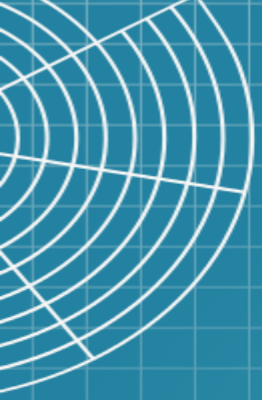
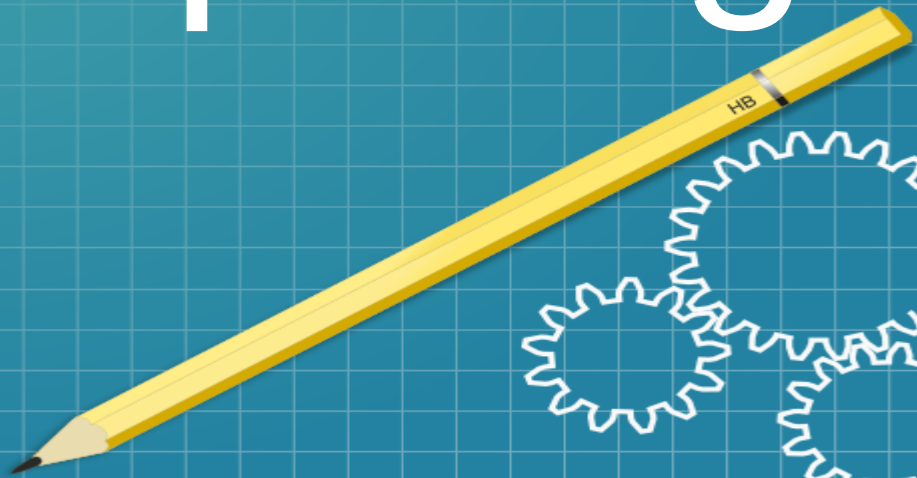
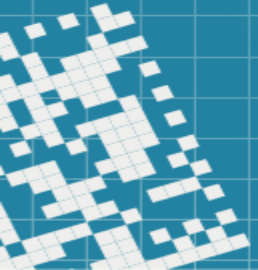
Calculus of Cloud Computing







Overview

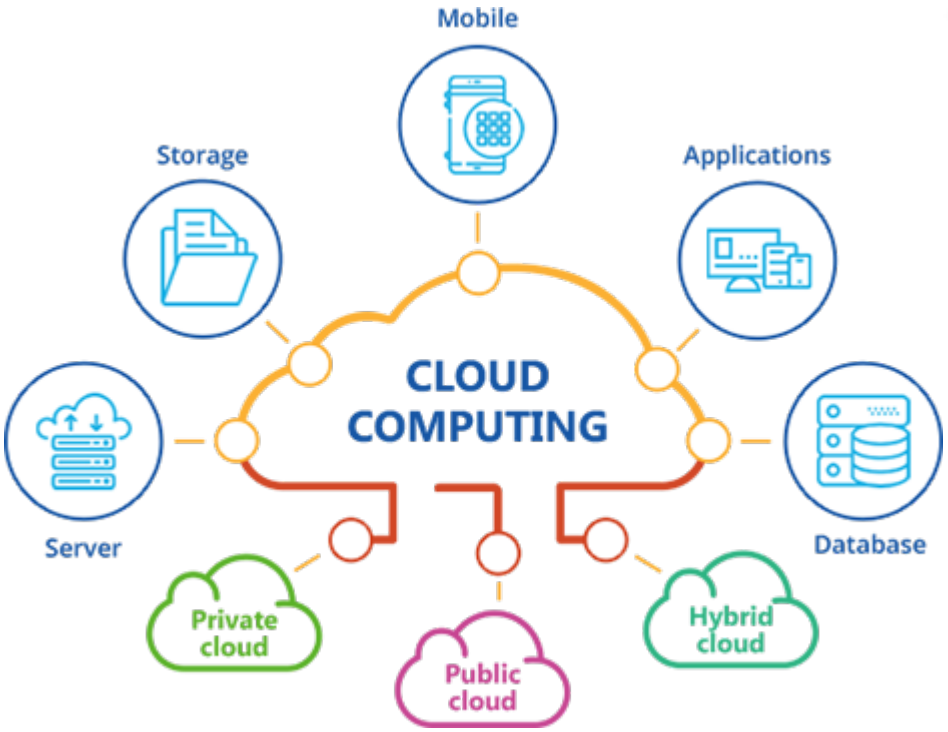
- Introduction
  - Service Models of CC
  - Deployment Models of CC
  - Characteristics of CC
- Defining Cloud Computing
- Calculus of Cloud Computing
  - How to understand resources in cloud computing?
  - How to understand types of cloud?
  - How to understand cloud services
  - Cloud Analytics = Big data Analytics + Cloud Computing

Introduction

Cloud computing has attracted increasing attention in academics and industry in the past decade.

