Agricultural IoT

Introduction to IoT

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Overview

Introduction

- IoT-enabled technologies are widely used for increasing crop productivity, generating significant revenue, and efficient farming.
- Agricultural IoT systems perform crop health monitoring, water management, crop security, farming vehicle tracking, automatic seeding, and automatic pesticides spraying over the agricultural fields.
- Different sensors necessarily have to be deployed over agricultural fields.
- The sensed data from these sensors are required to be transmitted to a centralized entity such as a server, cloud, and fog devices.
- A user should be able to access these services from handheld devices or computers.

Agricultural IoT

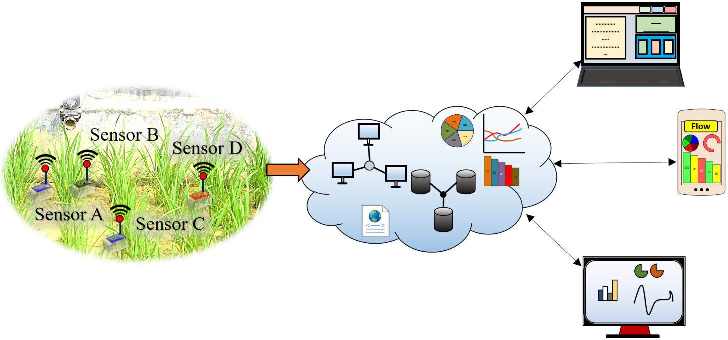


Figure: An architecture of agricultural IoT

Components of agricultural IoT

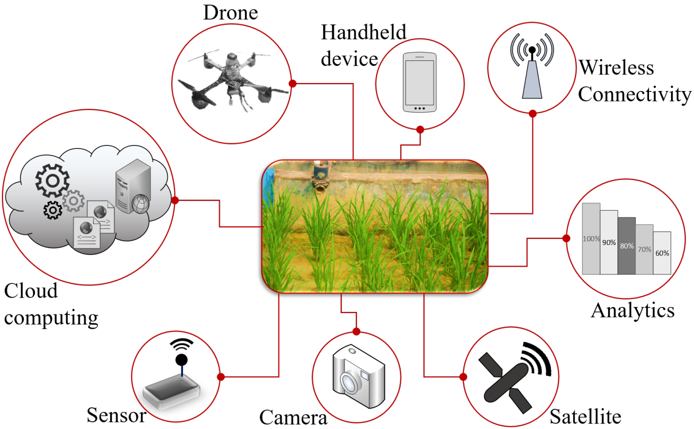


Figure: Components of agricultural IoT

Components of Agricultural IoT

- **Cloud computing**:
  - The agricultural sensors produce a huge amount of agricultural data that need to be analyzed.
  - Based on the data analysis, action needs to be taken, such as switching on the water pump for irrigation.
  - 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.
  - For agricultural data analysis and storage, the cloud plays a crucial role.
- **Sensors**:
  - 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.

Components of Agricultural IoT

- **Camera**:
  - Imaging is one of the main components of agriculture
  - The 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 fields.
  - 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.

Components of Agricultural IoT

- **Analytics**:
  - 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**:
  - 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.

Components of Agricultural IoT

- **Handheld devices**:
  - E-agriculture has become very popular.
  - One of the fundamental components of e-agriculture is a handheld device such as a cell phone.
  - Farmers can access different agricultural information, such as soil and crop conditions of their fields and market tendency, over their cellphones.
  - Additionally, farmers can also control different field equipment, such as pumps, from their phones.
- **Drones**:
  - 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

Agricultural-chain

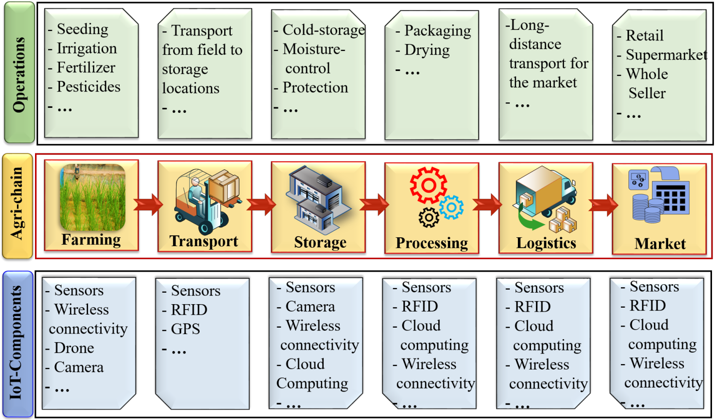


Figure: Use of IoT components in the agricultural chain

Advantages of Agricultural IoT

- **Automatic seeding**:
  - IoT-based agricultural systems are capable of autonomous seeding and planting over the agricultural fields.
  - These systems significantly reduce manual effort, error probability, and delays in seeding and planting.
- **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 crops' health.
- **Water management**:
  - Various IoT-based solutions are available efficient water distribution of over agricultural field.
  - 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.

