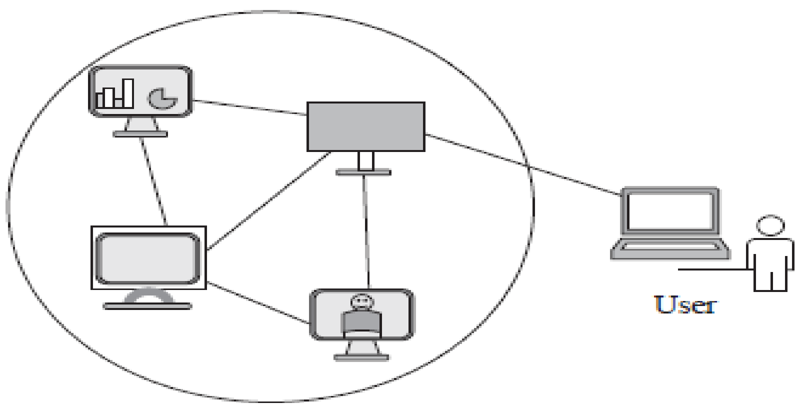
Module 4

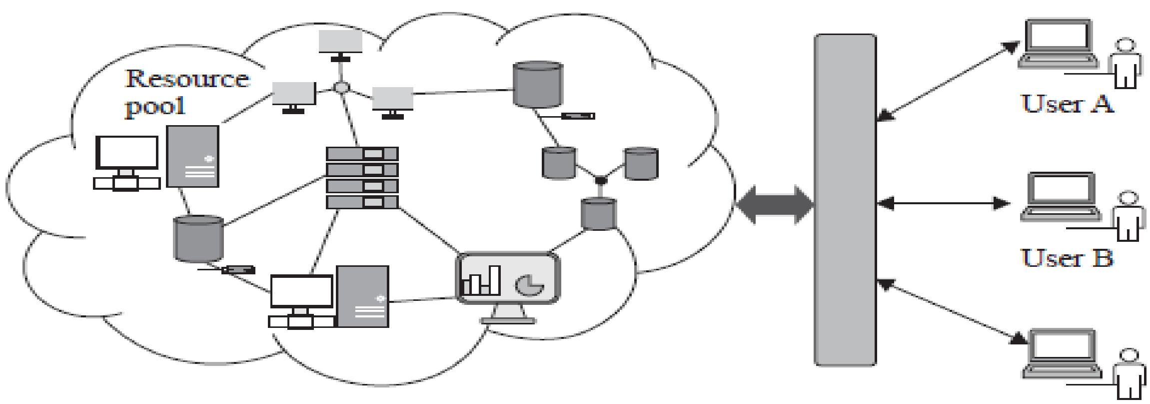
Associated IoT Technologies

Cloud Computing:

- 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.
- These resources are allocated to the end users as per requirement, on a payment basis.
- In cloud computing architecture, an end user can request for customized resources such as storage space, RAM, operating systems, and other software to a cloud service provider (CSP) as shown
- For example, a user can request for a Linux operating system for running an application from a CSP; another end user can request for Windows 10 operating system from the same CSP for executing some application.



