IoT In Agriculture

Manjula K B[1], Jagdish H Godihal[2]

[1]Assistant Professor, Brindavan College of Engineering, Bengaluru
Professor, Civil Department, School of Engineering, Presidency University, Bengaluru

ABSTRACT

The integration of Internet of Things (IoT) technologies has brought about a revolution in the agriculture sector, enabling farmers to enhance crop yield, optimize profits, and fortify farming practices. This paper explores the growing significance of IoT in precision farming, encompassing crop safety, water management, cultivation vehicle tracking, scheduled sowing, and automated insecticide spraying. To implement an effective IoT-based farming system, diverse sensors are deployed across agricultural fields, capturing vital data that is subsequently transmitted to a central collection entity, such as a server, cloud, or fog device. The collected data undergoes processing and analysis to generate a range of valuable farming services. Ultimately, users can access these services conveniently through their laptops or portable devices, empowering them with actionable insights for efficient farming practices. This study delves into the profound impact of IoT-enabled technologies on modern agriculture, shedding light on how precision farming is revolutionizing the industry, improving productivity, and promoting sustainable agricultural practices for a prosperous future.

i. Introduction

At the moment, IoT-enabled technologies are widely employed to increase crop yield, make significant profits, and strengthen farming. The growth of the IoT paradigm aids in precise farming. Crop safety, water handling, cultivation vehicle tracing, scheduled sowing, and automated insecticide spraying are all accomplished via agricultural IoT systems. Different sensors must be utilized across cultivating fields in an IoT-based farming system, and the detected data from these sensors must be sent to a collection entity such as a server, cloud, or fog device. Additionally, this data needs to be processed and analyzed in order to create a variety of farming services. Finally, a user should be able to use these services through their laptops or portable devices. Figure 1.1 displays the basic planning.

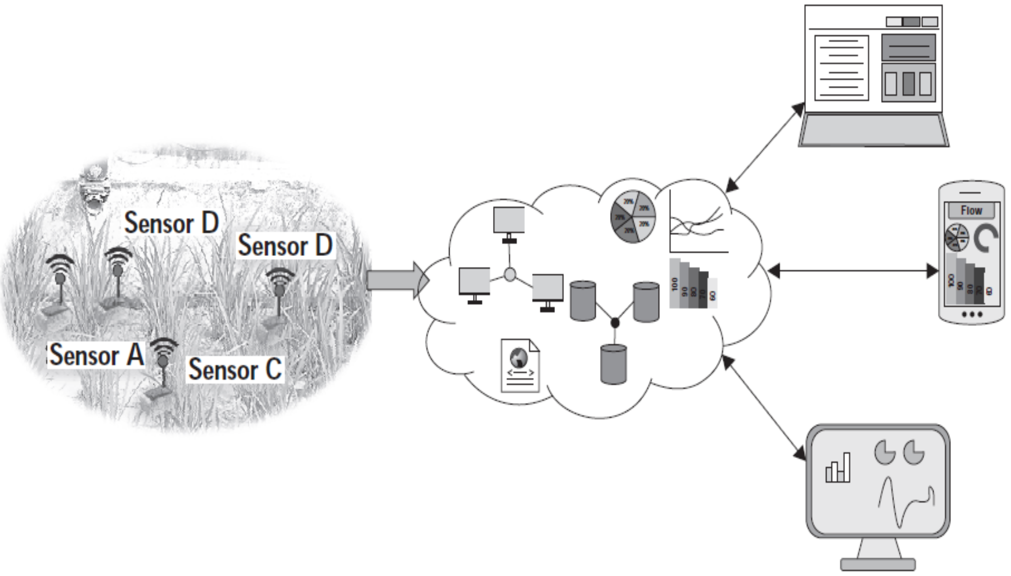


Figure 1.1 planning of agricultural IoT

a. Components of an Agricultural IoT

Farmers benefit from increased crop output and decreased overhead associated with manually operating agricultural equipment in the fields thanks to the development of the agricultural IoT. Agricultural IoT is made possible by a variety of elements, as shown in Figure 1.2, including analytics, drones, cloud computing, sensors, handheld devices, and wireless connectivity.

