



NANYANG
TECHNOLOGICAL
UNIVERSITY
SINGAPORE

CE/CZ4052 Cloud Computing

Basics, IaaS, PaaS, SaaS

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Outline

Real-world examples of the cloud

Definitions of cloud computing

Key cloud concepts and characteristics

Deployment scenarios

Cloud: Massive Scale

Facebook [GigaOM, 2012]

30K in 2009 -> 60K in 2010 -> 100K in 2012

Microsoft [DC knowledge]

> 1 million, 2013

AWS EC2 [Randy Bias, 2009]

40K, 8 cores per machine

Google [DC knowledge]

> 900K, 2013

Data center: outside



Google | google.com/datacenters

Copyright: Google

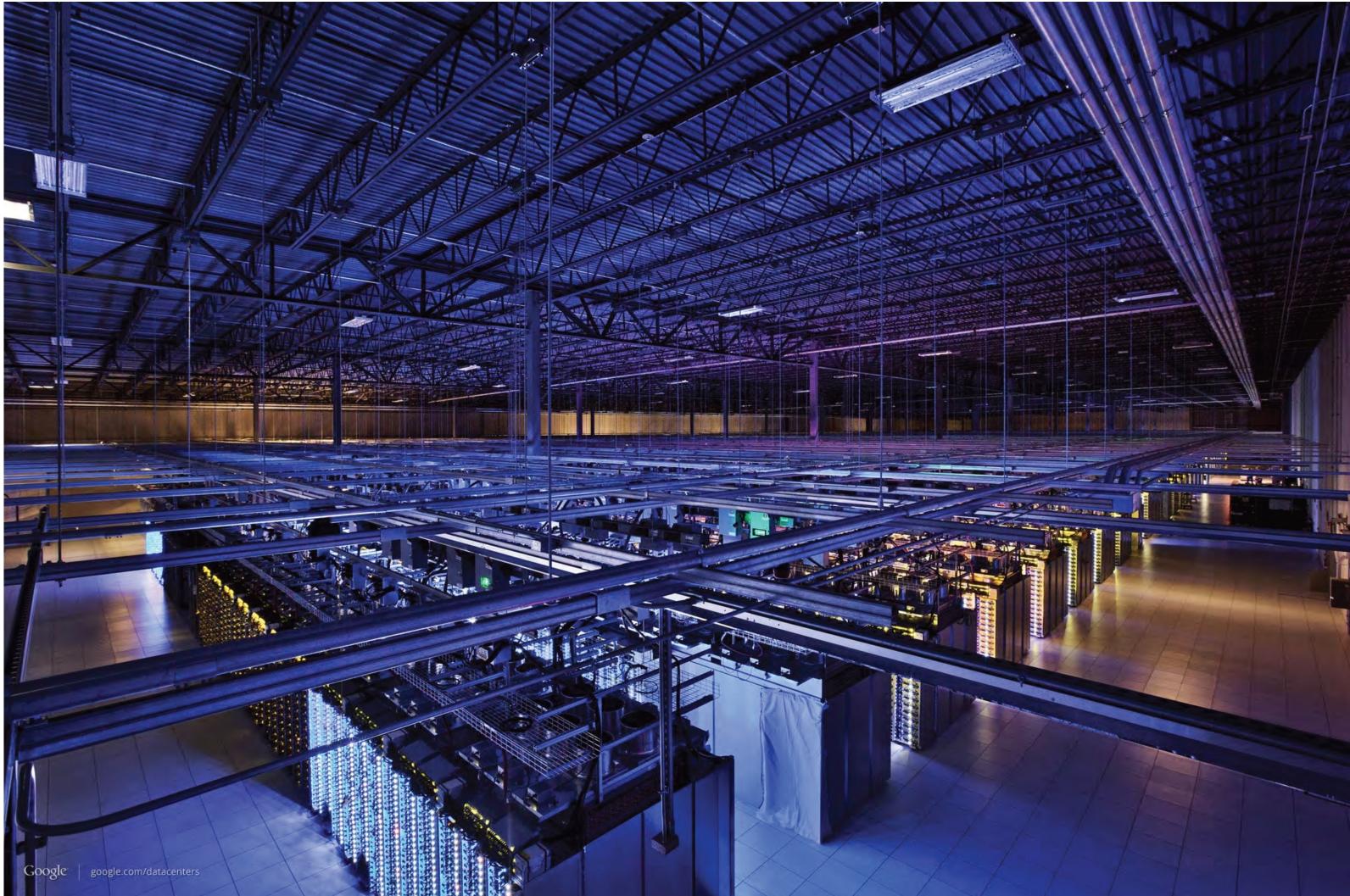
Data center: outside



Copyright: Google

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Data center: inside



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Server racks



