

Internet of Things with Smart Agriculture

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ABSTRACT

The Internet of Things (IoT) continues to transform modern agriculture by enabling intelligent, connected, and data-driven farming practices. Smart agriculture integrates IoT technologies with advanced sensing, cloud computing, artificial intelligence (AI), and data analytics to improve productivity, sustainability, and resource management. Through interconnected devices such as environmental sensors, smart controllers, drones, and automated agricultural equipment, farmers can monitor and manage farming activities in real time with greater precision and efficiency. IoT-enabled agricultural systems collect continuous data related to soil moisture, temperature, humidity, nutrient levels, crop health, weather conditions, and livestock status. This real-time information supports precision agriculture by allowing optimal use of resources including water, fertilizers, pesticides, and energy, thereby minimizing operational costs and reducing environmental impact. Modern IoT platforms further enhance agricultural decision-making by integrating cloud-based storage, edge computing, and predictive analytics for faster and more accurate responses to changing field conditions. Recent developments combine IoT with machine learning and artificial intelligence to enable predictive farming applications such as yield estimation, disease detection, automated irrigation scheduling, and early pest identification. Wireless communication technologies including Wi-Fi, LoRaWAN, Zigbee, NB-IoT, and 5G improve connectivity across agricultural environments and support remote monitoring and control of equipment and farm infrastructure.

INTRODUCTION

The Internet of Things (IoT) refers to a network of physical devices, vehicles, appliances, and other physical objects that are embedded with sensors, software, and network connectivity, allowing them to collect and share data. IoT devices—also known as “smart objects”—can range from simple “smart home” devices like smart thermostats, to wearables like smartwatches and RFID-enabled clothing, to complex industrial machinery and transportation systems. Technologists are even envisioning entire “smart cities” predicated on IoT technologies.

IoT enables these smart devices to communicate with each other and with other internet-enabled devices. Like smartphones and gateways, creating a vast network of interconnected devices that can exchange data and perform various tasks autonomously. This can include:

- monitoring environmental conditions in farms
- managing traffic patterns with smart cars and other smart automotive devices
- controlling machines and processes in factories
- tracking inventory and shipments in warehouses

The potential applications of IoT are vast and varied, and its impact is already being felt across a wide range of industries, including manufacturing, transportation, healthcare, and agriculture. As the number of internet-connected devices continues to grow, IoT is likely to play an increasingly important role in shaping our world. Transforming the way that we live, work, and interact with each other.

In an enterprise context, IoT devices are used to monitor a wide range of parameters such as temperature, humidity, air quality, energy consumption, and machine performance. This data can be analyzed in real time to identify patterns, trends, and anomalies that can help businesses optimize their operations and improve their bottom line.

Let's us look closely at our mobile device which contains GPS Tracking, Mobile Gyroscope, Adaptive brightness, Voice detection, Face detection etc. These components have their own individual features, but what about if these all communicate with each other to provide a better environment? For example, the phone brightness is adjusted based on my GPS location or my direction.

Connecting everyday things embedded with electronics, software, and sensors to internet enabling to collect and exchange data without human interaction called as the Internet of Things (IoT).

The term "Things" in the Internet of Things refers to anything and everything in day to day life which is accessed or connected through the internet.

