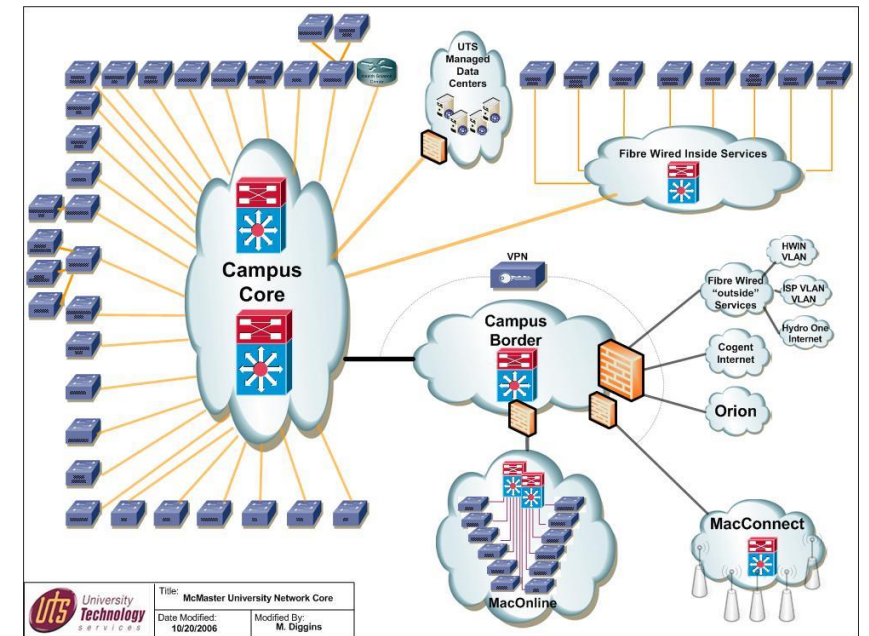
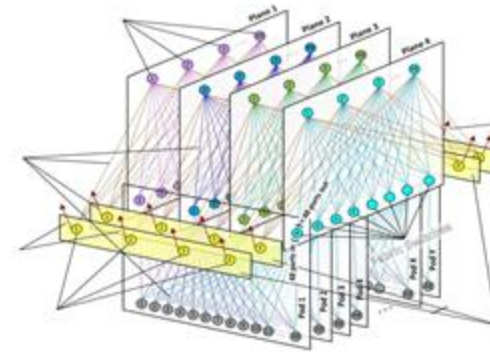


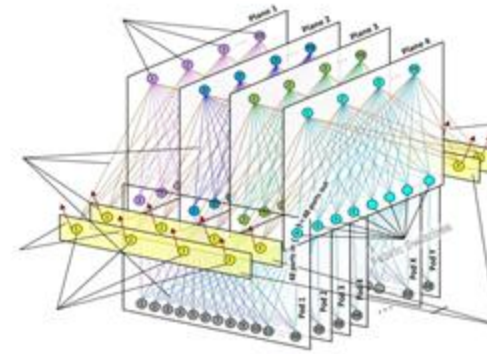
Large Systems:

Design ≠
Implementation ≠
Administration

2024-2025

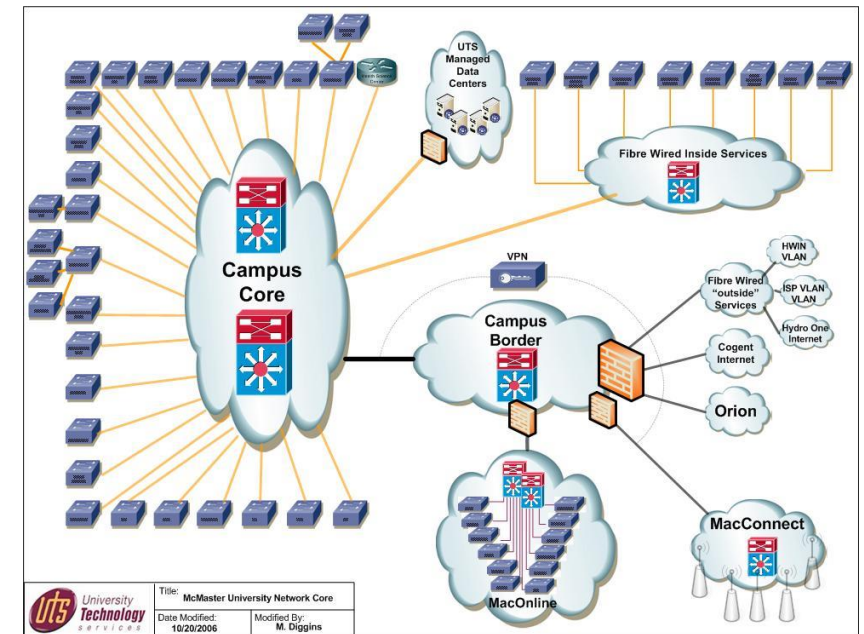


Large Systems:



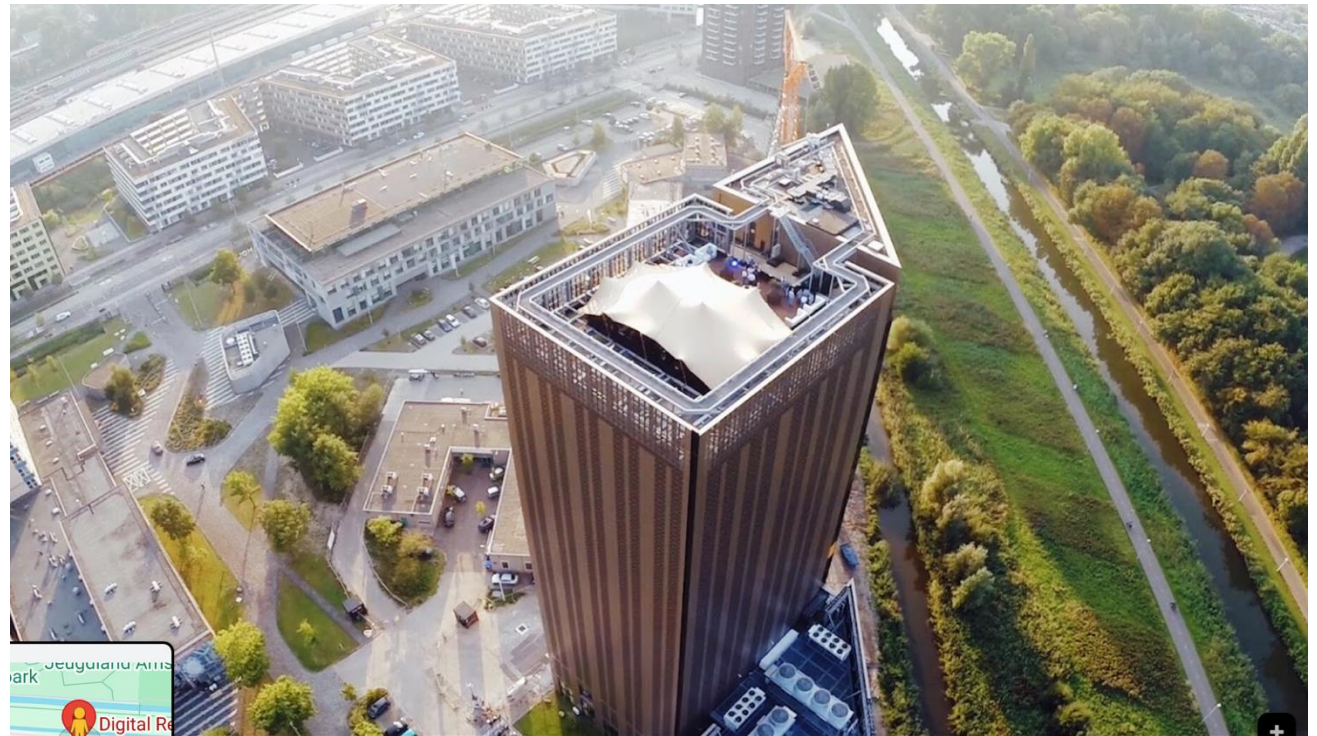
➤ Week4-L8: Introduction to Cloud Computing

