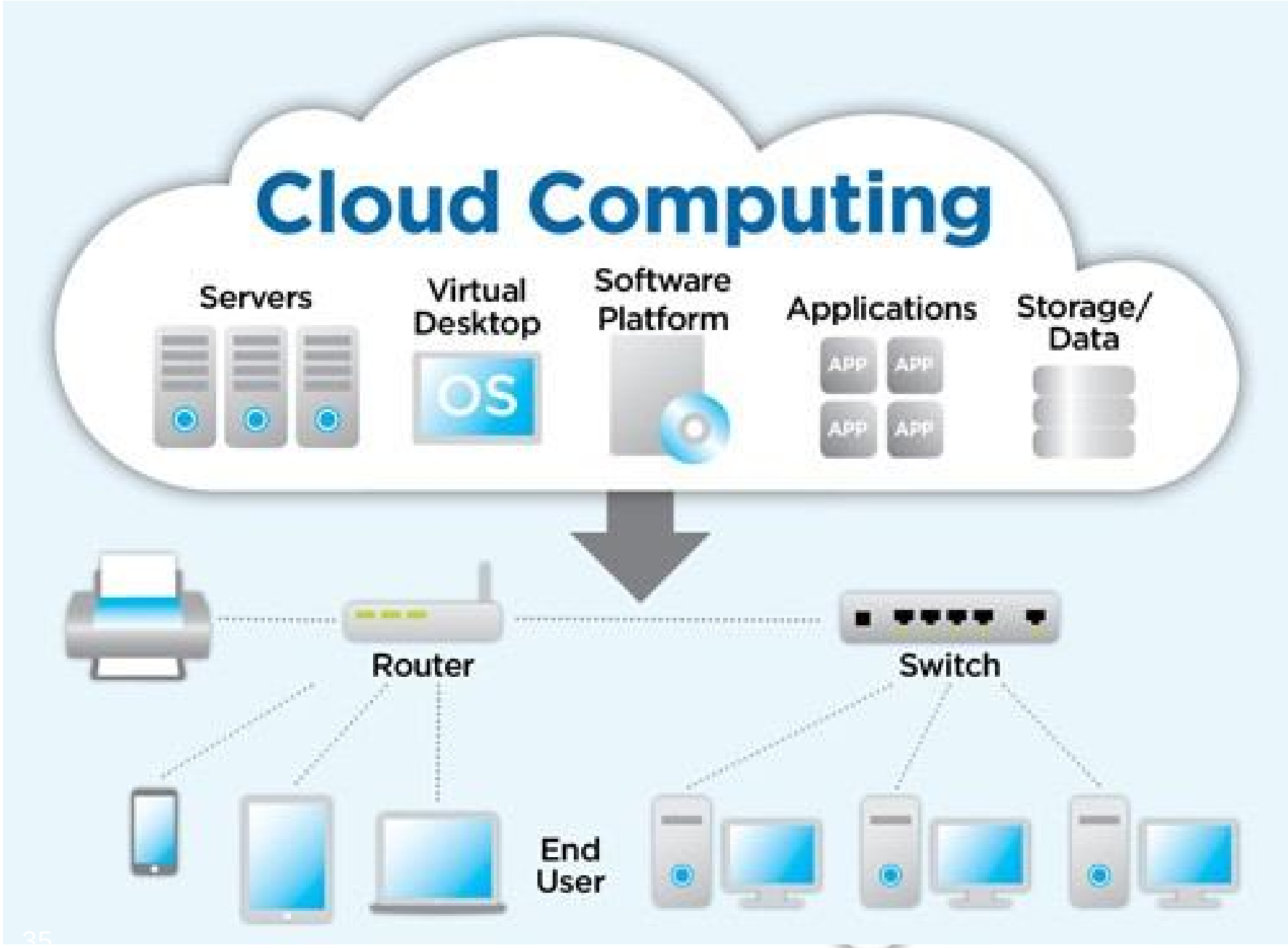
Everything as a Service



Cloud Computing Means Many Different Things To Different People

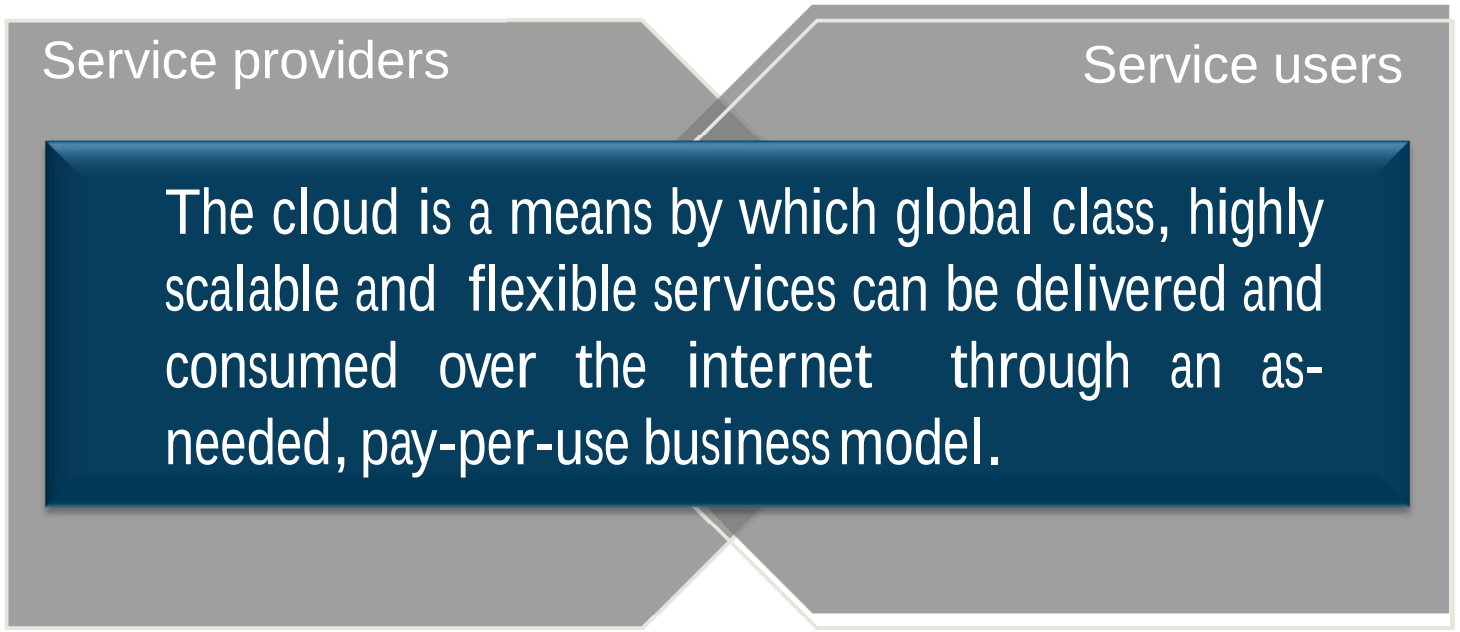
Characteristics of Cloud

- On-demand – compute, storage or platform are self provisioned or auto provisioned
- Broad network access - Ubiquitous access from desktops, laptops or mobiles – develop light applications
- Resource pooling – share resources (h/w) - millions of concurrent users eg: skype, facebook
- Rapid elasticity –increase or decrease the computing resources as needed
- Measured service –pay as you go
- Resiliency – the capacity to recover from failures

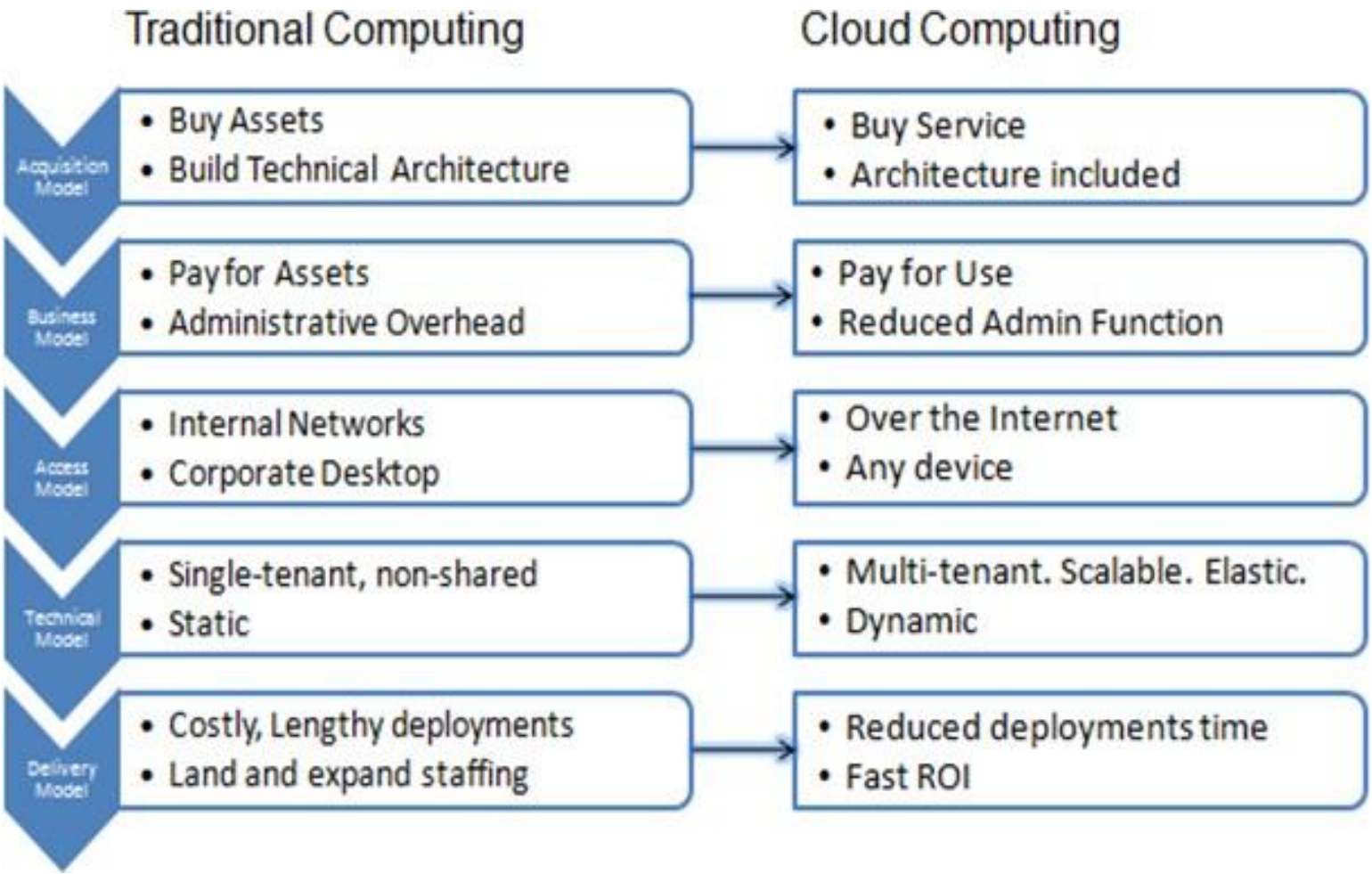


From http://blogs.zdnet.com/Hinchcliffe

What do we mean by cloud?



Traditional Vs Cloud Computing



Major components of Cloud

- Concept -Virtualization

OS Virtualization

- **Virtualization** is the "creation of a virtual (rather than actual) version of something, such as a server, a desktop, a storage device, an operating system or network resources".
- Virtualization provides a standard operating system so that it can run different applications handled by multiple users on a single computer at a time.
- The operating systems do not interfere with each other even though they are on the same computer.
  - Decoupling OS from the Hardware and applications
  - Advantage: Fail in hardware will not affect the software.

What is the concept behind the Virtualization?

- Creation of a virtual machine over existing operating system and hardware is known as Hardware Virtualization. A Virtual machine provides an environment that is logically separated from the underlying hardware.
- The machine on which the virtual machine is going to create is known as **Host Machine** and that virtual machine is referred as a **Guest Machine**

Types of Virtualization:

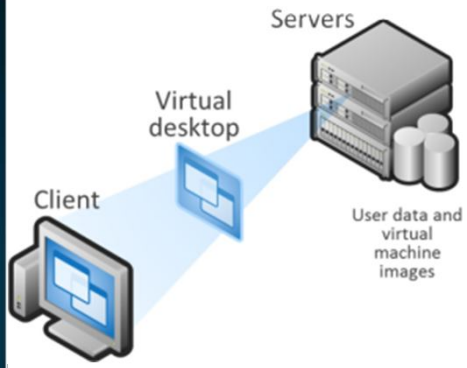
- Network Virtualization
- Storage Virtualization
- Server Virtualization.
- Hardware Virtualization.
- Operating system Virtualization..

Virtualization vs. Cloud Computing

- Virtualization changes the hardware-software relations and is one of the foundational elements of cloud computing technology that helps utilize cloud computing capabilities to the full.
- Cloud computing refers to the service that results from that change.
- It describes the delivery of shared computing resources, SaaS and on-demand services through the Internet.
- Virtualization and cloud computing work together to provide different types of services

Virtualization types explanation

- **Network virtualization** in cloud computing is a method of combining the available resources in a network by splitting up the available **bandwidth** into different channels, each being separate and distinguished. They can be either assigned to a particular server or device or stay unassigned completely.
- **Storage Virtualizing** gives the user an ability to pool the hardware storage space from several interconnected storage devices into a simulated single storage device that is managed from one single command console. This storage technique is often used in storage area networks.



Virtualization

Hardware	Network	Storage	Memory	Software	Data	Desktop
• Full • Bare-Metal • Hosted • Partial • Para	• Internal Network Virtualization • External Network Virtualization	• Block Virtualization • File Virtualization	• Application Level Integration • OS Level Integration	• OS Level • Application • Service	• Database	• Virtual desktop infrastructure • Hosted Virtual Desktop

- **Server Virtualization** is the masking of server resources. It simulates physical servers by changing their identity, numbers, processors and operating systems. It also makes a lot of resources available for sharing and utilizing, while maintaining the capacity to expand them when needed.
- **Data Virtualization** is abstracting the technical details usually used in data management, such as location, performance or format that are directly related to business needs.