Photo credit: Google

Server: inside



Copyright: xsnet

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Server cage



Network room

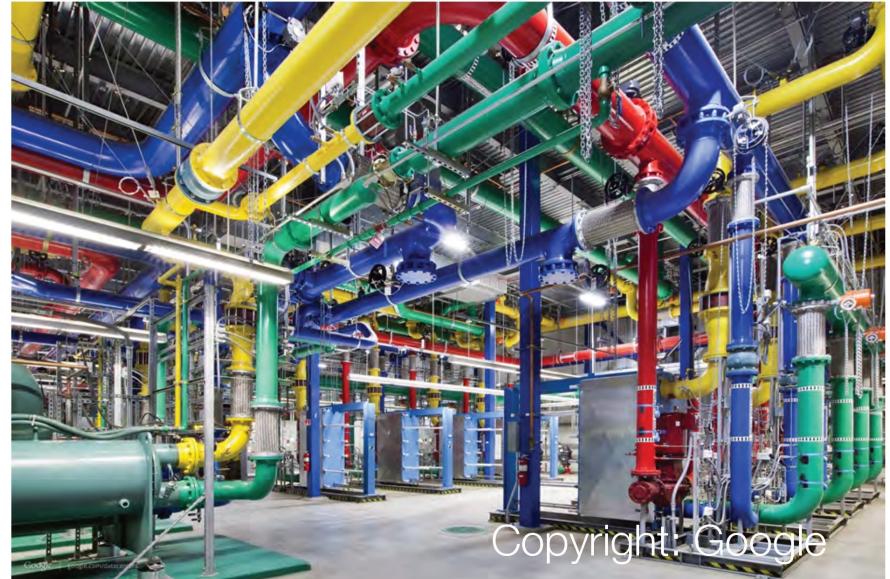


Google | google.com/datacenters

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Cooling functionality



Power functionality



Copyright: GigaOM



Explore Google Datacenter

<https://www.youtube.com/watch?v=XZmGGAbHqa0>

Copyright: Nation of Change

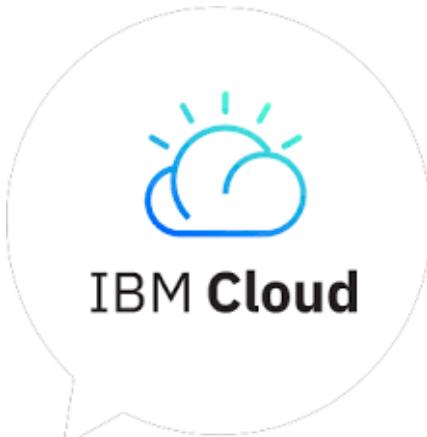
Cloud providers



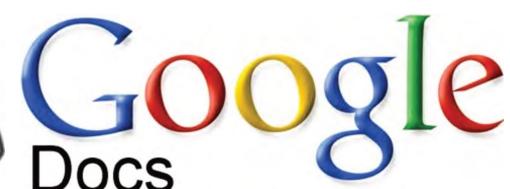
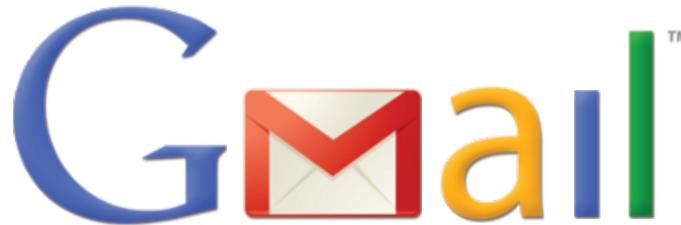
Google Cloud Platform



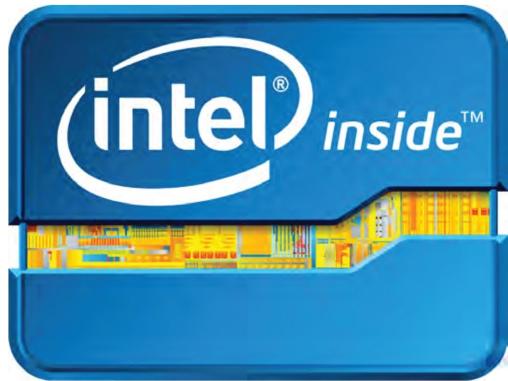
iCloud



Cloud-based services



Cloud vendors



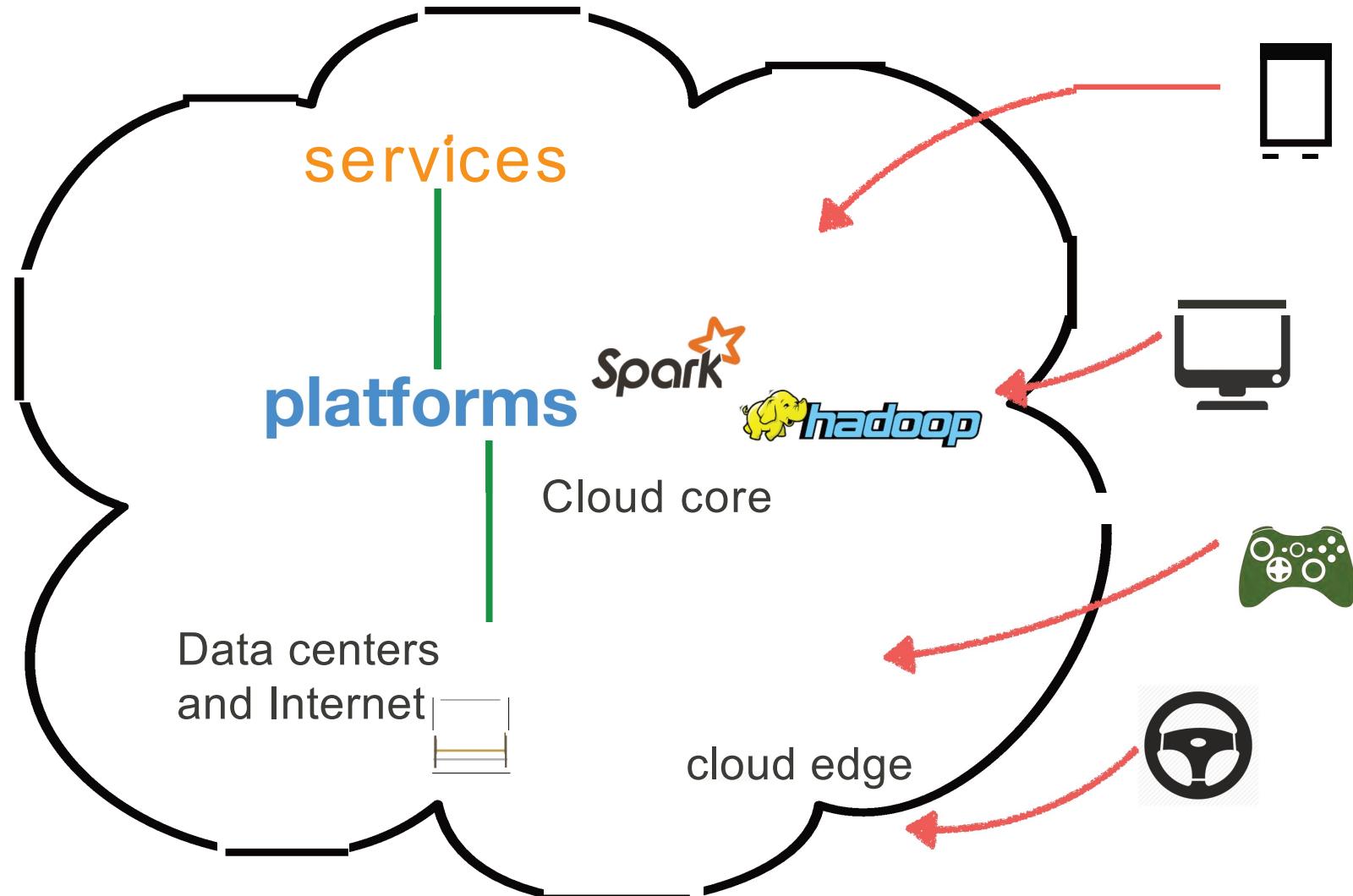
databricks

vmware®



CITRIX®
XenServer

So what is a cloud?