The core of cloud computing has 3 service models, 4 deployment models and 5 characteristics.

- 3 Service Models
  - IaaS, PaaS and SaaS
- 4 Deployment Models
  - Public, Private, Community and Hybrid Cloud
- 5 Characteristics
  - On-demand self service, Broad network access, Resource pool, rapid elasticity and measured service.


Mobile
Storage
Applications
CLOUD
COMPUTING
Server
Database
Private
cloud
Public
cloud
Hybrid
cloud

Service Models of CC

3 Service Models

- Software as a Service aka SaaS
- Platform as a Service aka PaaS
- Infrastructure as a Service aka IaaS

Service Models of CC

Software as a Service (SaaS)

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 either a thin client interface, such as a web browser (e.g., web-based email), or a program interface. 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.

Service Models of CC

Platform as a Service (PaaS)

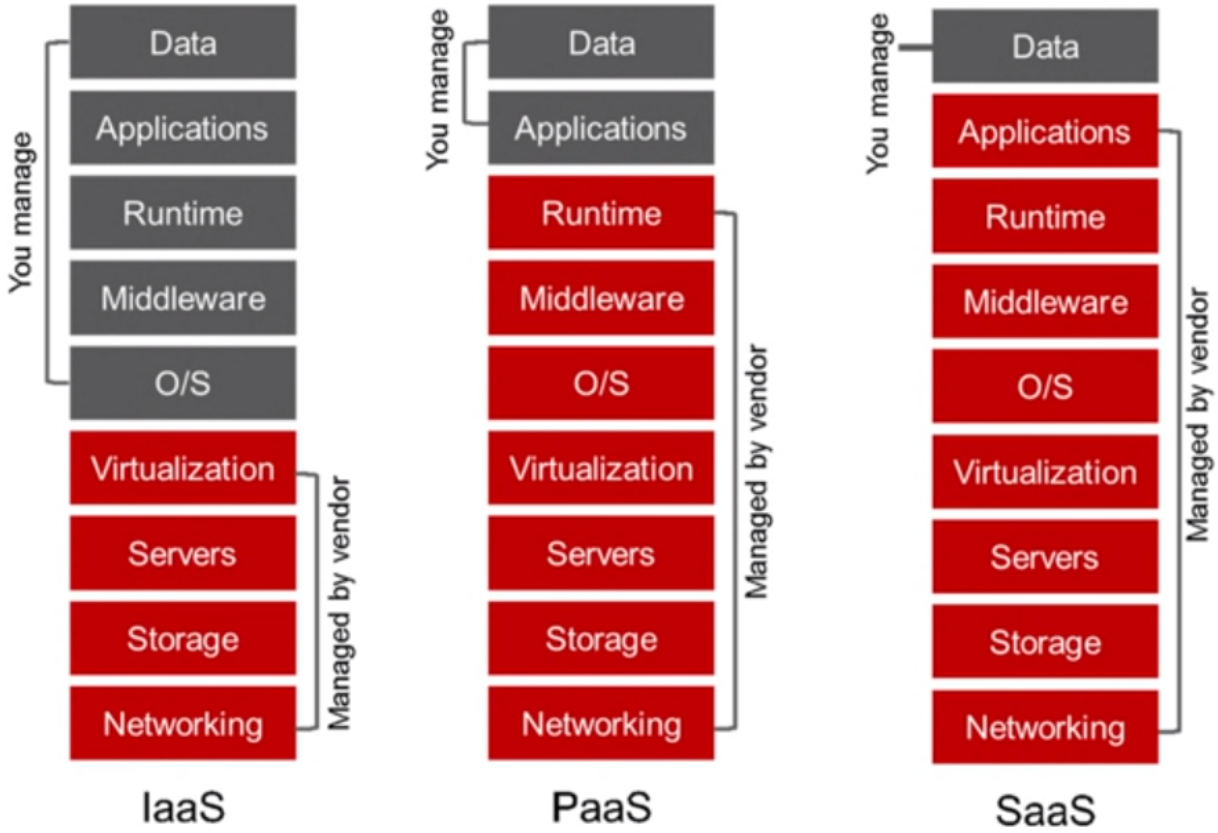
The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including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

Service Models of CC

Infrastructure as a Service (IaaS)

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 sytems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls).