Virtualization merits and demerits

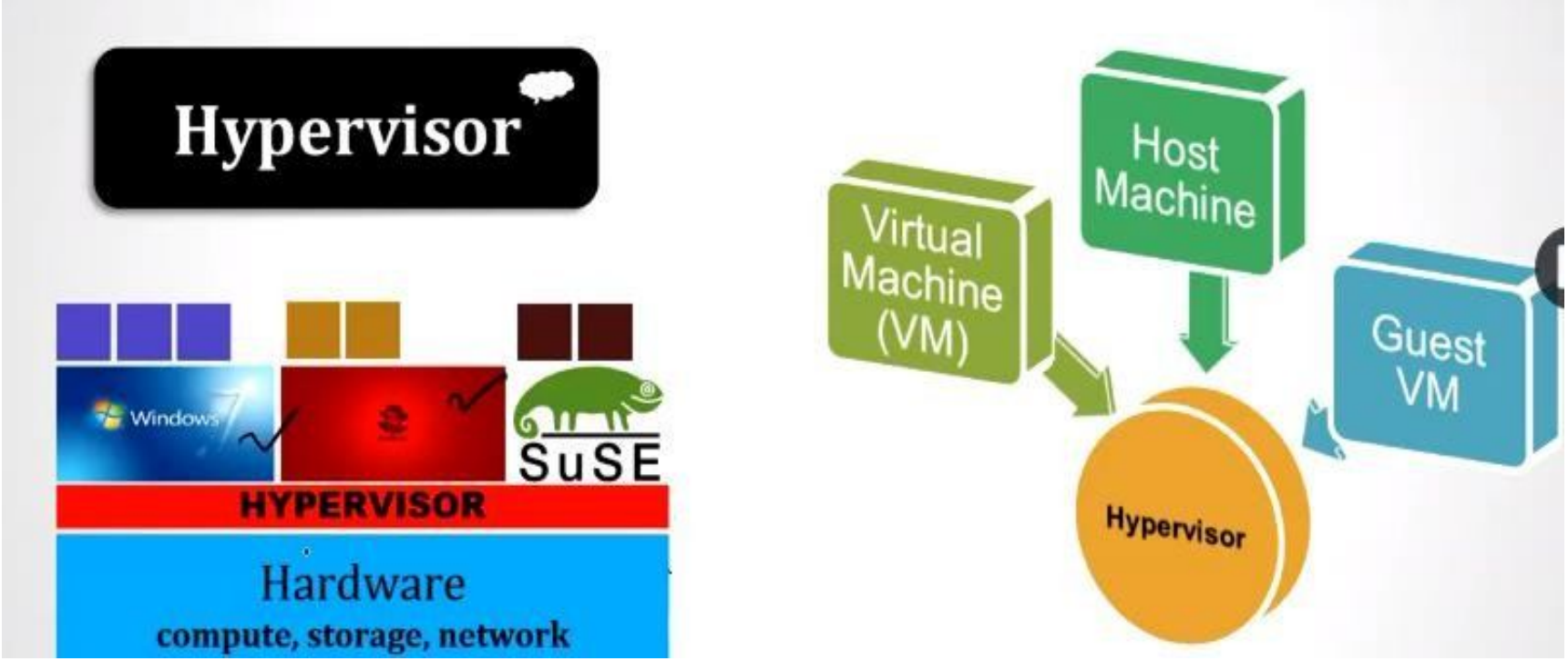
- There are many benefits of Virtualization, like it optimizes hardware resource utilization, saves energy and costs and makes it possible to run multiple applications and various operating systems on the same SERVER at the same time. Provides ability to manage resources effectively.
  - Increases efficiency of IT operations.
  - Provides for easier backup and disaster recovery.
  - Increases cost savings with reduced hardware expenditure.
- **Disadvantage**s of virtualization are almost negligible when compared to the multiple advantages it offers.
- Software licensing costs.
- Necessity to train IT staff in virtualization

- **Desktop Virtualizing** you to emulate a workstation load, rather than a server. This allows the user to access the desktop remotely. Since the workstation is essentially running in a data centre server, access to it can be both more secure and portable.

- **Application Virtualization:** Software virtualization in cloud computing abstracts the application layer, separating it from the operating system. This way the application can run in an encapsulated form without being dependant upon the operating system.

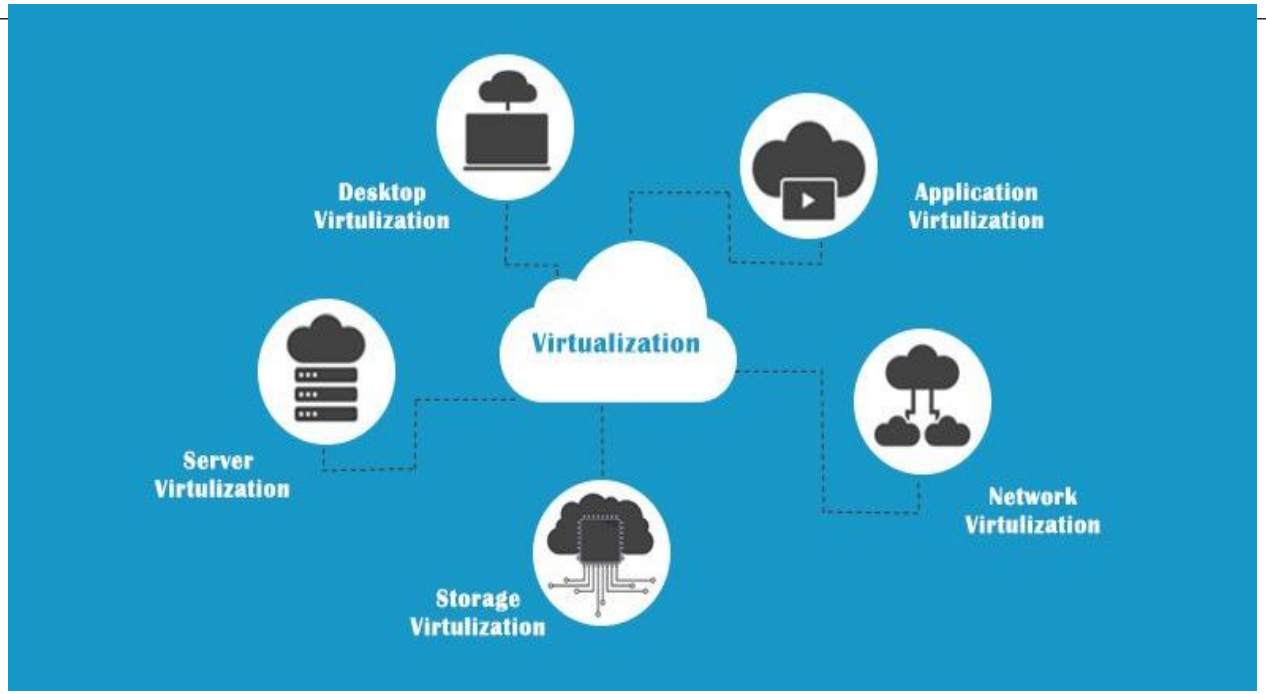
Hypervisor

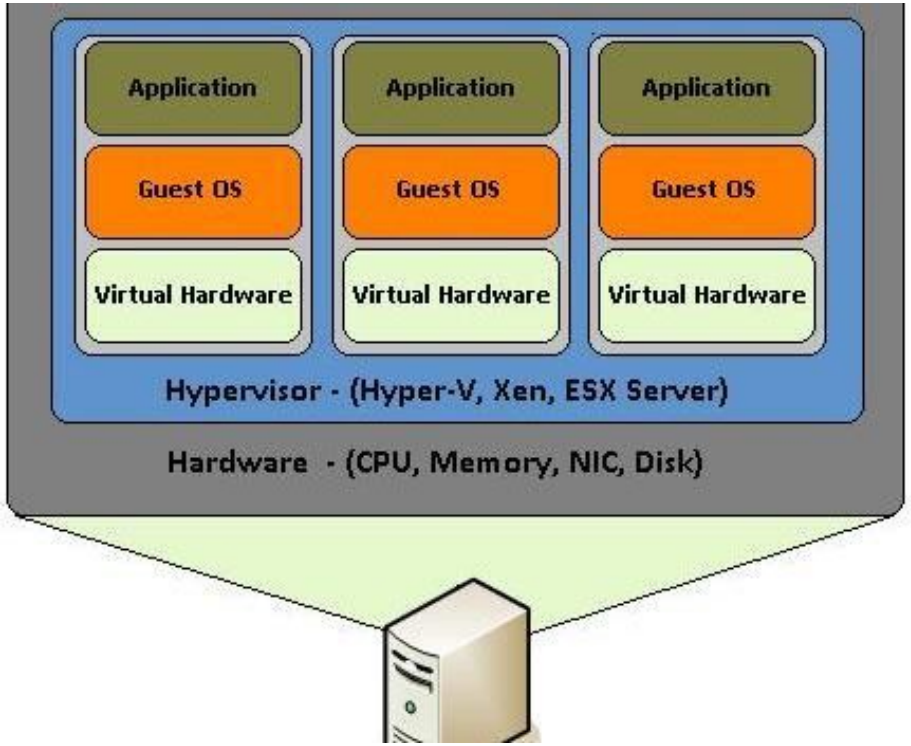
- Hypervisor- a piece of software which does virtualization

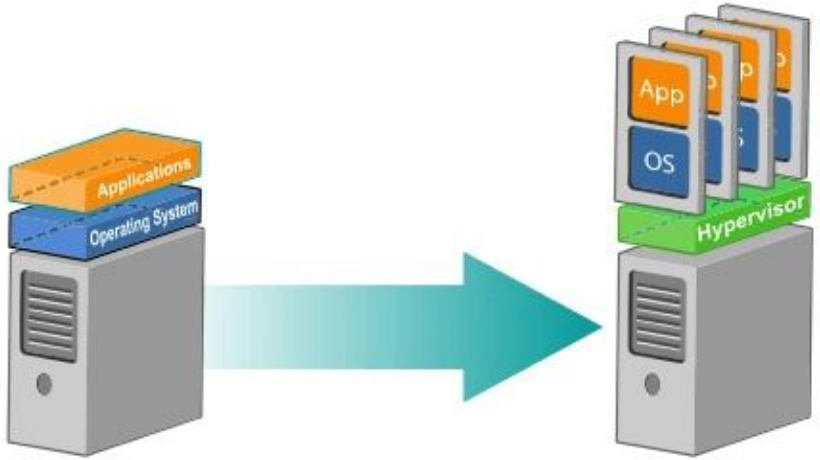


How it works?

- **Hypervisors are virtual machine monitor(VMM)** that enables numerous **virtual operating systems** to simultaneously run on a computer system. These virtual machines are also referred **as guest machines** and they all share the hardware of the physical machine like memory, processor, storage and other related resources. This improves and enhances the utilization of the underlying resources.
- The hypervisor isolates the operating systems from the primary **host machine**. The job of a hypervisor is to cater to the needs of a **guest operating system** and to manage it efficiently. Each virtual machine is independent and do not interfere with each another although they run on the same host machine.


Desktop
Virtulization
Application
Virtulization
Virtualization
Server
Virtulization
Network
Virtulization
Storage
Virtulization


Application
Application
Application
Guest OS
Guest OS
Guest OS
Virtual Hardware
Virtual Hardware
Virtual Hardware
Hypervisor - (Hyper-V, Xen, ESX Server)
Hardware - (CPU, Memory, NIC, Disk)


Applications
Operating System
App
OS
Hypervisor

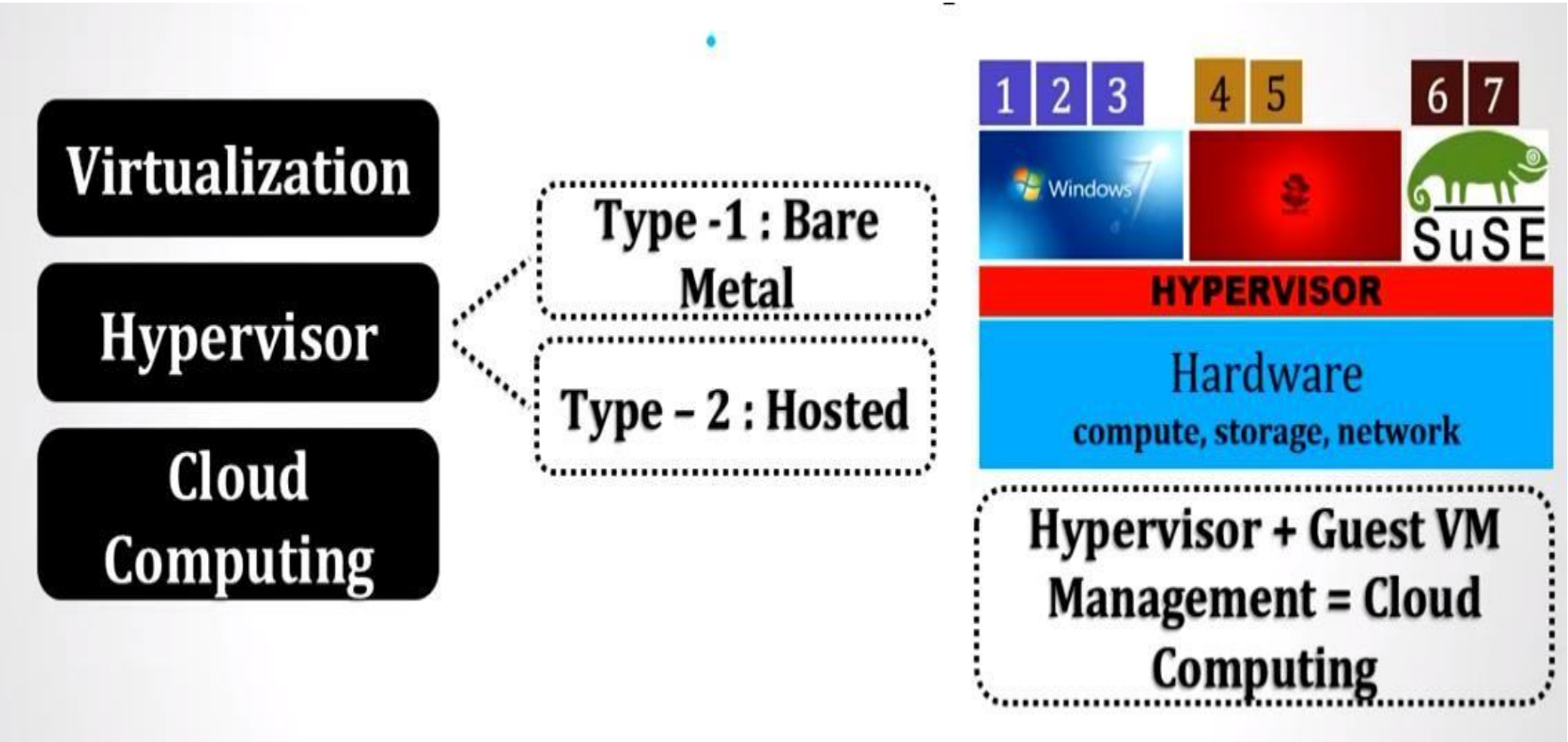
Hypervisors are divided into two types:

- Type one is the **bare-metal** hypervisor that are deployed directly over the host's system hardware without any underlying operating systems or software.

- Some examples of the **Type 1** hypervisors are Microsoft Hyper-V hypervisor, VMware ESXi, Citrix XenServer.

- **Type 2** is a hosted hypervisor that runs as a software layer within a physical operating system.
- The hypervisor runs as a separate second layer over the hardware while the operating system runs as a third layer.
- The hosted hypervisors include Parallels Desktop and VMware Player.