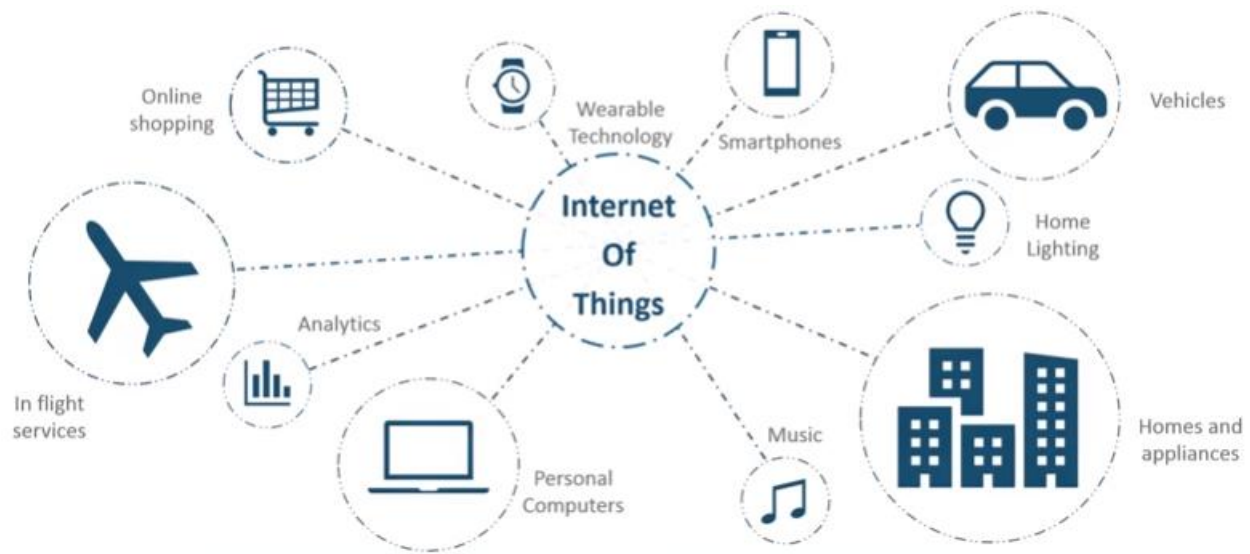


Figure 1 Internet of Things

IoT is an advanced automation and analytics system which deals with artificial intelligence, sensor, networking, electronic, cloud messaging etc. to deliver complete systems for the product or services. The system created by IoT has greater transparency, control, and performance.

As we have a platform such as a cloud that contains all the data through which we connect all the things around us. For example, a house, where we can connect our home appliances such as air conditioner, light, etc. through each other and all these things are managed at the same platform. Since we have a platform, we can connect our car, track its fuel meter, speed level, and also track the location of the car.

If there is a common platform where all these things can connect to each other would be great because based on my preference, I can set the room temperature. For example, if I love the room temperature to to be set at 25 or 26-degree Celsius when I reach back home from my office, then according to my car location, my AC would start before 10 minutes I arrive at home. This can be done through the Internet of Things (IoT).

Features of IoT

We have listed some of the features that make IoT what it is in the present digital scenario. IoT devices have several sets of features that are common. They are:

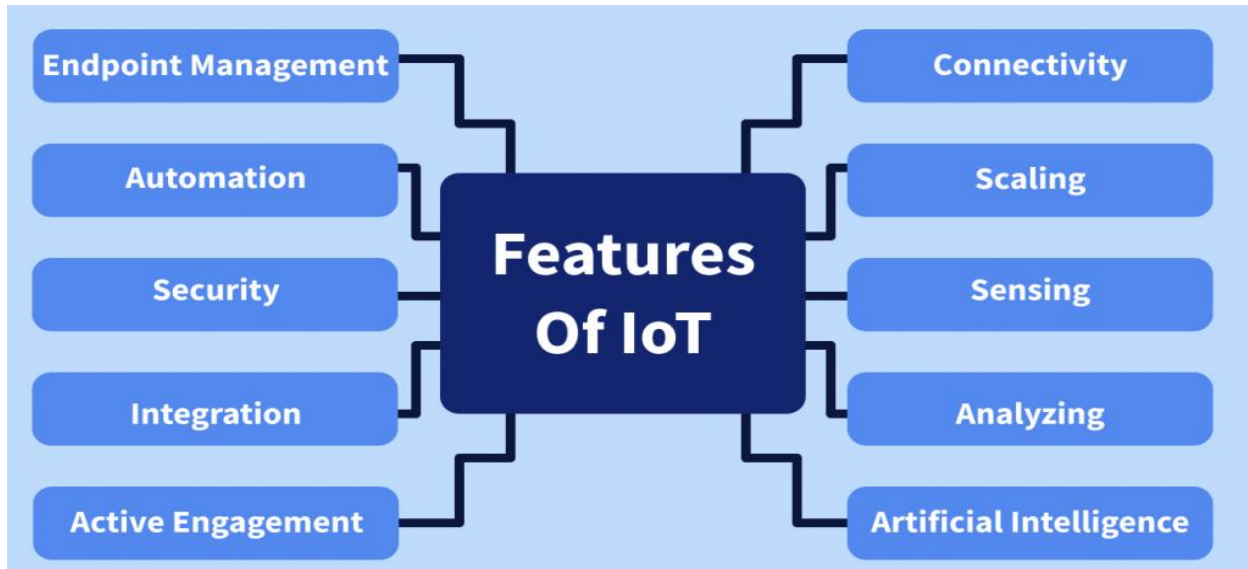


Figure 2 Features of IoT in agriculture

Connectivity

The heart and soul of IoT is its connectivity. Connectivity means the establishment of a connection between different devices (or nodes) so that they can communicate on their own. In IoT, various devices, sensors, computers, and data buses need to interact and communicate with each other. A fast, safe, and secure connection is a must for IoT to be of any business use. IoT also connects devices with cross-domain technology like cloud computing, artificial intelligence, and blockchain technology. We can connect them over radio waves, Wi-Fi, Bluetooth, or wires.

Scaling

IoT systems are designed in such a way that the number of devices, sensors, or computers can be scaled up and down according to the need. An IoT system should be elastic enough so that it can handle workload during peak demand hours and can resort back to the normal state when the demand is low.

Sensing

IoT devices gather information about their surroundings (such as temperature, light, sound, acceleration, pressure) and then, after analyzing the data, take a decision. Thus, sensors help in automation by gathering information and taking actions that would otherwise, be done by humans. The raw data gathered, and the analyzed data, serve as the basis of the functioning of IoT. For example, in an automatic door, sensors would collect data through sensors such as radar sensors and optical sensors. If it detects a person coming, it will open the door automatically. Some sensors used in IoT are- Humidity sensor, temperature sensor, Accelerometer, Gyroscope, Motion sensor, image sensor, level sensor, and Proximity sensor.

Analyzing

We know IoT gathers raw information through sensors, but why does IoT need data? What does IoT do with all that raw data? Data as such has no value of its own. It is meaningless and useless until it is purposefully processed to gain some meaningful insights from it. IoT gathers raw data to extract something meaningful out of it. Analyzing the raw data in terms of its structure, correlation, and usability is necessary because, if processed properly, it can be very useful. In the above-mentioned example of the automatic door for instance, after analyzing the data through sensors, it should be able to differentiate between a person and an animal.

Artificial Intelligence

IoT becomes a lot more useful when combined with artificial intelligence. For instance, if you are out of groceries, your smart refrigerator can notify you to bring some on your way back home. Things like these have been made possible by the application of artificial intelligence. IoT devices collect raw data from their surroundings and convert them into something useful and insightful. The IoT devices and systems are also trained with various machine learning models so that they can better understand the changes in their surroundings and perform better.

Smaller Device

Devices and equipment (like semiconductor chips, sensors) are getting smaller and smaller these days. In IoT, these small-built devices efficiently deliver precision and performance. It is fascinating to think that devices so small can deliver so much and enhance our quality of living (for example, small sensors can tell us the quality of air in that area, protecting us from pollution).

Dynamic Nature

IoT systems should be dynamic in to change according to the changes in their environment to be of any business use. Let us understand this with an example. A smart air conditioner should be able to set the temperature of the room according to the prevalent weather conditions using the data gathered by the temperature sensor. It must also be able to set the perfect humidity level inside the room according to the changes in the humidity level of the surroundings.

