INTRODUCTION TO CLOUD COMPUTING

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AGENDA

Introductions & Knowledge Acquisition Plan

Course Handout

Introduction to Cloud Computing

Origins and Motivation

Layers and Type of Cloud Services

Cloud Infrastructure and Deployment

Course Title	Cloud Computing
Course No(s)	SE* ZG527 / SS ZG527 / CSI* ZG527
Credit Units	5 1-2-2, (total 5 units or credits) ie 1 unit for class room hours, 2 unit for lab hours, 2 units for student preparation. Typically 1 unit translates to 32 hours
Course Author	Chandra Shekar RK / Nayan Khare
Version No	1.5
Date	03/02/2020

Course Objectives

No	Objective
CO1	Students will learn the fundamental ideas behind Cloud Computing, the evolution of the paradigm, its applicability; benefits, as well as current and future challenges;
CO2	Students will learn the basic ideas and principles in data centre design and management
CO3	Students will learn about cloud components and technologies and relevant distributed file systems
CO4	Students will learn a variety of programming models and develop working experience

Text Book(s)

T1	Dinkar Sitaram and Geetha Manjunath. Moving to the Cloud. Syngress (Elsevier) Pub, 2011
T2	Rajkumar Buyya, James Broburg & Anderzej M.G, Cloud Computing – Principles and Paradigms. John Wiley Pub, 2011

Reference Book(s) & other resources

R1	Cloud Computing bible by Barrie Sosinsky, Wiley Publishers, 2010
R2	Virtualization A Beginner's guide, Danielle Ruest, Nelson Ruest, TMH, 2009
R3	Cloud Computing bible by Barrie Sosinsky, Wiley Publishers, 2010
R4	Cloud security, a comprehensive guide to secure cloud computing, by Ronald L.Krutz et al, Wiley Publishers, 2010

Modular Content Structure

1. **Introduction to Cloud Computing**
   - 1.1. Cloud Computing, services, deployment models
   - 1.2. Introduction to Cloud Computing
   - 1.3. Origins and Motivation
   - 1.4. Types of Clouds and Services
   - 1.5. Cloud Infrastructure and Deployment

2. **Virtualization Techniques and Types**
   - 2.1. Introduction to Virtualization
   - 2.2. Use & demerits of Virtualization
   - 2.3. Types of Virtualization
   - 2.4. x86 Hardware Virtualization
   - 2.5. Manage the resources for the SaaS, PaaS and IaaS models
   - 2.6. *Introduction to NFV – VNF*

3. **Infrastructure as a Service**
   - 3.1. Introduction to IaaS
   - 3.2. IaaS examples
   - 3.3. Reference Model of AWS
   - 3.4. Amazon cloud services - Compute, Database, Storage
   - 3.5. Region Vs Availability zones
   - 3.6. Case Study - Openstack
   - 3.7. Managing Virtual Resources on the Cloud: Provisioning and Migration
     - 3.7.1. Virtual Machine Provisioning and Manageability
     - 3.7.2. VM Provisioning Process
     - 3.7.3. Virtual Machine Migration Services
     - 3.7.4. Migrations Techniques
     - 3.7.5. VM Provisioning and Migration in action

4. **Containers (New)**
   - 4.1. Linux Containers - LXC and LXD
   - 4.2. Dockers - Elements, Images, Files, Containers
   - 4.3. Cloud and *Container* orchestration technologies

5. Platform as a Service and SaaS

- 5.1. Introduction to PaaS
- 5.2. PaaS examples
- 5.3. Windows Azure
- 5.4. 5 Principles of UI Design - AWS PaaS
- 5.5. Introduction to SaaS
- 5.6. Pros and Cons of SaaS model and applications

6. Capacity management and Scheduling in cloud computing

- 6.1. Capacity management and Scheduling
- 6.2. Distributed management of virtual machines
- 6.3. Reservation-based provisioning of virtualized resource
- 6.4. Provisioning to meet SLA commitments
- 6.5. Stages of VM life cycle within OpenNebula
- 6.6. Network model for OpenNebula

7. Issues and Challenges : Availability, Multi-Tenancy, Security and SLA

- 7.1. Multi-Tenancy, 4 levels of multi tenancy
- 7.2. Multi-tenant models for cloud
- 7.3. Introduction to cloud security
- 7.4. Cloud security Issues
- 7.5. Threat Model
- 7.6. Top 5 cloud security threats
- 7.7. who is responsible for managing security
- 7.8. Service License Agreements: Lifecycle and Management
- 7.9. Traditional approaches to SLO management
- 7.10. SLA Management in Cloud
- 7.11. Automated Policy based management
- 7.12. Managing Clouds: Services and Infrastructure

8. Distributed File System (DFS) and Hadoop

- 8.1. Introduction to Distributed File System (DFS)
- 8.2. Case Study HDFS
- 8.3. Hadoop components and importance of MapReduce
- 8.4. Setting started - Amazon EMR
- 8.5. Amazon EMR - Plan and Configure clusters (# only for CSI)
- 8.6. AMazon EMC - Manage Clusters (# only for CSI)
- 8.7. Understanding MapReduce (* Not for CSI)
- 8.8. Explore word count Java program (* Not for CSI)
- 8.9. MapReduce Facts (* Not for CSI)

Learning Outcomes:

No	Learning Outcomes
LO1	**Explain** the core concepts of the cloud computing paradigm: how and why this paradigm shift came about, the characteristics, advantages and challenges brought about by the various models and services in cloud computing
LO2	**Apply** the fundamental concepts in data-centres to understand the tradeoffs in power, efficiency and cost
LO3	**Discuss** system virtualization and outline its role in enabling the cloud computing system model.
LO4	**Illustrate** the fundamental concepts of cloud storage and demonstrate their use in storage systems such as Amazon S3 and HDFS
LO5	**Analyze** various cloud programming models and apply them to solve problems on the cloud

Note to Faculty:

Some modules or topics are specific only to certain programmes. The faculty is instructed to choose the relevant topics/modules depending on the programme in which this course is being offered. Same needs to be reflected in the contact session plan.

 # Specific to MTech, CSI (Computing Systems & Infrastructure)

*** Specific to MTech (SW Systems) and MTech (SW Engg)**

LET'S DISCUSS THE BASICS!

What happens when we plug an electric appliance, say a mobile phone, into an outlet – Electricity Virtualization!