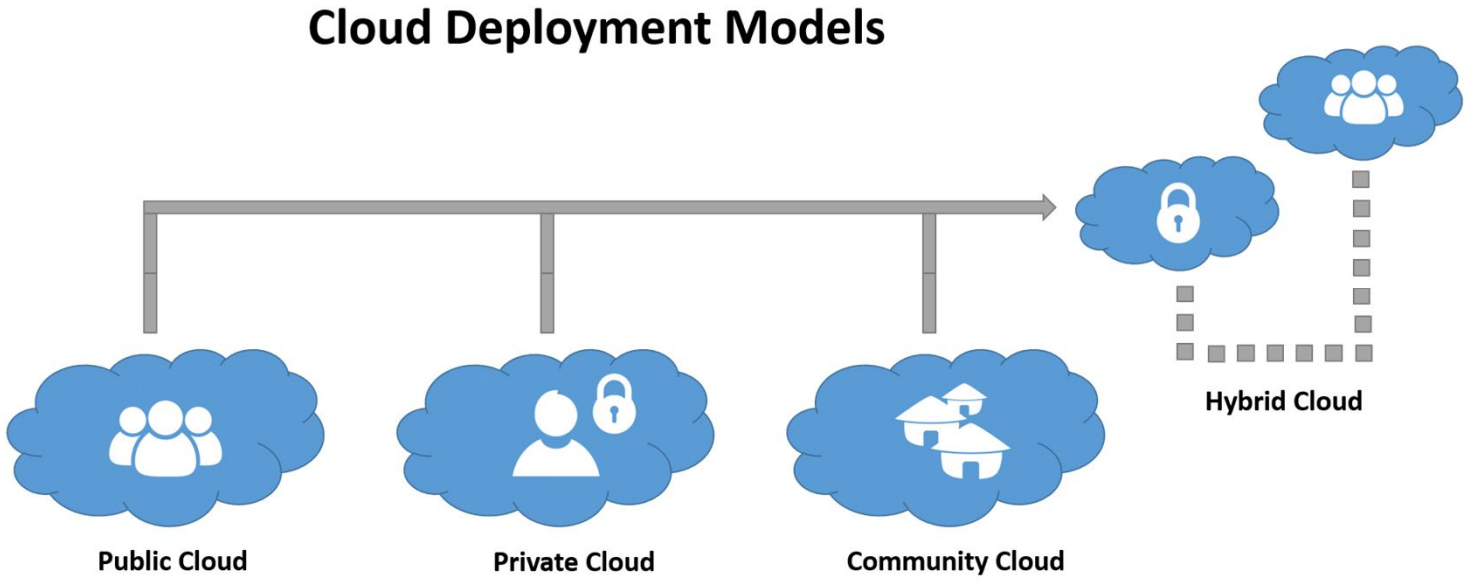
Types of Hypervisors



CLOUD DEPLOYMENT MODELS

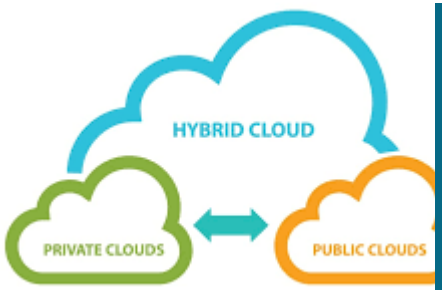
In addition to proposing a definition of cloud computing, NIST has defined four deployment models for clouds

- Private Cloud
- Public Cloud
- Community Cloud
- Hybrid Cloud.

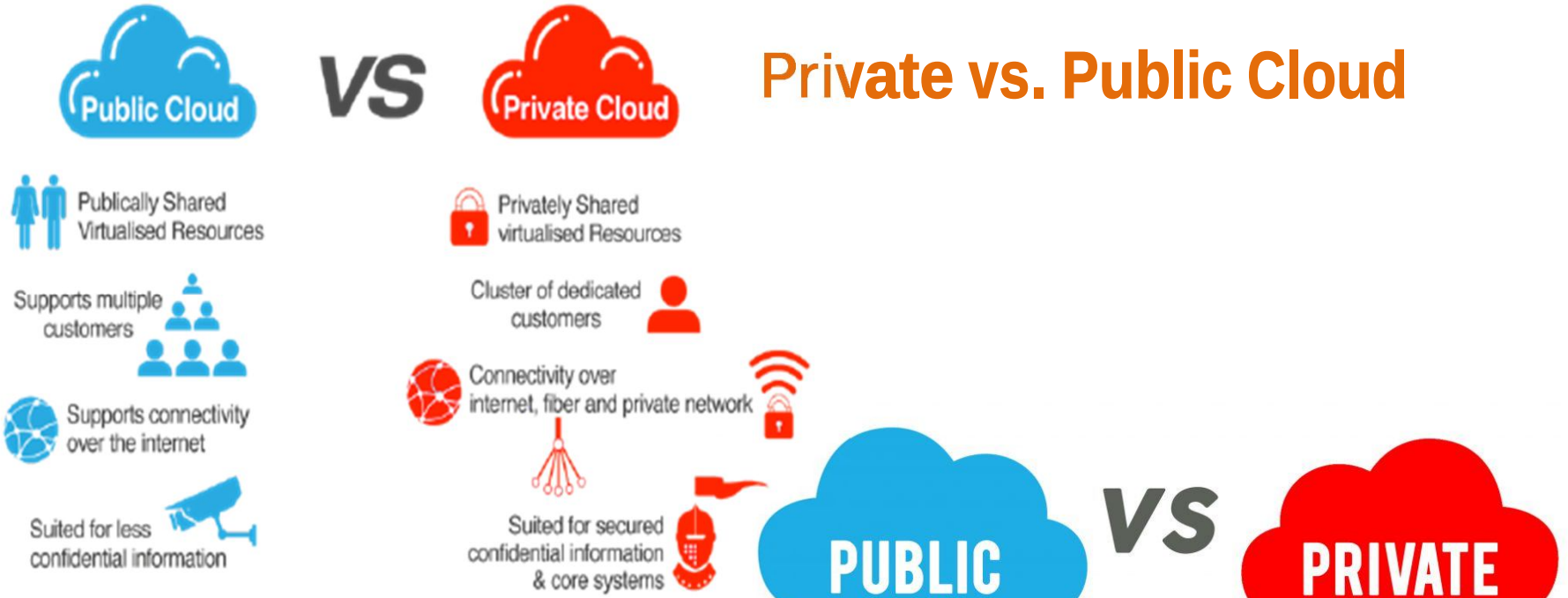


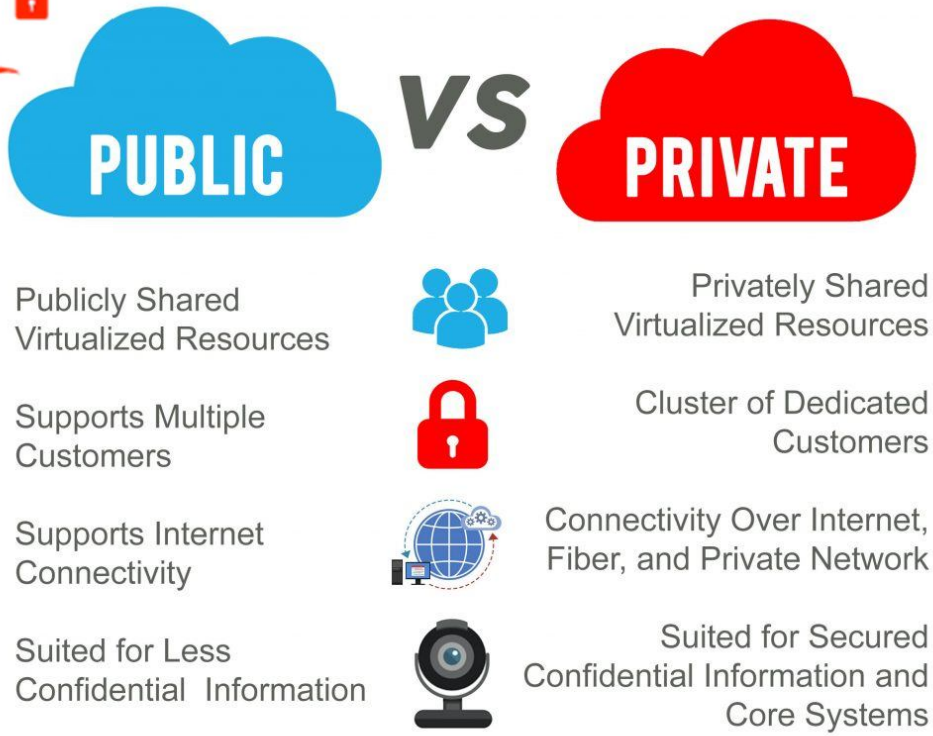
- **Private** cloud is a cloud computing infrastructure that is built for a single enterprise. It is the next step in the evolution of a corporate data center of today where the infrastructure is shared within the enterprise.
- **Community** cloud is a cloud infrastructure shared by a community of multiple organizations that generally have a common purpose.
  - An example of a community cloud is **OpenCirrus**, which is a cloud computing **research testbed** intended to be used by universities and research institutions.
- **Public** cloud is a cloud infrastructure owned by a cloud service provider that provides cloud services to the public for commercial purposes. E.g. **NewCloud**

- **Hybrid** clouds are mixtures of these different deployments.
  - For example, an enterprise may rent storage in a public cloud for handling peak demand.
- The combination of the enterprise's private cloud and the rented storage then is a hybrid cloud.



Private vs. Public Cloud





Cost Comparison 2011

Table 1.1 Hypothetical Cost of Public vs. Private Cloud

	Private Cloud			Public Cloud		
(in USD)	*Year 1*	*Year 2*	*Year 3*	*Year 1*	*Year 2*	*Year 3*
Hardware	70,000	40,000	20,000			
Setup Costs	30,000			5,000		
Software (Licensing)	200,000	400,000	700,000			
Labor costs	200,000	200,000	200,000			
Service costs				300,000	600,000	1,000,000
WAN costs				15,000	30,000	56,000
Cost for year	500,000	640,000	920,000	320,000	630,000	1,056,000
Total	2,060,000			2,006,000		

Public Cloud

- Services are owned and operated by a third party provider.
- The maintenance cost is borne by the service provider.
- Pay-as-you-go model.Thus, the setting and operating cost is less.
- Shared Responsibilities for Security- Provider and Consumer.
- All resources are hosted on cloud providers infra.

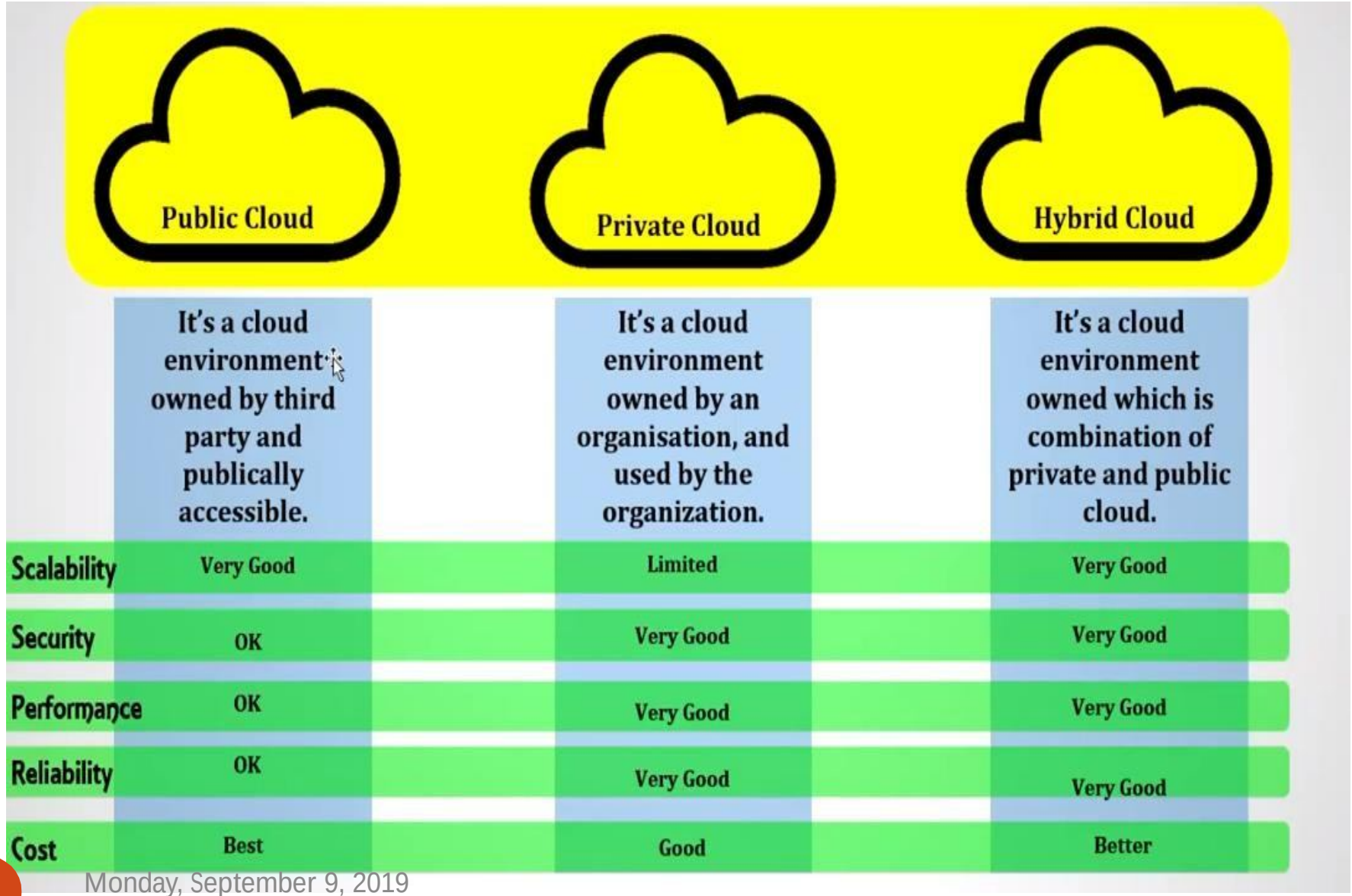
Hybrid Cloud

- Combines both public cloud and on-premises infra/apps .
- Greater flexibility & more deployment options.
- Cloud bursting is also possible.
- Network complexities & compliance issues.
- Can be extremely expensive and difficult to implement.