(a) Network computing

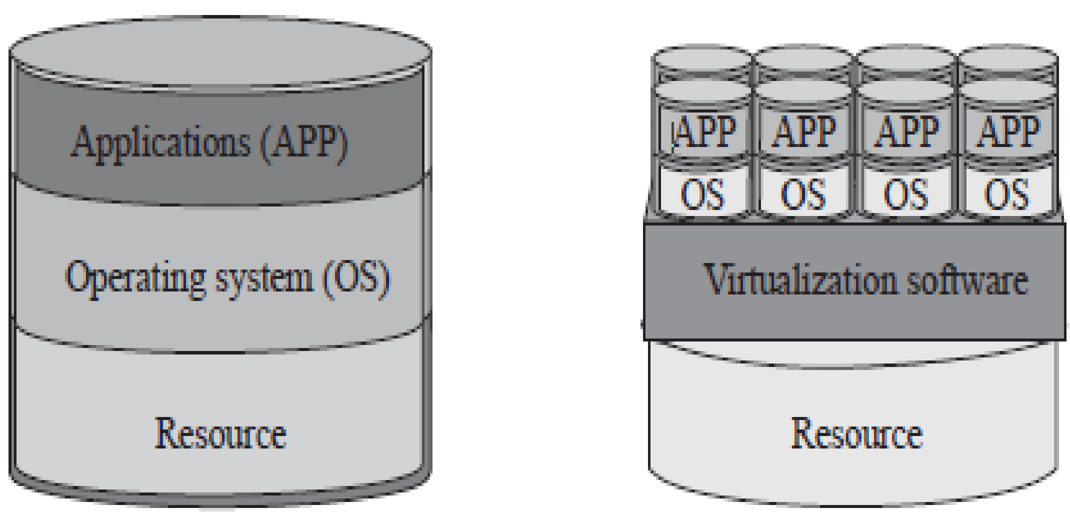


- **The cloud services are accessible from anywhere and at any time by an authorized user through Internet connectivity.**
- Cloud computing comprises a shared pool of computing resources, which are accessible dynamically, on-demand basis by the users.
- This shared pool of resources includes networks, storage, processor, and servers.
- The services of cloud computing are based on the pay-per-use model.
- In cloud computing, a user pays for the cloud services as per the duration of their resource usage.

On the other hand, there is a CSP, that provides cloud services to end user organizations.

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 perceives that the resource is unlimited and is dedicatedly provided to him/her.



(a) Desktop (b) Virtualization

Advantages of virtualization

- With the increasing number of interconnected heterogeneous devices in IoT, the importance of virtualization also increases.
- Typically, there are different software such as VMware, which enable the concept of virtualization.
- With the increasing importance of cloud computing, different organizations and individuals are using it extensively.
- there is always a risk of system crash at any instant of time. In such a scenario, cloud computing plays a vital role by keeping backups through virtualization.
- Primarily, there are two entities in a cloud computing architecture:
- 1.End users
- 2.CSP.
- Both end users and CSP are benefited in several aspects through the process of virtualization.

Advantages for End Users

1.Variety: The process of virtualization in cloud computing enables an end user organization to use various types of applications based on the requirements.

3.Portability: Portability signifies the availability of cloud computing services from anywhere in the world, at any instant of time. [For example, a person flying from the US to the UK still has access to their documents, although they cannot physically access the devices on which the data is stored. This has been made possible by platforms such as Google Drive.]

4. **Elasticity**: Through the concept of virtualization, an end user can scale-up or scale-down resource utilization as per requirements

Advantages for CSP

1.Resource Utilization: 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 the cloud computing architecture, resources can be re-utilized for multiple users.

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Types of virtualization

- Based on the requirements of the users, we categorized virtualization as

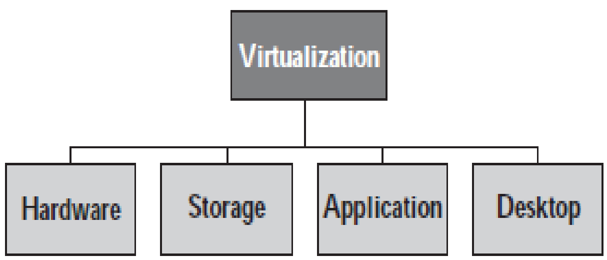


Figure 10.3 Types of virtualization

- **1.Hardware Virtualization:** This type of virtualization indicates the sharing of hardware resources among multiple users.
- For example, a single processor appears as many different processors in a cloud computing architecture.
- Different operating systems can be installed in these processors and each of them can work as stand-alone machines.
- 2.Storage Virtualization: In storage virtualization, the storage space from different entities are accumulated virtually, and seem like a single storage location.
- Through storage virtualization, a user’s documents or files exist in different locations in a distributed fashion. but the users are under the impression that they have a single dedicated storage space provided to them.

- Application Virtualization: A single application is stored at the cloud end., as per requirement, a user can use the application in his/her local computer without ever actually installing the application.
- Similar to storage virtualization, in application virtualization, the users get the impression that applications are stored and executed in their local computer.
- Desktop Virtualization: This type of virtualization allows a user to access and utilize the services of a desktop that resides at the cloud.
- The users can use the desktop from their local desktop.

Cloud Models

As per the National Institute of Standards and Technology (NIST) and Cloud Computing Standards Road map Working Group.