Shashikant Ilager
shashikantilager.com



Today's SURF data center visit

- Location: Science park 120
- Please verify your slot and be at entrance of the data center tower



Papers..

- Make sure your presentation fits within 10 minutes + 5 min QA
- Max 10-12 slides
- Recommended structure*
 - Introduction: Motivation and Problem statement (1-2 slides)
 - Related work: SOTA and research gap (1-slide)
 - Proposed work: Methodology and technique (3-4 slides)
 - Performance evaluation: Experimental setup, results and insights (1-2 slides)
 - Conclusions and future directions (1 slide)

* You can choose your slide structure based on paper type and your own convenience

Trends in Distributed Systems

Distributed systems has been undergoing a period of significant change and this can be traced back to a number of influential trends:

- The emergence of **pervasive networking** technology
 - **Pervasive** means "diffused throughout every part of."
- The emergence of **ubiquitous computing** coupled with the desire to support user mobility in distributed systems;
 - **Ubiquitous** means everywhere
- The increasing demand for **multimedia services**.
- The view of distributed systems as **utility**.

Distributed Computing as Utility

Distributed resources can be viewed as a commodity or utility similar to *water* or *electricity*.

Resources are provided by appropriate service suppliers and **rented** rather than **owned** by an end user.

The term **cloud computing** is used to capture this vision.

Cloud Computing Definitions

A report from the *University of California Berkeley* [1] defines cloud as the “data center hardware and software that provide services”

summarized the key characteristics of cloud computing as:

- “(1) the illusion of infinite computing resources;
- (2) the elimination of an up-front commitment by cloud users; and
- (3) the ability to pay for use ... as needed ...”

The National Institute of Standards and Technology (NIST):

“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.”

[1] M. Armbrust, A. Fox, R. Griffith, A. D. Joseph, and R. Katz, Above the Clouds: A Berkeley View of Cloud Computing, UC Berkeley Reliable Adaptive Distributed Systems Laboratory White Paper, 2009.

Cloud Computing

An IT paradigm that enables access to **shared pools** of configurable system resources in form of **services** that can be rapidly provisioned with minimal management effort, often over the **Internet**.

Why Clouds?

Every 18 months?

Conventional Computing

- Buy & Own
 - Hardware, System Software, Applications
 - Often to meet peak needs.
- Install, Configure, Test, Verify, Evaluate, Manage
- ...
- Finally, use it!
- \$\$\$\$....\$(VERY expensive!)

Cloud Computing

- Subscribe
- Use



- \$ - pay for what you use, based on Quality of Service (QoS).

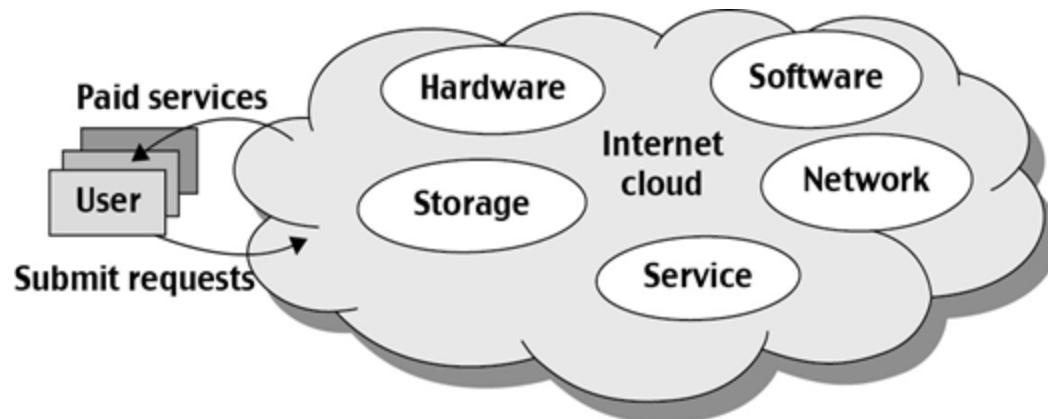
(Courtesy of Rajkumar Buyya, 2012)