Service Models of CC

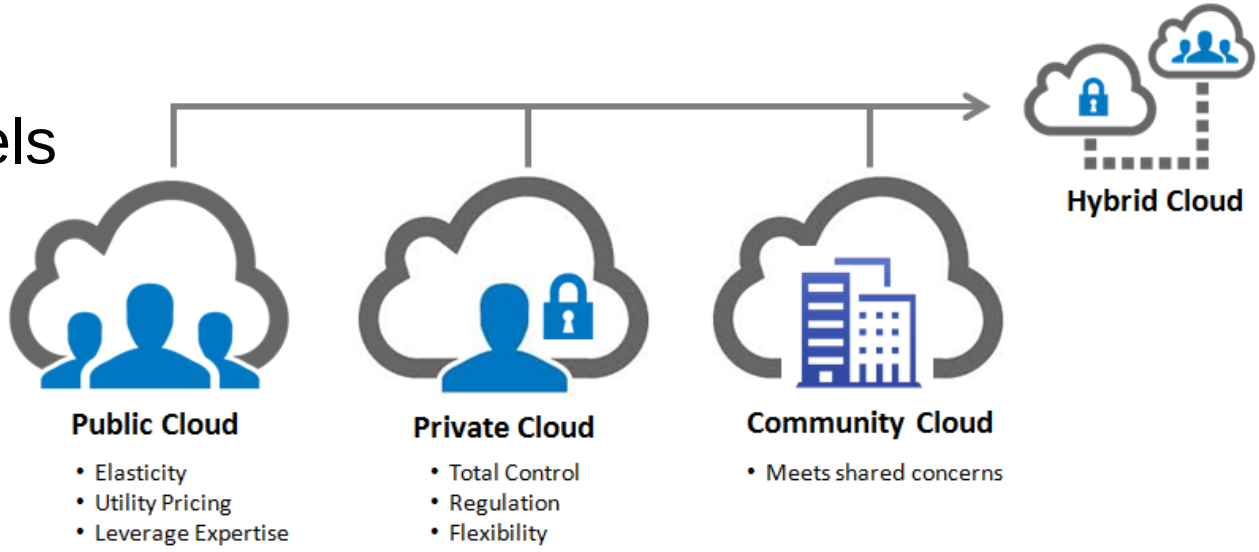


Deployment Models of CC

Cloud deployment models indicate how the cloud services are made available to users.

4 Deployment Models

- Public,
- Private,
- Community and
- Hybrid Cloud



Deployment Models of CC

Public Cloud

As the name suggests, this type of cloud deployment model supports all users who want to make use of a computing resource, such as hardware (OS, CPU, memory, storage) or software (application server, database) on a subscription basis. Most common uses of public clouds are for application development and testing, non-mission-critical tasks such as filesharing, and e-mail service.

Deployment Models of CC

Private Cloud

True to its name, a private cloud is typically infrastructure used by a single organization. Such infrastructure may be managed by the organization itself to support various user groups, or it could be managed by a service provider that takes care of it either on-site or off-site. Private clouds are more expensive than public clouds due to the capital expenditure involved in acquiring and maintaining them. However, private clouds are better able to address the security and privacy concerns of organizations today.

Deployment Models of CC

Hybrid Cloud

In a hybrid cloud, an organization makes use of interconnected private and public cloud infrastructure. Many organizations make use of this model when they need to scale up their IT infrastructure rapidly, such as when leveraging public clouds to supplement the capacity available within a private cloud. For example, if an online retailer needs more computing resources to run its Web applications during the holiday season it may attain those resources via public clouds.

Deployment Models of CC

Community Cloud

This deployment model supports multiple organizations sharing computing resources that are part of a community; examples include universities cooperating in certain areas of research, or police departments within a county or state sharing computing resources. Access to a community cloud environment is typically restricted to the members of the community.

Characteristics of CC

The five essential characteristics of cloud computing:

- On-demand self service,
- Broad network access,
- Resource pool,
- Rapid elasticity and
- Measured service.

Characteristics of CC

On-demand self-service

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

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., mobile phones, tablets, laptops and workstations).

Characteristics of CC

Resource pooling

The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that 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). Examples of resources include storage, processing, memory and network bandwidth.

Characteristics of CC

Rapid elasticity

Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time.