Extend this concept to IT – delivering useful functions while hiding how the internals work

Can we consider Computing to be fully virtualized – Yes, if this is the case. Computers to be built from distributed components such as processing, storage, data, and software resources

- Virtualization
- Abstraction

…. LET'S DISCUSS THE BASICS!

Cluster, Grid and Cloud Computing – allow access to computing power in a fully virtualized manner

- Aggregation of resources
- Single System View
- Computing as a utility

- Utility Computing is a business model for on-demand delivery of computing power.

- Reason for the naming?

…. BASICS!

Cluster, Grid and Cloud Computing – allow access to computing power in a fully virtualized manner

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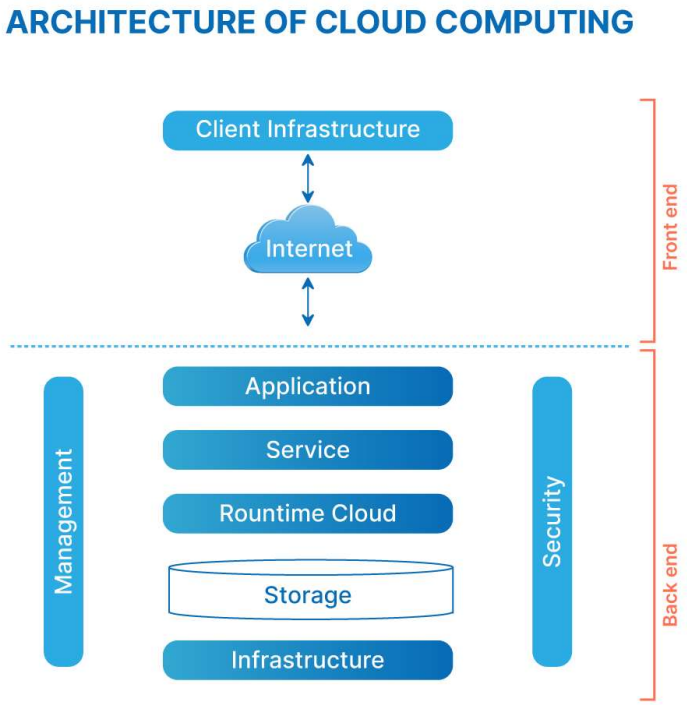
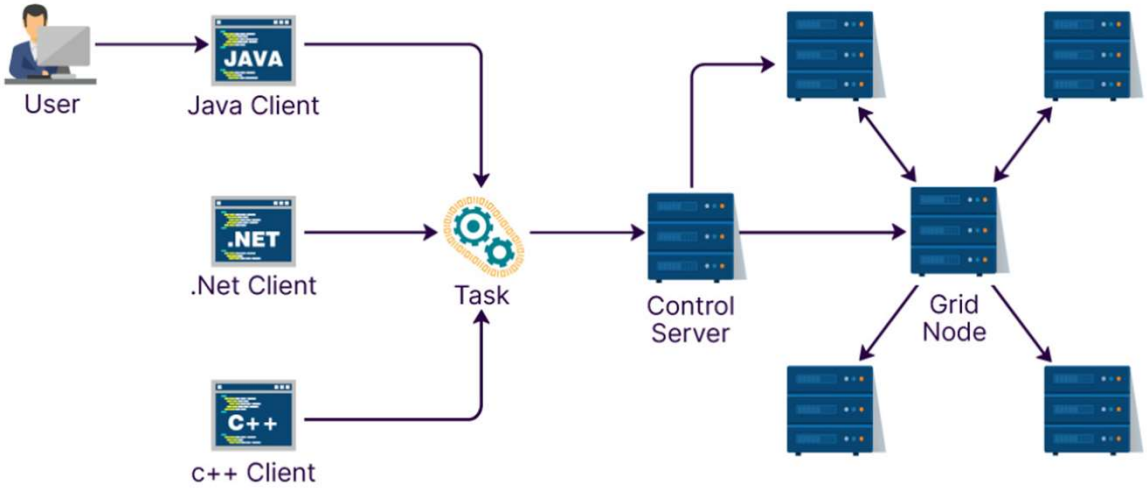
CLOUD COMPUTING



- Service – 3 flavours
  - PaaS
  - SaaS
  - IaaS
- Runtime Cloud – VMs and Runtime environments

One of the ways of looking at cloud computing

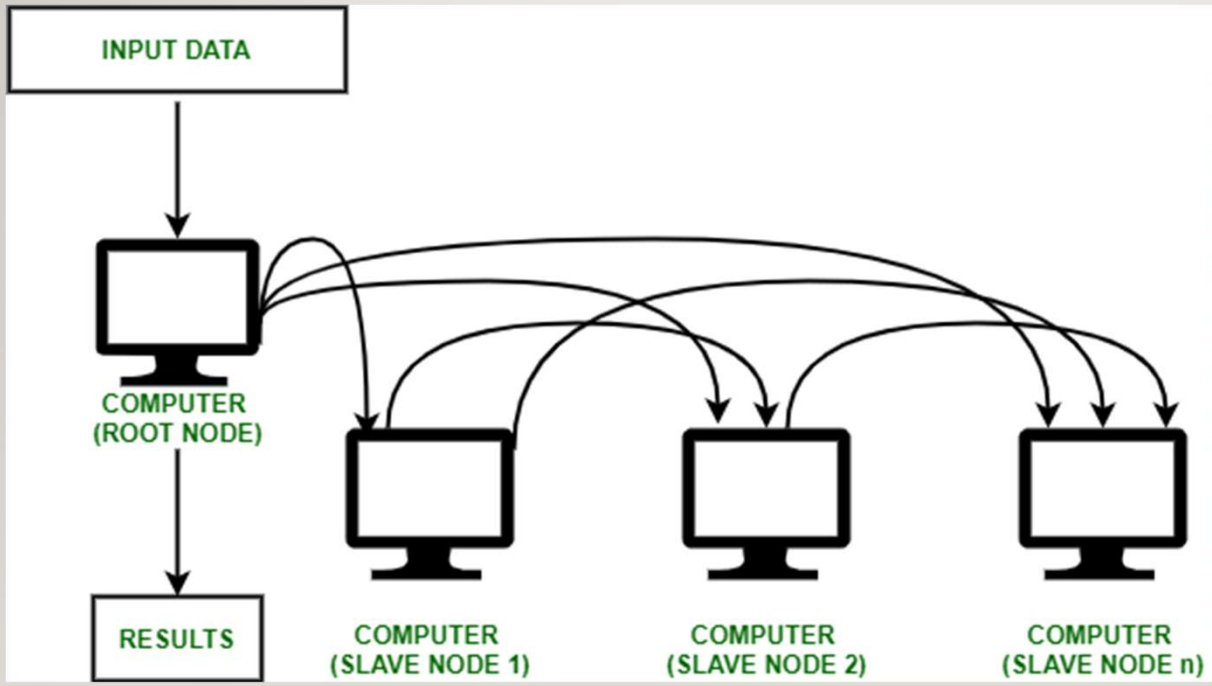
GRID COMPUTING



- Distributed Computing
- Solutions for Complex Problems
- Resources in the grid work together to complete a task
- Heterogeneous Nodes