The cloud model can be divided into two parts:

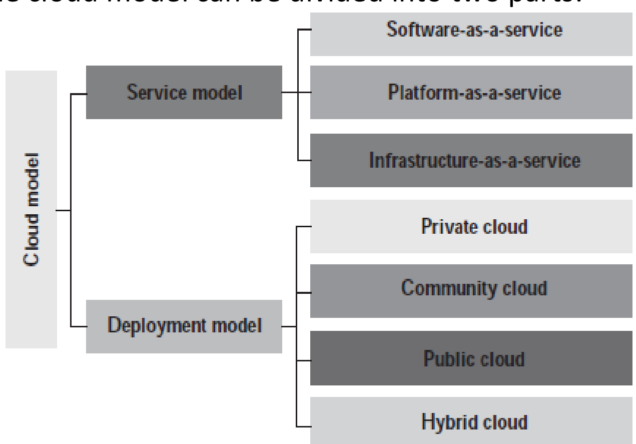


Figure 10.4 Cloud model

- (1) Service model
- (2) Deployment model

The service model is categorized as:

- 1.Software-as-a-Service (SaaS)
- 2.Platform-as-a-Service (PaaS)
- 3.Infrastructure-as-a-Service (IaaS).

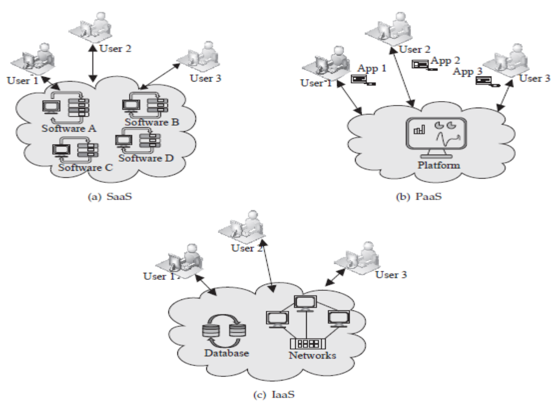
Deployment model is further categorized as:

- 1.Private cloud,
- 2.Community cloud,

- 3. Public cloud,
- 4. Hybrid cloud.

1.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.
- A user does not need to worry about the update of the software applications.
- These software are accessible from any location.
- One example of SaaS is Microsoft Office 365.



2.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.

- An example of PaaS is Google App Engine.
- 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.
- An example of IaaS is Google Compute Engine.

2.Deployment Model

- **(a) Private Cloud:** This type of cloud is owned explicitly by an end user organization. The internal resources of the organization maintain the private cloud.
- **(b) 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.

(c) 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.

- **(d) Hybrid Cloud:** This type of cloud comprises two or more clouds (private,public, or community).

Service-Level Agreement in Cloud Computing

- The most important factors in cloud computing are the 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.
- Therefore, 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.

SLA is important because of the following reasons:

- 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. Therefore, 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.
- Thus, in such a situation, a CSP can explicitly mention in the SLA that they are not responsible for inefficient service.

Metrics for SLA

- Depending on the type of services, an SLA is constructed with different metrics.

Few common metrics that are required to be included for constructing an SLA are as follows:

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

Cloud Implementation

1.Cloud simulation:

- real deployment of the cloud is a complex and costly procedure.
- Thus there is a requirement for simulating the system through a cloud simulator before real implementation.
- There are many cloud simulators that provide pre-deployment test services for repeatable performance evaluation of a system.
- Typically, 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 environmentCurrently, different types of cloud simulators are available.

A few cloud simulators are listed here:

- 1.CloudSim
- 2.CloudAnalyst
- 3.GreenCloud

CloudSim has different features, which are listed as follows:

- (1) The CloudSim simulator provides various cloud computing data centers along with different data center network topologies in a simulation environment.
- (2) Using CloudSim, virtualization of server hosts can be done in a simulation.
- (3) A user is able to allocate virtual machines (VMs) dynamically.
- (4) It allows users to define their own policies for the allocation of host resources to VMs.
- (5) It provides flexibility to add or remove simulation components dynamically.
- (6) A user can stop and resume the simulation at any instant of time.

CloudAnalyst:

- (a) Description: CloudAnalyst 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.

(1) The CloudAnalyst simulator is easy to use due to the presence of the GUI.

(2) It allows a user to add components and provides a flexible and high level of configuration.