Basic Concept

Cloud is the “invisible” backend to many applications

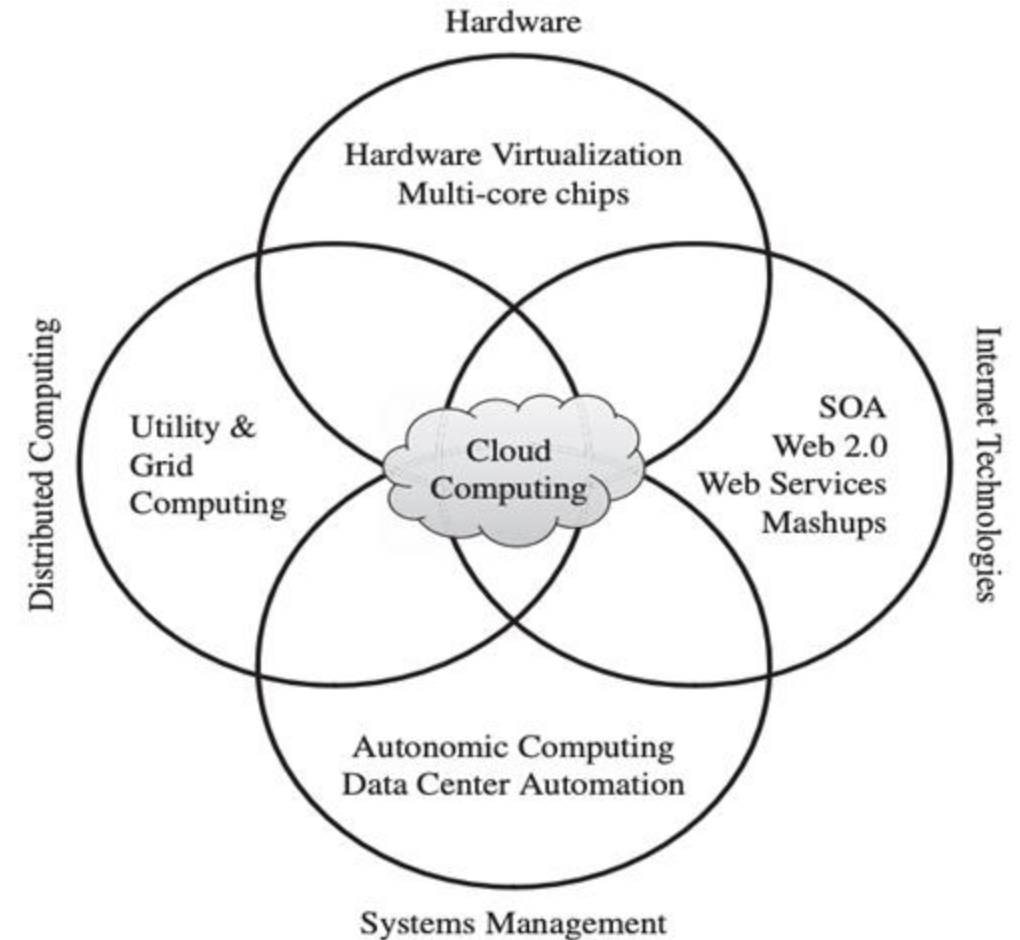
- e.g., Dropbox, LinkedIn, Github, Office 365, Amazon, Office365, Slack,...

The name comes from the use of a cloud-shaped symbol as an abstraction for the complex infrastructure.



The long-held dream of computing as a utility

- The long-held dream of delivering computing as a utility has been realized with the advent of **cloud computing**
- Over the years, **several technologies** have matured and significantly contributed to make cloud computing viable
 - Utility & Grid Computing
 - Webservices
 - Virtualization
 - Autonomic Computing



Utility and Grid Computing

- When plugging an electric appliance into an outlet, we care neither how electric power is generated nor how it gets to that outlet.
- Electricity is **virtualized**:
 - that is, it is readily available from a wall socket that hides power generation stations and a huge distribution grid.
- Technologies such as **cluster**, **grid**, and **cloud computing**, have all aimed at allowing access to large amounts of computing power in a fully virtualized manner, by aggregating resources and offering a single system view.
- Utility computing
 - a business model for on-demand delivery of computing power; consumers pay providers based on usage (“pay as-you-go”),
 - Similar to the way in which we currently obtain services from traditional public utility services such as water, electricity, gas, and telephony.

Alessandro Volta in Paris in 1801 inside French National Institute shows the battery while in the presence of Napoleon I

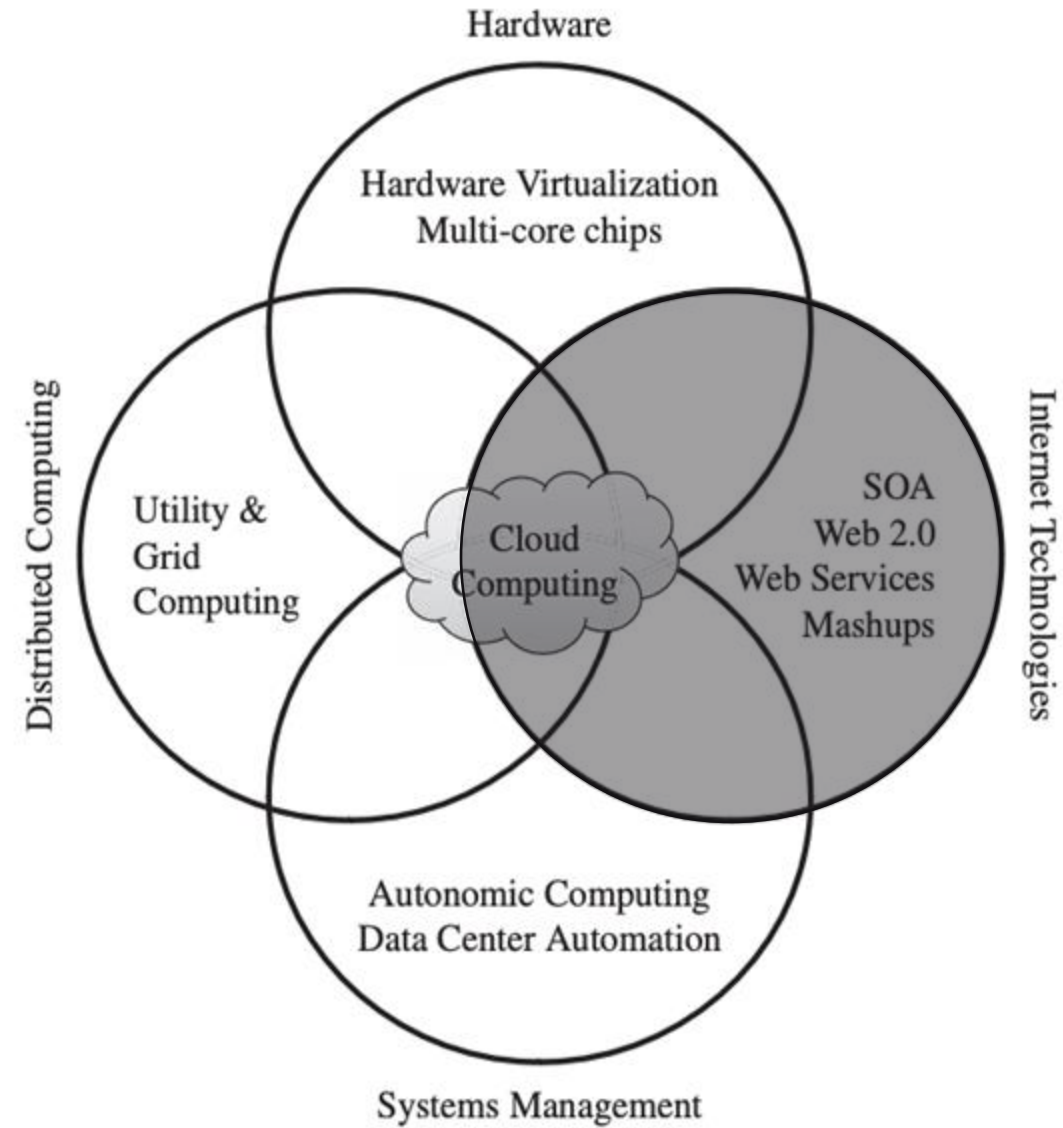


(Zoological Section "La Specula" of National History Museum of Florence University)

What !?!?
This is a mad
man...