Any complex and time consuming activity can be addressed

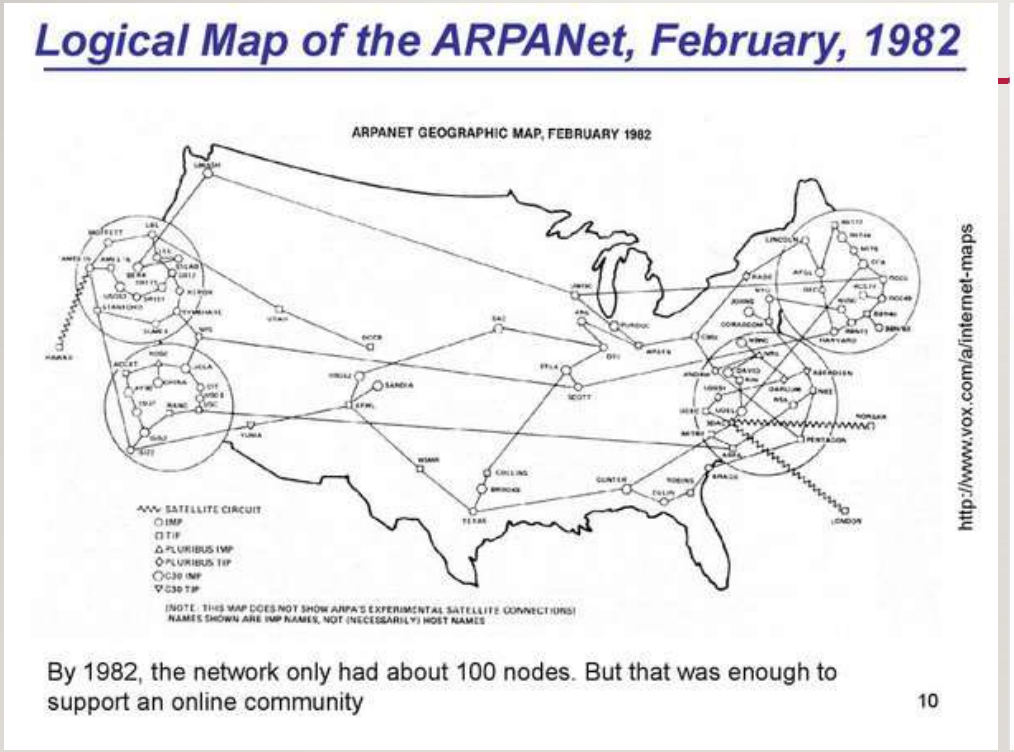
CLUSTER COMPUTING



- Homogeneous Nodes
- Nodes in the same Location
- Whole System to be considered as one single system

To the outside world, it is just one system

WHY IS IT NAMED CLOUD?



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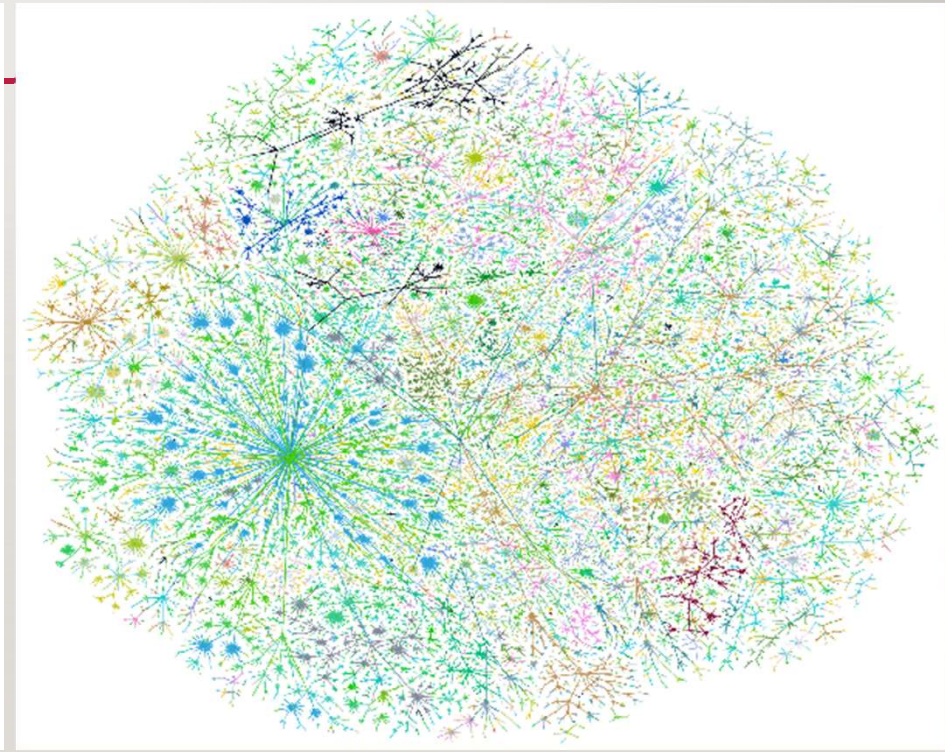

