Cloud Computing

Computing for Internet of Things

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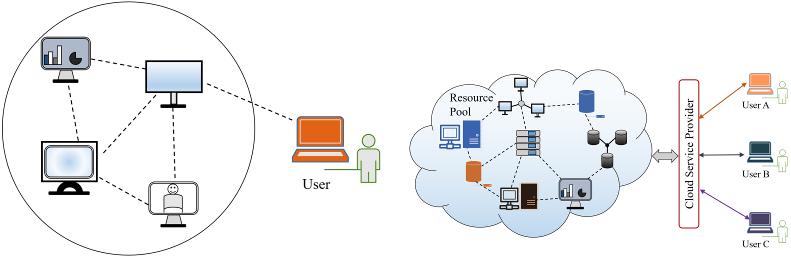
Overview

Introduction

- Cloud computing is more than traditional network computing.
- Unlike network computing, cloud computing comprises a pool of multiple resources such as servers, storage, and network from single/multiple organizations.
- An end user can request for customized resources such as storage space, RAM, operating systems, and other software to a cloud service provider (CSP).
- The concept is the same as paying utility bills based on consumption.
- In cloud computing, a user pays for the cloud services as per the duration of their resource usage.

Introduction



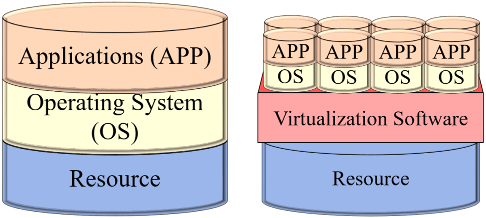
(a) Network computing (b) Cloud computing

Figure: Network computing versus cloud computing

Virtualization

- The key concept of cloud computing is virtualization.
- The technique of sharing a single resource among multiple end user organizations or end users is known as virtualization.
- In the virtualization process, a physical resource is logically distributed among multiple users.
- A user is in the illusion that the resource is unlimited and is dedicatedly provided to him/her.
- Virtualization software separates the resources logically so that there is no conflict among the users during resource utilization.

Virtualization



(a) Desktop (b) Virtualization

Figure: Traditional desktop versus virtualization

Advantages of Virtualization: for End users

- **Variety**: The process of virtualization in cloud computing enables an end user organization to use various types of applications based on the requirements.
- **Availability**: The concept of virtualization makes available a considerable amount of resources as per user requirements.
- **Portability**: Portability signifies the availability of cloud computing services from anywhere in the world, at any instant of time.
- **Elasticity**: Through the concept of virtualization, an end user can scale-up or scale-down resource utilization as per requirements.

Advantages of Virtualization: for CSP

- **Resource Utilization**:
  - A CSP in a cloud computing architecture procures resources on their own or get them from third parties.
  - These resources are distributed among different users dynamically as per their requirements.
  - A segment of a particular resource provided to a user at a time instant, can be provided to another user at a different time instant.
  - Thus, in a cloud computing architecture, resources can be re-utilized for multiple users.
- **Effective Revenue Generation**: A CSP generates revenue from the end users based on resource utilization.

Types of Virtualization

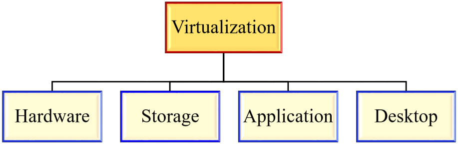


Figure: Types of virtualization

- **Hardware Virtualization**: This type of virtualization indicates the sharing of hardware resources among multiple users.
- **Storage Virtualization**: In storage virtualization, the storage space from different entities are accumulated virtually, and seem like a single storage location.
- **Application Virtualization**: A single application is stored at the cloud end and as per requirement, a user can use the application in his/her local computer without ever actually installing the application.
- **Desktop Virtualization**: This type of virtualization allows a user to access and utilize the services of a desktop that resides at the cloud.