....and in the future,
I imagine a Worldwide
Power (Electrical)
Grid





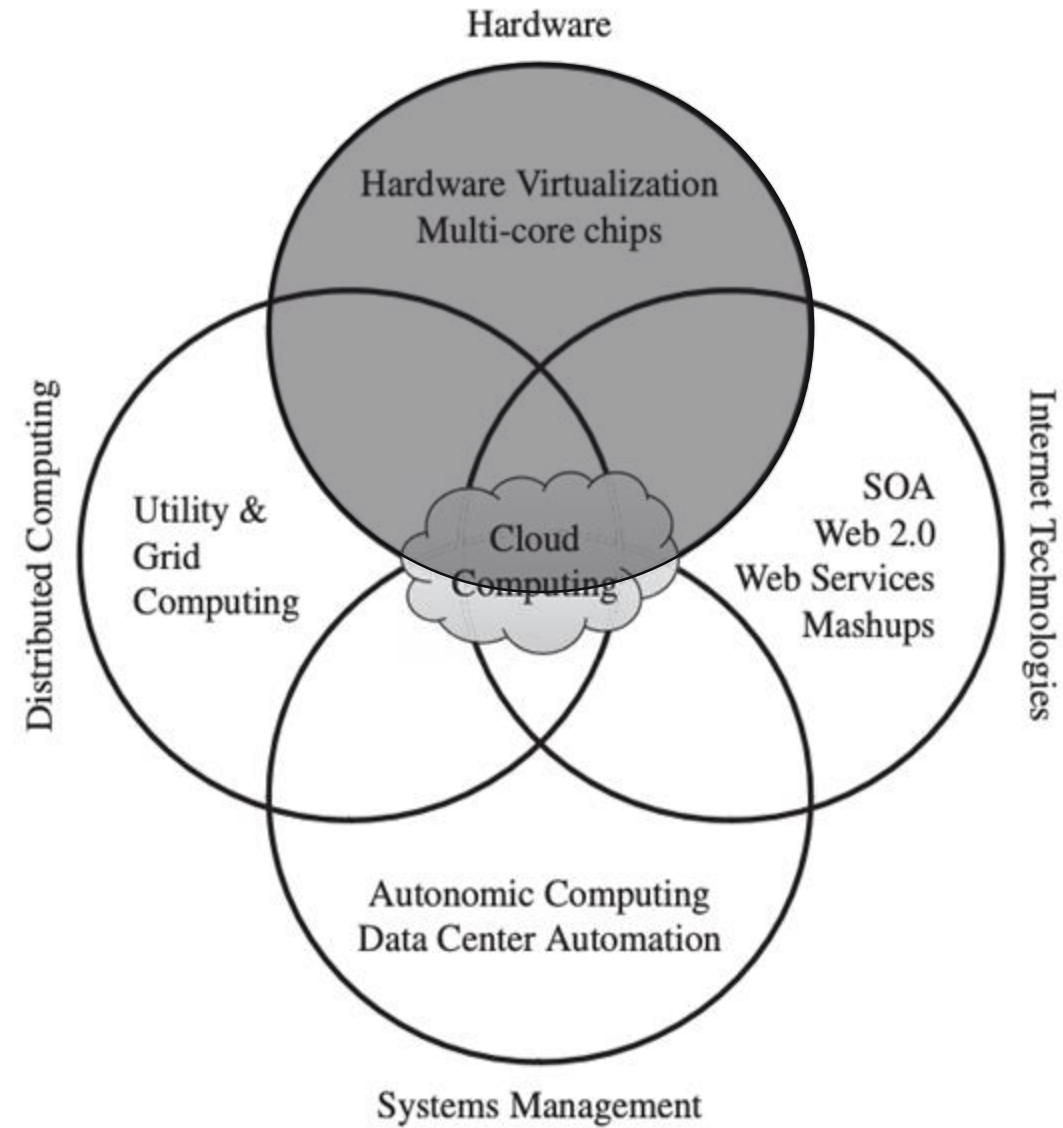
Web Services

A **Web service** is a software system designed to support interoperable machine-to-machine interaction over a network using HTTP and technologies such as XML, SOAP, WSDL, and UDDI.

Web services are increasingly important in distributed systems.

- They support **interoperability** across the global Internet, including the key area of business to-business integration and also the emergent ‘mashup’ culture enabling third-party developers to create innovative software on top of the existing service base.
- A **mashup** describes a Web application that combines multiple services into a single application.

Many service providers, such as Amazon, Facebook, and Google, make their service APIs publicly accessible using standard protocols such as SOAP and REST.