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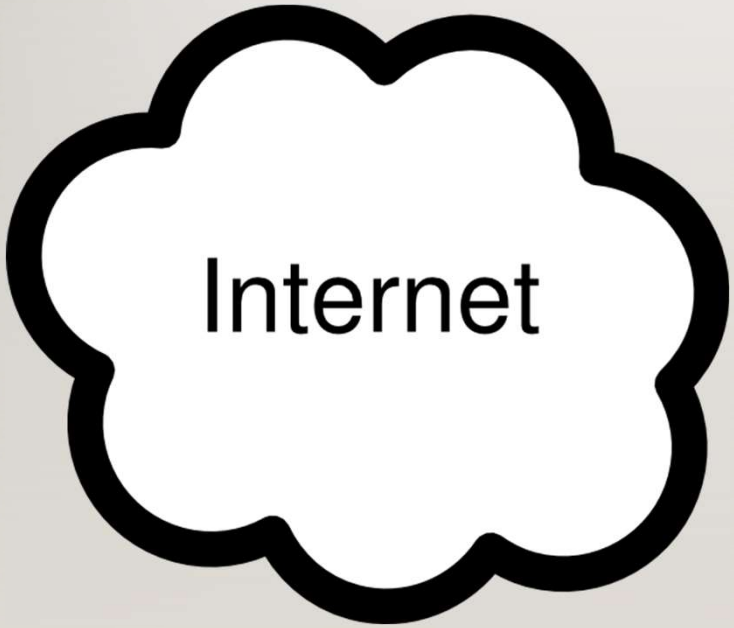
WHY IS IT NAMED CLOUD?



Inspiration from the cloud symbol

It could have as well been named anything else… say Sky Computing!

At some point in time, a specific term gets more traction and gets accepted

Too many debates wrt who gets the credit for coining the term

CLOUD COMPUTING DEFINITIONS

Cloud computing has been coined as an umbrella term to describe a category of sophisticated on-demand computing services initially offered by commercial providers, such as Amazon, Google, and Microsoft. It denotes a model on which a computing infrastructure is viewed as a "cloud," from which businesses and individuals access applications from anywhere in the world on demand. The main principle behind this model is offering computing, storage, and software "as a service."

Cloud is a parallel and distributed computing system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements (SLA) established through negotiation between the service provider and consumers.

Clouds are a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically reconfigured to adjust to a variable load (scale), allowing also for an optimum resource utilization.

This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the Infrastructure Provider by means of customized Service Level Agreements."

So many definitions of Cloud Computing and the list continues ….

… CLOUD COMPUTING DEFINITIONS

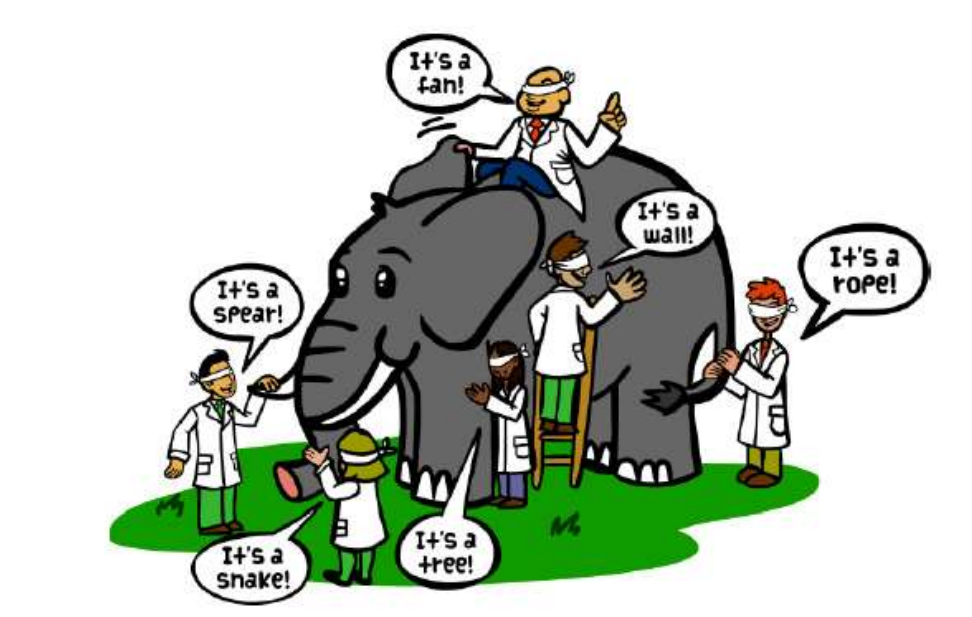
Clouds are hardware - based services offering compute, network, and storage capacity where: Hardware management is highly abstracted from the buyer, buyers incur infrastructure costs as variable OPEX, and infrastructure capacity is highly elastic.

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

Generic definition: Data center hardware and software that provide services.

So many definitions of Cloud Computing and the list continues ….

WHAT DO WE DO – WHICH ONE IS CORRECT



It all depends on the aspect from which we see/view

COMMON CHARACTERISTICS GIVEN BY NATIONAL INSTITUTE OF STANDARDS (NIST)

Pay-Per-Use (no ongoing commitment, utility prices) *

Elastic capacity (illusion of infinite resources)