(3) A user can perform repeated experiments, considering different parameter values.

(4) It can provide a graphical output, including a chart and table.

(5)

GreenCloud

(a) Description: GreenCloud is developed as an extension of a packetlevel network simulator, NS2. This simulator can monitor the energy consumption of different network components such as servers and switches.

(1) GreenCloud is an open-source simulator with user-friendly GUI.

(2) It provides the facility for monitoring the energy consumption of the network and its various components.

(3) It supports the simulations of cloud network components.

(4) It enables improved power management schemes.

(5) It allows a user to manage and configure devices, dynamically, in simulation.

For the real implementation of cloud, there are various open-source cloud platforms available such as

- 1. OpenStack
- 2.CloudStack
- 3. Eucalyptus.
- The OpenStack 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.

Features of OpenStack

- (i) OpenStack allows a user to create and deploy virtual machines.
- (ii) 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.
- (iv) 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 commercial cloud: Amazon web services (AWS)
- Besides the open-source cloud, there are various commercial cloud infrastructures available in the market.

- Few of the popular commercial cloud infrastructures are Amazon Web Services (AWS), Microsoft Azure, and Google App Engine.
- A user can launch and manage server instances in AWS.
- Typically, a web interface is used to handle the instances.
- Additionally, AWS provides different APIs (application programming interfaces), tools, and utilities for users.
- Like 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.
- **Features of AWS**
- (i) It provides flexibility to scale and manage the server capacity.
- (ii) AWS provides control to OS and deployment software
- (iii) It follows the pay-per-use model.
- (iv) The cloud allows a user to establish connectivity between the physical network and private virtual network
- (v) The developer tools in this cloud infrastructure help a user for fast development and deployment of the software.
- vi) AWS provides excellent management tools, which help a user to monitor and automate different components of the cloud.
- (vii) The cloud provides machine learning facilities, which are very useful for data scientists and developers.
- (viii) For extracting meaning from data, analytics play an important role. AWS also provides a data analytics platform.

Sensor-cloud: Sensor as a service

- In a sensor-cloud, virtualization of sensors plays an essential role in providing services to multiple users.
- Typically, in a sensor-cloud architecture, multiple users receive services from different sensor nodes, simultaneously.
- a particular sensor may be used for serving multiple user applications, simultaneously.

- The main aim of sensor-cloud infrastructure is to provide an opportunity for the common mass to use Wireless Sensor Networks (WSNs) on a payment basis. Similar to cloud computing, sensor-cloud architecture also follows the pay-per-use model

Importance of sensor-cloud

- The sensor-cloud infrastructure is based on the concept of cloud computing, in which a user application is served by a set of homogeneous or heterogeneous sensor nodes.
- These sensor nodes are selected from a common pool of sensor nodes, as per the requirement of user applications.

Using the sensor-cloud infrastructure, a user receives data for an application from multiple sensor nodes without owning them.

- if a user wants to use traditional WSN for a certain application
- he/she has to go through different pre-deployment and post-deployment hurdles.

Architecture of a sensor-cloud platform

- In a traditional cloud computing architecture, two actors, cloud service provider (CSP) and end users (customer) play the key role.
- Unlike cloud computing, in sensor-cloud architecture, the sensor owners play an important role along with the service provider and end users.
- a sensor-cloud service provider (SCSP). The detailed architecture of a sensor-cloud is depicted in Figure