Advantages of Agricultural IoT

- **Real-time and remote monitoring**:
  - 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.
- **Production overview**:
  - 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 Study 1

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

- We focus on an IoT-based agricultural system developed by Bauer *et al*. [1]
- The authors focus on the in-situ assessment of the leaf area index (LAI), which is considered as an essential parameter for the growth of most crops.
- LAI is a dimensionless quantity which indicates the total leaf area per unit ground area.
- For determining the canopy (the portion of the plant, which is above the ground) light, LAI plays an essential role.

Case Study 1

Architecture:

- The system is consists of 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.
- Two types of sensors are used – (i) ground-level sensor (G) and (ii) reference sensor (R).
- These sensors measure photosynthetically 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 form a star topology.
- A solar panel is used to charge the cluster head.
- The system is based on IoT architecture and a cluster head is attached to a central base station, which acts as a gateway.
- The gateway connects to an IoT infrastructure

Case Study 1

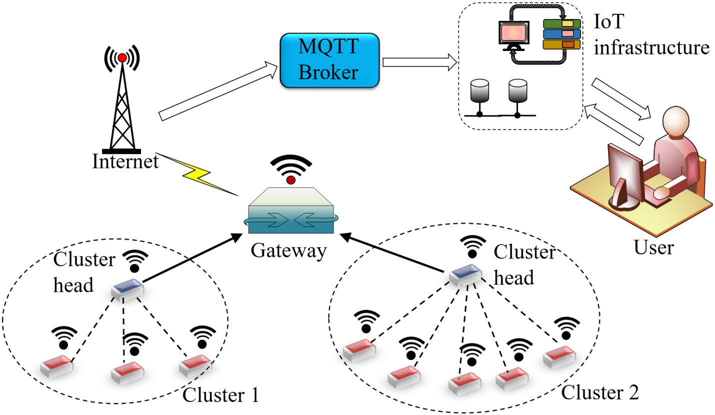


Figure: System architecture

Case Study 1

Hardware:

- The commercial off-the-shelf (COTS) TelosB platform is used in the system.
- The TelosB motes are equipped with three types of sensors – temperature, humidity, and light sensors.
- With the help of an optical filter and diffuser accessory on the light sensors, the PAR is calculated to estimate the LAI.
- A Raspberry-Pi (a tiny processor board, works as computer) is used as a cluster head, which connects with four ground sensor motes.
- Humidity and wet plants intermittently cause attenuation to the system, which is minimized with the help of forward error coding (FEC) technique.

Case Study 1

Hardware:

- The real deployment of the LAI assessment system involves various environmental and wildlife challenges.
- For reliable data delivery, both wired and wireless connectivity are included in the system.
- In the first deployment generation, USB power supply is used to power-up the sensors motes.
- The USB is used for configuring the sensor board and accessing the failure as per requirement.
- In this setup, a mechanical timer is used to switch off the sensor nodes during the night.
- In the second deployment generation, the cluster is formed with wireless connectivity.
- The ground sensor motes consist of external antennas, which help to communicate with the cluster head
- A Raspberry-Pi with long-term evolution (LTE) is used as a gateway.

Case Study 1

Communication:

- The LAI system consists of multiple components, such as WSN, IoT gateway, and IoTbased network.
- 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.
- A prevalent data transport protocol – MQTT – is used in the system.
- The wireless LAN is used for connecting the cluster head with a gateway.
- The TelosB motes are based on the IEEE 802.15.4 wireless protocol.

Case Study 1

Software:

- 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.
- For wired and wireless deployments, the sampling rate used are 30 and 6 samples/hour, respectively.
- The TinyOS is capable of activating low-power listening modes of a mote, which is used for switching a mote into low-power mode during its idle state.
- In the ground sensor, TelosB motes broadcast the data frame, and the cluster head (Raspberry-Pi) receives it.
- This received data is transmitted to the gateway.
- Besides acquiring ground sensor data, the Raspberry-Pi works as a cluster head.
- In this system, the cluster head can re-boot any affected ground sensor node automatically.

Case Study 1

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.
- The visualization of the data is performed at the server itself.
- When a sensor fails, the server informs the users.
- The server can provide different system-related information to the smartphone of the registered user.

Case Study 2

Smart irrigation management system

- In precision agriculture, the regular monitoring of different agricultural parameters, such as water level, soil moisture, fertilizers, and soil temperature are essential.
- For monitoring these agricultural parameters, a farmer needs to go to his/her field and collect the data.
- Excess water supply in the agricultural field can damage the crops.
- On the other hand, insufficient water supply in the agricultural field also affects the healthy growth of crops.
  item Thus, efficient and optimized water supply in the agricultural field is essential.