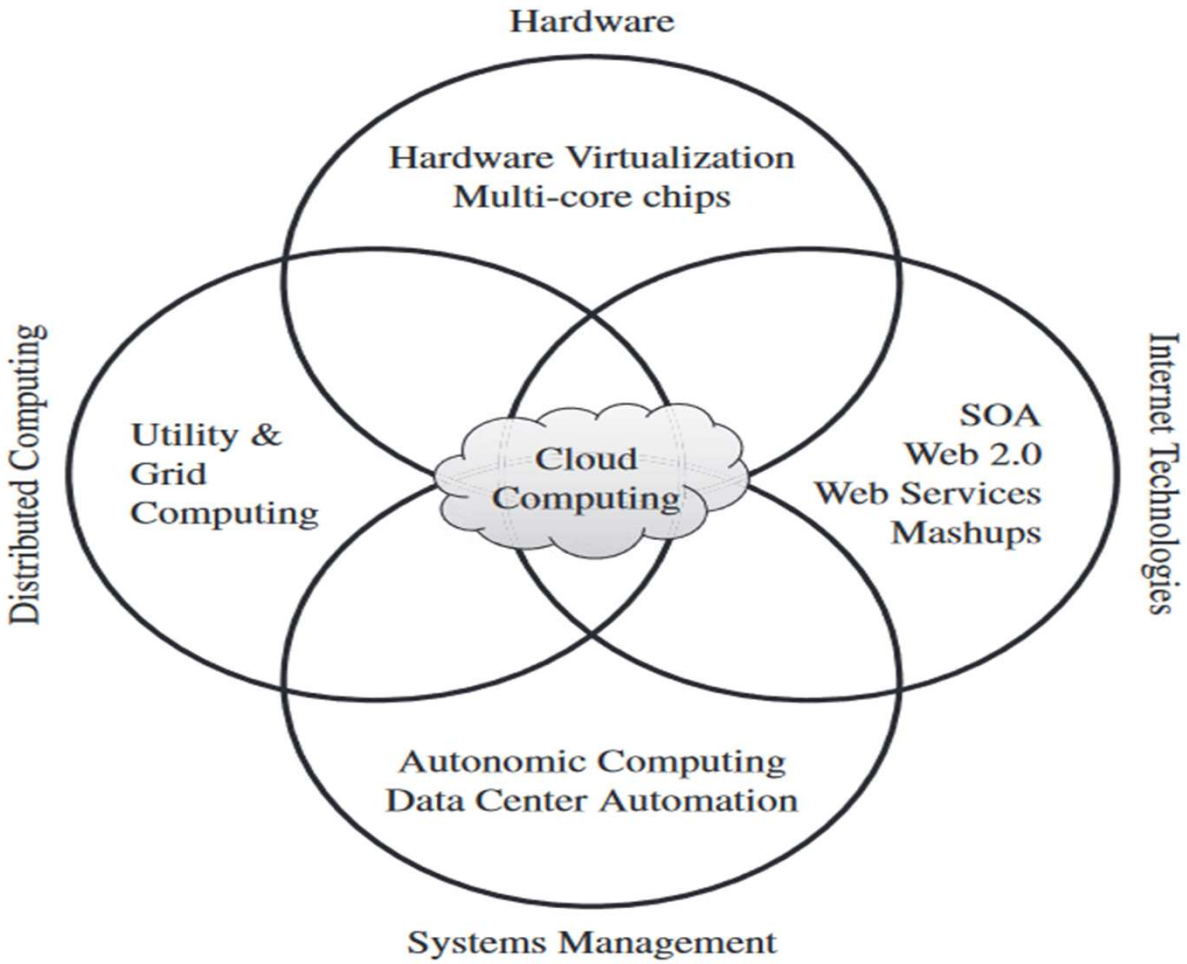
On Demand Self Service

Abstraction/Virtualisation of resources

Broad Network Access

* → Exceptions do happen as the concepts evolve For example – make a commitment and get discounts for usage. But, even in that case it is essentially Pay-Per-Use

Instead of getting drowned into the various perspectives, let us note down the common characteristics



Convergence of various advances enabled cloud computing

MOTIVATION

Let's find out by doing role plays

- Proprietor of a Startup
- A CEO of a well established Company providing Software solutions
- Head of a College
- A Solution Architect

We saw the origin and various definitions. But, why Cloud?

KEYWORDS

Agility & Innovation

Cost

Scalability

OPEX / CAPEX

Ease of Management

Architecture Freedom

Infrastructure Freedom/Lower Cost of Ownership

Faster Return on Investment (ROI)

Well, there would have been so many positives that we noted during the roleplay

AREN'T THERE ANY ISSUES OR CONCERNS - IS IT ALL GREEN?

Security

Compliance

Interoperability and Vendor lock-in

I have no control!!!!!

Each of these concerns (except the last!) do get addressed by Cloud Vendors and/or by the clients utilizing the Cloud

Every aspect has both positives and some negatives or at least concerns. Cloud Computing is not an exception