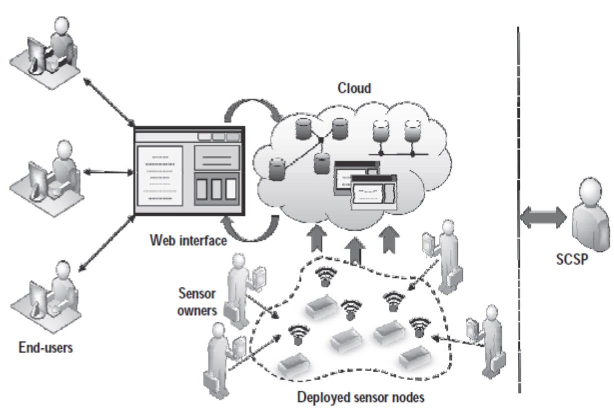


Figure 10.7 Architecture of a sensor-cloud platform

Actors in sensor-cloud architecture

- Typically, in a sensor-cloud architecture, three actors are present. briefly described the role of each actor below
- (i) End User: This actor is also known as a customer of the sensor-cloud services.
- Typically, an end user registers him/herself with the infrastructure through a Web portal.
- Thereafter, he/she chooses the template of the services that are available in the sensor-cloud architecture to which he/she is registered 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.
- (ii) Sensor Owner: sensor-cloud architecture is based on the concept of Se-aaS.
- Therefore, 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.
- On the other hand, a sensor owner receives rent depending upon the duration and usage of his/her sensor node(s). (iii) Sensor-Cloud Service Provider (SCSP): An SCSP is responsible for managing the entire sensor-cloud infrastructure 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.
- Typically, 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 from Different Viewpoints

- User Organizational View: This view of sensor-cloud architecture is simple.

- In a sensor-cloud, end users interact with a Web interface for selecting templates of the services.
- Thereafter, 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.

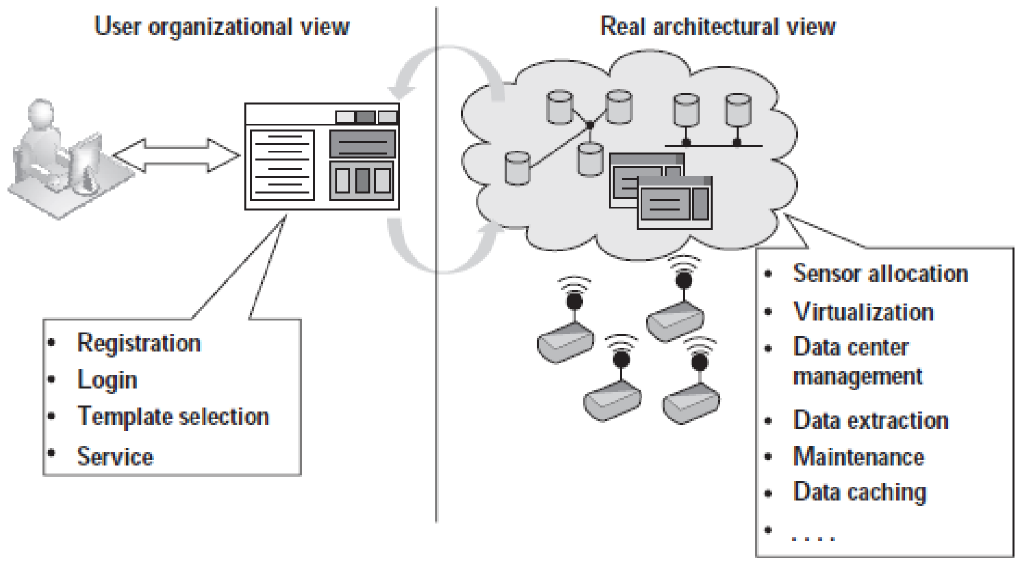


Figure 10.8 Sensor-cloud architecture

- **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.