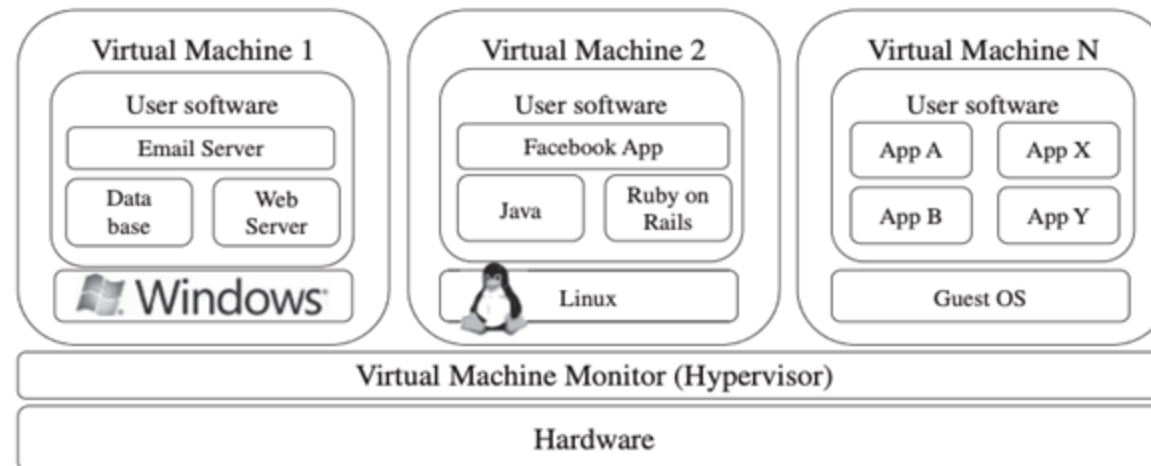


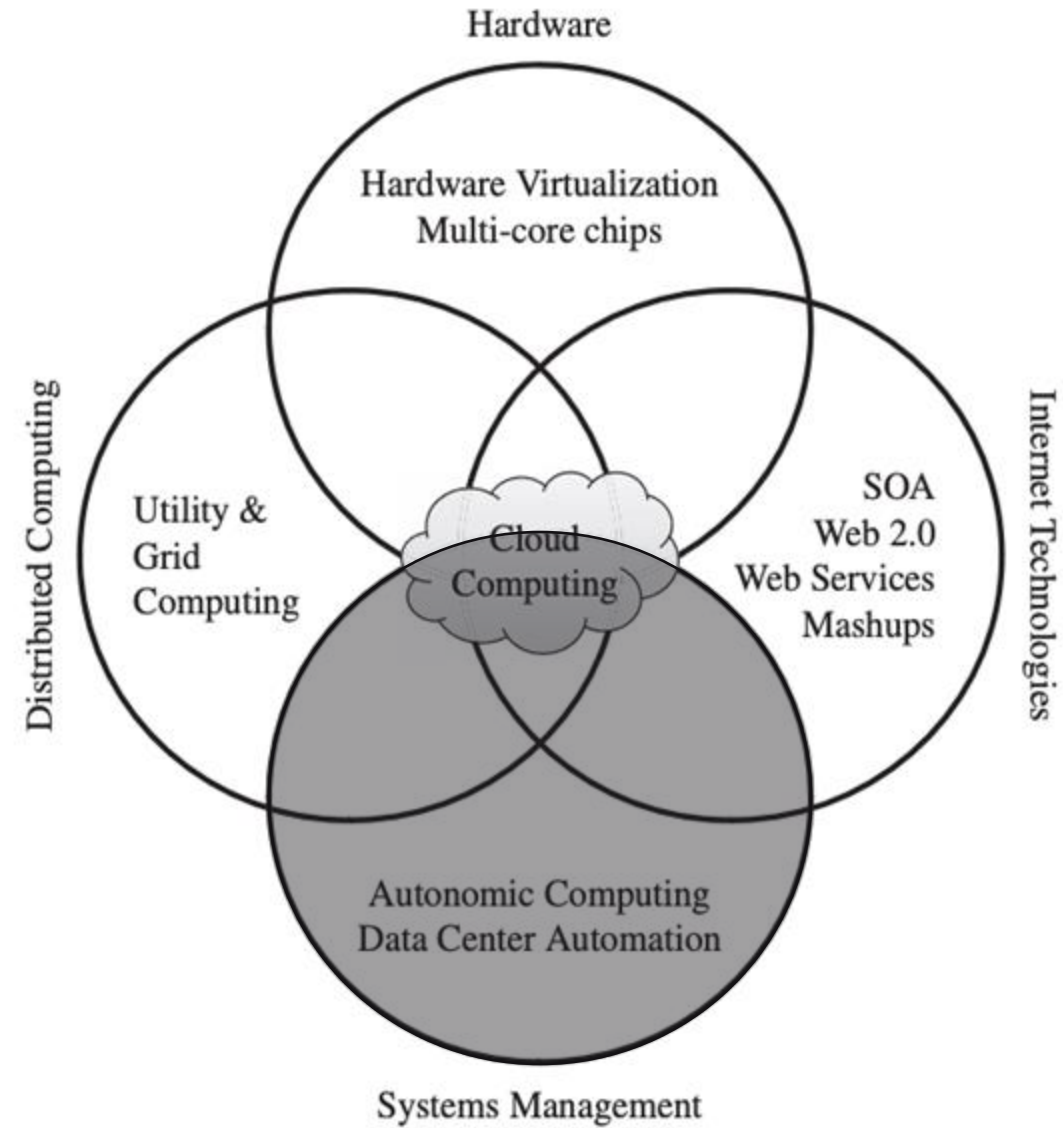
Hardware Virtualization

Virtualization hides the physical characteristics of a computing platform from the users, presenting instead an abstract computing platform

The software that controlled virtualization is called **hypervisor** or **virtual machine monitor**, e.g., Xen, KVM, VMWare ESXi.

Multi-core chips, paravirtualization, hardware-assisted virtualization, and live migration of VMs—has contributed to an increasing adoption of virtualization on server systems.



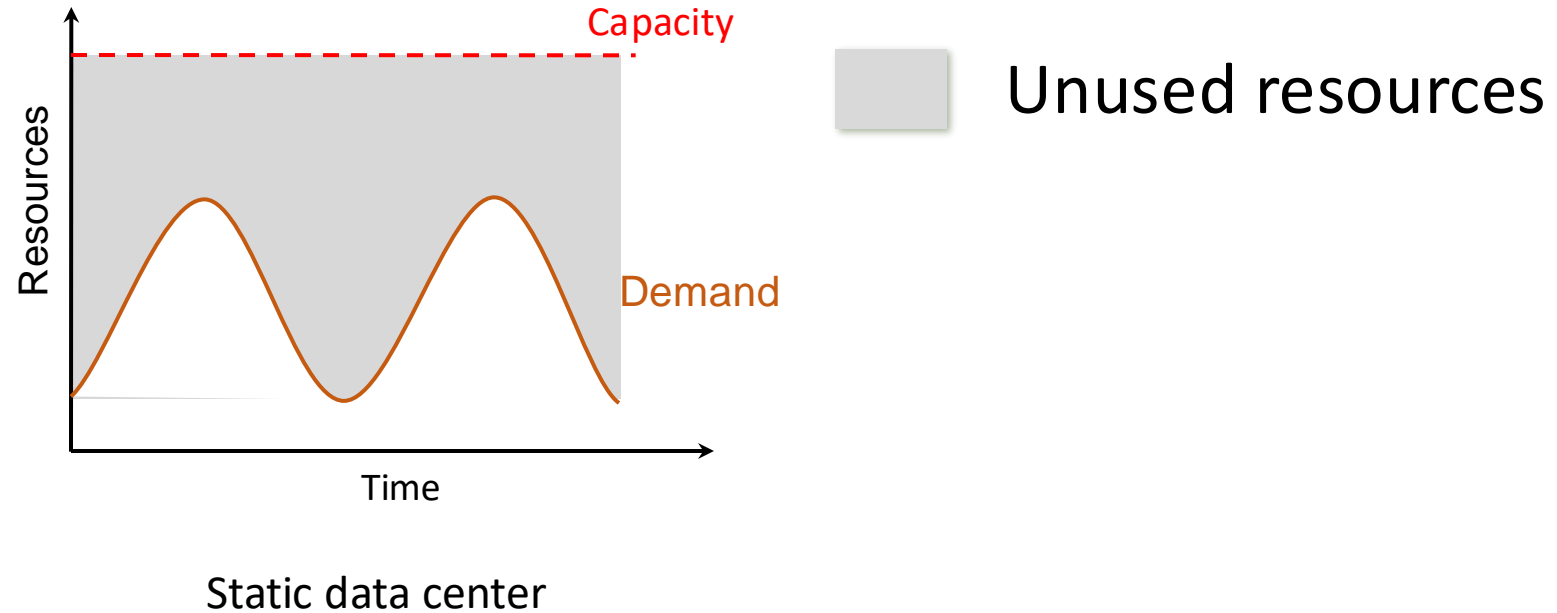


Autonomic Computing

- The increasing complexity of computing systems
 - motivated research on **autonomic computing**.
- Autonomic computing refers to the **self-managing** characteristics of distributed computing resources, adapting to unpredictable changes while hiding intrinsic complexity to operators and users.
- IBM's Autonomic Computing Initiative has contributed to define the four properties of autonomic systems:
 - self-configuration
 - self-optimization
 - self-healing
 - self-protection.
- IBM has also suggested a reference model for autonomic control loops of autonomic managers, called MAPE-K (Monitor Analyse Plan Execute—Knowledge)