LAYERS AND TYPE OF CLOUD SERVICES

IaaS Infrastructure as a Service

PaaS Platform as a Service

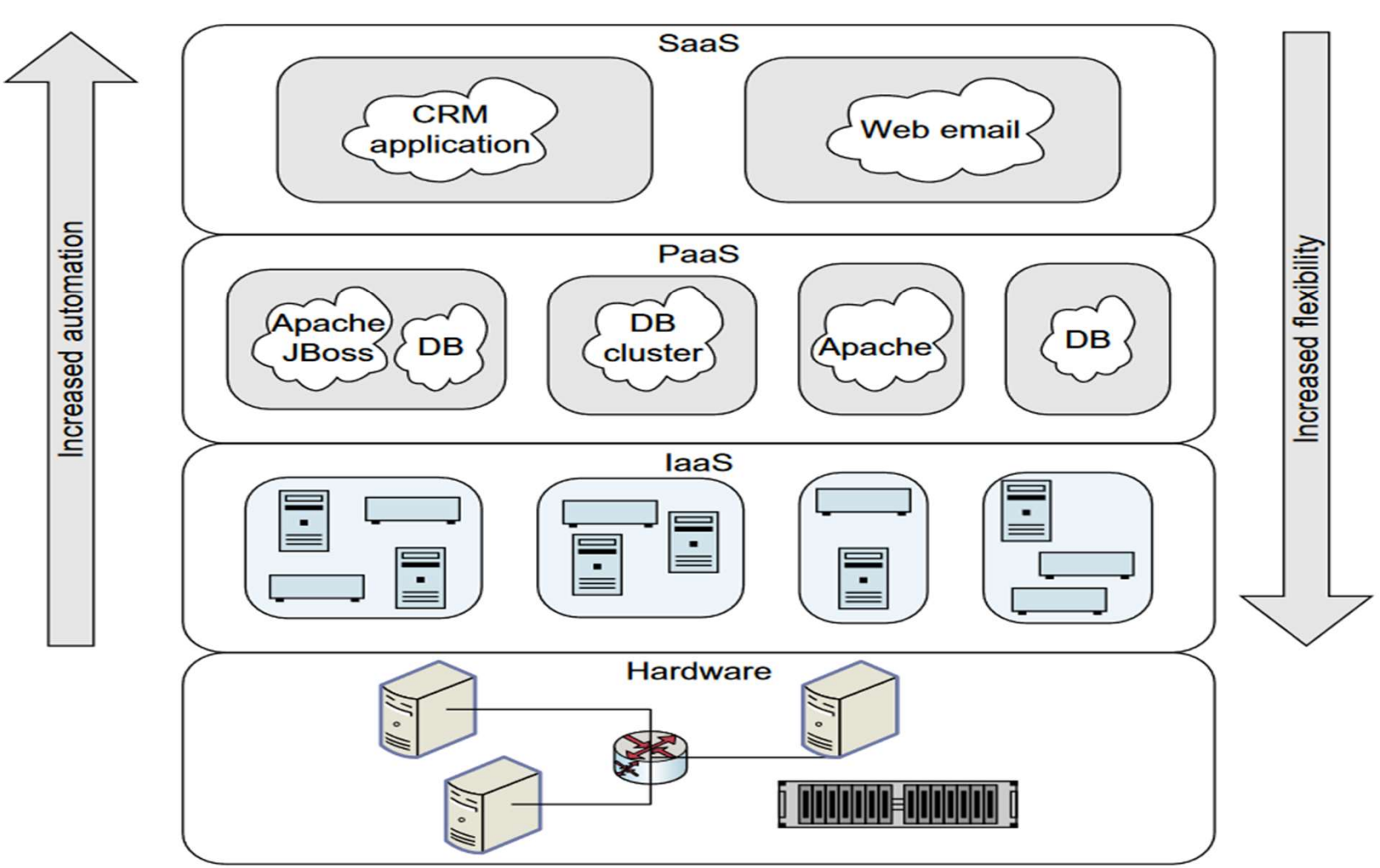
SaaS Software as a Service

Focus is on a specific layer in a computer's runtime stack – the hardware, the system software (or platform) and the application, respectively

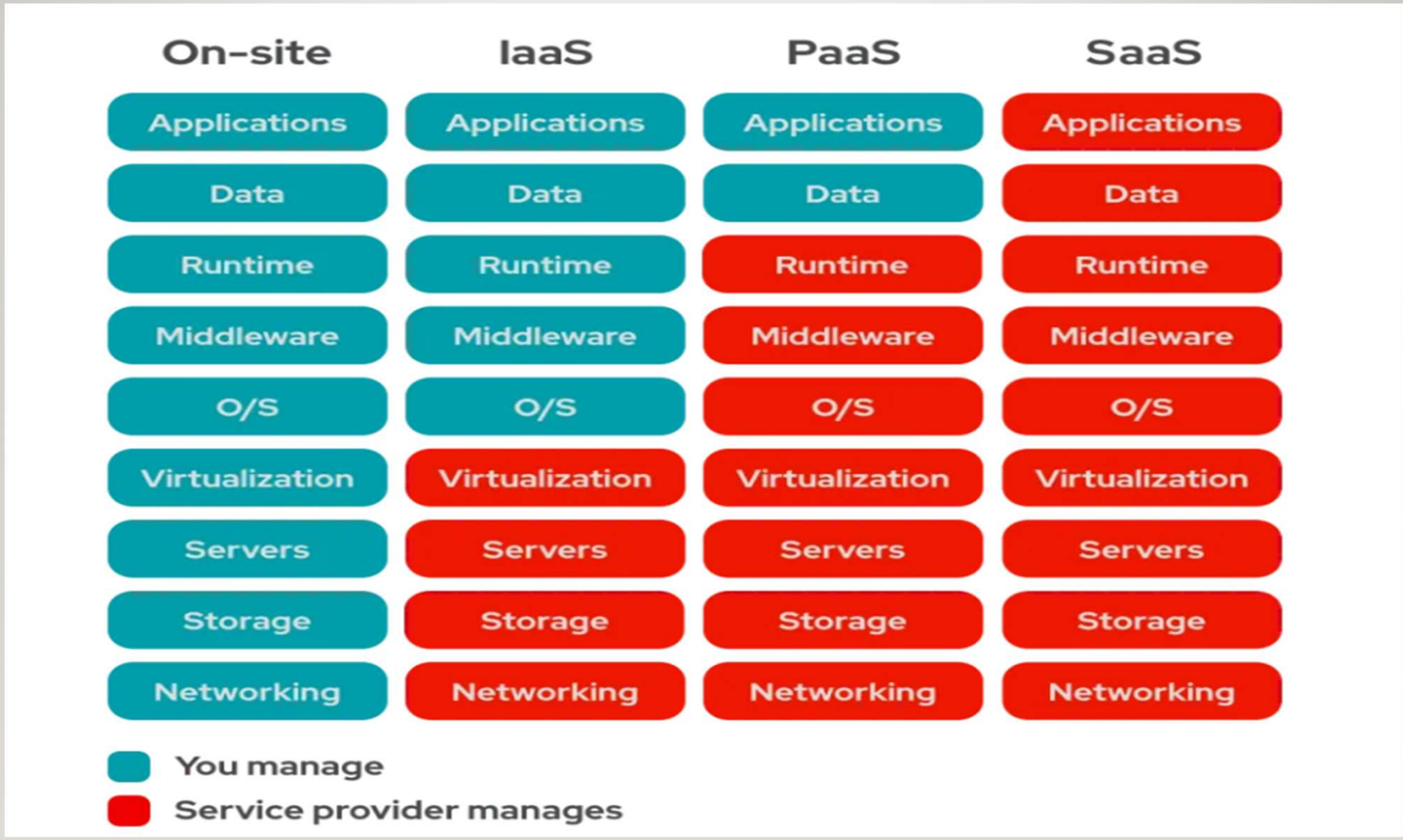
Abstraction level of the capability that is provided

Service Class	Main Access & Management Tool	Service content
 SaaS	Web Browser	**Cloud Applications** Social networks, Office suites, CRM, Video processing
 PaaS	Cloud Development Environment	**Cloud Platform** Programming languages, Frameworks, Mashups editors, Structured data
 IaaS	Virtual Infrastructure Manager	**Cloud Infrastructure** Compute Servers, Data Storage, Firewall, Load Balancer

Services of a higher layer can be composed from the services of the underlying layer

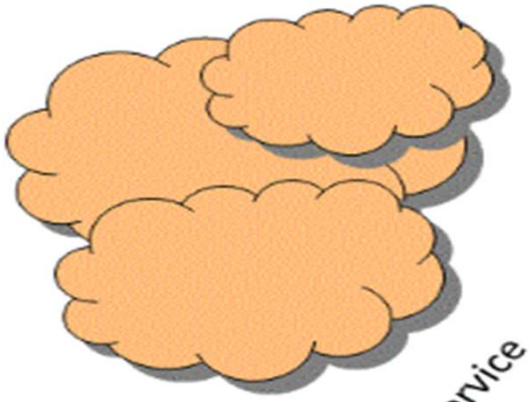


Flexibiilty vs Ease of Maintenance and Usage



The question of what you do manage – summarizes it all!