Measured service

Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth and active user accounts). Resource usage can be monitored, controlled and reported, providing transparency for the provider and consumer.

Defining Cloud Computing

There are many definitions of cloud computing

1. Cloud computing is shared pools of configurable computer system resources and higher-level services that can be rapidly provisioned with minimal management effort, often over the Internet (Wikipedia, 2019).

2. The National Institute of Standards and Technology's (NIST) defines cloud computing as 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 (NIST, 2018).

Defining Cloud Computing

The first definition given by Wikipedia considers cloud computing as computer system resources and higher-level services so that cloud computing is not related to science, engineering and technology, nor management.

The second given by the National Institute of Standards and Technology's (NIST) considers cloud computing as a model for accessing computing resources.

A model is a part of science, engineering and technology, nor management. But a model is not science, engineering and technology, nor management. Therefore, the above definitions have related to science, engineering and technology, nor management. Can we state that **the definition of cloud computing is too much market-oriented, industry-oriented, far from the academic flavor**. This is the reason why we consider cloud computing for our universities and students as well as scholars.

Calculus Of Cloud Computing

This section proposes the calculus of cloud computing, which treats many aspects of cloud computing using **mathematical methods** and **thinking**.

Calculus is a branch of mathematics that **“deals with rates of change”**, based on the Oxford Advanced Learners’ Dictionary.

The term calculus is also used for naming specific methods of calculation or notation as well as some theories, such as **propositional calculus** and **process calculus**.

Calculus Of Cloud Computing

How to understand resources in cloud computing?

When defining cloud computing, (Wikipedia, 2019) uses computer system resources, whereas NIST uses computing resources. (Erl, Mahmood, & Puttini, 2013) uses IT resources as resources of cloud computing (Varghese & Buyya, 2019) uses resources for cloud computing.

This means that the resources of cloud computing should be either computer system resources or computing resources or IT resources. Are computer system resources, computing resources and IT resources same?

No, mathematically,

$$IT \subseteq ICT \subseteq \text{computing}.$$

That is,

$$\text{IT resources} \subseteq \text{ICT resources} \subseteq \text{computing resources}.$$

Calculus Of Cloud Computing

The above analysis leads to a new question. What are the resources of cloud computing. At least we have known that the resources contain Computer system resources, IT resources, ICT resources, computing resources, storage resources, etc.

Question:

Can we consider all these resources in the cloud computing as big data?

Calculus Of Cloud Computing

Can we consider all these resources in the cloud computing as big data?

If yes, then we have

$$\text{IT resources} \subseteq \text{ICT resources} \subseteq \text{computing resources} \subseteq \text{big data}.$$

In such a way, big data is the strategic resources of cloud computing. Big data is the basic and raw materials for resources and services processing in cloud computing.

Calculus Of Cloud Computing

How to understand types of cloud?

Hybrid Cloud is a multi-cloud with a combination of public and private clouds or a combination of public and private IT infrastructure.

Hybrid cloud = public cloud + private cloud

Hybrid cloud = public cloud ∨ private cloud ∨ community cloud

Calculus Of Cloud Computing

How to understand cloud services?

IaaS, PaaS and SaaS

These three services are at three levels. Therefore, the relationships among them can be represented as

$$IaaS \oplus PaaS < IaaS \oplus SaaS$$

Calculus Of Cloud Computing

Cloud Analytics = Big data Analytics + Cloud Computing

Wu, Buyya and Ramamohana (2016) represent Big data Analytics mathematically as

- Big data Analytics = Machine learning + Cloud Computing ---(1)

Machine learning is a part of artificial intelligence, that is machine learning $\cup$ artificial intelligence. Then we can have

- Big data Analytics = Artificial intelligence + Cloud Computing ---(2)

Now,

- Big Data analytics = Big data + Big data analysis + Big DW + Big DM + Big SM + Big ML + Big Visualization

Then we have,

- Cloud Analytics = Big data + Big data analysis + Big DW + Big DM + Big SM + Big ML + Big Visualization + Cloud Computing

*DW is data warehousing,**DM is data mining, ^SM is statistical modeling, ^^ML is machine learning

Conclusion

This was proposed a unified framework for cloud computing as a science, technology, engineering, system, service and industry. It also presented the calculus of cloud computing, which treats many aspects of cloud computing using mathematical methods (including logic and set theory) and thinking. The proposed approaches here will facilitate the research and development of cloud computing, intelligent analytics, and business intelligence as well as artificial intelligence.

Thank You