Economics of Cloud Users

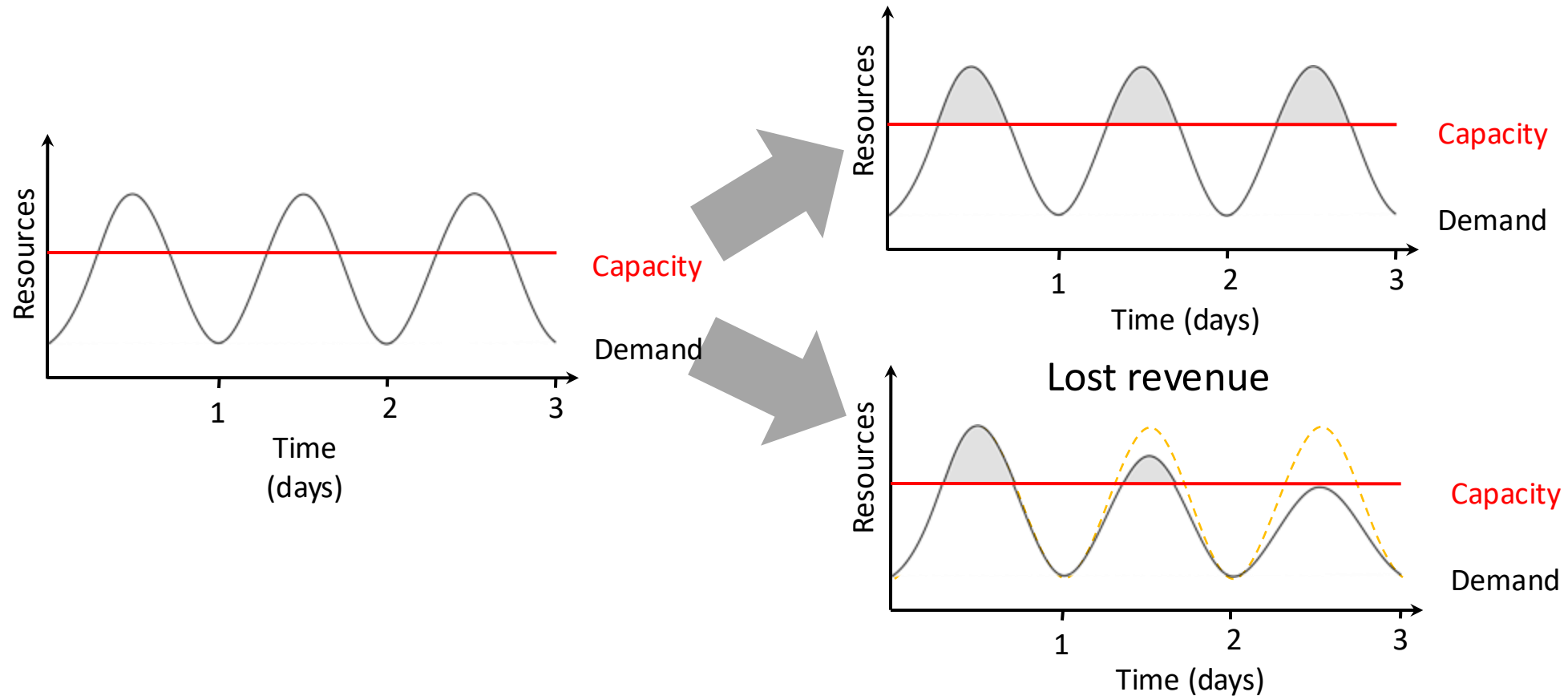
Risk of over-provisioning: underutilization



Slide Credits: Berkeley RAD Lab

Economics of Cloud Users

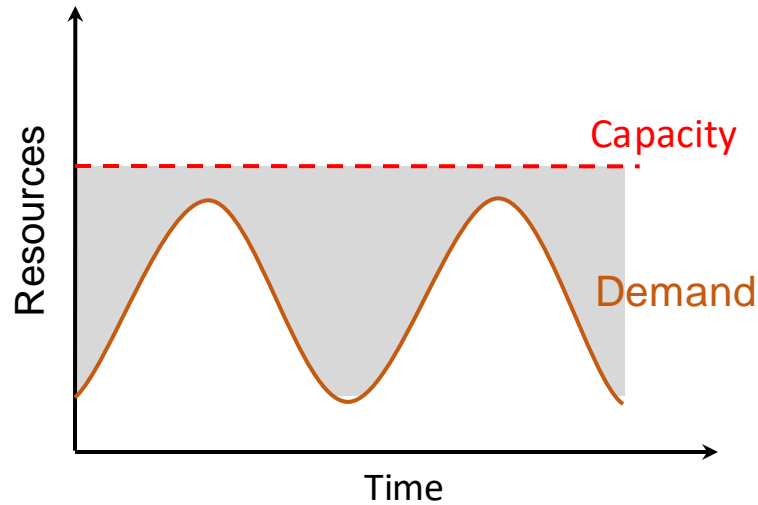
Heavy penalty for under-provisioning



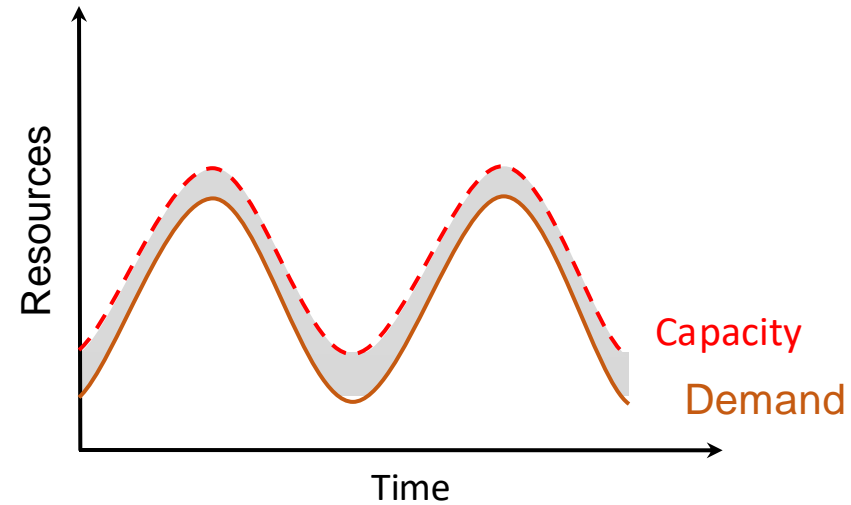
Slide Credits: Berkeley RAD Lab

Economics of Cloud Users

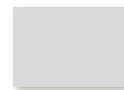
Pay by use instead of provisioning for peak