A definition

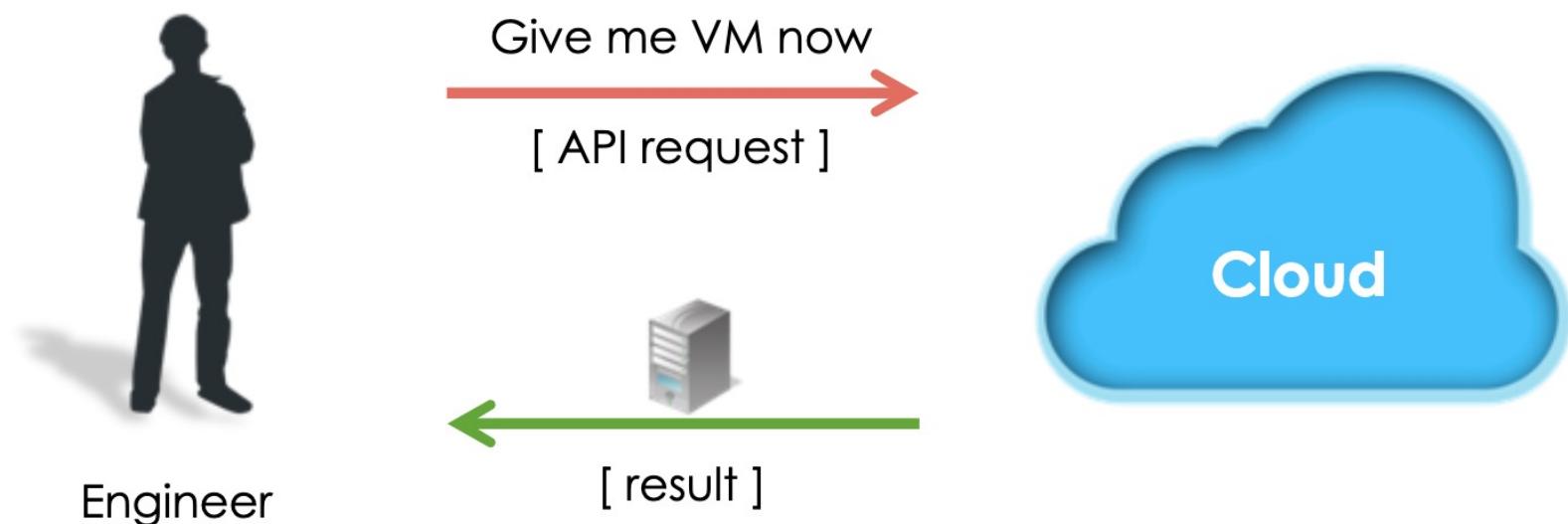
Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider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

Four types of cloud computing: private clouds, public clouds, hybrid clouds and multiclouds

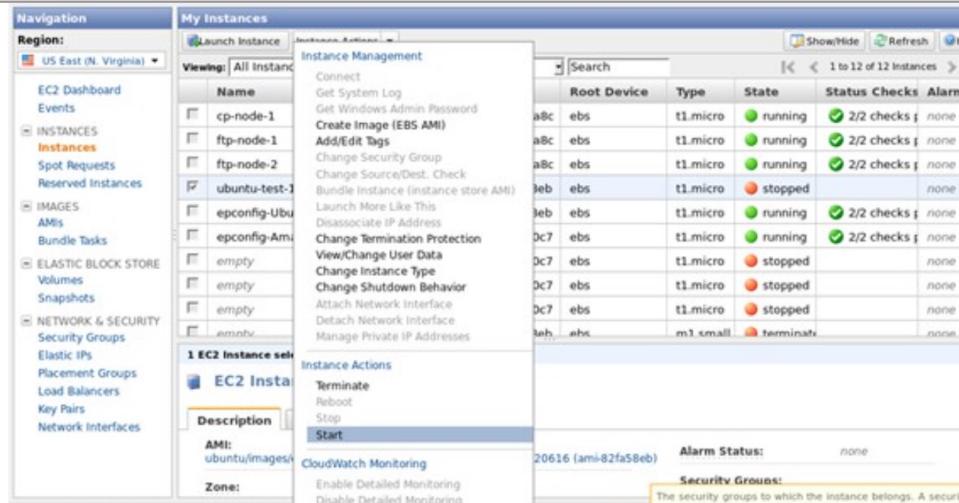
National Institute of Standards and Technology (NIST), U.S. Department of Commerce

On-demand self-service

Suppose you open a start-up, and needs 20 servers for the business, cloud computing enables on-demand service



On-demand self-service



```
$ ec2-start-instances i-b3a850c8
INSTANCE          i-b3a850c8      stopped pending
```

```
$ ec2-describe-instances i-b3a850c8
RESERVATION      r-0a7cf16e      852587906425      default
                  i-b3a850c8      ami-82fa58eb      ec2-107-22-37-50.compute-1.amazonaws.com      ip-10-122-235-23.ec2.internal      running
                  amkeys 0          t1.micro        2012-09-03T14:13:56+0000
                  us-east-1a       aki-825ea7eb      monitoring-
disabled        107.22.37.50    10.122.235.23      ebs
                           paravirtual   xen
                           XNsFe1343912068109 sg-da0169b3      default false
BLOCKDEVICE      /dev/sda1        vol-f8d0c899      2012-09-03T14:21:00Z      true      TAG      instance      i-
b3a850c8        Name      ubuntu-test-1TAG      instance      i-
b3a850c8        Role      webserver
```

On-demand self-service

A consumer can unilaterally provision computing capabilities, such as servers and network storage, as needed automatically without requiring human interaction with each service provider.

Cloud computing makes the underlying technology, beyond the user device, almost invisible and transparent to users

Advantages for consumers: flexible, minimal overhead, quick and easy

Broad network access



Broad network access

Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., smart phones, tablets, laptops, and workstations).