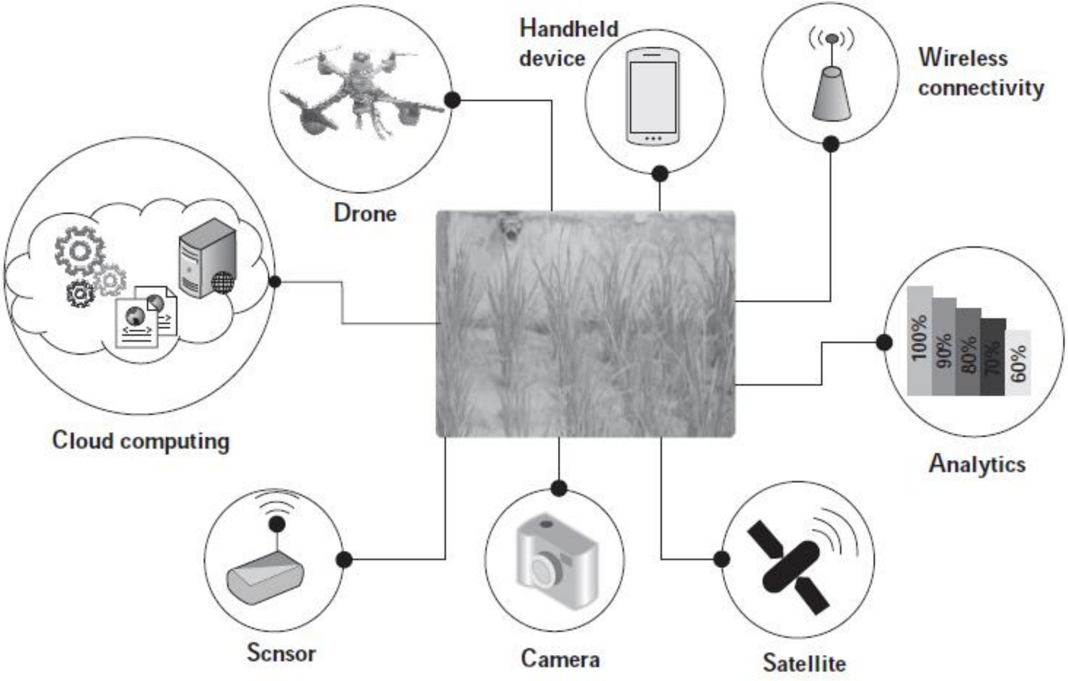


Figure 1.2 Components of Agricultural IoT

Below is an explanation of each component of an agricultural IoT:

- Cloud computing: By leveraging sensors like cameras and soil monitoring equipment that assess soil moisture, humidity, and pH levels, the cloud plays a crucial part in agricultural applications. These sensors produce large volumes of agricultural data that demand careful processing. Following data analysis, certain actions might be carried out, such as turning on the irrigation water pump. Additionally, since these sensors' data may be used in the future, it needs to be kept for a long time. As a result, cloud computing is a crucial part of agricultural data processing and archiving.
- Sensors: Modern farming techniques in agriculture rely heavily on sensors, which give farmers the ability to optimize their agricultural operations and make data-driven decisions. These sensors are used to gather crucial information about numerous environmental and crop-related aspects, resulting in increased production and better resource management. Typical sensor types in agriculture include the following:

Soil Moisture Sensors: These sensors assess the amount of moisture in the soil, giving important information about the need for irrigation and avoiding overwatering or underwatering of crops.

Weather Sensors: These sensors record information about the weather, including temperature, humidity, wind speed, and precipitation. This knowledge helps with weather pattern forecasting, planting schedule optimization, and crop protection from severe weather.

Crop Health Sensors: Crop health sensors keep an eye on the well-being and state of the plants, spotting early symptoms of ailments, pest infestations, or nutritional deficits. This makes it possible for prompt intervention and focused therapies to protect crops.