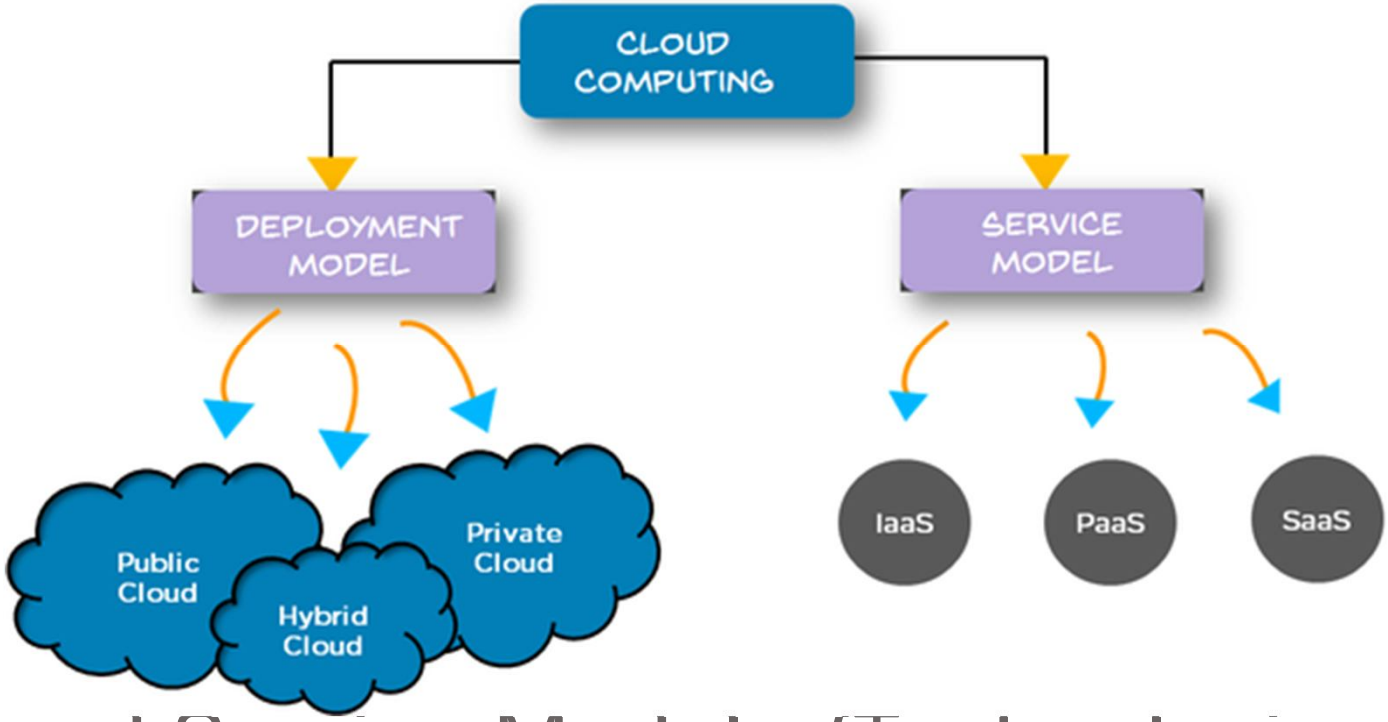
Private Cloud

- Cloud Infra used by only one organisation - can be on-premises or off-premises
- Higher security as the resources are not shared.
- Greater flexibility to control the cloud environment.
- Opportunity to control the entire cloud infra stack.
- Implementation is more complex than using a public cloud.

Cloud Deployment models



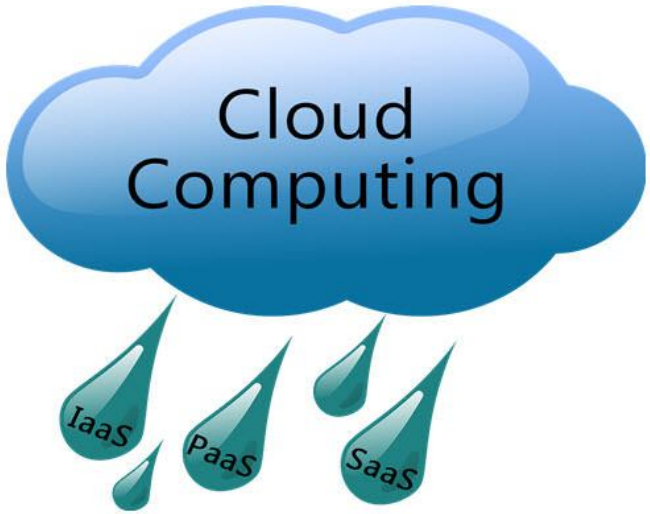
	Public Cloud	Private Cloud	Hybrid Cloud
	It's a cloud environment owned by third party and publically accessible.	It's a cloud environment owned by an organisation, and used by the organization.	It's a cloud environment owned which is combination of private and public cloud.
Scalability	Very Good	Limited	Very Good
Security	OK	Very Good	Very Good
Performance	OK	Very Good	Very Good
Reliability	OK	Very Good	Very Good
Cost	Best	Good	Better



Cloud Service Models / Technologies

- IaaS
- PaaS
- SaaS

- **Example:** AWS, Azure, Google Cloud



IaaS

- ***Infrastructure as a Service (IaaS):*** The consumer uses "*fundamental computing resources*" such as processing power, storage, networking components or middleware.
- **Infrastructure as a Service (IaaS)** means you're buying access to raw computing hardware over the Net, such as servers or storage. Since you buy what you need and pay-as-you-go, this is often referred to as utility computing.

- **Market Players**

IaaS

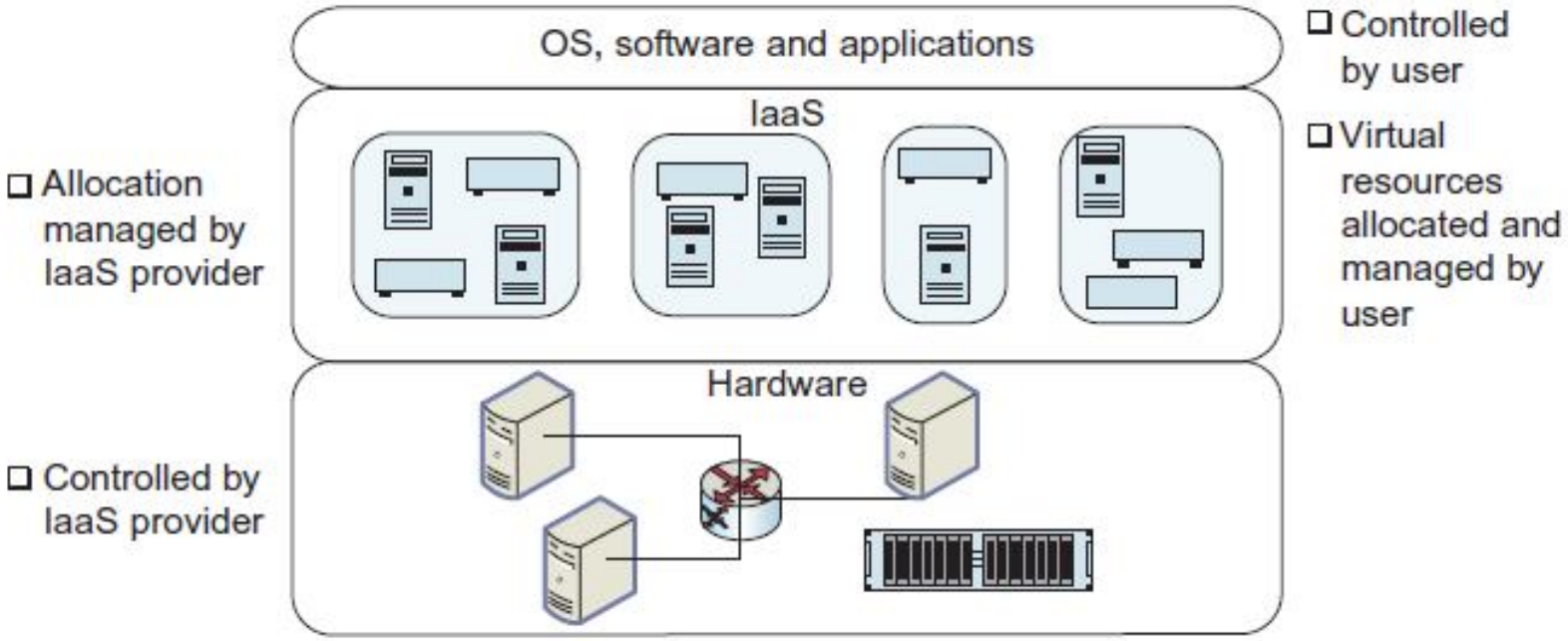
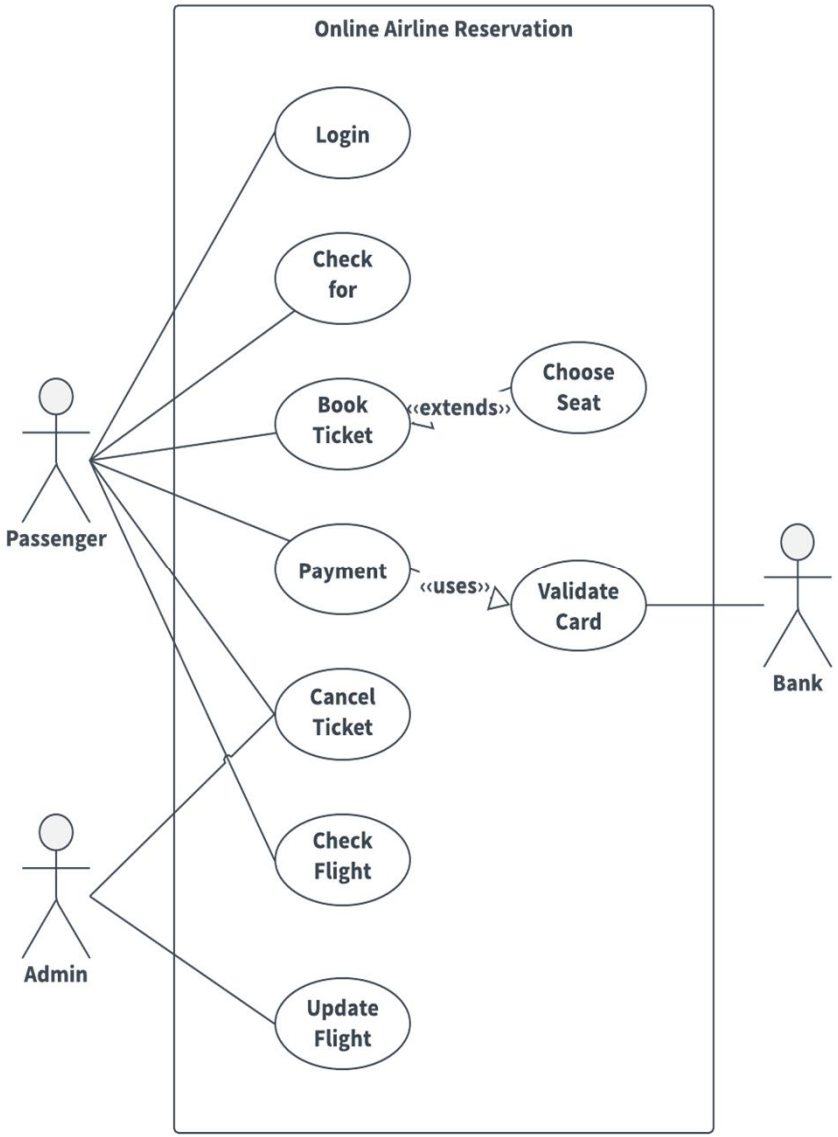


FIGURE 1.5

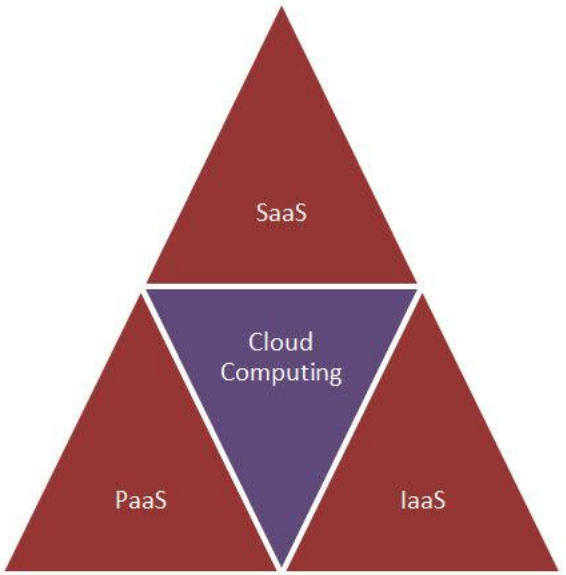
The consumer can control the operating system, storage, deployed applications and possibly networking components such as firewalls and load balancers, but not the cloud infrastructure beneath them. E.g. web hosting (Hostinger, Siteground etc.)

IaaS



- **Use case**: A company that provides platform for **online ticket booking** system for airlines
- The company may have their own OS, DB, Http Server
- User can use a normal browser and access the http server to fetch the information from the website
  - In this scenario, the company don't want to own the necessary infrastructure – storage, computing and networking
- ***Cloud service providers*** – can provide the infrastructure for the airlines ticket booking system.
- User can get on-demand virtual server, and able to run any service i.e, OS and applications.

- The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources.
- Consumer is able to deploy and run arbitrary software, which can include operating systems and applications.
- The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems; storage, deployed applications, and possibly limited control of select networking components (e.g., host firewalls).



PaaS

- ***Platform as a Service (PaaS):*** The consumer uses a hosting environment for their applications.
- The consumer controls the applications that run in the environment but does not control the software, hardware or network infrastructure on which they are running.

E.g. App Cloud (from salesforce.com) and the Google App Engine are examples of PaaS.

- **Platform as a Service (PaaS)** means you develop applications using Web-based tools so they run on systems software and hardware provided by another company.
  - So, for example, you might develop your own ecommerce website but have the whole thing, including the shopping cart, checkout, and payment mechanism running on a merchant's server

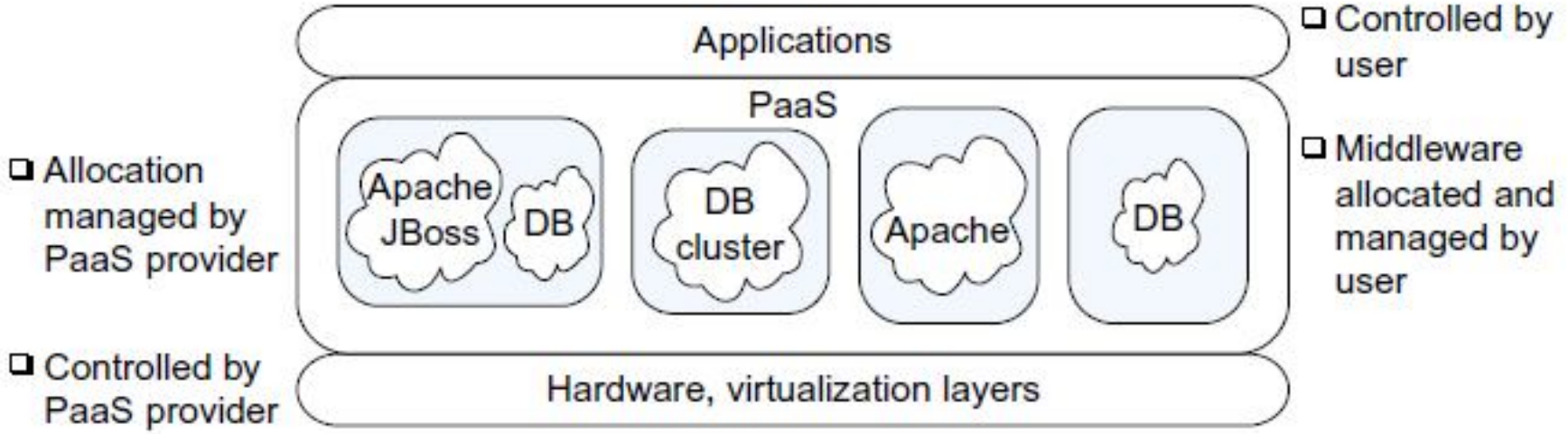


FIGURE 1.6

PaaS

- Use Case: The developer can directly use the environment for application development without bothering about underlying machine or OS.
- A Developer may require for developing
  - Editor, complier, storage and version controlling system
  - Below that there is OS and a infrastructure
  - Cloud service provider provides, infrastructure, OS, Code base(editor, …)
- In the PaaS models, cloud providers delivers the infrastructure along with platform, including operating system, programming language execution environment, database and web server etc.