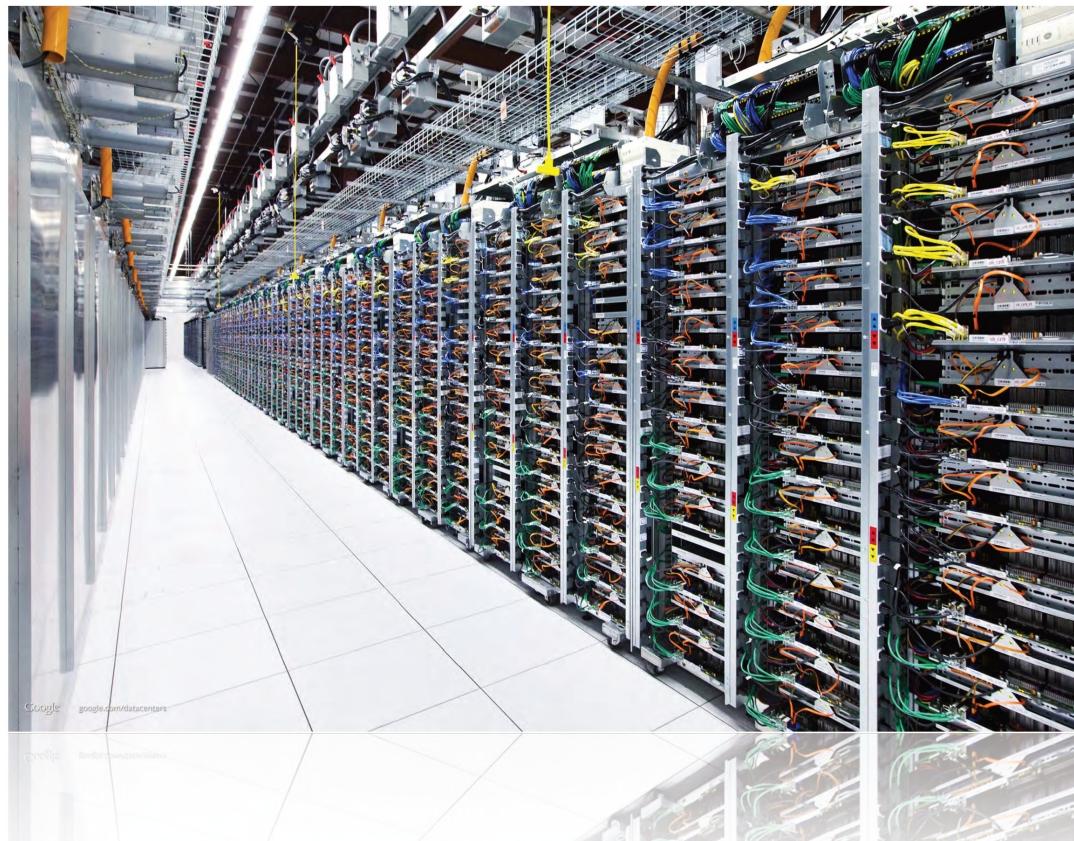
Advantages for consumers: "Always-on" experience, like utilities (electricity)

Allows big amount of data to be collected from cloud edge

Cloud computing enables scalable machine learning techniques to power Artificial Intelligence (AI) applications

Resource pooling

From the provider's perspective



Resource pooling

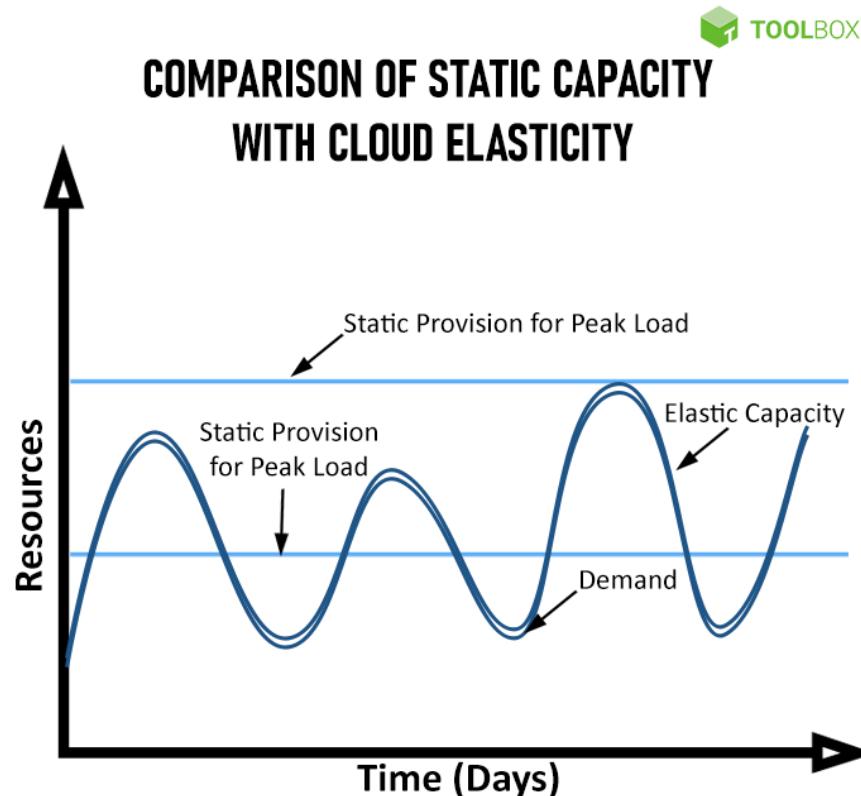
The provider's resources are pooled to serve consumers using a multi-tenant model, with different physical and virtual resources dynamically allocated according to **consumer** demand.

Location independence: the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter).