Crop Growth Sensors: These sensors monitor the development of crops, giving information on growth rates and pointing out prospective improvement areas.

Nutrient Sensors: In order to help farmers apply accurate amounts of fertilizer, reduce waste, and support sustainable agricultural practices, nutrient sensors measure the levels of nutrients in the soil.

Livestock Monitoring Sensors: In animal farming, sensors are used to track the vital signs of cattle, including their body temperature, heart rate, and level of activity.

Irrigation and Water Level Sensors: By monitoring the water levels in irrigation systems or reservoirs, these sensors efficiently manage water resources and reduce water waste.

Farmers can use precision agriculture techniques, optimize resource allocation, and make knowledgeable decisions to improve crop yields, lower costs, and encourage environmentally friendly farming practices by utilizing the data obtained from these sensors.

Cameras: Agriculture involves a lot of imaging, therefore multispectral, thermal, and RGB cameras are widely used in scientific agricultural IoT. These cameras are used for a variety of tasks, including measuring nitrogen levels, identifying temperature and water stress in crops, and assessing crop damage from flooding or pest infestation. Additionally, crop security methods use video cameras.

- Satellites: Satellites are essential for today's precision agriculture, acting as useful instruments for information extraction from field imagery. The use of these satellite images in agriculture is very common; they make it easier to monitor crop health and identify dry zones across large areas.

- Analytics: Modern agriculture is being revolutionized in a big way by analytics. Currently, farmers use analytics to make a variety of agricultural decisions, such as accurate calculations of the amounts of fertilizer and water needed for a field and choosing the best crop for the forthcoming season. Furthermore, because it is used to evaluate data across the entire agricultural supply chain, analytics has an impact beyond local decision-making. Farmers may even estimate crop demand in the market using data analytics, thus boosting the efficacy and efficiency of agricultural techniques.

Wireless connectivity: An important foundational element of agricultural IoT systems is wireless connectivity. Real-time monitoring and analysis are made possible by the seamless transmission of sensor data from the field to the cloud or server. Farmers can also access a variety of application services via handheld devices thanks to the effective communication made possible by wireless connectivity with the cloud/server.

- Handheld devices: E-agriculture has grown significantly in popularity in recent years. The mobile device, such as a smartphone, is a key component of e-agriculture and is essential for farmers. These tools enable farmers to quickly access a plethora of agricultural data, such as crucial information about the soil and crop conditions in their fields and market trends. Additionally, smartphones give farmers the ability to directly manage various pieces of field equipment, such pumps, which streamlines and improves the efficiency of agricultural operations.

Drones: Currently, the use of drones in a variety of industries, including surveillance, healthcare, product delivery, photography, and agriculture, has grown significantly in popularity. Drone imaging has become a competitive alternative to satellite imaging, particularly in agriculture.

Drones are used extensively in agriculture for duties including crop monitoring, pesticide spraying, and irrigation, continuing their role in boosting land mapping pictures. Additionally, the phrase "agricultural food chain" (agri-chain) refers to the many stages of agricultural activity, from the agricultural fields to the final customers, within the agricultural sector.

Image 1.3 The diagram shows the many procedures that go into a typical agricultural food chain. Additionally, it emphasizes how various IoT components are used in these agricultural tasks. The first step in this agri-chain is farming, which includes activities like seeding, irrigation, fertilizer application, and pesticide application. Various IoT parts are used to carry out these duties. For instance, drones are used to apply pesticides, and wireless connectivity enables the direct transfer of on-field soil condition reports to users' handheld devices or the cloud. Soil health is also monitored using soil moisture and temperature sensors.

After farming, the next phase of the agri-chain is transportation, which involves moving crops from the field to short-term storage facilities and then to long-term storage facilities.