Active Engagement

IoT connects its devices and products with cross-domain technologies like cloud computing, artificial intelligence, blockchain technology, etc. An active engagement between these products and technologies is essential to gather and manipulate data to make it of business use. Raw data has huge potential and can improve business decisions considerably. Therefore, an active engagement between various IoT products and these technologies is the need of the hour.

Integration

IoT integrates various cross-domain technologies like cloud computing, artificial intelligence, big data, and deep learning to provide users with a wonderful experience. Internet of things is no more internet of things, it has, in fact, become the internet of everything. An entire ecosystem of integrated devices performs with great efficiency to enhance our quality of living.

Automated

Every technology comes with a certain degree of automation. In the case of IoT, the theme is all about automation. IoT was developed to make people's life and business easier with automation, i.e., IoT farming system automates irrigation and prevents wastage of water as well.

Security

Security is one of the major concerns among the users of IoT. IoT systems carry and store a lot of sensitive information, so the security of the devices and the data flowing between them should be given foremost priority. Proper security and safety measures are implemented while designing an IoT system to prevent a possible breach of security. Resources and investment required to ensure a safe and conductive IoT system are huge, but its safety and security must be ensured. Failing to do so can lead to mistrust among its users and businesses and can reduce its demand.

Endpoint Management

A well-trained and carefully implemented IoT is an asset for the business world. However, it is important to be the endpoint management of IoT systems, otherwise, the whole system might collapse. For example, let us say your smart fridge orders groceries to a retailer when you are out of it. But, if you are not at the home for some days, it might lead to the wastage of groceries and is a failure of IoT. Therefore, endpoint management is a necessary characteristic of the Internet of things.

Cloud Platforms

IoT cloud platforms are providing good IoT solutions for developing innovative applications. It also provides the three cloud service types such as shown in below

IoT cloud platforms that are available along with their supported protocols, application development, monitoring management, visualization, cost, and research. Many IoT cloud platforms are accessible to users who are present in the market. Among all those 25 platforms are chosen to implement their ideas about their working, their strengths, their weaknesses related to their domain they appropriate. Cloud computing allows users for direct accessing to the client systems for monitoring, management, research, data visualization, and preprocessing purposes.