- The capability provided to the consumer is to deploy onto the cloud infrastructure consumer created or acquired Applications created using programming languages and tools supported by the provider.
- The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and Possibly application hosting environment configurations.

SaaS

- ***Software as a Service (SaaS):*** The consumer uses an application, but does not control the operating system, hardware or network infrastructure on which it's running. E.g. ***Zoho*** is a SaaS provider offering a variety of office applications online.

- In the SaaS model, cloud providers deliver the needed application required by the end user running on cloud platform and the end user need not to maintain the Hardware or the OS or the actual Application itself

SaaS

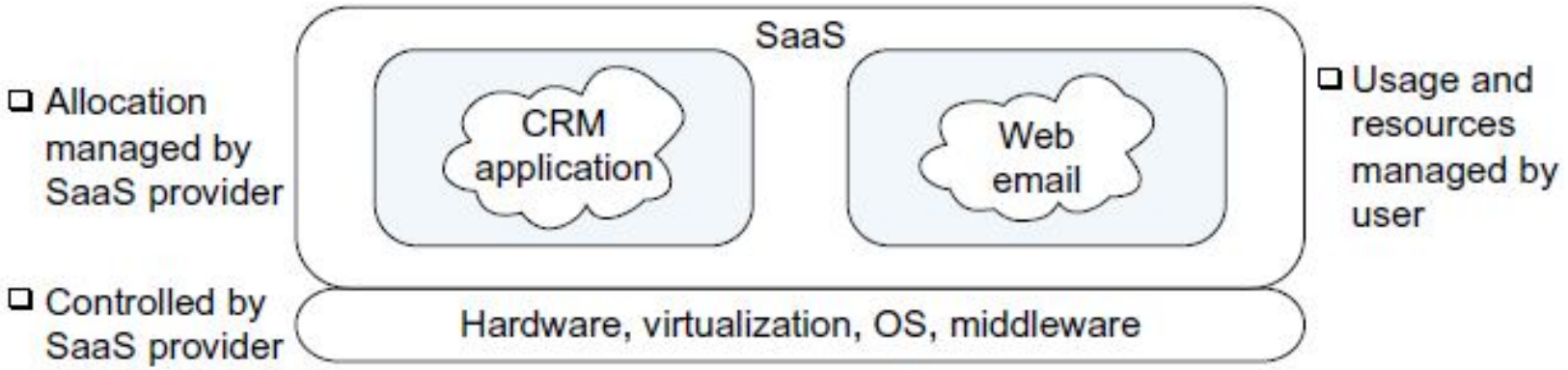
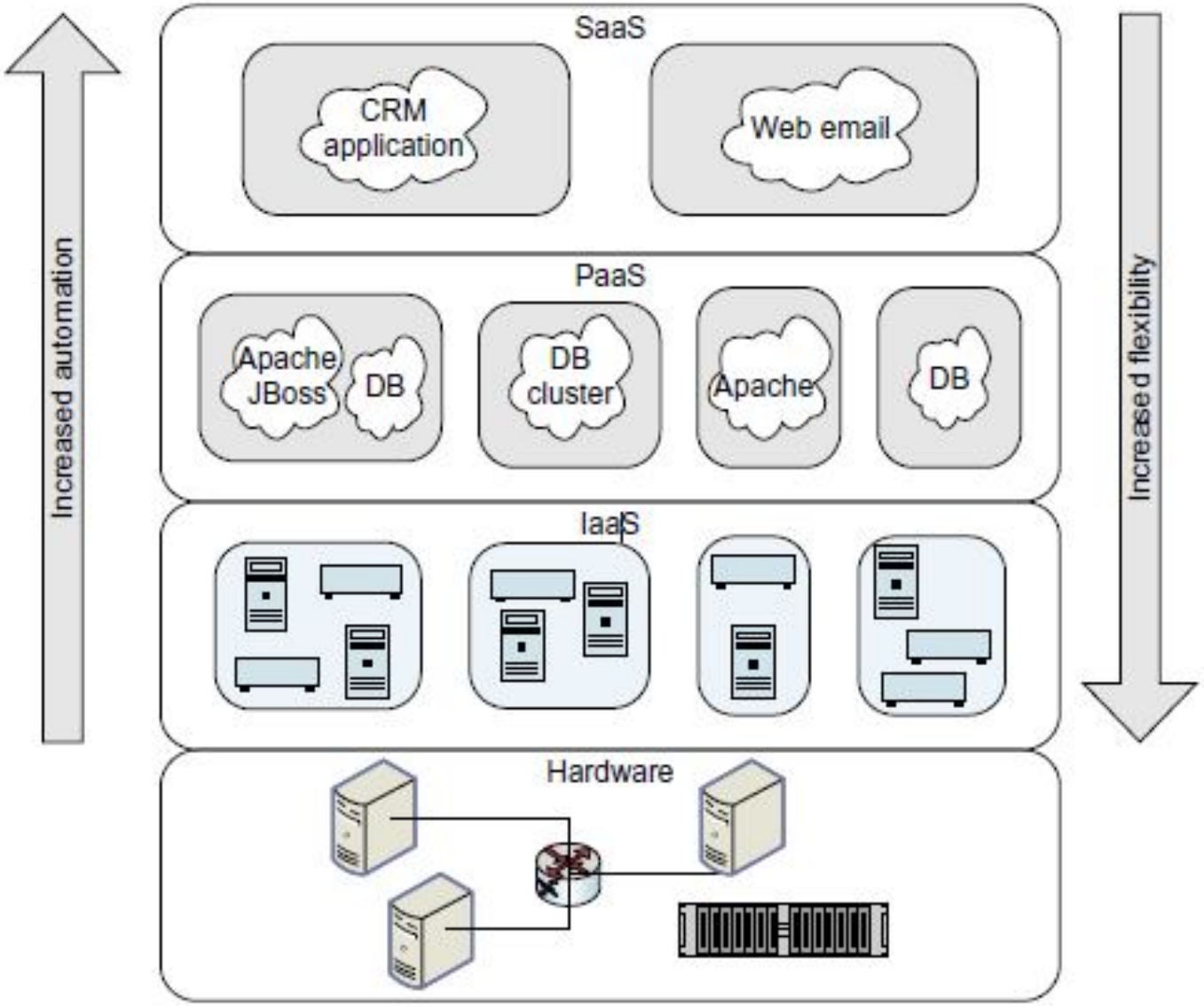
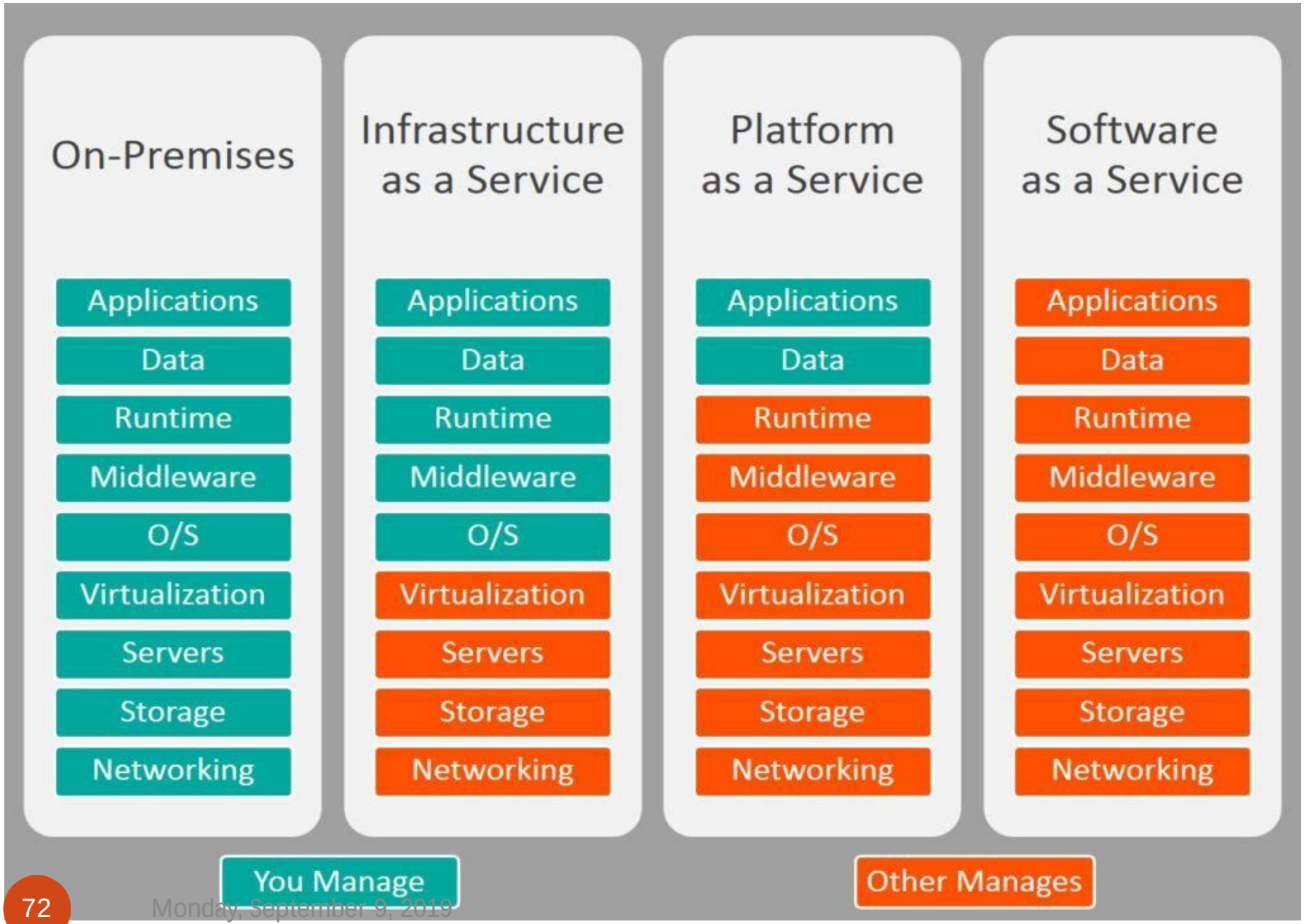


FIGURE 1.7

Software as a Service (SaaS) means you use a complete application running on someone else's system. **Web-based email** and **Google Documents** are perhaps the best-known examples

Cloud Architecture




On-Premises
Applications
Data
Runtime
Middleware
O/S
Virtualization
Servers
Storage
Networking
Infrastructure as a Service
Applications
Data
Runtime
Middleware
O/S
Virtualization
Servers
Storage
Networking
Platform as a Service
Applications
Data
Runtime
Middleware
O/S
Virtualization
Servers
Storage
Networking
Software as a Service
Applications
Data
Runtime
Middleware
O/S
Virtualization
Servers
Storage
Networking
You Manage
Other Manages

In the SaasS Cloud Model, the serIn the SaaS Cloud Model, the service provider supplies the hardware infrastructure and Software products. Applications are run and interacted with via a web browser, hosted desktop or remote client.

Software as a Service

PaaS in the cloud is provided as a set of software and product development tools hosted on the providers infrastructure. Developers can develop and deploy their software solutions on a cloud platform.

Platform as a Service

In the IaaS model, service providers offer computers, storage and network components such as firewalls, in the form of a services.

Infrastructure as a Service

IaaS
Infrastructure as a Service
host

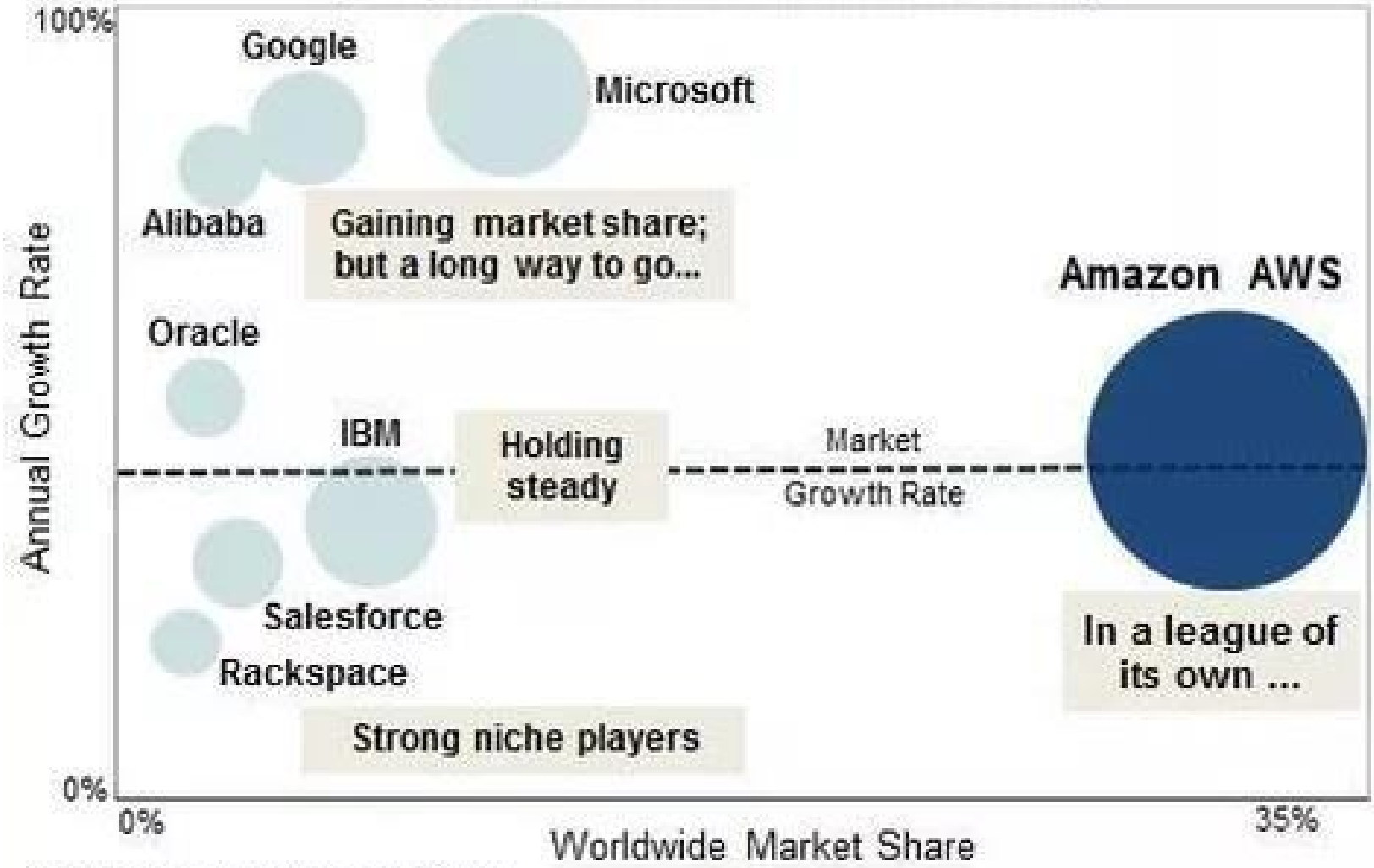
PaaS
Platform as a Service
build

SaaS
Software as a Service
consume

Market Players

Cloud Provider Competitive Positioning

(IaaS, PaaS, Hosted Private Cloud - Q3 2017)