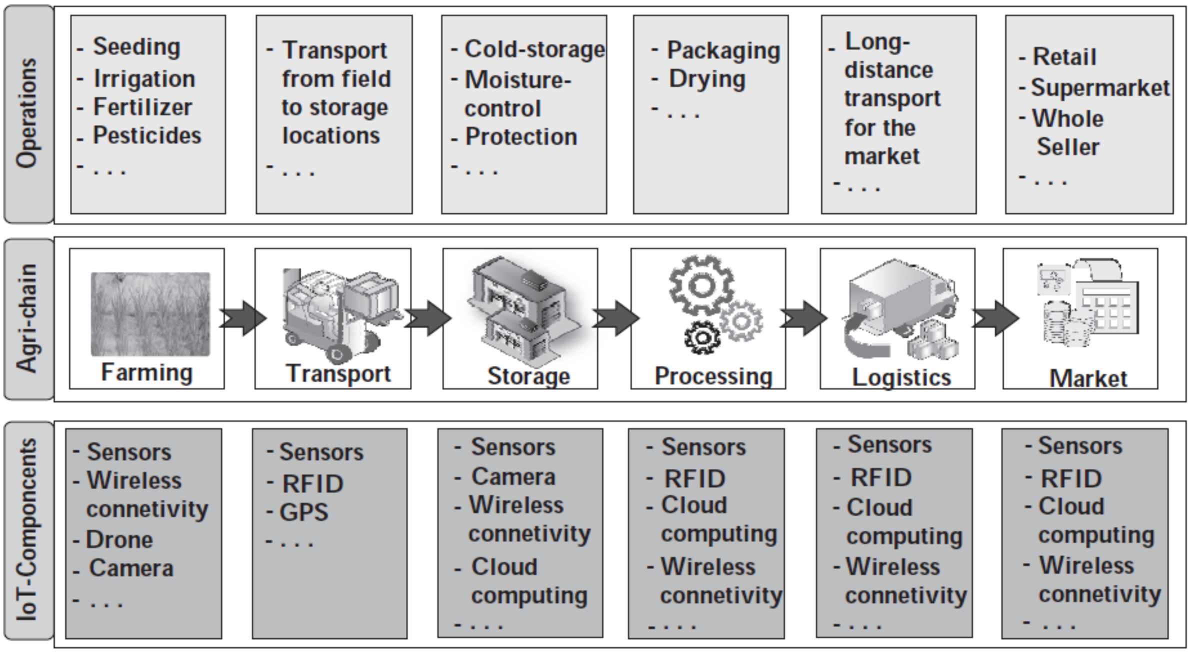


Figure 1.3 Use of IoT components in the agricultural chain

Transport activities within the agricultural food chain profit from the deployment of intelligent vehicles capable of automatically loading and unloading produce. These smart devices must be tracked using the global positioning system (GPS), and radio frequency identification (RFID) gathers data on the location of particular crop containers in warehouses.

The agri-chain needs storage to ensure that crops are kept fresh for a long time. Cold storage is frequently used to provide the appropriate protection and environmental conditions. Cameras are employed to keep an eye on and protect the harvested crops, and their feeds are wirelessly relayed to distant servers or cloud infrastructure. The type and quantity of crops stored in each area can be tracked and recorded.

The agri-chain's processing, which includes adequate crop drying and packaging, is essential. Before the crops are sold, several sensors help with the drying and packaging operations, and the information is captured and saved in the cloud. Using intelligent vehicles with sensors for autonomous loading and unloading, logistics make it easier to transport boxed crops to markets. GPS monitors the locations of the loaded crops, and wireless connectivity records all logistical data in the cloud.

In the end, the packaged goods go through logistical routes to the market and are made available to customers. Sales and purchase information is tracked and stored in the cloud for future use.

b. IoT benefits for agriculture

The quick development of IoT components and contemporary technical improvements have gradually raised agricultural production. The autonomous execution of many agricultural processes is made possible by agricultural IoT. The following are some specific benefits of agricultural IoT:

(i) IoT-based agricultural systems have the ability to automatically seed and plant over agricultural fields. These methods dramatically reduce manual labor, the likelihood of mistakes, and planting and seeding time delays.
(ii) Effective distribution of pesticides and fertilizers: Solutions that are effective at applying and managing the quantity of pesticides and fertilizers have been created using agricultural IoT. These solutions are based on an examination of the health of the crop.