Advantage for providers: efficiency in utilization

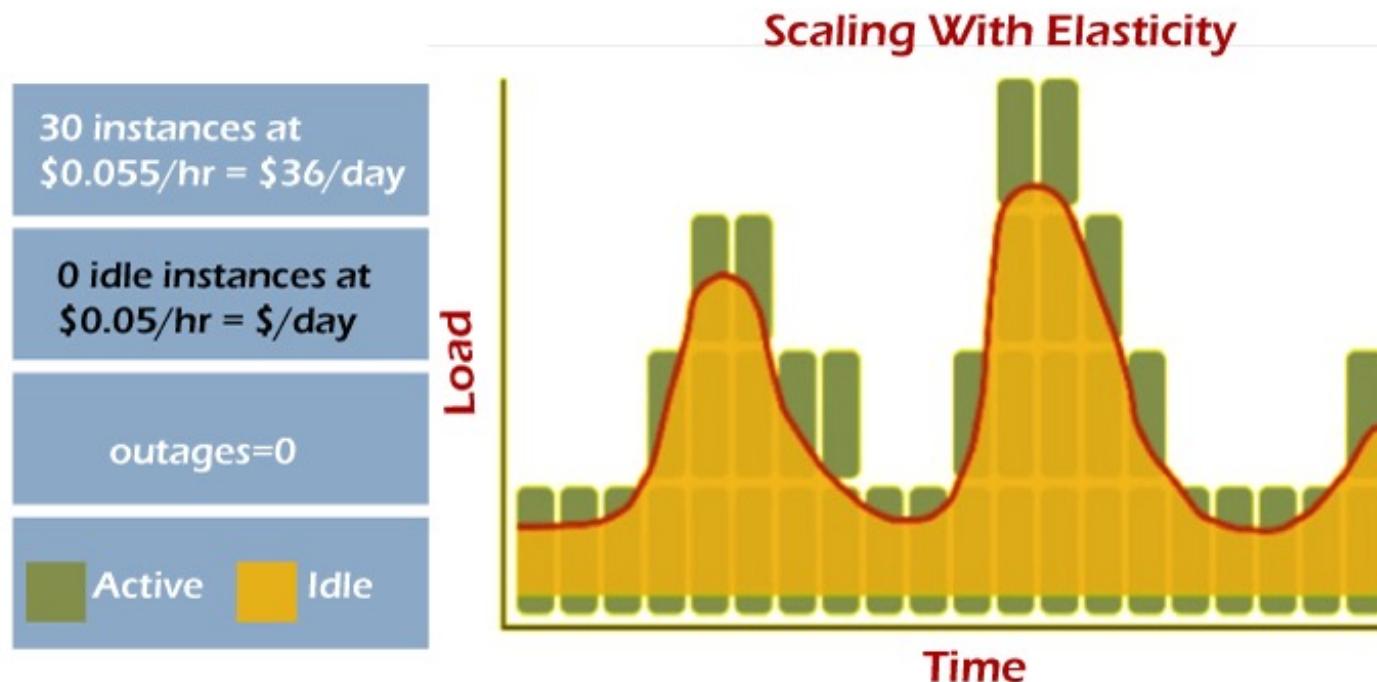
Cloud rapid elasticity

Resources can be rapidly and elastically scaled up and down. Suppose your business grows and needs 40 servers now. Elastic provisioning outperforms static provisioning



Cloud rapid elasticity

With cloud computing



Advantage for consumers: flexible, quick and easy

Cloud economics

A cloud automatically controls and optimizes resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service

Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer

Cloud economics to match supply and demand. How to optimize cloud resources to match computing and storage demands?

Cloud economics: Who determines price and pricing strategies

Pay-as-you-go, pay only for what you use

Social cloud computing

Generalize cloud computing to include the sharing, bartering and renting of computing resources across peers whose owners and operators are verified through a social network or reputation system

Basis of emerging Web 3.0 applications past the confines of formal commercial data centers operated by cloud providers to include anyone interested in participating within the cloud services sharing economy

Berkeley Open Infrastructure for Network Computing
Subutai P2P Edge Cloud Platform (<https://subutai.io>)
Decentralized applications (dApps)

Cloud Summary

Cloud computing is an umbrella term used to refer to Internet based development and services

A number of characteristics define cloud data, applications services and infrastructure:

Remotely hosted: Services or data are hosted on remote infrastructure.

Ubiquitous: Services or data are available from anywhere.

Commodified: The result is a utility computing model similar to traditional that of traditional utilities, like gas and electricity - you pay for what you would want!

Outline

Infrastructure-as-a-Service (IaaS)

Platform-as-a-Service (PaaS)

Software-as-a-Service (SaaS)

Opportunities and Challenges

Advantages and Disadvantages of cloud computing

IaaS

Infrastructure-as-a-Service (IaaS)

Providers give you the computing infrastructure made available as a service. You get "bare-metal" machines.

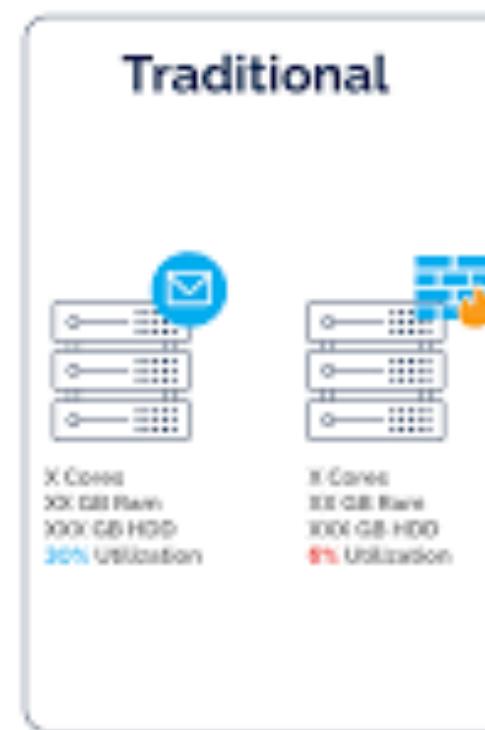
Providers manage a large pool of resources (i.e., servers), and use virtualization to dynamically allocate servers

Customers "rent" these physical resources to customize **their own infrastructure**

You operate the Operating System (OS) and all the software on the servers by yourself

IaaS

Infrastructure-as-a-Service (IaaS) Virtualization and Virtual Machines



IaaS Applications

Netflix rents thousands of servers, terabytes of storage from Amazon Web Services (AWS)

Develop and deploy specialized software for transcoding, storage, streaming, analytics, etc. on top of service delivery

Able to support tens of millions of connected devices used by 40+ million users from 40+ countries



Virtualization

□ Virtual workspaces:

- An abstraction of an execution environment that can be made dynamically available to authorized clients by using well-defined protocols,
- Resource quota (e.g. CPU, memory share),
- Software configuration (e.g. O/S, provided services).

□ Implement on Virtual Machines (VMs):

- Abstraction of a physical host machine,
- Hypervisor intercepts and emulates instructions from VMs, and allows management of VMs,
- VMWare, Xen, etc.