Cloud Service Models

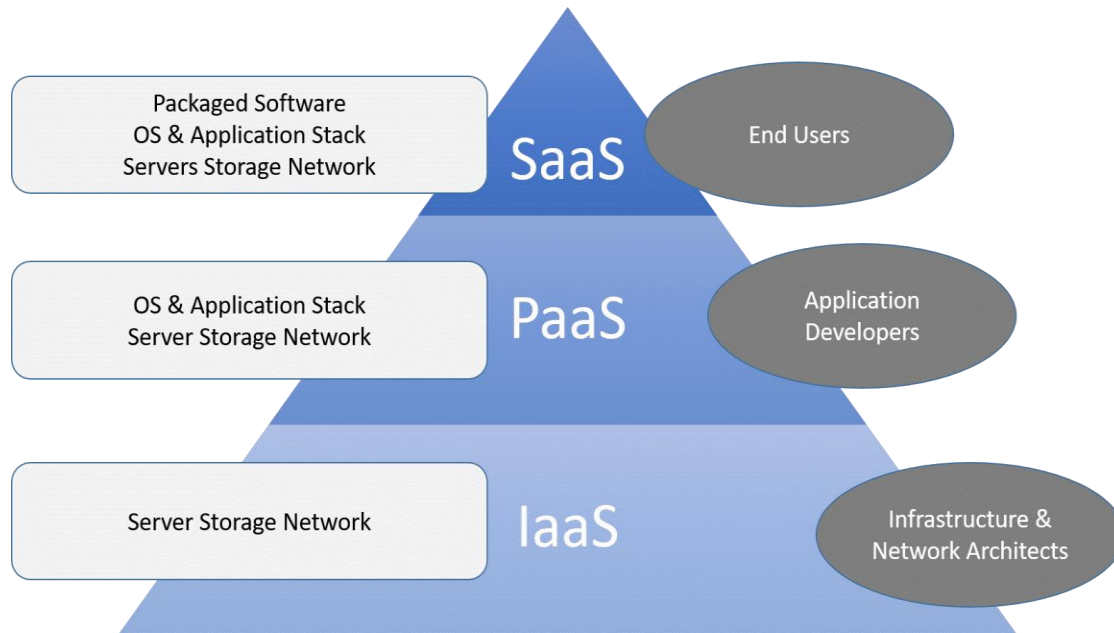


Figure 3 Cloud service Type

Cloud Based Services

Cloud Computing means using the internet to store, manage, and process data instead of using your own computer or local server. The data is stored on remote servers, that are owned by companies called cloud providers such as Amazon, Google, Microsoft). These companies charge you based on how much you have used their services.

Types of Cloud Computing

Most cloud computing services fall into three broad categories:

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

These are sometimes called the **cloud computing stack** because they are built on top of one another. Knowing what they are and how they are different, makes it easier to accomplish your goals. These abstraction layers can also be viewed as a **layered architecture** where services of a higher layer can be composed of services of the underlying layer i.e, SaaS can provide Infrastructure.

Software as a Service(SaaS)

Software-as-a-Service (SaaS) means using software over the internet instead of installing in on your computer. You don't have to worry about downloading, updating, or maintaining anything- the company that provides the software handles all of that.

Example:

Think of **Google Docs**. You don't need to install it. You just open your browser, log in, and start using it. Google stores your work and keeps the software updated. You just use it when you need it.

SaaS is usually offered on pay-as-you-go basis, and you can access it from any device with internet. It's also called **web-based-software** or **on-demand software** because you can use it anytime, anywhere, without setup.

Advantages of SaaS

1. **Cost-Effective:** Pay only for what you use.
2. **Reduced time:** Users can run most SaaS apps directly from their web browser without needing to download and install any software. This reduces the time spent in installation and configuration and can reduce the issues that can get in the way of the software deployment.

3. **Accessibility:** We can Access app data from anywhere.
4. **Automatic updates:** Rather than purchasing new software, customers rely on a SaaS provider to automatically perform the updates.
5. **Scalability:** It allows the users to access the services and features on-demand.

The various companies providing *Software as a service* are Cloud9 Analytics, Salesforce.com, Cloud Switch, Microsoft Office 365, Big Commerce, Eloqua, dropBox, and Cloud Tran.

Disadvantages of Saas :

1. **Limited customization:** SaaS solutions are typically not as customizable as on-premises software, meaning that users may have to work within the constraints of the SaaS provider's platform and may not be able to tailor the software to their specific needs.
2. **Dependence on internet connectivity:** SaaS solutions are typically cloud-based, which means that they require a stable internet connection to function properly. This can be problematic for users in areas with poor connectivity or for those who need to access the software in offline environments.
3. **Security concerns:** SaaS providers are responsible for maintaining the security of the data stored on their servers, but there is still a risk of data breaches or other security incidents.
4. **Limited control over data:** SaaS providers may have access to a user's data, which can be a concern for organizations that need to maintain strict control over their data for regulatory or other reasons.

Platform as a Service

PaaS is a type of cloud service that gives developers the tools they need to build and launch apps online without setting up any hardware and software themselves.

With PaaS, everything runs on the provider's server and is accessed through a web browser. The provider takes care of things like servers, storage, and operating systems. Developers just focus on writing and managing the app.

Example:

Imagine you're planning a school's annual day event. You have two options.

1. Build the Venue yourself (buy land, set up a stage, arrange lighting, etc.).
2. Or **rent a ready-to-use** venue and just focus on the actual event.