Agricultural IoT

- **Components of an agricultural IoT**

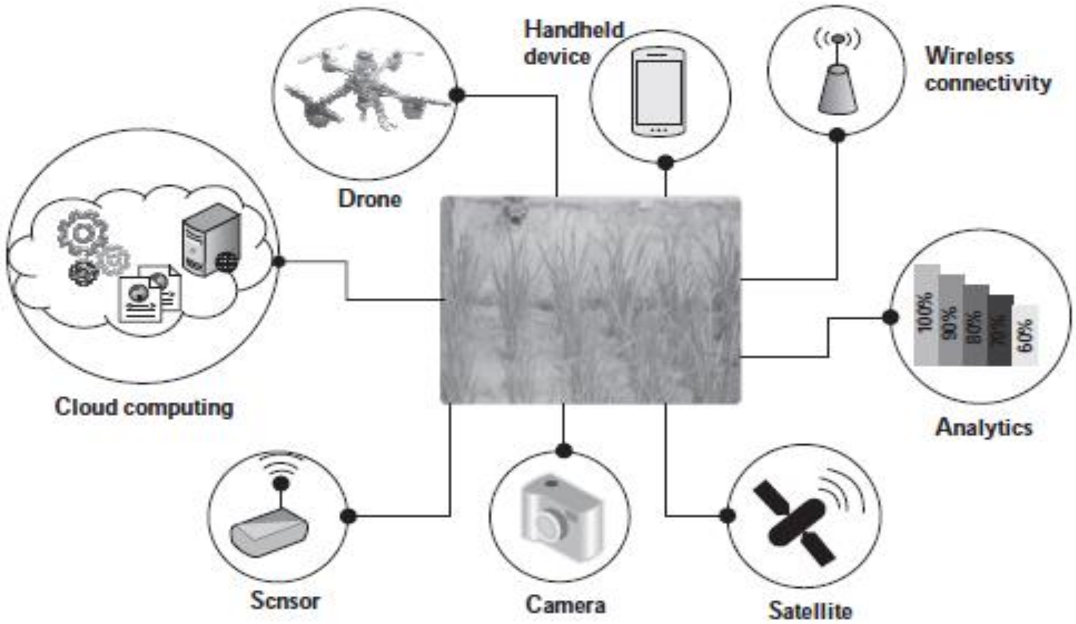


Figure 12.2 Components of agricultural IoT

The different components of an agricultural IoT are discussed as follows:

- Cloud computing: Sensors such as the camera, devices to measure soil moisture, soil humidity, and soil pH-level are used for serving different agricultural applications.
- These sensors produce a huge amount of agricultural data that need to be analyzed.
- Sometimes, based on the data analysis, action needs to be taken, such as switching on the water pump for irrigation.
- Further, the data from the deployed sensors are required to be stored on a long-term basis since it may be useful for serving future applications.

Sensors: The sensors are the major backbone of any IoT application. Similarly, for agricultural IoT applications,

- the sensors are an indispensable component.
- A few of the common sensors used in agriculture are sensors for soil moisture, humidity, water level, and temperature.

Cameras: Imaging is one of the main components of agriculture.

- Therefore, multispectral, thermal, and RGB cameras are commonly used for scientific agricultural IoT.

- These cameras are used for estimating the nitrogen status, thermal stress, water stress, and crop damage due to inundation, as well as infestation.
- Video cameras are used for crop security

Satellites: In modern precision agriculture, satellites are extensively used to extract information from field imagery.

- The satellite images are used in agricultural applications to monitor different aspects of the crops such as crop health monitoring and dry zone assessing over a large area.

Analytics: Analytics contribute to modern agriculture massively.

- Currently, with the help of analytics, farmers can take different agricultural decisions, such as estimating the required amount of fertilizer and water in an agricultural field and estimating the type of crops that need to be cultivated during the upcoming season.
- Analytics is not only responsible for making decisions locally;
- it is used to analyze data for the entire agricultural supply chain.
- Data analytics can also be used for estimating the crop demand in the market.

Wireless connectivity: One of the main components of agricultural IoT is wireless connectivity.

- Wireless connectivity enables the transmission of the agricultural sensor data from the field to the cloud/server.
- It also enables farmers to access various application services over handheld devices, which rely on wireless connectivity for communicating with the cloud/server.

Handheld devices: Over the last few years, e-agriculture has become very popular.

- One of the fundamental components of e-agriculture is a handheld device such as a smartphone.
- Farmers can access different agricultural information, such as soil and crop conditions of their fields and market tendency, over their Smartphones.
- Additionally, farmers can also control different field

  equipment, such as pumps, from their phones.

Drones: Currently, the use of drones has become very attractive in different

- applications such as surveillance, healthcare, product delivery, photography, and
- agriculture. Drone imaging is an alternative to satellite imaging in agriculture.

- In continuation to providing better resolution land mapping visuals, drones are
- used in agriculture for crop monitoring, pesticide spraying, and irrigation.