Case Study 2

Smart irrigation management system

- This case study highlights a prototype of an irrigation management system [2], developed at the Indian Institute of Technology Kharagpur, funded by the Government of India.
- The primary objective of this system is to provide a Web-based platform to the farmer for managing the water supply of an irrigated agricultural field.
- The system is capable of providing a farmer friendly interface by which the field condition can be monitored.
- With the help of this system, a farmer can take the necessary decision for the agricultural field based on the analysis of the data.
- The farmer need not worry about the complex background architecture of the system.
- It is an affordable solution for the farmers to access the agricultural field data easily and remotely.

Case Study 2

Architecture: The architecture of this system consists of three layers – Sensing and actuating layer, remote processing and service layer, and application layer.

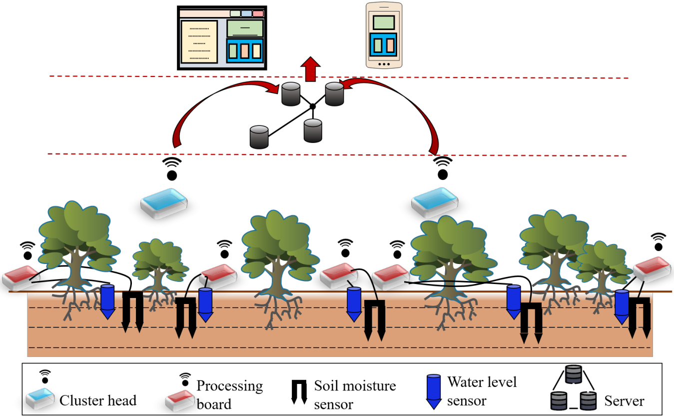
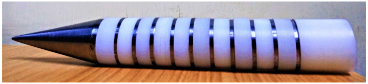


Figure: System architecture

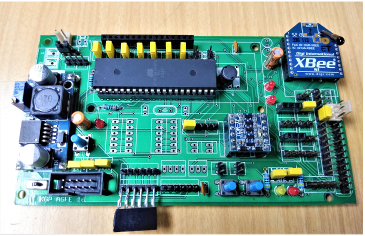
Case Study 2

- **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
  - These sensor nodes sense the value of soil moisture and water level.
  - 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.
  - An electrically erasable programmable read-only memory (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

Introduction



(a) Water-level sensor



(b) Processing board

Figure: Water-level sensor and processing board used in the system

Case Study 2

- **Processing and Service layer**:
  - This layer acts as an intermediate layer between the sensing and actuating layer and the application layer.
  - The sensed and process data is stored in the server for future use.
  - These data are accessible at any time from any remote location by authorized users.
  - Depending on the sensed values from the deployed sensor nodes, the pump actuates to irrigate the field.
  - The processing board as depicted is developed for the system.

Case Study 2

- **Application layer**:
  - The farmer can access the status of the pump, whether it is in switch on/off, and the value of different soil parameters from his/her cell phone.
  - This information is accessible with the help of the integrated GSM facility of the farmers' cell phone.
  - An LED array indicator and LCD system is installed in the farmers' house, which helps the farmer to track the condition of his respective fields.
  - A farmer can also manually access field information with the help of a Web-based application.
  - The farmer can control the pump using his/her cell phone from a remote location.

Case Study 2

Deployment

- The system has been deployed and experimented in two agricultural fields: (i) an agricultural field at the Indian Institute of Technology Kharagpur (IIT Kharagpur), India, and (ii) Benapur, a village near IIT Kharagpur, India.
- Both the agricultural fields were divided into 10 equal sub-fields of $3m^2$.
- In order to examine the performance, the system was deployed at over 4 sub-fields.
- Each of these sub-fields consists of a solenoid valve, a water level sensor, and a soil moisture sensor, along with a processing board.
- The remaining six sub-fields were irrigated through a manual conventional irrigation process.
- The comparison analysis between these six and four fields summarily reports that the designed system's performance is superior to the conventional manual process of irrigation.

References

1. Bauer, J. and N. Aschenbruck. 2018. "Design and Implementation of an Agricultural Monitoring System for Smart Farming". In IoT Vertical and Topical Summit on Agriculture Tuscany (IOT Tuscany), May 2018.
2. Roy, Sanku Kumar, Sudip Misra, Narendra Singh Raghuwanshi, and Amitava Roy. 2017. "A Smart Irrigation Management System using WSNs". Indian Patent File No.: 201731031610.
3. Roy, S. K., A. Roy, S. Misra, N. S. Raghuwanshi and M. S. Obaidat. 2015. "AID:APrototype for Agricultural Intrusion Detection using Wireless Sensor Network," in Proceeding of the IEEE International Conference on Communications (ICC), London, 2015. pp. 7059–7064.

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