Cloud Services



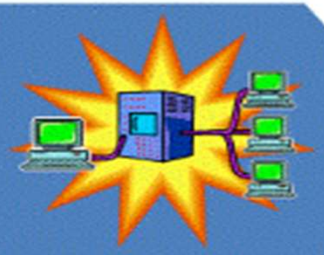
Software as a Service

Applications
(SaaS)

Platform as a Service

Developers Services
(PaaS)

Physical Server; CPU, RAM
Storage
Data Center Networks
(IaaS)



Infrastructure as a Service

IAAS DEFINITON

The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the 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).

Ownership of the VM

User use as it is his/her own machine

PAAS DEFINITON

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.

Focus on your application/development

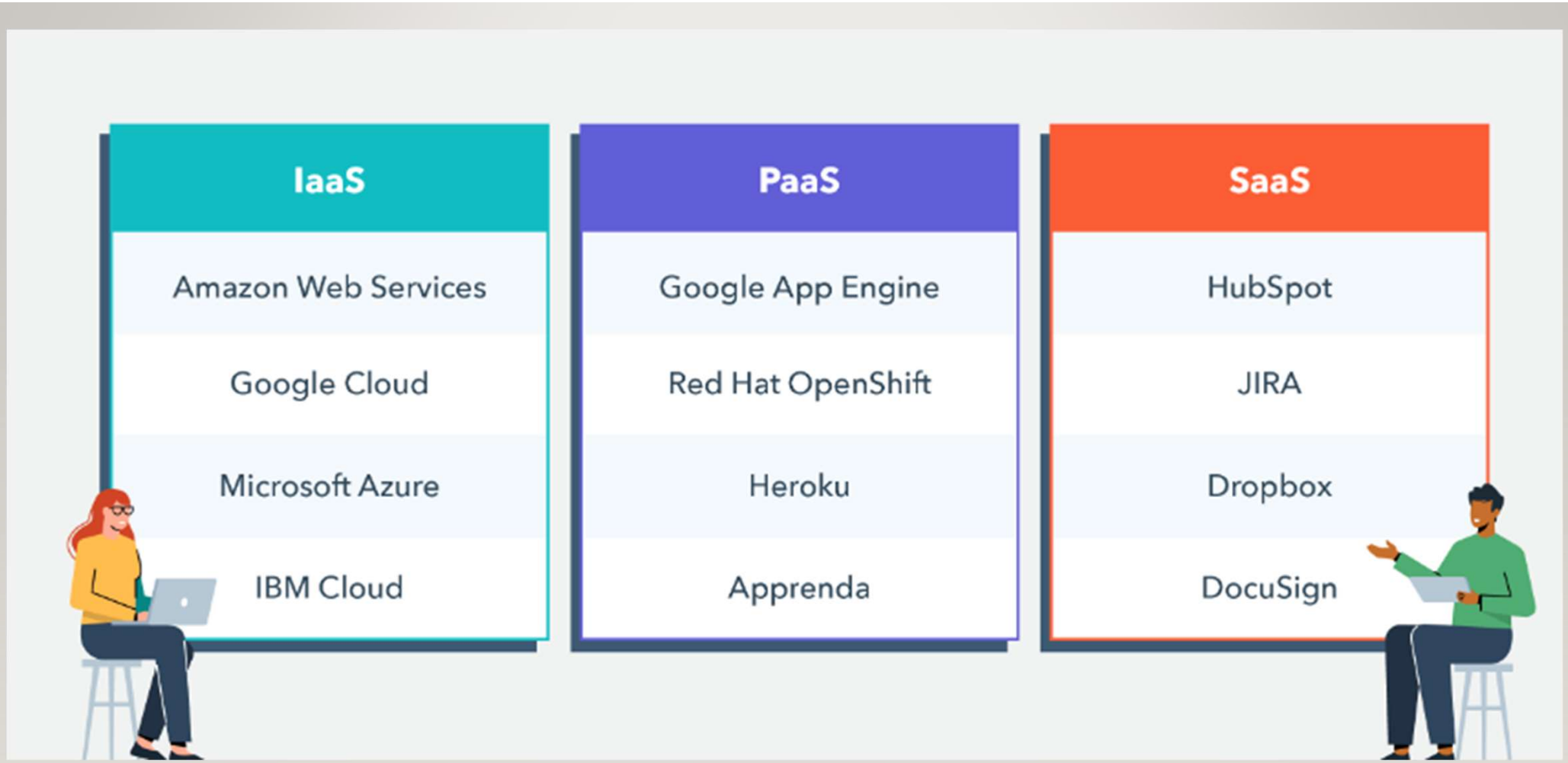
User can focus on the development goal

SAAS DEFINITON

The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based email). The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.

Need just a Web Browser!

Easiest one among the three



Ease of Usage vs Ease of Control and Customization

CLOUD DEPLOYMENT MODELS

Private Cloud

Public Cloud

Community Cloud

Hybrid Cloud.

It all boils down to the priorities of an organization, the funding available, the agility needed to complete, the benefits of the collaborative exercises etc.