PaaS is like renting the venue- it saves time, efforts, and setup costs, so you can completely focus on what matters: **building your app**.

You don't control the back-end (like servers), but you do control the app you create and how it behaves.

Advantages of PaaS:

1. **Simple and convenient for users:** It provides much of the infrastructure and other IT services, which users can access anywhere via a web browser.
2. **Cost-Effective:** It charges for the services provided on a per-use basis thus eliminating the expenses one may have for on-premises hardware and software.
3. **Efficiently managing the lifecycle:** It is designed to support the complete web application lifecycle: building, testing, deploying, managing, and updating.
4. **Efficiency:** It allows for higher-level programming with reduced complexity thus, the overall development of the application can be more effective.

The various companies providing *Platform as a service* are Amazon Web services Elastic Beanstalk, Salesforce, Windows Azure, Google App Engine, cloud Bees and IBM smart cloud.

Disadvantages of Paas:

1. **Limited control over infrastructure:** PaaS providers typically manage the underlying infrastructure and take care of maintenance and updates, but this can also mean that users have less control over the environment and may not be able to make certain customizations.
2. **Dependence on the provider:** Users are dependent on the PaaS provider for the availability, scalability, and reliability of the platform, which can be a risk if the provider experiences outages or other issues.
3. **Limited flexibility:** PaaS solutions may not be able to accommodate certain types of workloads or applications, which can limit the value of the solution for certain organizations.

Infrastructure as a Service

Infrastructure as a service (IaaS) is a cloud service where companies rent IT resources like servers, storage, and networks instead of buying and managing them.

It's like outsourcing your computer hardware. The cloud provider gives you the basic building blocks (like virtual machines, storage, and internet access), and you use them to run your apps and services. You pay based on how much you use - by the hour, week, or month. The way, you don't need to spend a lot of money on buying hardware.

Example:

Imagine you want to start a website. Instead of buying your own server, you rent on a cloud provider's server. You use their storage and networking, but you control what runs on it-like your website or app. That's IaaS, You get the flexibility and power of your own setup, without the cost and trouble of maintaining hardware.

Advantages of IaaS:

1. **Cost-Effective:** Eliminates capital expense and reduces ongoing cost and IaaS customers pay on a per-user basis, typically by the hour, week, or month.
2. **Website hosting:** Running websites using IaaS can be less expensive than traditional web hosting.
3. **Security:** The IaaS Cloud Provider may provide better security than your existing software.
4. **Maintenance:** There is no need to manage the underlying data center or the introduction of new releases of the development or underlying software. This is all handled by the IaaS Cloud Provider.

The various companies providing *Infrastructure as a service* are Amazon web services, Bluestack, IBM, Openstack, Rackspace, and Vmware.

Disadvantages of IaaS :

1. **Limited control over infrastructure:** IaaS providers typically manage the underlying infrastructure and take care of maintenance and updates, but this can also mean that users have less control over the environment and may not be able to make certain customizations.
2. **Security concerns:** Users are responsible for securing their own data and applications, which can be a significant undertaking.
3. **Limited access:** Cloud computing may not be accessible in certain regions and countries due to legal policies.

Architecture Of IOT

The 7-layer IoT architectural view, also known as the Open System Interconnection (OSI) model, is a refined representation of the essential IoT architecture layers. This 7-layer architecture of IoT is designed to tackle the increasing challenges of IoT systems by providing a clear structure for data flow, security, and efficiency. Visualizing these layers in an IoT architecture diagram helps illustrate how each layer interacts to create a cohesive and secure IoT environment, optimizing communication, data management, and connectivity in modern technological ecosystems.

The 7 IoT layers in the architecture of IoT, often depicted in an IoT architecture diagram, are grouped into three main categories:

1. Hardware Layers
2. Transport Layer
3. Software Layers

1. Hardware Layers

- **Physical Layer**

The physical layer consists of the devices and transmits data in binary form (as 0s and 1s). It also includes wireless network connections and network components like repeaters, modems, cabling, etc. This layer is crucial in the IoT architecture because it forms the base of the 7-layer architecture of IoT.