Source: Synergy Research Group

CLOUD WARS

Top 10 Rankings – Nov. 7, 2017

1. **Microsoft** – *Nadella on $20.4B run rate w/end-to-end customer-centric cloud*
2. **Amazon** -- *AWS needs software! 10 software companies Amazon might look at*
3. **IBM** – *Rometty strikes gold helping customers convert legacy IT to private cloud*
4. **Salesforce** – *Benioff must extend SFDC impact from SaaS deeply into PaaS*
5. **SAP** – *McDermott accelerating major product-line overhaul to HANA and cloud*
6. **Oracle** –*Ellison on cybercrime: 'Make no mistake, this is a war—and we're losing'*
7. **Google** – *Tons of potential but still unclear if/how it wants to play in enterprise*
8. **ServiceNow** – *Jumps ahead of Workday: revenue up 40%, new products boom*
9. **Workday** – *Q2 revenue surges 41% as Bhusri jumps into PaaS marketplace*
10. **VMware** – *revenue & stock jump on deals w/AMZN MSFT IBM GOOG for hybrid*

AWS vs. Azure vs. Google vs. IBM Enterprise Scorecard

Area	AWS	Azure	Google	IBM
% Adoption	68%	58%	19%	15%
YoY Growth in Adoption	15%	35%	26%	50%
% Adoption in Beginners	47%	49%	18%	14%
% with Footprint >50 VMs	58%	44%	17%	14%
YoY Growth in Footprint> 50 VMs	14%	38%	42%	56%

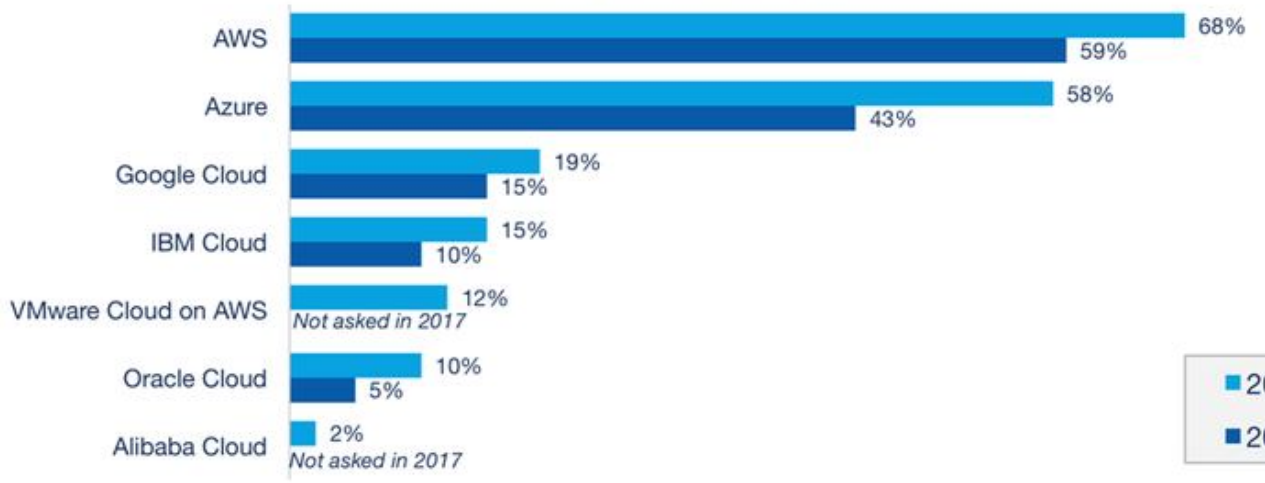
AWS leads

Other vendors lead AWS

Source: RightScale 2018 State of the Cloud Report

Enterprise Public Cloud Adoption 2018 vs. 2017

% of Respondents Running Applications



Source: RightScale 2018 State of the Cloud Report

RIGHTSCALE

Advantages – Business Drivers

- Scalability – scale up and down easily
- Reduced Cost – pay-as-you-go
- Agility – ability to rapidly provision
- Automation – services are automatically attached on specifications
- Backup and Recovery – replicate easily
- Remote Update – access from anywhere
- Resiliency – the capacity to recover from failures

Challenges

- Security and Privacy
- Regulatory and Legal issues
- Inter-Operability
- Performance
- Portability
- Reliability & Availability
- Computing Performance
- Service Quality-Service level Agreement

Break for Setting up of AWS

Technology Challenges for Cloud

To scale of cloud computing is much, much larger than that of traditional computing environments – as it will be shared by many users, applications, enterprises , it impact to service models.

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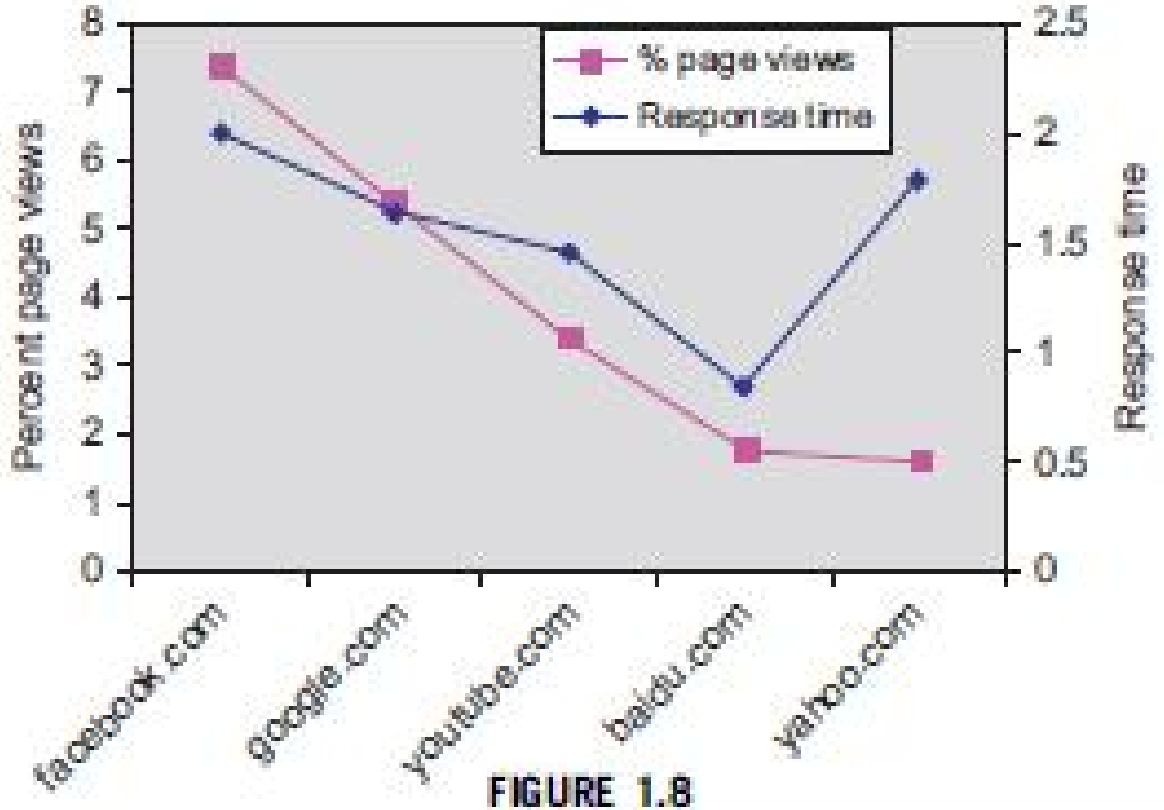


FIGURE 1.8

Traffic statistics for popular web sites.

Challenges

- **Figure 1.8** shows dropping curve is the fraction of five Web requests that went to that web site while the V-shaped curve is the response time of the web site.
- It can be seen that the top web site – Facebook.com – accounts for about 7.5% of all Web traffic. Facebook supports 7 million concurrent users(2012). (Currently 2.41 Billon)
- In spite of the high traffic, the response time – close to 2 seconds – is still better than average.
- To scale both compute and storage resources very rapidly need appropriate infrastructure.
- New techniques for **multitenancy**, or **fine-grained sharing** of resources, are needed for supporting such large numbers of users.
- Security is a natural concern in such environments as well.

- In such large-scale environments, hardware failures and software bugs can be expected to occur relatively frequently.
- The failures can trigger other failures, leading to an avalanche of failures cause outages.
  - Such a failure avalanche occurred once in 2011 in Amazon's data center. A networking failure triggered a re-mirroring (making a replica or mirror) of data.
  - However, the re-mirroring traffic interfered (prevent) with normal storage traffic, causing the system to believe that additional mirrors had failed.
  - This in turn triggered further re-mirroring traffic, which interfered with additional normal storage traffic, triggering still more re-mirroring (see **Figure 1.9**), bringing down the whole system.
  - Availability is therefore one of the major **challenges affecting clouds**.

Amazon's Data Centre 2011

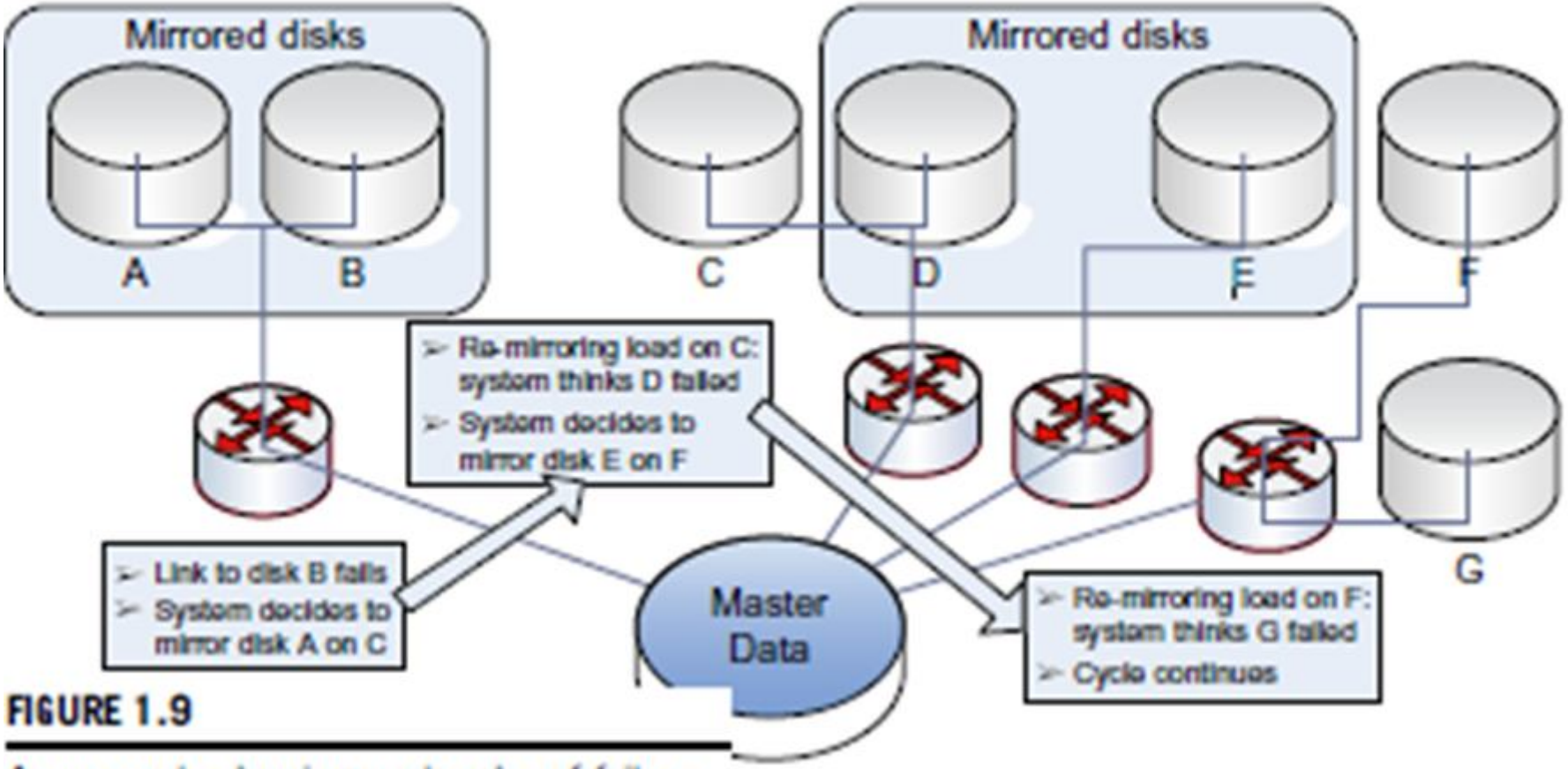


FIGURE 1.9

An example showing avalanche of failures.

Multi-tenancy

- Tenant is any legal entity responsible for data and is provided on a contractual basis. *Tenant is a contract signee.*
- Tenant – application environment that requires isolation from others
- Multi-tenancy refers to a software architecture in which a single instance of a software runs on a server and serves multiple tenants
- *In short, one instance many customers.*
- **What we want to achieve?**
  - Reduce infrastructure costs by sharing hardware resources
  - Simplify software maintenance by keeping a single code base
  - Simplify infrastructure maintenance by having fewer nodes

Basic models of Multi-tenancy types

- Shared nothing – Each customer has a **separate** copy of the application and the database for their exclusive use. Sometimes, the **hardware** is also separated from each customer for security concerns.
- This is essentially for application hosting rather than application tenancy.
- Shared Application – Application is shared among the customers but the databases are separate for each customer
- Shared Everything – Both Application and the database are shared among all customers

- Isolating the **databases** is easier and faster to build whereas shared approach includes larger development effort
- Backups and restores are simpler operations in isolated approach whereas in shared approach **one tenants** back up may impact on other active customers.

- Isolating databases may have **flexibility** but will give serious effects when product release or upgrades is done.