Cloud Models

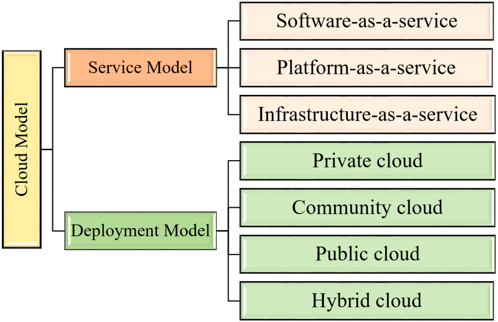
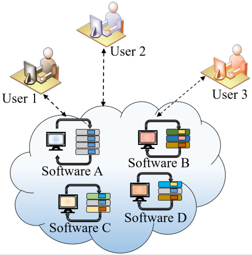


Figure: Cloud Model [1]

Cloud Models: Service Model

Software-as-a-Service (SaaS)

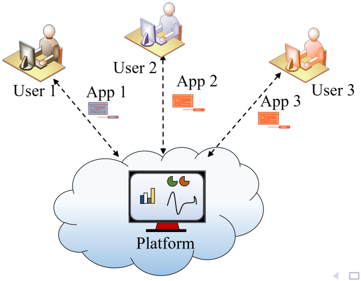
- This service provides access to different software applications to an end user through Internet connectivity.
- For accessing the service, a user does not need to purchase and install the software applications on his/her local desktop.
- The software is located in a cloud server, from where the services are provided to multiple end users.
- SaaS offers scalability, by which users have the provision to use multiple software applications as per their requirements.



Cloud Models: Service Model

Platform-as-a-Service (PaaS)

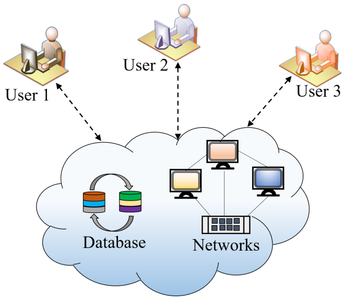
- PaaS provides a computing platform, by which a user can develop and run different applications.
- The cloud user need not go through the burden of installing and managing the infrastructure such as operating system, storage, and networks.
- The users can develop and manage the applications that are running on top of it.



Cloud Models: Service Model

Infrastructure-as-a-Service (IaaS)

- IaaS provides infrastructure such as storage, networks, and computing resources.
- A user uses the infrastructure without purchasing the software and other network components.
- In the infrastructure provided by a CSP, a user can use any composition of the operating system and software.



Cloud Models: Deployment Model

- **Private Cloud**: This type of cloud is owned explicitly by an end user organization. The internal resources of the organization maintain the private cloud.
- **Community Cloud**: This cloud forms with the collaboration of a set of organizations for a specific community. For a community cloud, each organization has some shared interests.
- **Public Cloud**: The public cloud is owned by a third party organization, which provides services to the common public. The service of this cloud is available for any user, on a payment basis.
- **Hybrid Cloud**: This type of cloud comprises two or more clouds (private, public, or community).

Service-Level Agreement

- Actors in cloud computing – end user/customer and CSP.
- Cloud computing architecture aims to provide optimal and efficient services to the end users and generate revenue from them as per their usage.
- For a clear understanding between CSP and the customer about the services, an agreement is required to be made, which is known as service level agreement (SLA).
- An SLA provides a detailed description of the services that will be received by the customer.
- Based on the SLA, a customer can be aware of each and every term and condition of the services before availing them.
- An SLA may include multiple organizations for making the legal contract with the customers.

Importance of SLA

- **Customer Point of View**:
  - Each CSP has its SLA, which contains a detailed description of the services.
  - If a customer wants to use a cloud service, he/she can compare the SLAs of different organizations.
  - A customer can choose a preferred CSP based on the SLAs.
- **CSP Point of View**:
  - In many cases, certain performance issues may occur for a particular service, because of which a CSP may not be able to provide the services efficiently.
  - A CSP can explicitly mention in the SLA that they are not responsible for inefficient service.

Metrics for an SLA

A few common metrics that are required to be included for constructing an SLA, which are as follows:

- **Availability**: This metric signifies the amount of time the service will be accessible for the customer.
- **Response Time**: The maximum time that will be taken for responding to a customer request is measured by response time.
- **Portability**: This metric indicates the flexibility of transferring the data to another service.
- **Problem Reporting**: How to report a problem, whom and how to be contacted, is explained in this metric.
- **Penalty**: The penalty for not meeting the promises mentioned in the SLA.

Cloud Simulation

- It is challenging to estimate the performance of an IoT system with the cloud before real implementation.
- The real deployment of the cloud is a complex and costly procedure.
- There is a requirement for simulating the system through a cloud simulator before real implementation.
- A cloud simulator provides the following advantages to a customer:
  - Pre-deployment test before real implementation
  - System testing at no cost
  - Repeatable evaluation of the system
  - Pre-detection of issues that may affect the system performance
  - Flexibility to control the environment

CloudSim

- **Description**: CloudSim [3] is a popular cloud simulator that was developed at the University of Melbourne. This simulator is written in a Java-based environment. In CloudSim, a user is allowed to add or remove resources
- **Features**:
  - The CloudSim simulator provides various cloud computing data centers along with different data center network topologies in a simulation environment.
  - Using CloudSim, virtualization of server hosts can be done in a simulation.
  - A user is able to allocate virtual machines (VMs) dynamically
  - It allows users to define their own policies for the allocation of host resources to VMs.
  - It provides flexibility to add or remove simulation components dynamically.
  - A user can stop and resume the simulation at any instant of time.