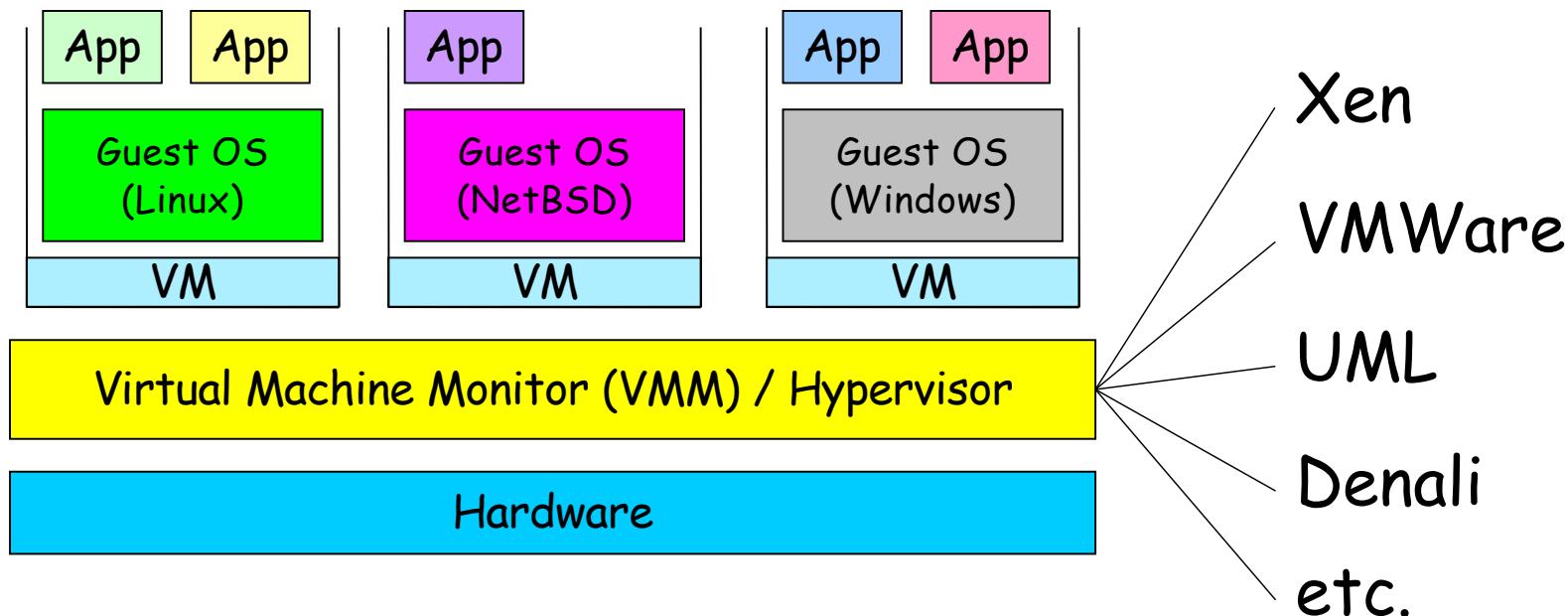
□ Provide infrastructure API:

- Plug-ins to hardware/support structures



Virtual Machines

VM technology allows multiple virtual machines to run on a single physical machine.



Performance: Para-virtualization (e.g. Xen) is very close to raw physical performance!

PaaS

Platform-as-a-Service (PaaS)

Providers give users with a software platform or middleware where applications run

You develop and maintain and deploy your own software on top of the platform

The hardware needed to run the software is automatically managed by the platform. There are limitations on explicit management of resources.

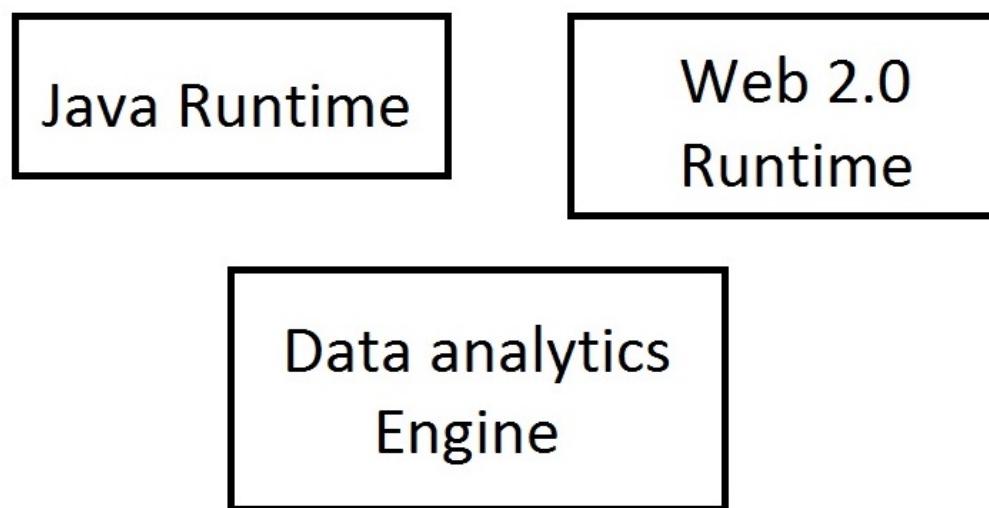
Examples: SQL as a service (SQLaaS), Matlab, Gurobi

PaaS

You have automated scalability without the need to respond to request load increase or decrease

Ideal for deployment of mobile apps, web apps etc.

Application programming interface (API) support via popular languages like Python, Javascript, Java, PHP, and Go



SaaS

Software-as-a-Service (SaaS)

Providers give you a piece of software/application, and take care of updating, maintaining and troubleshooting the application.

As end user, you simply use the software using the Internet.

Business model of SaaS: business-to-business (B2B), business-to-clients (B2C) that cover numerous retail end users

Applications of SaaS

Nowadays, many institutions use Google Apps, Apple cloud and Office 365 for emails, video meeting, calendar, etc.

Business use SaaS for payment and transactions. Legal industry relies on SaaS for compliance, creative industry relies on SaaS for artwork (e.g., computer-generated images). Engineers rely on SaaS to design circuits/software. Students rely on SaaS to learn and collaborate.

What are scientific applications of SaaS?