Applications deployment

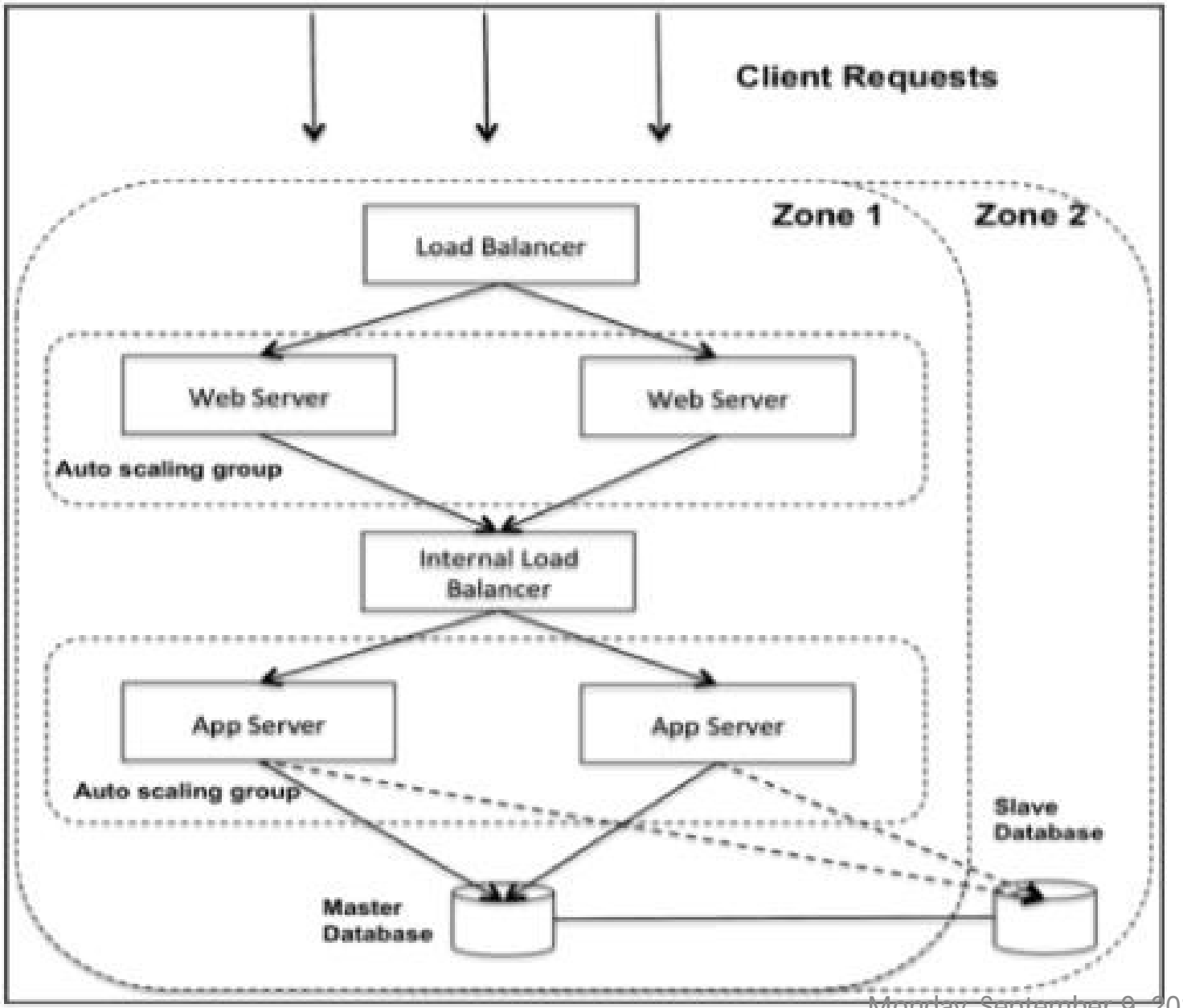
- Migrating on-premise applications to the cloud
  - Lift and shift
  - Rehosting
- Building cloud native applications

Designing Cloud Applications

- Design the application as collection of services
  - Data -> services ->composite services ->applications
- Decouple the data
  - Breakout the data and processing separate
  - Then data and process can be on any private or public instance
  - Database reads and writes across the open Internet can cause latency
- Consider communications between application components
  - combine communications into a single stream of data or a group of messages, rather than constantly communicating
  - Consider using caching systems.These provide additional database performance by locally storing commonly accessed data, thereby reducing all database read requests back to the physical database.

-contd..

- Model and design for performance and scaling
  - overall performance
  - understanding how the application will scale under an increasing load.
- Make security systematic within the application
  - Pick a security approach and technology prior to building your application that will be effective for the type of application you're running and that will address any compliance or other data-level security issues.

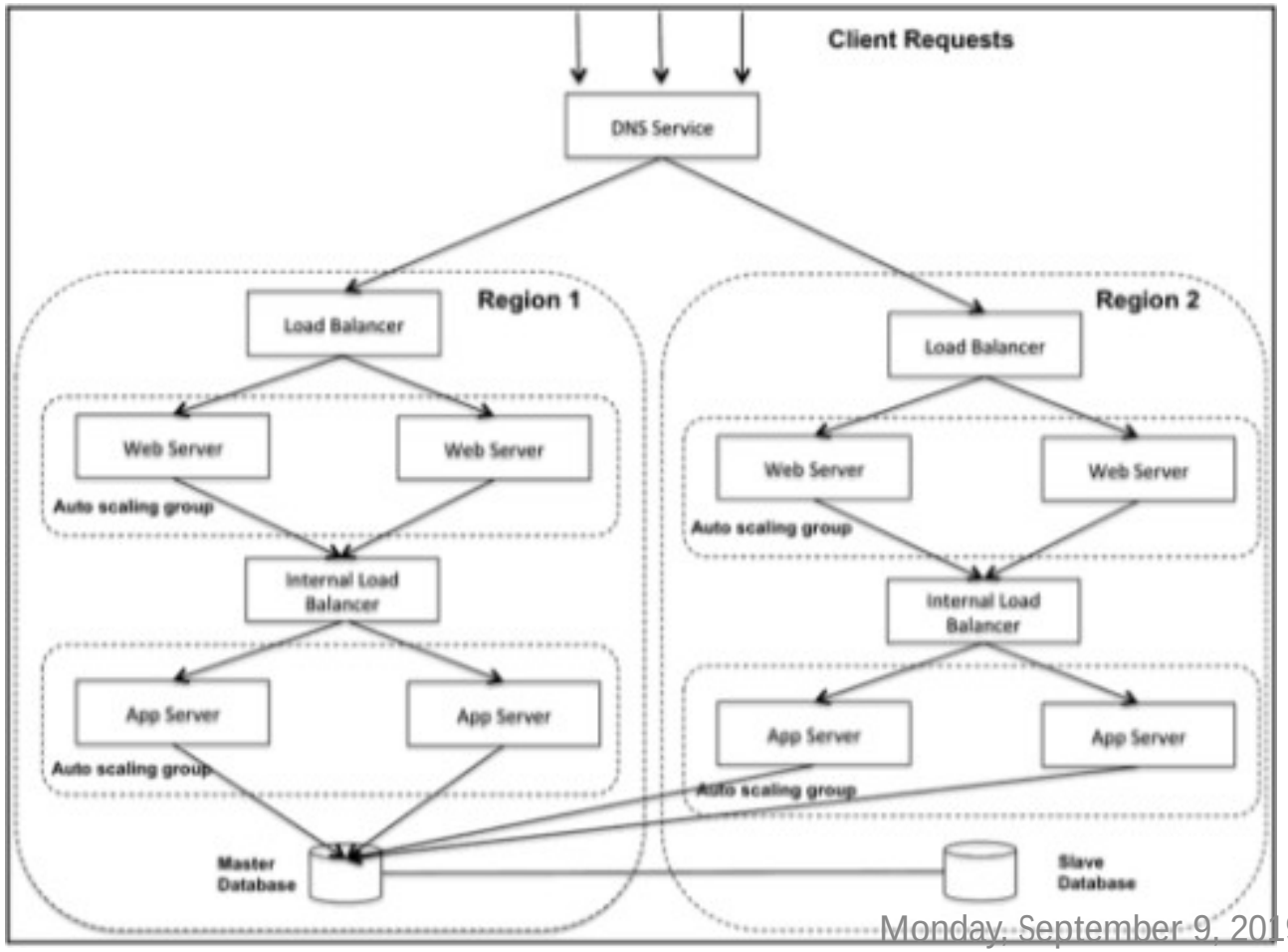

Client Requests
Zone 1
Zone 2
Load Balancer
Web Server
Web Server
Auto scaling group
Internal Load Balancer
App Server
App Server
Auto scaling group
Slave Database
Master Database

-contd..

- 3-tier architecture – web tier, an application or business tier, data tier
- Auto-scaling and load balancers for web servers and application servers
- Exhibits Master-slave database model across two different zones or data centers
- The master database is synchronously replicated to the slave
- Overall architecture represents a simple way to achieve highly scalable and highly available application in the cloud environment

AWS - Architecture

- Cloud applications can be deployed in multiple locations



Multi-tenancy in Databases

- What is more important asset to the business? - DATA
- Trust between the vendor and the customer is the key factor
- Tenant database is a corner-stone of the tenant management
- Data architecture for multi-tenant system should be
  - Robust, secure, efficient, cost-effective
- Three- approaches to manage multi-tenant data (database layer)
  - Separate database processes, shared machine
  - Shared database processes, separate tables
  - Shared table

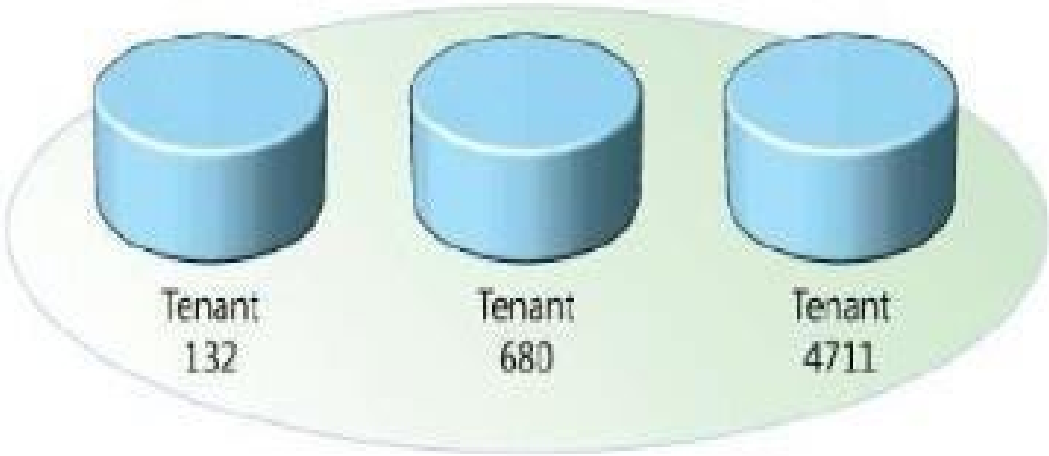
-contd

- Addressing data-at-rest security requirements
  - Tenant level
  - End user level
- Addressing data extensibility requirements

Each tenant gets their own database process and multiple tenants share the same machine.

Computing resources and application code are generally shared between all the tenants on a server, but each tenant has its own set of data that remains logically isolated from data that belongs to all other tenants.

- Advantages
- Disadvantages

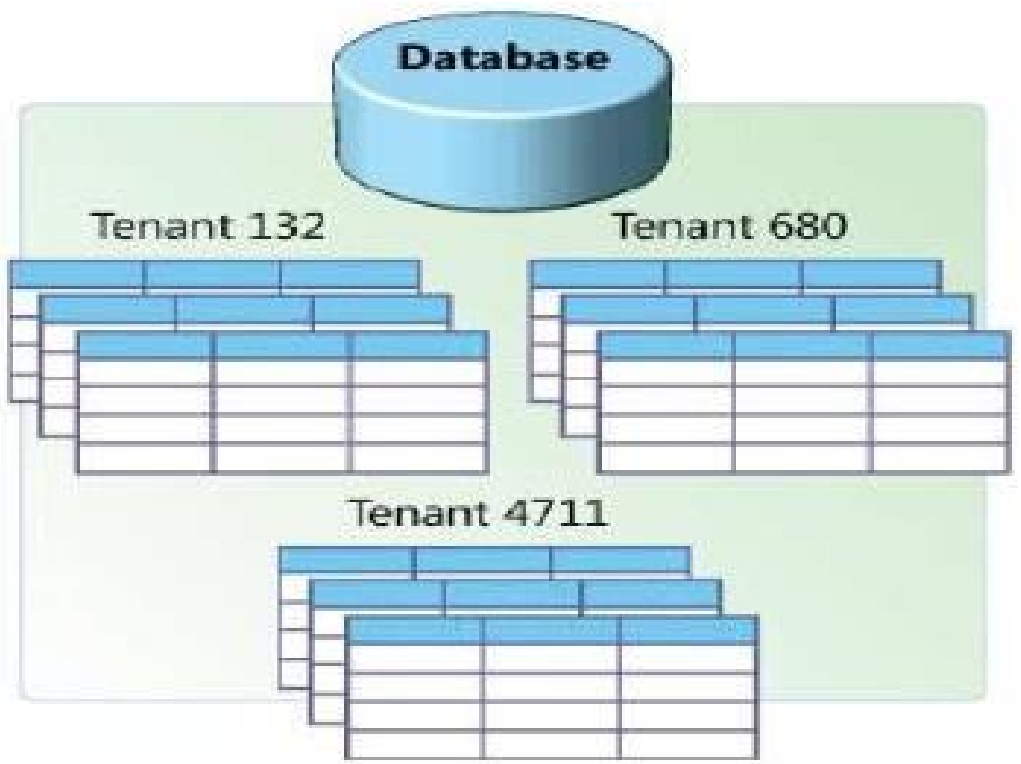


Separate Database Process, Shared Machine

Each tenant gets their own tables and multiple tenants share the same database process.

It involves housing multiple tenants in the same database, with each tenant having its own set of tables that are grouped into a schema created specifically for the tenant.

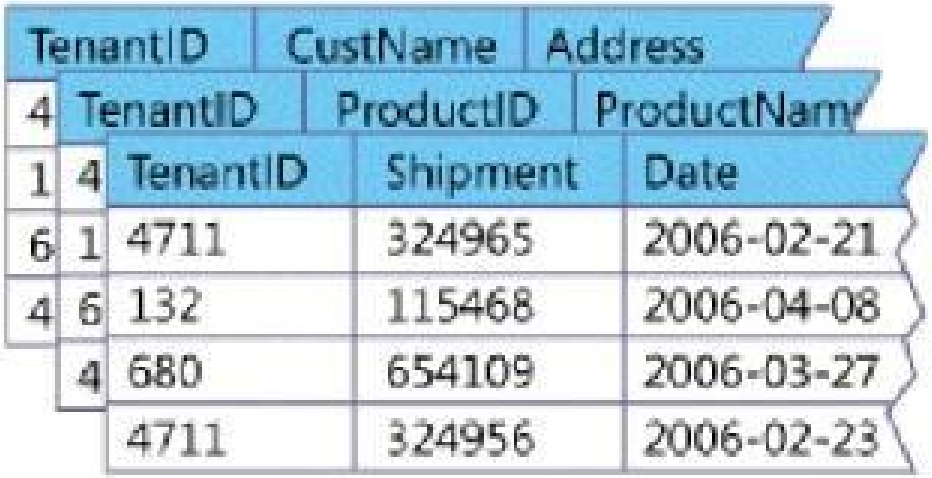
- Advantages
- Disadvantages



Shared Database Process, Separate Tables

It involves using the same database *and* the same set of tables to host multiple tenants' data. A given table can include records from multiple tenants stored in any order; a Tenant ID column associates every record with the appropriate tenant.