Advantages of IoT in agricultureAutomatic seeding:

- IoT-based agricultural systems are capable of autonomous seeding and planting over the agricultural fields.
- Efficient fertilizer and pesticide distribution: Agricultural IoT has been used to
- develop solutions that are capable of applying and controlling the amount of
- fertilizers and pesticides efficiently.
- These solutions are based on the analysis of crop health.
- Water management: The excess distribution of water in the agricultural fields may affect the growth of crops.
- On the other hand, the availability of global water resources is finite.
- The constraint of limited and often scarce usable water resources is an influential driving factor for the judicious and efficient distribution of agricultural water resources.
- Using the various solutions available for agricultural IoT, water can be distributed efficiently, all the while, increasing field productivity and yields.
- The IoT-enabled agricultural systems are capable of monitoring the water level and moisture in the soil, and accordingly, distribute the water to the agricultural fields.
- Real-time and remote monitoring:
- Unlike traditional agriculture, in IoT-based farming, a stakeholder can remotely monitor different agricultural parameters,
- such as crop and soil conditions, plant health, and weather conditions.
- using a smart handheld device (e.g., cellphone), a farmer can actuate on-field farming machinery such as a water pump, valves, and other pieces of machinery.
- Easy yield estimation: Agricultural IoT solutions can be used to record and aggregate data, which may be spatially or temporally diverse, over long periods.
- These records can be used to come up with various estimates related to farming and farm management.
- The most prominent among these estimates is crop yield,which is done based on established crop models and historical trends.

- Production overview: The detailed analysis of crop production, market rates, market demand are essential factors for a farmer to estimate optimized crop yields and decide upon the essential steps for future cropping practices.
- Unlike traditional practices, IoT-based agriculture acts as a force multiplier for farmers by enabling them to have a stronger hold on their farming as well as crop management practices, and that too mostly autonomously.
- Agricultural IoT provides a detailed product overview on the farmers' handheld devices.

Case Studies: In-situ assessment of leaf area index using IoT-based agricultural system

1.Architecture

2.Communication

3.Hardware

4.Software

5.IOT Architecture

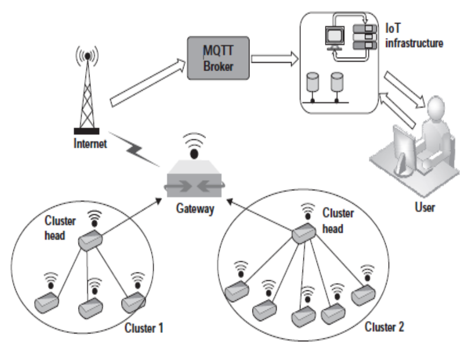


Figure 12.4 System architecture

1.Architecture:

- The integrated the hardware and software components
- One of the important components in this system is the wireless sensor network (WSN), which is used as the LAI assessment unit.
- The uses two types of sensors:
- (i) ground-level sensor (G)
- (ii) reference sensor (R).
- These sensors are used to measure photo synthetically active radiation **(PAR).** The distance between the two types of sensors must be optimal so that these are not located very far from one another.
- In this system, the above-ground sensor (R) acts as a cluster head while the other sensor nodes (Gs) are located below the canopy.
- These Gs and R connect and Agricultural IoT 277 form a star topology.
- A solar panel is used to charge the cluster head.
- The system is based on IoT architecture.

- Therefore, a cluster head is attached to a central base station,which acts as a gateway.
- Further, this gateway connects to an IoT infrastructure
- **2.Hardware**
- For sensing and transmitting the data from the deployment fields to a centralized unit, such as a server and a cloud, different hardware components are used in the system.
- The commercial off-the-shelf (COTS) TelosB platform is used in the system
- The TelosB motes are equipped with three types of sensors:
- 1.temperature,
- 2.humidity
- 3.light sensors.
- With the help of an optical filter and diffuser accessory on the light sensors, the PAR is calculated to estimate the LAI.
- **The system is based on the cluster concept.**
- A Raspberry-Pi is used as a cluster head, which connects with four ground
- sensor motes.
- The Raspberry-Pi is a tiny single board, which works as a computer and is used to perform different operations in IoT.
- Humidity and wet plants intermittently cause attenuation to the system, which is minimized with the help of forward error coding (FEC) technique.
-

3.Communication:

- The LAI system consists of multiple components, such as WSN, IoT gateway, and IoTbased network.
- All of these components are connected through wired or wireless links.
- The public land mobile network (PLMN) is used to establish connectivity between external IoT networks and the gateway.
- The data are analyzed and visualized with the help of a farm management information system (FMIS), which resides in the IoT-based infrastructure.

4.Software:

- Software is an essential part of the system by which different operations of the system are executed.