(iii) Managing water: Crop growth may be hampered by excessive water use in agricultural settings. On the other side, there are a limited number of water resources available worldwide. The limitation of precious and frequently limited usable water resources is a significant motivator for the rational and effective distribution of agricultural water resources. Water can be supplied effectively while also boosting field productivity and yields with the numerous agricultural IoT technologies that are already available. The IoT-enabled agricultural devices are capable of tracking the moisture and water content in the soil and then distributing water to the fields accordingly.

(iv) Remote and in-person monitoring: A stakeholder can remotely monitor many agricultural metrics, such as crop and soil conditions, plant health, and weather conditions, in IoT-based farming, in contrast to traditional agriculture. A farmer can also activate on-field farming equipment like a water pump, valves, and other pieces of machinery using a smart handheld device (such as a cell phone).

(v) Easily estimating yield: Agricultural IoT solutions can be used to record and aggregate data over extended periods of time that may be diverse in terms of space or time. These documents can be used to generate a number of estimates for farming and farm administration. Crop yield is the most important estimate, and it is made using known crop models and historical trends.

(vi) summary of the production: For a farmer to predict optimized crop yields and choose the necessary measures for future cropping practices, a complete analysis of crop output, market rates, and market demand is crucial. Contrary to conventional methods, IoT-based agriculture gives farmers a greater degree of control over their farming and crop management procedures, and that too largely on their own. The farmers' handheld devices are provided with a thorough product overview through agricultural IoT.

ii. Case Studies

In this section, we go through a few case studies that give an overview of how IoT infrastructure for agriculture has really been implemented in practice.

This case study examines an Internet of Things (IoT)-based agricultural system created by Bauer et al. [1]. This system's main objective is the in-situ evaluation of the leaf area index (LAI), a significant factor influencing the growth of many crops. An important factor in determining canopy light, or the amount of the plant above the ground, is LAI, which stands for the dimensionless quantity of total leaf area per unit of ground area. Let's now examine the architecture of the system.

For the purpose of LAI assessment, the authors combined hardware and software components to build an IoT-based agricultural system. The wireless sensor network (WSN) that serves as the LAI assessment unit is a crucial component of this system. The ground-level sensor (G) and the reference sensor (R), which measures photosynthetically active radiation (PAR), were both used by the authors. The space between these sensors must be carefully calculated to provide optimal performance, avoiding excessive separation. The additional sensor nodes (Gs) are positioned below the canopy, producing a star topology, with the above-ground sensor (R) serving as the cluster head. The cluster head is recharged by a solar panel.

According to the system's IoT architecture, the cluster head communicates to a central