Static data center



Data center in the cloud



Unused resources

Cloud Deployment Models

Private

- Organization has its own private cloud, might be on-premise or off-premise

Public

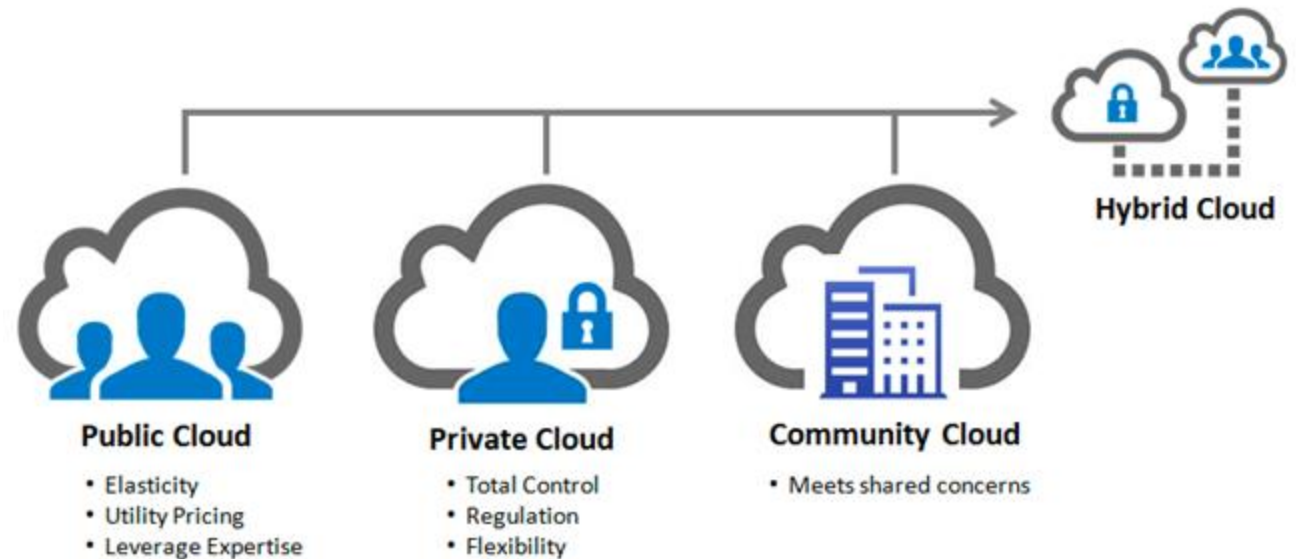
- Organizations shares cloud with general public.

Community

- Shared by several entities that have common purpose.

Hybrid

- Any combination of two or more private, community or public clouds.



Cloud Service Models

Software as a Service (SaaS)

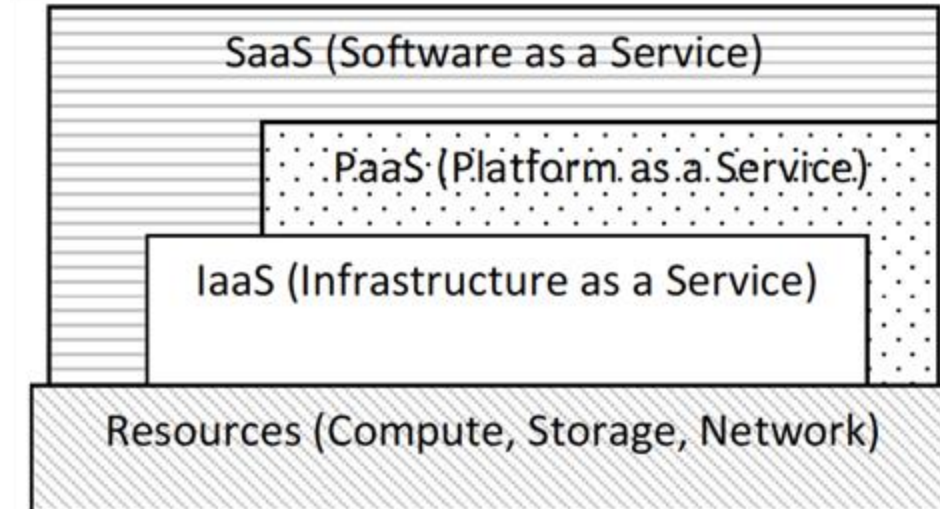
- provides applications and software to the customer in utility-based model which is accessible from a thin client interface such as a Web browser/ Mobile apps
 - Salesforce.com

Platform as a Service (PaaS)