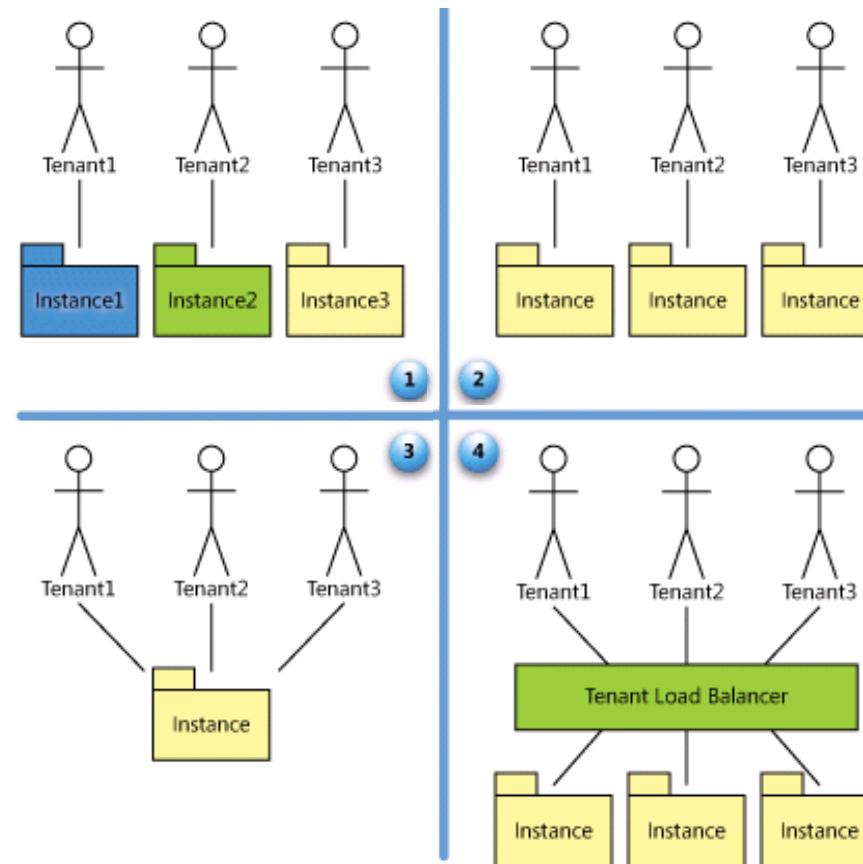
SaaS Maturity Model

Level 1: Ad-Hoc/Custom –
One Instance per customer

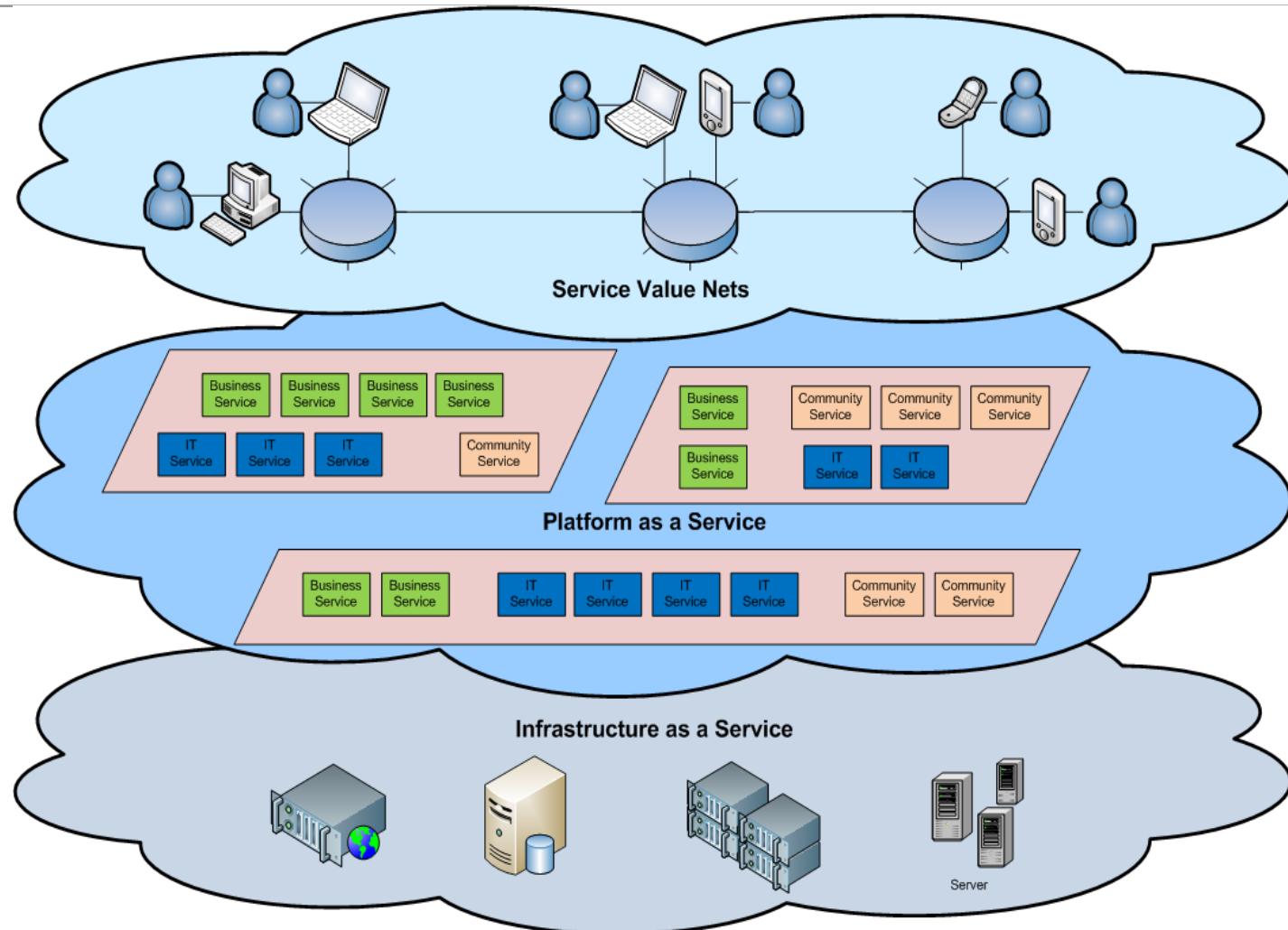
Level 2: Configurable per
customer

Level 3: configurable & Multi-
Tenant-Efficient

Level 4: Scalable, Configurable
& Multi-Tenant-Efficient



Comparison of IaaS, PaaS, SaaS



Convenience/Ease of management/Business Models
Tradeoff between flexibility and "built-in" functionality

Opportunities and Challenges

The use of the cloud provides a number of opportunities:

IaaS enables services to be used without any understanding of their infrastructure.