- Advantages
- Disadvantages



Shared Table

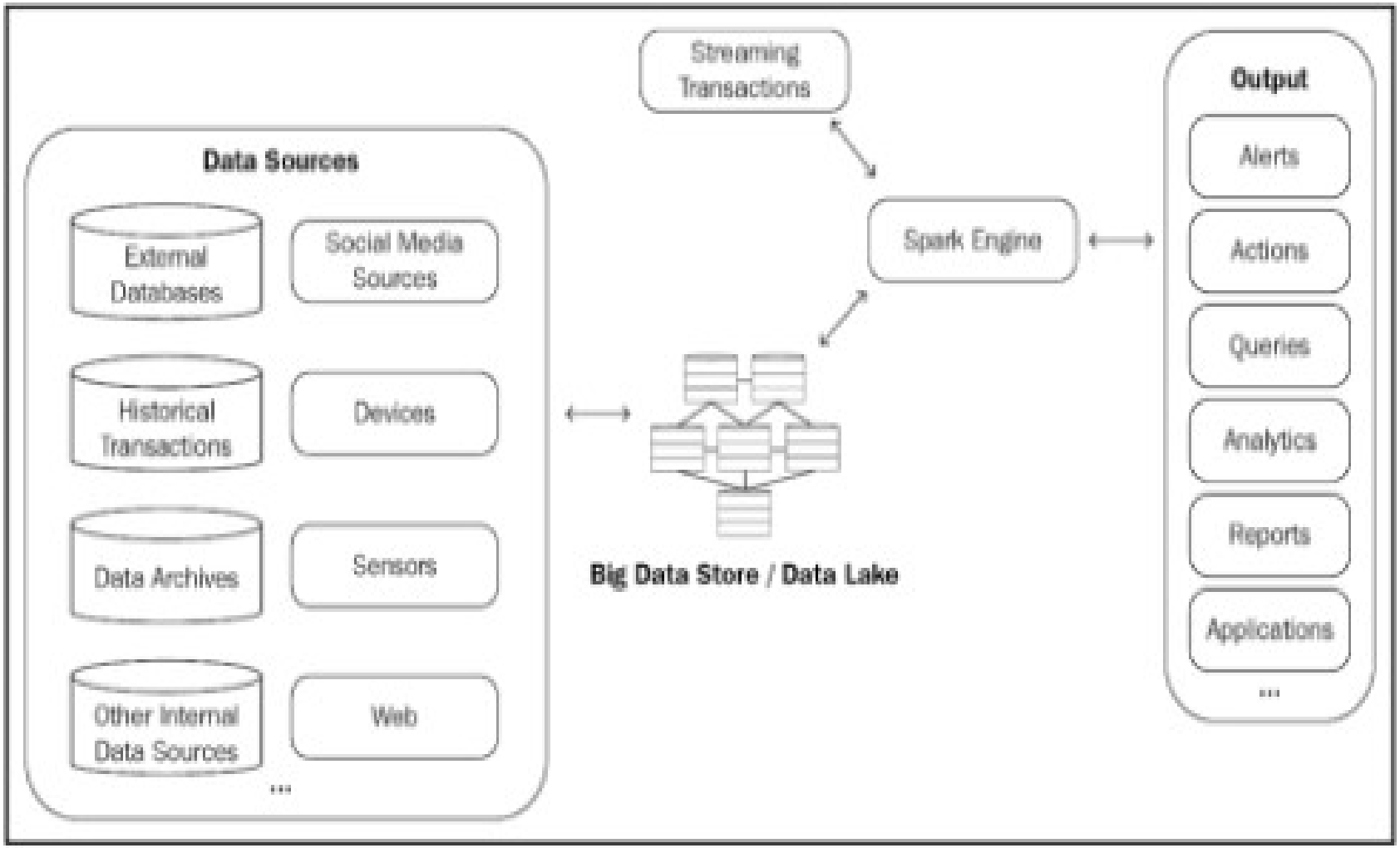
Cloud application design principles

- Designing for scale
- Automating cloud infrastructure
- Designing for failure
- Designing for parallel processing
- Designing for performance
- Designing for eventual consistency

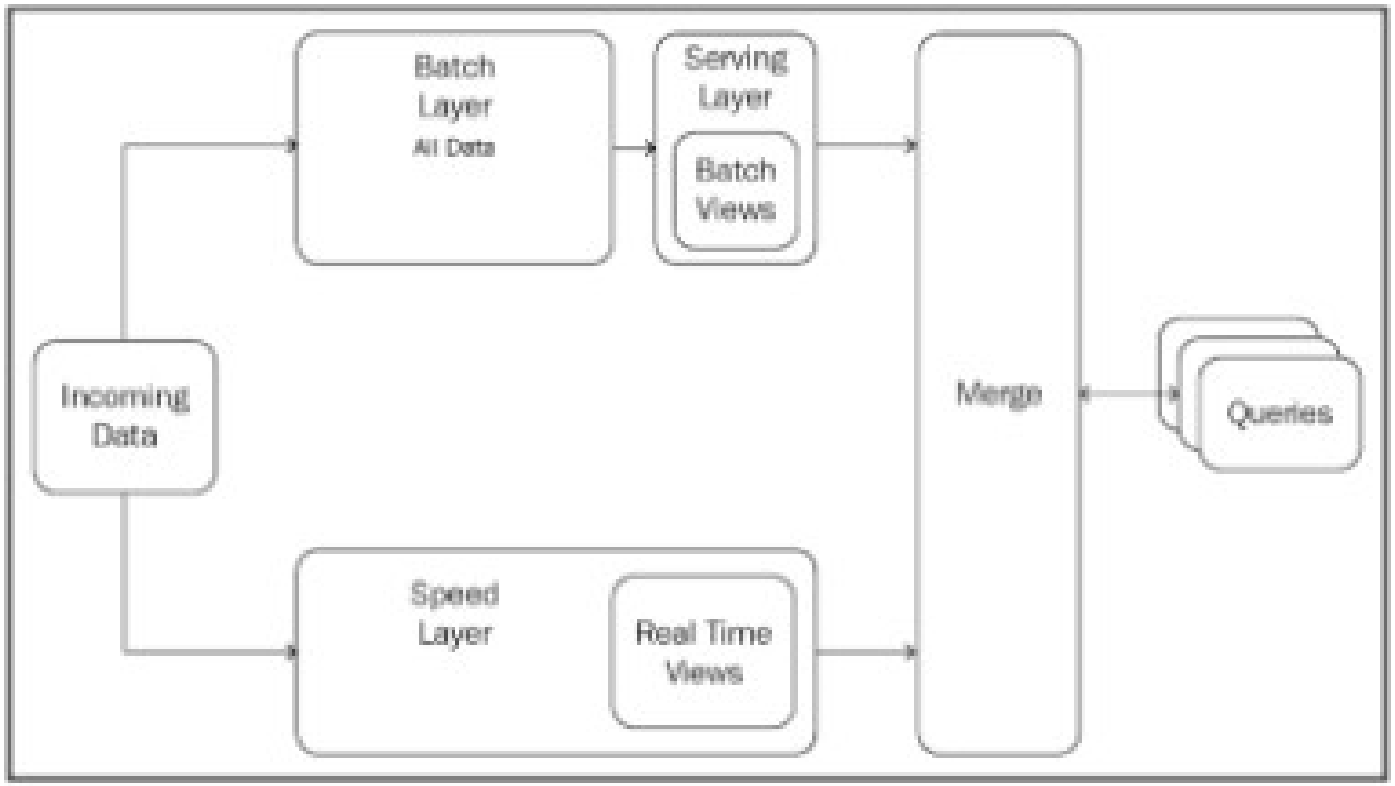
Emerging cloud application architectures

- **Batch processing:** the processing of previously collected jobs in a single batch.
- **Streaming applications:** A **streaming application** is a program that has its necessary components downloaded as needed instead of being installed ahead of time on a computer. **Application streaming** is a method of delivering virtualized **applications**.
- **Machine learning pipelines:** Cloud consist of several steps to train a model, but the term '**pipeline**' is misleading as it implies a one-way flow of data. Instead, machine learning pipelines are cyclical and iterative as every step is repeated to continuously improve the accuracy of the model and achieve a successful algorithm.

Spark-based Architecture

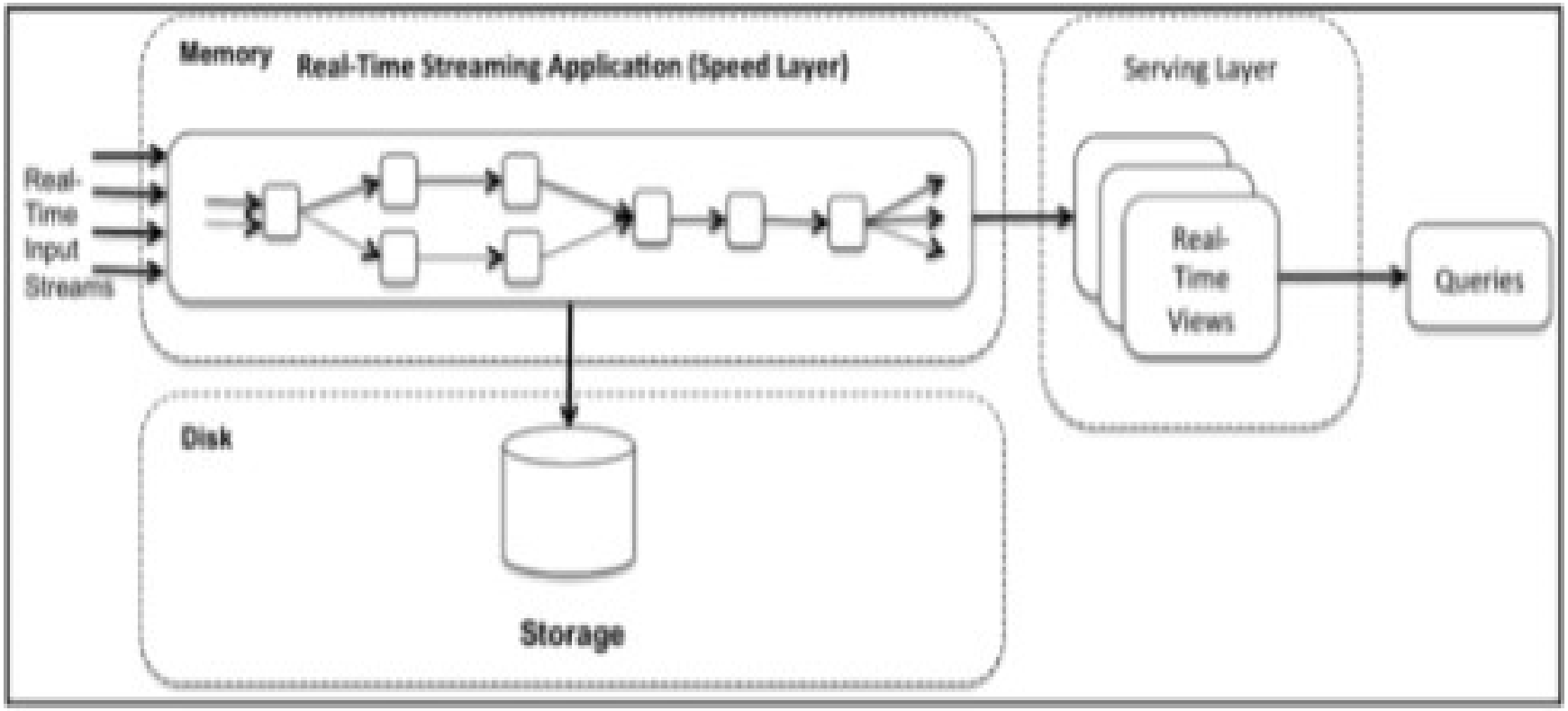


Lamda Architecture



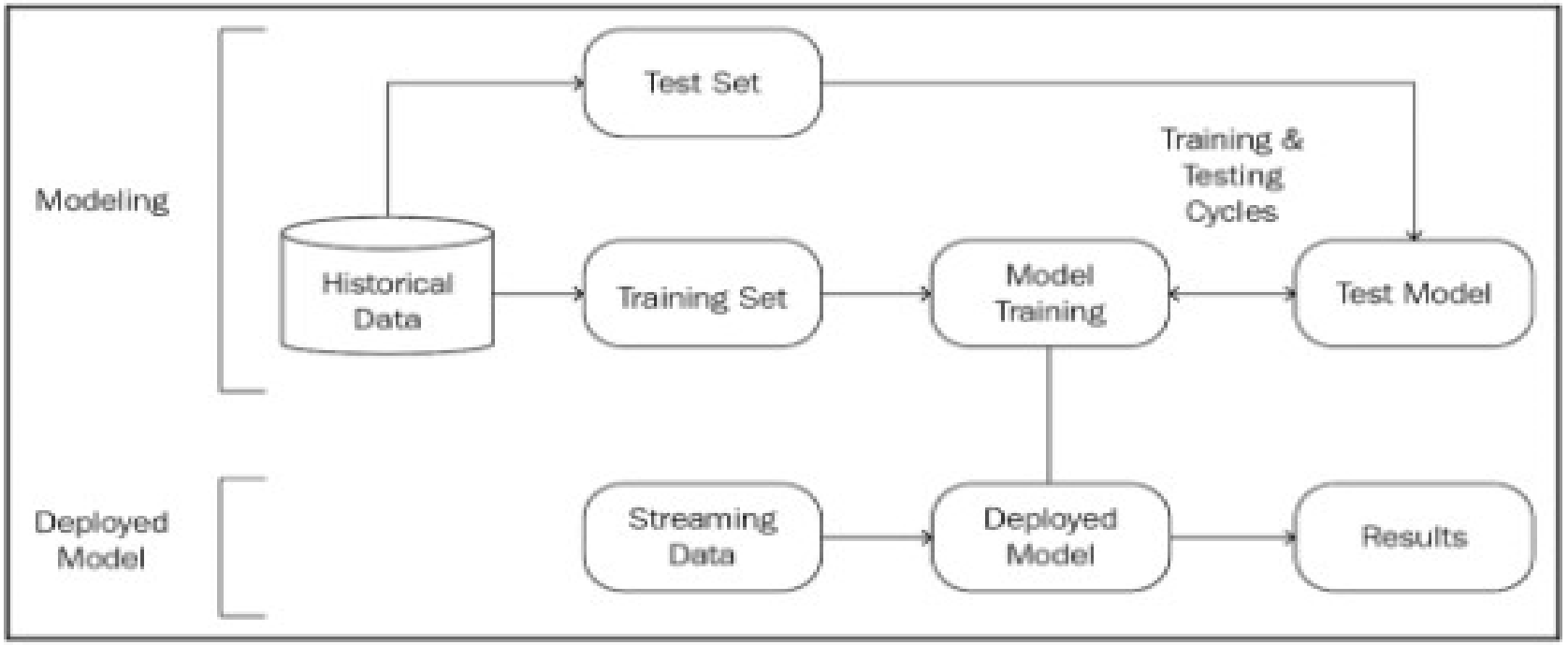
Lambda architecture is a data processing **architecture** designed to handle massive quantities of data by taking advantage of both batch and stream-processing methods.

Kappa architecture



Kappa Architecture is a software **architecture** pattern. Kappa Architecture is a simplification of Lambda Architecture. A Kappa Architecture system is like a Lambda Architecture system with the batch processing system removed. To replace batch processing, data is simply fed through the streaming system quickly.

Machine pipelining



End of Unit 1