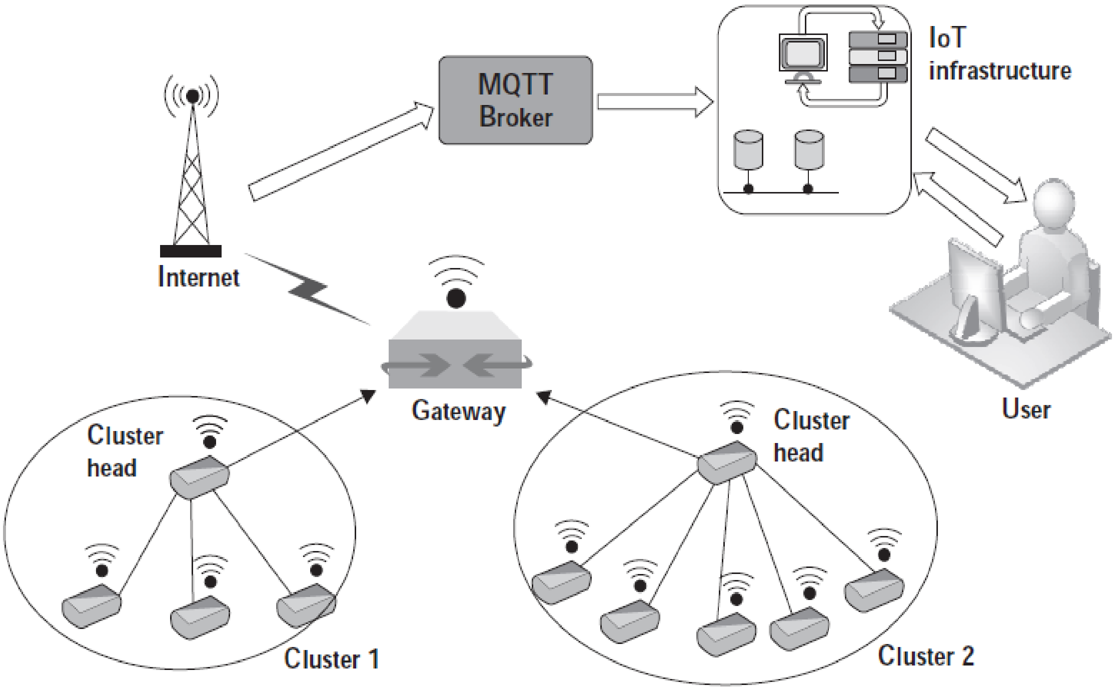


Figure 1.4 System architecture

iii. Hardware

The system makes use of a variety of hardware elements to enable data sensing and transfer from the fields to a centralized unit, such as a server or cloud. A crucial component of the system is the TelosB platform, which is commercial off-the-shelf (COTS) and furnished with temperature, humidity, and light sensors. The light sensors use an optical filter and diffuser attachment to compute PAR, or photosynthetically active radiation, in order to measure LAI.

The cluster-based system connects four ground sensor motes to a Raspberry Pi, which acts as the cluster head. A small single-board computer known as the Raspberry Pi makes a variety of IoT functions possible. The forward error coding (FEC) approach is utilized to alleviate attenuation brought on by humidity and moist plants.

The LAI evaluation system faces environmental and animal issues during real-world deployment. The authors use a redundant strategy that makes use of both wired and wireless connectivity to provide dependable data transmission. The sensor motes are powered by a USB power supply in the initial deployment generation. Additionally, the sensor board can be configured through USB, and failure data can be accessed as necessary. During the night, a mechanical timer turns off the sensor nodes.

In the second generation of deployment, a wirelessly connected cluster is created. In order to communicate with the cluster head, ground sensor motes are equipped with external antennas. A Raspberry Pi with long-term evolution (LTE) serves as the communication gateway for this configuration.

The LAI system consists of a number of interconnected wired and wirelessly connected components, including a WSN, an IoT gateway, and an IoT-based network. Public land mobile network (PLMN) connectivity is established between external IoT networks and the gateway. The farm management information system (FMIS) within the IoT-based infrastructure is used to analyze and visualize data.

A wireless LAN is used to link the cluster head with a gateway. The IEEE 802.15.4 wireless protocol is used by TelosB motes to communicate.

iv. Software

The system relies heavily on software to do a variety of tasks. The system uses TinyOS, an open-source, low-power operating system that is frequently used in many WSN applications, to run the TelosB motes. The obtained sensor node data in this configuration is recorded with a timestamp and sequence number (SN).

30 samples are taken every hour by the system for wired deployments (first generation). However, the sampling rate is drastically decreased to 6 samples per hour for wireless deployments (second generation). The mote can enter low-power mode while at rest to TinyOS's ability to activate low-power listening modes.

TelosB motes broadcast data frames in the ground sensor, which the cluster head (a Raspberry Pi) receives and subsequently sends to the gateway. The Raspberry Pi not only collects ground sensor data but also serves as a cluster head and may restart any system ground sensor node that is harmed.

v. IoT Architecture

The system's Internet server houses the MQTT broker, which is in charge of obtaining data from the WSN. An Apache server is used to build the system's graphical user interface (GUI), enabling data visualization on the server itself. The server warns users in the event of a sensor failure and sends other system-related data to registered users' smartphones.