CloudAnalyst

- **Description**: CloudAnalyst [4] is based on CloudSim. This simulator provides a graphical user interface (GUI) for simulating a cloud environment, easily. The CloudAnalyst is used for simulating large-scale cloud applications.
- **Features**:
  - The CloudAnalyst simulator is easy to use due to the presence of the GUI.
  - It allows a user to add components and provides a flexible and high level of configuration.
  - A user can perform repeated experiments, considering different parameter values.
  - It can provide a graphical output, including a chart and table.

GreenCloud

- **Description**: GreenCloud [2] is developed as an extension of a packet level network simulator, NS2. This simulator can monitor the energy consumption of different network components such as servers and switches.
- **Features**:
  - GreenCloud is an open-source simulator with user-friendly GUI.
  - It provides the facility for monitoring the energy consumption of the network and its various components.
  - It supports the simulations of cloud network components.
  - It enables improved power management schemes.
  - It allows a user to manage and configure devices, dynamically, in simulation.

An open-source cloud: OpenStack

- The OpenStack [7] is free software, which provides a cloud IaaS to users.
- A user can easily use this cloud with the help of a GUI-based web interface or through the command line.
- OpenStack supports a vastly scalable cloud system, in which different pre-configured software suites are available.

Components in OpenStack

Component	Function
Nova	K-means
Neutron	Networking
Cinder	Block storage
Keystone	Identity
Glance	Image
Swift	Object storage
Horizon	Dashboard
Trove	Database
Sahara	Elasticmap reduce
Manila	Shared file system
Designate	DNS
Searchlight	Search
Barbican	Key manager

Features of OpenStack

- OpenStack allows a user to create and deploy virtual machines.
- It provides the flexibility of setting up a cloud management environment.
- OpenStack supports an easy horizontal scaling: dynamic addition or removal of instances for providing services to multiple numbers of users.
- This cloud platform allows the users to access the source code and share their code to the community.

A commercial cloud: Amazon Web Services (AWS)

- A user can launch and manage server instances in AWS [8]. Typically, a web interface is used to handle the instances.
- AWS provides different APIs (application programming interfaces), tools, and utilities for users.
- Similar to other commercial clouds, Amazon AWS follows the pay-per-use model.
- This cloud infrastructure provides a virtual computing environment, where different configurations, such as CPU, memory, storage, and networking capacity are available.

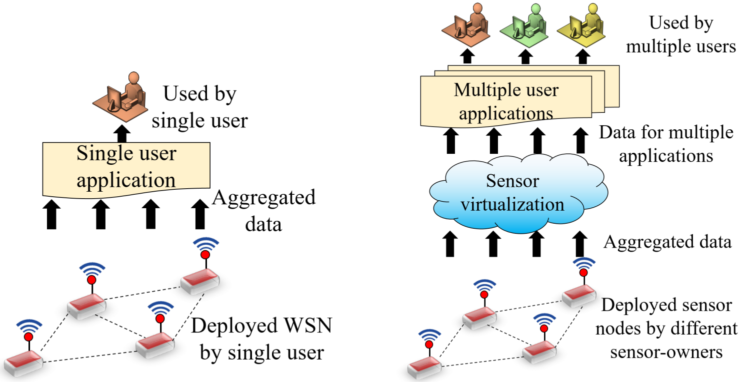
AWS: Features

- It provides flexibility to scale and manage the server capacity.
- AWS provides control to OS and deployment software.
- It follows the pay-per-use model.
- The cloud allows a user to establish connectivity between the physical network and private virtual network
- The developer tools in this cloud infrastructure help a user for fast development and deployment of the software.
- AWS provides excellent management tools, which help a user to monitor and automate different components of the cloud.
- The cloud provides machine learning facilities, which are very useful for data scientists and developers.
- For extracting meaning from data, analytics play an important role. AWS also provides a data analytics platform.