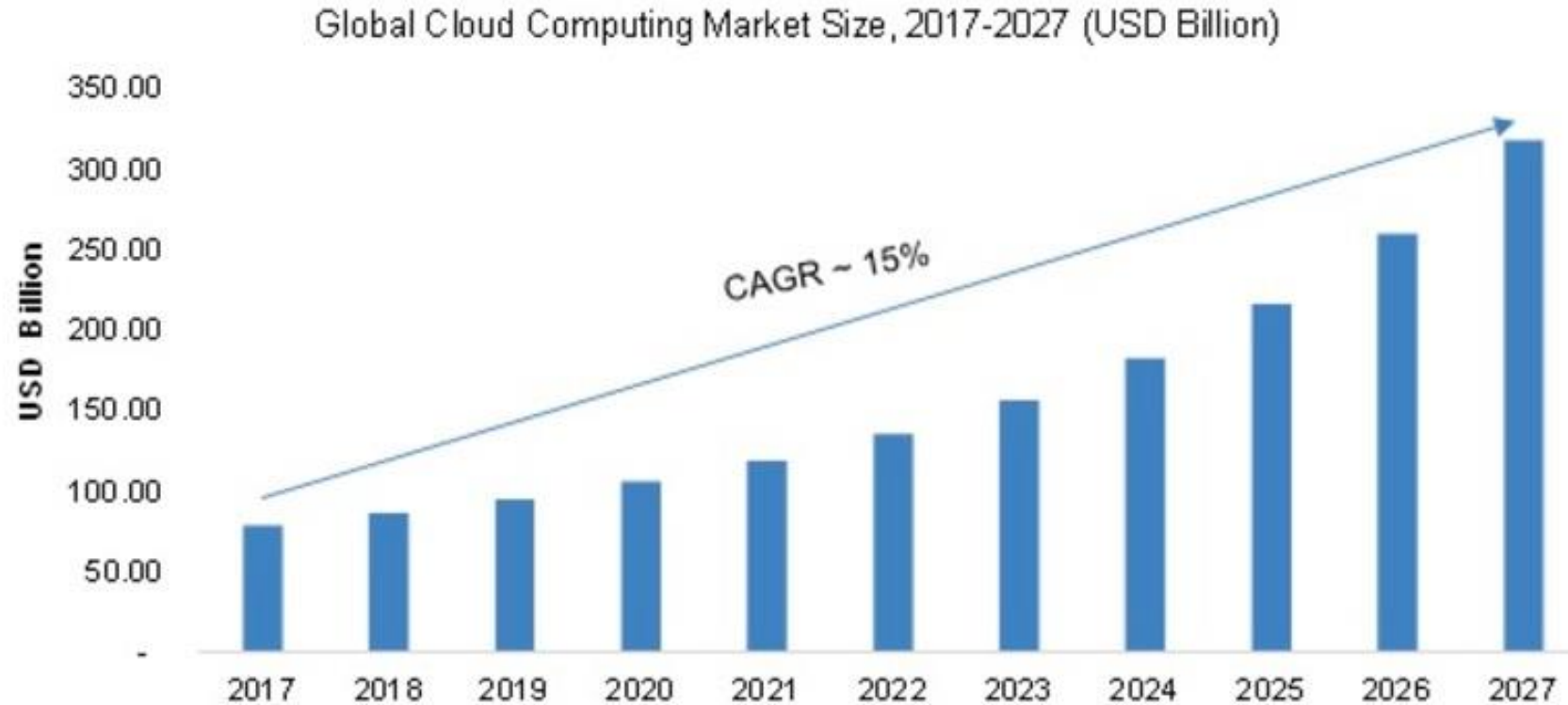
- provides programming languages and tools to deploy application onto the cloud infrastructure
 - Google App Engine

Infrastructure as a Service (IaaS)

- provides capabilities for the customers to provision computational resources such as processing, storage, network, and other fundamental computing resources Virtual Machines(VMs)/Containers
 - Example: Amazon EC2/S3, Azure
















Cloud Computing Market Research Report - Global Forecast to 2027



<https://www.marketresearchfuture.com/reports/cloud-computing-market-1013>

Amazon Web Services (1)

 Compute EC2 Lightsail ↗ ECR ECS EKS Lambda Batch Elastic Beanstalk Serverless Application Repository	 Robotics AWS RoboMaker	 Analytics Athena EMR CloudSearch Elasticsearch Service Kinesis QuickSight ↗ Data Pipeline AWS Glue AWS Lake Formation MSK	 Business Applications Alexa for Business Amazon Chime ↗ WorkMail
	 Blockchain Amazon Managed Blockchain		 End User Computing WorkSpaces AppStream 2.0 WorkDocs WorkLink
	 Satellite Ground Station		
 Storage S3 EFS FSx S3 Glacier Storage Gateway AWS Backup	 Management & Governance AWS Organizations CloudWatch AWS Auto Scaling CloudFormation CloudTrail Config OpsWorks Service Catalog Systems Manager Trusted Advisor Managed Services Control Tower AWS License Manager AWS Well-Architected Tool Personal Health Dashboard ↗ AWS Chatbot	 Security, Identity, & Compliance IAM Resource Access Manager Cognito Secrets Manager GuardDuty Inspector Amazon Macie ↗ AWS Single Sign-On Certificate Manager Key Management Service CloudHSM Directory Service WAF & Shield Artifact Security Hub	 Internet Of Things IoT Core Amazon FreeRTOS IoT 1-Click IoT Analytics IoT Device Defender IoT Device Management IoT Events IoT Greengrass IoT SiteWise IoT Things Graph
 Database RDS DynamoDB ElastiCache Neptune Amazon Redshift Amazon QLDB Amazon DocumentDB			 Game Development Amazon GameLift

Amazon Web Services (2)



Migration & Transfer

- AWS Migration Hub
- Application Discovery Service
- Database Migration Service
- Server Migration Service
- AWS Transfer for SFTP
- Snowball
- DataSync



Networking & Content Delivery

- VPC
- CloudFront
- Route 53
- API Gateway
- Direct Connect
- AWS App Mesh
- AWS Cloud Map
- Global Accelerator 



Developer Tools

- CodeStar
- CodeCommit
- CodeBuild
- CodeDeploy
- CodePipeline
- Cloud9
- X-Ray



Media Services

- Elastic Transcoder
- Kinesis Video Streams
- MediaConnect
- MediaConvert
- MediaLive
- MediaPackage
- MediaStore
- MediaTailor
- Elemental Appliances & Software



Machine Learning

- Amazon SageMaker
- Amazon Comprehend
- AWS DeepLens
- Amazon Lex
- Machine Learning
- Amazon Polly
- Rekognition
- Amazon Transcribe
- Amazon Translate
- Amazon Personalize
- Amazon Forecast
- Amazon Textract
- AWS DeepRacer



Mobile

- AWS Amplify
- Mobile Hub
- AWS AppSync
- Device Farm



AR & VR

- Amazon Sumerian



Application Integration

- Step Functions
- Amazon EventBridge
- Amazon MQ
- Simple Notification Service
- Simple Queue Service
- SWF



AWS Cost Management

- AWS Cost Explorer
- AWS Budgets
- AWS Marketplace Subscriptions



Customer Engagement

- Amazon Connect
- Pinpoint
- Simple Email Service

AWS Academy

- Access to AWS resources for education
- Assignment 4 is based on AWS EC2 services
- Each student gets \$50 credits and can access AWS without credit card details*

* With some restrictions compared to general accounts

Summary

- Cloud computing is all about delivering computing services over the Internet.
- Technologies significantly contributed to make cloud computing viable: Grid computing, web services, virtualization, autonomic computing
- Cloud Deployment Models: private, community, public, hybrid
- Cloud Service Models: IaaS, PaaS, SaaS
- Cloud and distributed computing skills are at the top of the most demanded job skills right now.

In reality, cloud computing looks like this. ...



[E.g., Google Data Center , CyrusOne Middenmeer, Netherlands](#)

Cloud computing application models...

Even Driven Architectures and Serverless Computing- **To be covered in next weeks AWS guest lecture**

References

- *Distributed Systems: Concepts and Design*, G. Coulouris, J. Dollimore, T. Kindberg, G. Blair,
5th ed. 2012 , ©Pearson Education Chapter 1, Characterization of Distributed Systems
- *Cloud Computing: Principles and Paradigms* ,Rajkumar Buyya, James Bromberg, Andrzej M. Goscinski
©John Wiley & Sons, 2010, Chapter 1 Introduction to Cloud Computing