The Indian Government financed the development of the smart irrigation management system at the Indian Institute of Technology Kharagpur addresses the requirement for routine monitoring of crucial agricultural factors such as water level, soil moisture, nutrients, and soil temperature. In the past, farmers had to personally visit their fields to gather this information, running the risk of damaging crop growth from both excess and insufficient water delivery.

This technology offers farmers a web-based platform for effective water supply management in their irrigated fields as a prototype for an irrigation management system. Farmers can easily monitor field conditions and analyze data thanks to the user-friendly interface, freeing them from having to worry about the system's intricate background infrastructure. Farmers may simply and remotely access agricultural field data with this cost-effective solution.

The Sensing and Actuating layer, the Remote Processing and Service layer, and the Application layer make up the three distinct levels that make up the architecture of this system. Based on the needs of the system, each layer is built to perform particular duties. Figure 1.5 illustrates the system's architecture, and now let's explore the detailed functionalities of each layer:

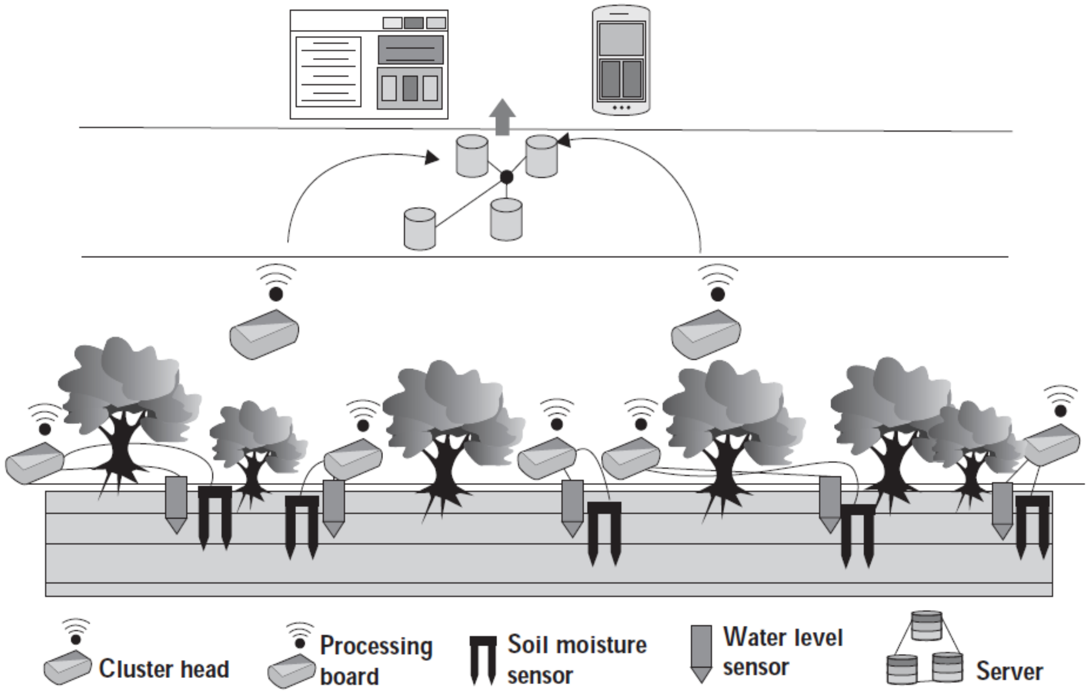
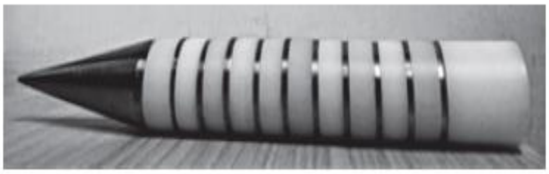