CLOUD DEPLOYMENT MODELS

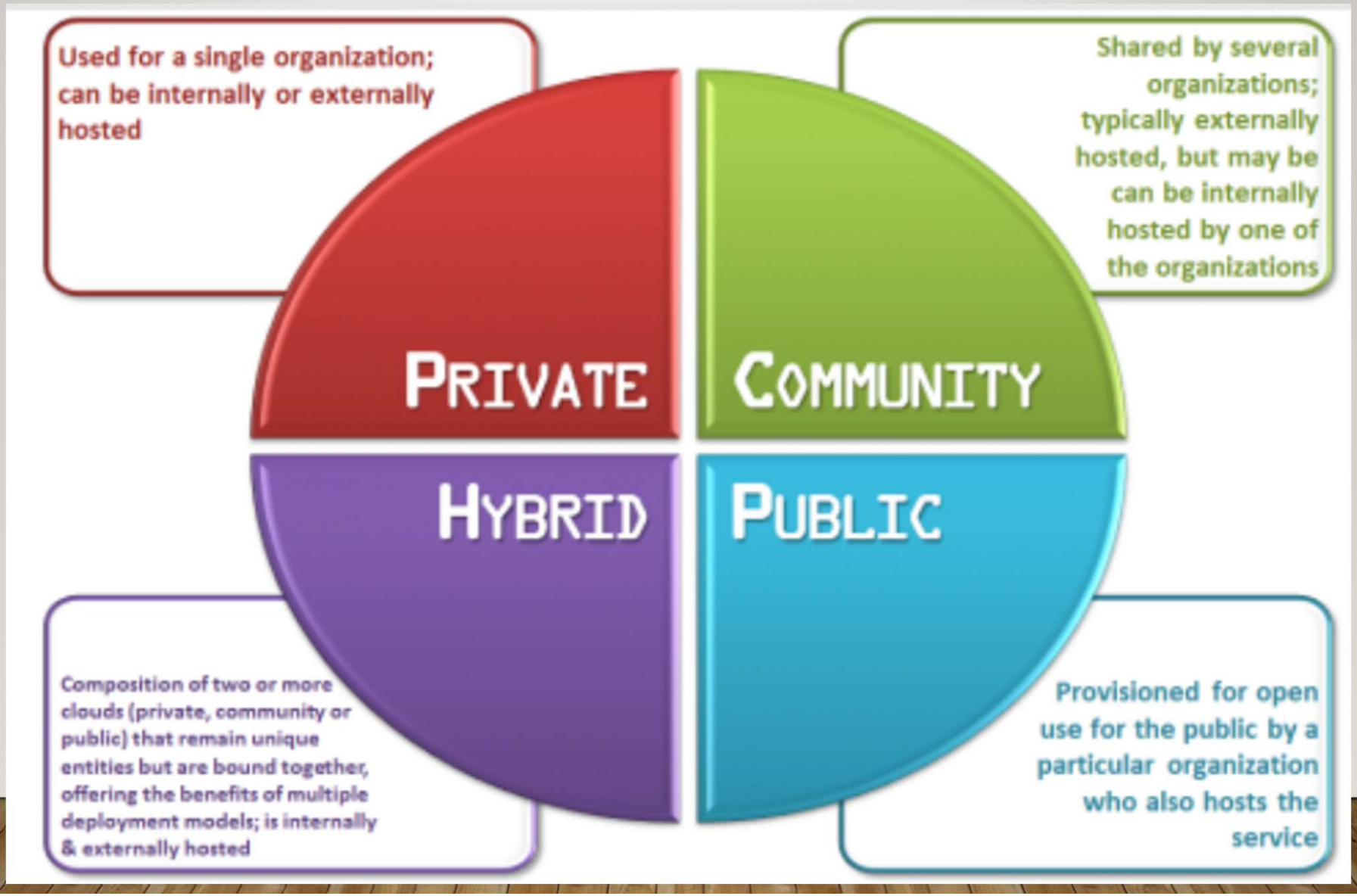
Private cloud - Cloud computing infrastructure built exclusively for a single enterprise.
It is the next step in the evolution of a corporate data center of today where the infrastructure is shared within the enterprise.

Community Cloud - Cloud computing 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 - Cloud computing infrastructure owned by a cloud service provider that provides cloud services to the public for commercial purposes.

Hybrid clouds – Cloud computing infrastructure which can be considered as a mixture of the above 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

Economic Models, Capability and Priorities are the factors considered by an organization for the choice


Used for a single organization; can be internally or externally hosted
Shared by several organizations; typically externally hosted, but may be can be internally hosted by one of the organizations
PRIVATE
COMMUNITY
HYBRID
PUBLIC
Composition of two or more clouds (private, community or public) that remain unique entities but are bound together, offering the benefits of multiple deployment models; is internally & externally hosted
Provisioned for open use for the public by a particular organization who also hosts the service

PUBLIC CLOUD

High elasticity

Subscription-based

Low cost

Highly Scalable

No CapEx

The cloud vendor is the entity that is completely responsible for the public cloud. Develop, Manage, and Maintain the resource pool shared between multiple tenants from across the network.

Minimal Technical Control, Lack of Cost Control, Lack of Security

PRIVATE CLOUD

Customized Security

Efficient performance

High CapEx

Data center - on-premise / operated by a third-party vendor off-site. Computing resources are isolated and delivered via a secure private network. Nothing is shared with any other organization or entities.

- Highly regulated industries and government agencies
- Sensitive data
- High Control/ High Security wrt the infra and the workloads
- Large enterprises that require advanced data center technologies to operate efficiently and cost-effectively
- Organizations that can afford to invest in high performance and availability technologies (last but not the least)

High TCO, Scalability may become an issue for unpredictable workloads

HYBRID CLOUD

Additional Computing Capacity does not require high CapEx

Decide to be Homogenous or Heterogeneous with the Cloud

Cost Control

Policy Driven

Scale with Security

Increase in reliability

- Organizations serving multiple verticals facing different IT security, regulatory, and performance requirements
- Optimizing cloud investments without any compromises
- Strategic approach to cloud investments - continuously switch and tradeoff between the best cloud service suited at the point in time.

Price tracking, Management, Added Complexity as the organization operates and manages a mix of resources

ASSIGNMENT 1

1. IaaS
2. IaaS
3. IaaS
4. IaaS
5. PaaS
6. PaaS
7. PaaS
8. SaaS
9. Docker
10. OpenStack

SCRIPT

- Team – finalizes a topic and provides the details along with the planned date of presentation/discussion
- Students – Install/Understand the tool/topic prior to the class
- Prof – Overview of the Tool, Features
- Team – Tutorial / Hands On Usage of the Tool features
- Prof – define "Mini" Lab Excercise with the tool for Beginners; Students - do during class or post class
- Prof – Advanced usage of the tool in Project, Best Practices
- Team – Case study of usage of tool in a project

Timeframe – Spread over the complete semester

ASSIGNMENT 2

- Define the project scope with 5 people working in parallel
- Progressively, develop the project
- Demonstrate
- Share learnings, challenges, problems faced and resolved

- Lab 1 and Lab 2 Sessions for Review

CLOUD COMPUTING MATURITY IN YOUR PROJECT

- Please be prepared to discuss – just one student from a different team in each class.

- Take a Qualitative, Quantitative Approach
- Interview your project team
- gather information, as required
- Research available maturity models

- Points to cover during discussion–
  - A brief description of the project
  - Project Type – New Product Development / New Features / Feature Enhancements / Maintenance
  - Architecture / High Level Design – Just a minute – an elevator pitch!!!
  - Top 3 current Issues / Challenges?
  - What is your recommendation?

Timeframe – Spread over the entire contacts sessions, one