- **Data Link Layer**

The data link layer defines the structure in which the data moves in and out of the network entities and corrects errors that may have occurred at the physical layer. The two control protocols that the data link layer uses for security and error control are MACsec (Media Access Control security) and LLC (Logical Link Control). It plays a significant role in maintaining the integrity of the IoT architecture layers.



Figure 3 Architecture Of IOT

- **Network Layer**

The network layer is responsible for deciding which path the data packets should take for sending them back and forth between different networks. This layer divides the transport layer into network packets and carries out data transmission with the help of IP addressing, which is essential in ensuring the IoT architecture diagram maintains its efficiency.

2. Transport IoT Layer

The fourth layer in the IoT architecture, known as the Transport Layer, is often considered the heart of OSI. It uses transmission protocols like TCP (Transmission Control Protocol) and UDP (User Datagram Protocol) to ensure reliable data transfer services to the software layers. It is the most crucial layer in the 7-layer architecture of IoT as it facilitates transmission. This IoT architecture layer collects data from the network layer and provides services to the Application Layer while also debugging errors in data transmission and providing an acknowledgment of successful transfer.

3. Software Layers

- **Session Layer**

As the name suggests, the Session Layer opens a session between two systems to communicate with each other. It also determines how long the session will continue and when the session will end. This is vital in establishing robust IoT architecture layers.

- **Presentation Layer**

The Presentation Layer acts as a data translator for the network. It retrieves data from different points and delivers it to the Application Layer. This IoT architecture ensures that data is structured and presented in a usable format for both the Application and Network Layers. The 7-layer architecture of IoT relies on this layer for efficient communication between the lower and upper layers.

- **Application Layer**

The Application Layer is the closest to the end user in an IoT architecture diagram. It collects information from the end user and sends back the desired action. This IoT architecture layer consists of protocols that allow data transmission like HTTP and HTTPS, FTP, DNS, etc., making it essential in the complete IoT architecture.

CONCLUSIONS

This article presents a comprehensive and updated overview of the application of the **Internet of Things (IoT)** in modern agriculture and its growing role in transforming traditional farming into intelligent and sustainable agricultural systems. With continuous advancements in digital technologies, IoT-enabled agriculture is becoming a key solution for addressing challenges related to food production, resource optimization, climate variability, and farm management.

Modern agricultural environments increasingly rely on interconnected devices, smart sensors, actuators, and intelligent monitoring systems that communicate through the internet to support automated decision-making and real-time farm supervision. IoT technologies enable continuous monitoring of critical agricultural parameters such as soil moisture, temperature, humidity, crop health, nutrient availability, and environmental conditions, allowing farmers to make accurate and timely decisions.

Advanced platforms integrated with cloud computing, edge computing, and real-time analytics provide farmers with improved accessibility to agricultural data and remote management capabilities. Hardware technologies including Raspberry Pi, Arduino, NodeMCU, and smart controllers continue to support intelligent farming applications such as pest detection, precision irrigation, crop monitoring, weed identification, greenhouse automation, and yield optimization. Furthermore, modern wireless communication technologies including Wi-Fi, Zigbee, LoRaWAN, NB-IoT, GSM, and emerging 5G networks enhance connectivity and scalability across agricultural ecosystems. The integration of Artificial Intelligence (AI) and Machine Learning (ML) with IoT further improves predictive analytics, disease detection, resource allocation, and production forecasting.

Overall, agricultural automation supported by IoT contributes significantly to increasing crop productivity, reducing operational costs, minimizing environmental impact, and promoting sustainable farming practices. The future of smart agriculture lies in the continued integration of intelligent sensing, cloud platforms, wireless technologies, and data-driven decision systems to achieve resilient, efficient, and technologically advanced agricultural development.

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