Figure 1.5 Architecture: Smart irrigation management system

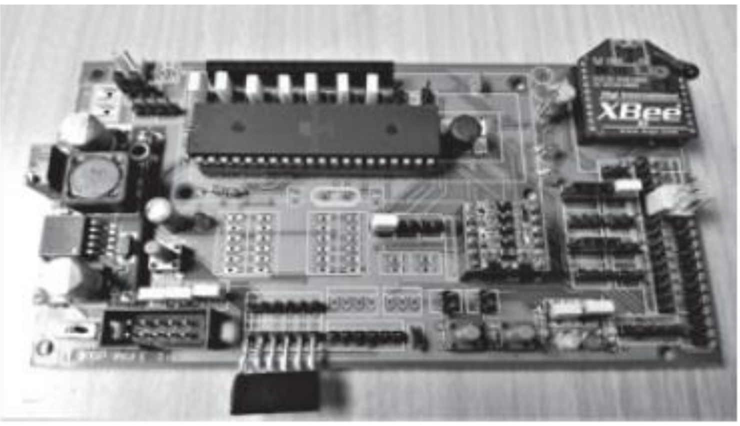
(i) Sensing and Actuating Layer: This layer is in charge of controlling a variety of physical components, such as communication modules, actuators, and sensor nodes. A specified sensor node inside the system acts as the cluster head, gathering information from other sensor nodes placed in the field to track soil moisture and water level. Two communication modules, ZigBee (IEEE 802.15.4) and General Packet Radio Service (GPRS), are installed in the cluster head. While GPRS is used to provide data to the distant server, ZigBee enables communication between the deployed sensor nodes and the cluster head.

A predefined threshold value for water levels and soil moisture is stored in an electronically erasable programmable read-only memory (EEPROM) included in the cluster head. A solenoid (pump) is actuated, starting the irrigation process, when the measured value from a deployed sensor node drops below this threshold. As shown in Figure 1.6(a), this system combines a typical EC-05 soil moisture sensor with a water level sensor created especially for this purpose.

(ii)Processing and Service layer: This layer manages the storage and processing of sensed data, acting as a bridge between the Sensing and Actuating layer and the Application layer. Authorized users can access the data remotely at any time and it is kept on the server for further use. The pump is turned on to perform field irrigation based on the sensed values from the deployed sensor nodes. For the project, a processing board, shown in Figure 1.6(b), has been created.



(a) Water level sensor



(b) Processing board

Figure 1.6 Water level sensor and processing board

(iii) Application layer: The farmer may easily retrieve the values of numerous soil metrics as well as the state of the pump, including whether it is on or off, right from their cell phone. The farmer's mobile device's embedded GSM function provides access to this data. The farmer's home also has an LCD system and an LED array indication installed, making it simple to monitor the state of each field. The farmer may also manually view field data via a Web-based application, and they can remotely operate the pump using a cell phone.

Deployment: In two agricultural fields, one at the Indian Institute of Technology Kharagpur (IIT Kharagpur), India, and the other in the village of Benapur, next to IIT Kharagpur, India, the system has been successfully implemented and tested. Ten equal subfields, each measuring 3 x 3 m^2, were created from each agricultural field. Four of these sub-fields, each with a solenoid valve, a water level sensor, a soil moisture sensor, and a processing board, were used to test the system's effectiveness. The remaining six sub-fields were manually irrigated using standard irrigation techniques. A comparison of the four and six fields showed that the developed system performs better than the traditional manual irrigation method.
Best in Class

v. Conclusion:

We examined several IoT applications in agriculture in this chapter, highlighting their importance along different links in the agricultural food chain. A thorough case study was conducted to analyze a fundamental part of agriculture, leaf area index evaluation, and it gave information about the system and the underlying hardware. We also covered a real-world irrigation management system to further highlight the value of IoT architecture in agricultural irrigation. These case studies demonstrate the useful uses and advantages of IoT in the agriculture industry, providing learners with important knowledge.

References

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