Cloud computing works using economies of scale:

- IaaS and PaaS potentially lower the outlay expense for start up companies, as they would no longer need to buy their own software or servers.
- Cost would be by on-demand pricing in IaaS, PaaS and SaaS.
- Cloud providers claim costs by establishing an ongoing revenue stream.

Data and services are stored remotely but accessible from “anywhere” in SaaS.

Opportunities and Challenges

In parallel there has been backlash against cloud computing:

Use of cloud computing means dependence on others and that could possibly limit flexibility and innovation:

- The others are likely become the bigger Internet companies like Google and IBM, who may monopolise the market.
- Some argue that this use of supercomputers is a return to the time of mainframe computing that the PC was a reaction against.

Security could prove to be a big issue:

- It is still unclear how safe out-sourced data to SaaS is and when using these services ownership of data in SaaS is not always clear.

There are also issues relating to policy and access:

- If your data is stored abroad whose policy do you adhere to?
- What happens if the remote server goes down?
- How will you then access files?
- There have been cases of users being locked out of accounts and losing access to data.

Advantages of Cloud Computing

IaaS leads to lower computer costs:

You do not need a high-powered and high-priced computer to run cloud computing's web-based applications.

Since applications run in the cloud, not on the desktop PC, your desktop PC does not need the processing power or hard disk space demanded by traditional desktop software.

When you are using web-based applications, your PC can be less expensive, with a smaller hard disk, less memory, more efficient processor...

In fact, your PC in this scenario does not even need a CD or DVD drive, as no software programs have to be loaded and no document files need to be saved.

Advantages of Cloud Computing

IaaS leads to unlimited storage capacity:

Cloud computing offers virtually limitless storage.

Your computer's current 1 Tbyte hard drive is small compared to the hundreds of Pbytes available in the cloud.

IaaS leads to increased data reliability:

Unlike desktop computing, in which if a hard disk crashes and destroy all your valuable data, a computer crashing in the cloud should not affect the storage of your data.

if your personal computer crashes, all your data is still out there in the cloud, still accessible

In a world where few individual desktop PC users back up their data on a regular basis, cloud computing is a data-safe computing platform!

Advantages of Cloud Computing

PaaS leads to improved performance:

With few large programs hogging your computer's memory, you will see better performance from your PC.

Computers in a cloud computing system boot and run faster because they have fewer programs and processes loaded into memory...

SaaS leads to reduced software costs:

Instead of purchasing expensive software applications, you can get most of what you need for free-ish!

- most cloud computing applications today, such as the Google Docs suite.

Better than paying for similar commercial software

- which alone may be justification for switching to cloud applications.

Advantages of Cloud Computing

PaaS and SaaS take care of instant software updates:

Another advantage to cloud computing is that you are no longer faced with choosing between obsolete software and high upgrade costs.

With web-based applications (i.e., SaaS), updates happen automatically

- available the next time you log into the cloud.

When you access a web-based application, you get the latest version

- without needing to pay for or download an upgrade.

SaaS leads to improved document format compatibility.

You do not have to worry about the documents you create on your machine being compatible with other users' applications or OSes

There are potentially no format incompatibilities when everyone is sharing documents and applications in the cloud.

Advantages of Cloud Computing

SaaS leads to universal document access:

That is not a problem with cloud computing, because you do not take your documents with you.

Instead, they stay in the cloud, and you can access them whenever you have a computer and an Internet connection

Documents are instantly available from wherever you are

SaaS leads to latest version availability:

When you edit a document at home, that edited version is what you see when you access the document at work.

The cloud always hosts the latest version of your documents

-as long as you are connected, you are not in danger of having an outdated version

Advantages of Cloud Computing

SaaS leads to easier group collaboration:

Sharing documents leads directly to better collaboration.

Many users do this as it is an important advantages of cloud computing

- multiple users can collaborate easily on documents and projects

Device independence.

You are no longer tethered to a single computer or network.

Changes to computers, applications and documents follow you through the cloud.

Move to a portable device, and your applications and documents are still available.

Disadvantages of Cloud Computing

Requires a constant Internet connection:

Cloud computing is impossible if you cannot connect to the Internet.

Since you use the Internet to connect to both your applications and documents, if you do not have an Internet connection you cannot access anything, even your own documents.

A dead Internet connection means no work and in areas where Internet connections are few or inherently unreliable, this could be a deal-breaker.

Disadvantages of Cloud Computing

Does not work well with low-speed connections:

Similarly, a low-speed Internet connection, such as that found with dial-up services, makes cloud computing painful at best and often impossible.

Web-based applications require a lot of bandwidth to download, as do large documents.

Features might be limited:

This situation is bound to change, but today many web-based applications simply are not as full-featured as their desktop-based applications.

- For example, you can do a lot more with Microsoft PowerPoint than with Google Presentation's web-based offering

Disadvantages of Cloud Computing

Can be slow:

Even with a fast connection, web-based applications can sometimes be slower than accessing a similar software program on your desktop PC.

Everything about the program, from the interface to the current document, has to be sent back and forth from your computer to the computers in the cloud.

If the cloud servers happen to be backed up at that moment, or if the Internet is having a slow day, you would not get the instantaneous access you might expect from desktop applications.

Disadvantages of Cloud Computing

Stored data might not be secure:

With cloud computing, all your data is stored on the cloud.

■ The question is How secure is the cloud?

Can unauthorised users gain access to your confidential data?

Stored data can be lost:

Theoretically, data stored in the cloud is safe, replicated across multiple machines.

But on the off chance that your data goes missing, you have no physical or local backup.

Put simply, relying on the cloud puts you at risk if the cloud lets you down.

Disadvantages of Cloud Computing

HPC Systems:

Not clear that you can run compute-intensive HPC applications that use MPI/OpenMP!

Scheduling is important with this type of application

- as you want all the VM to be co-located to minimize communication latency!

General Concerns:

Each cloud systems uses different protocols and different APIs

- may not be possible to run applications between cloud based systems

Amazon has created its own DB system (not SQL), and workflow system (many popular workflow systems out there)- so your normal applications will have to be adapted to execute on these platforms.