Sensors-as-a-Service (Se-aaS)

- Virtualization of resources is the backbone of cloud computing.
- Similarly, in a sensor-cloud, virtualization of sensors plays an essential role in providing *Sensors-as-a-Service* (Se-aaS) to multiple users.
- In a sensor-cloud architecture, multiple users receive services from different sensor nodes.
- The users remain oblivious to the fact that a set of sensor nodes is not dedicated solely to them for their application requirements.
- In reality, a particular sensor may be used for serving multiple user applications, simultaneously.
- The main aim of a sensor-cloud architecture is to provide an opportunity to the common mass to use wireless sensor networks (WSNs) on a payment basis.

Traditional WSN versus Sensor-cloud



(a) Trasitional WSN (b) Sensor-cloud

Figure: Traditional WSN versus sensor-cloud [5],[6]

Actors in Sensor-cloud

End user

- This actor is also known as a customer of the sensor-cloud services.
- An end user registers him/herself with the infrastructure through a Web portal.
- The end user chooses the template of the services that are available in the sensor-cloud architecture to which he/she is registered.
- Finally, through the Web portal, the end user receives the services
- Based on the type and usage duration of service, the end user pays the charges to the SCSP.

Actors in Sensor-cloud

Sensor owner

- The deployment of the sensors is essential in order to provide services to the end users.
- These sensors in a sensor-cloud architecture are owned and deployed by the sensor owners
- A particular sensor owner can own multiple homogeneous or heterogeneous sensor nodes.
- Based on the requirements of the users, these sensor nodes are virtualized and assigned to serving multiple applications at the same time.
- A sensor owner receives rent depending upon the duration and usage of his/her sensor node(s).

Actors in Sensor-cloud

Sensor-cloud Service Provider (SCSP)

- An SCSP is responsible for managing the entire sensor-cloud infrastructure (including management of sensor owners and end users handling, resource handling, database management, cloud handling etc.), centrally.
- The SCSP receives rent from end users with the help of a pre-defined pricing model. The pricing scheme may include the infrastructure cost, sensor owners' rent, and the revenue of the SCSP.
- Different algorithms are used for managing the entire infrastructure.
- The SCSP receives the rent from the end users and shares a partial amount with the sensor owners.
- The remaining amount is used for maintaining the infrastructure.
- In the process, the SCSP earns a certain amount of revenue from the payment of the end users.

Sensor-cloud: Architecture

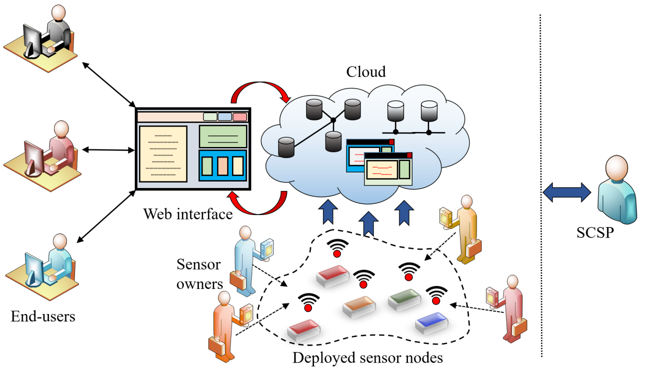


Figure: Architecture of a sensor-cloud platform

Different Viewpoints

1. User Organizational View:
   - In a sensor-cloud, end users interact with a Web interface for selecting templates of the services.
   - The services are received by the end users through the Web interface.
   - In this architecture, an end user is unaware of the complex processes that are running at the back end.
2. Real Architectural View:
   - The complex processing of sensor-cloud architecture is visualized through this view.
   - The processes include sensor allocation, data extraction from the sensors, virtualization of sensor nodes, maintenance of the infrastructure, data center management, data caching, and others.
   - For each process, there is a specific algorithm or scheme.

Different Viewpoints

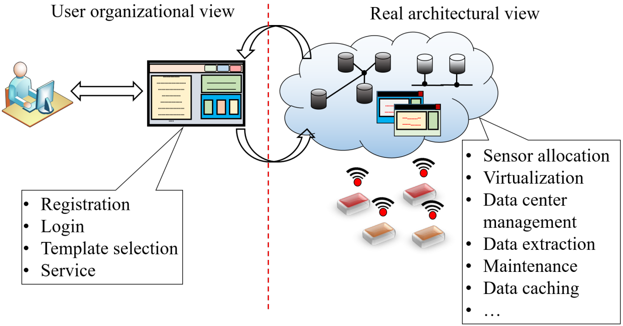


Figure: Sensor-cloud architecture from different viewpoints

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