- In order to operate the TelosB motes**,** TinyOS, an open-source, low-power operating system, is used. This OS is widely used for different WSN applications.
- Typically, in this system, the data acquired from the sensor node is stored with a timestamp and sequence number (SN).
- 5.IoT Architecture:
- The MQTT broker runs in the Internet server of the system. This broker is responsible for receiving the data from the WSN.
- In the system, the graphical user interface (GUI) is built using an Apache server

Smart irrigation management system

- Architecture
- Sensing and actuating layer
- Processing and service layer
- Application Layer
- Deployment

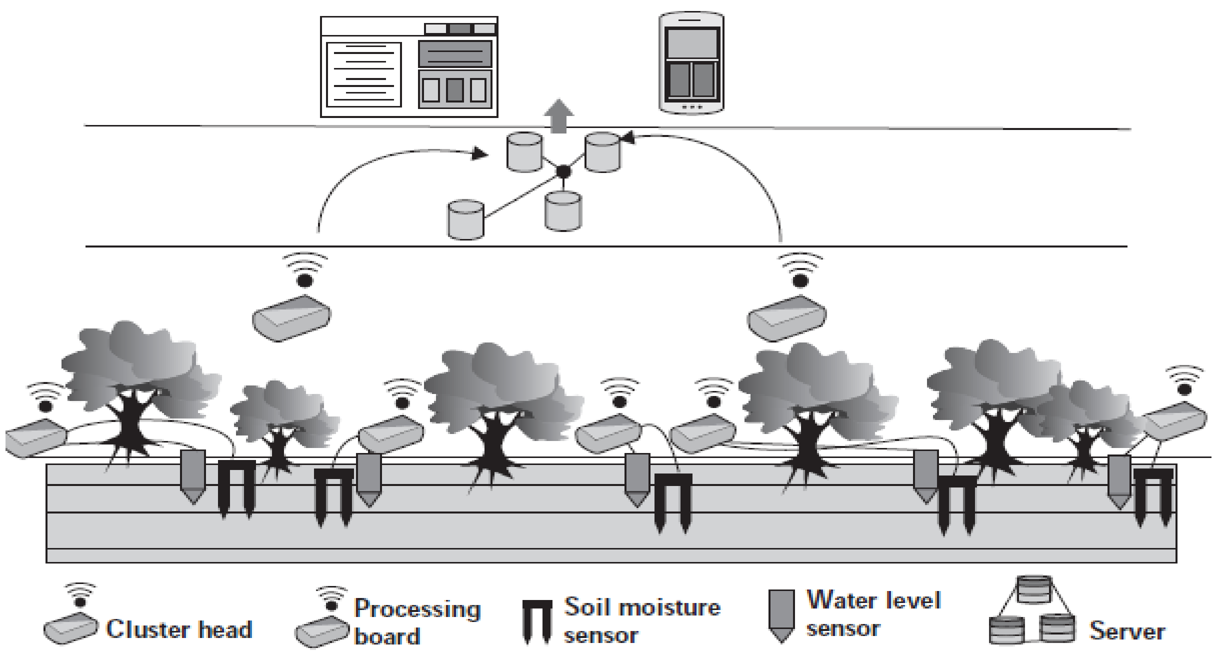


Figure 12.5 Architecture: Smart irrigation management system

Architecture:

- The architecture of this system consists of three layers: Sensing and actuating layer, remote processing and service layer, and application layer. These layers perform dedicated tasks depending on the requirements of the system.
- **Sensing and Actuating layer:** This layer deals with different physical devices, such as sensor nodes, actuators, and communication modules.
- In the system, a specially designated sensor node works as a cluster head to collect data from other sensor nodes, which are deployed on the field for sensing the value of soil moisture and water level.
- A cluster head is equipped with two communication
- **1.module: ZigBee (IEEE 802.15.4) and**
- **2.General Packet Radio Service (GPRS).**
- The communication between the deployed sensor nodes and the cluster head takes place with the help of ZigBee.
- The cluster heads use GPRS to transmit data to the remote server.
- (EEPROM), integrated with the cluster head, stores a predefined threshold value of water levels and soil moisture.
- When the sensed value of the deployed sensor node drops below this predefined threshold value, a solenoid (pump) activates to start the irrigation process.
- In the system, the standard EC-05 soil moisture sensor is used along with the water level sensor, which is specifically designed and developed for this project.