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A Study on Security, Privacy, Interoperability, and Scalability Challenges in Agricultural IoT Resource Optimization

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ABSTRACT-

The Internet of Things (IoT) is an innovative and rapidly evolving domain that has attracted substantial research attention. IoT involves a vast network of interconnected devices that utilize embedded sensors and communication technologies to enable smooth interaction both internally and externally. This connectivity empowers devices with intelligence, thereby improving the quality of human life. This paper delves into the core principles of IoT, its architectural framework, and the relationship between Wireless Sensor Networks (WSNs) and IoT systems. It also discusses the wide-ranging applications of IoT, the tools and technologies it employs, as well as its advantages and limitations. A particular focus is given to the potential of IoT in revolutionizing agriculture in India by optimizing resource management and increasing farm productivity. However, IoT implementation is hindered by several obstacles, such as scalability issues, security vulnerabilities, privacy concerns, data storage challenges, and regulatory constraints. One of the primary issues is interoperability—the capacity of diverse devices, systems, and applications to interact seamlessly. The ability of different IoT components to exchange and synchronize data is vital for the smooth functioning of the entire ecosystem. Overcoming these barriers is critical for unlocking IoT's full potential, promoting its widespread adoption, and contributing to the realization of a smarter, more connected world.

Keywords: Internet of Things, Wireless Sensor Networks, Interoperability, Agriculture, Scalability, Security

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1. Introduction

The term "Internet of Things" denotes to a network of connected objects that facilitates data exchange. IoT facilitates the remote/on-premises detection and control of objects, establishing direct/indirect connections between the physical and computer worlds. Kevin Ashton initially used the term "Internet of Things" in a presentation he gave to P&G to emphasise the value of RFID (Ashton 2009). The Internet of Things is a conglomeration of various hardware and software technologies underpinned by the notion of machine-to-machine (M2M) connectivity. The Internet of Things (IoT) uses various kinds of sensors to gather data and connects both living and nonliving objects. [1] Different kinds of objects can be given computational capabilities, enabling all kinds of devices to generate and exchange data with little to no human intervention. [2] M2M communication served as the foundation for the development of IoT technologies. IoT's foundational ideas were introduced by extending M2M by connecting things through wireless sensor networks and more sensors. [3] The full potential of the Internet of Things began to show when the foundation was expanded to include the concepts of SCADA (supervisory control and data acquisition). Smart gadgets that use embedded sensors and processors to gather data from the environment are common in IoT environments. [4] These data are sent to endpoints or the cloud via one or more gateways, where analysis is performed locally or remotely. The most of the time, there is little to no manual intervention. Figure 1 shows an example of an Internet of Things system.

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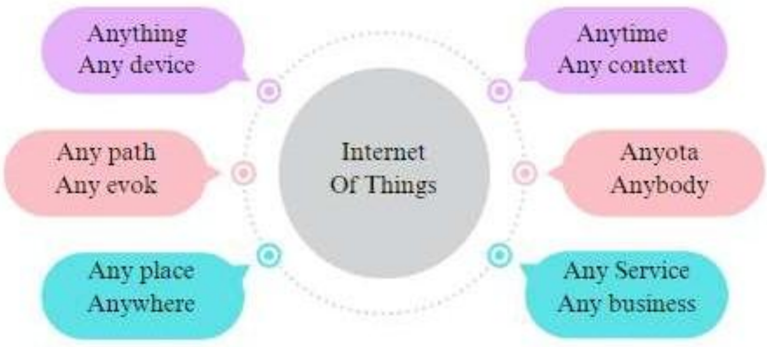

Fig.1 IoT.

With so many devices that promise to save money, energy, and time, the smart home has become the revolutionary ladder to success. [5] Prominent technology companies such as Samsung are attempting to take hold of this enormous market niche. Wearables are gadgets with software and sensors built in that gather user data and analyse it to draw conclusions about the wearer. [6] Companies such as Google, Samsung, and others have already made significant investments in the wearable business. The automotive sector is already undergoing a change because to companies like Tesla and BMW.

[7] With the goal of creating 100 smart cities in the future, the Indian government has begun work on the Smart Cities Mission (Smart Cities Mission 2015). [8] The Tamil Nadu Electricity Board has already begun work on replacing the current electric metres with smart metres in a gradual way. Israel, a leader in precision farming, is already advancing quickly towards smart farming. [9] These various examples of intelligent applications demonstrate that the IoT's realisation is already a reality, not just a pipe dream for the far future.

Due to the rapid growth of smartphones and tablet PCs, the number of gadgets that are linked to the Internet surpassed 12.5 billion in 2010, while the global population increased to 6.8 billion. [10] Additionally, it projects that by 2015, there will be 25 billion Internet-connected gadgets, and by 2020, there will be 50 billion.

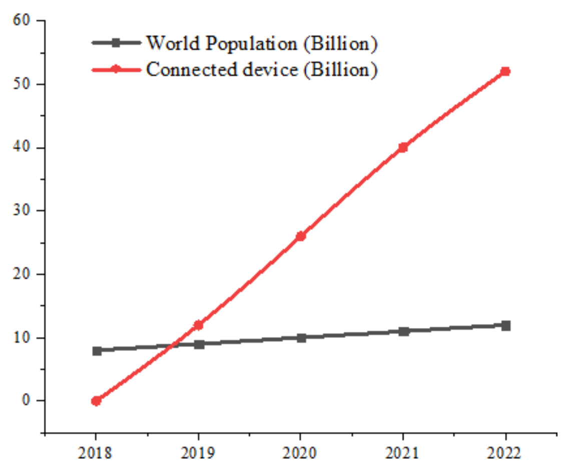

Fig.2: Global population and linked devices versus year.

2. Iot Architecture

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IoT architecture can be broadly divided into four tiers..

2.1 Sensor Layer

The embedded systems, sensor networks, readers, and RFID tags, and other soft sensors—various types of field-deployed sensors—make up the lowest layer of the Internet of Things architecture. These sensors are all equipped with features like RFID tags for identification and data storage, sensor networks for information gathering, etc. [11]

2.2 Network Layer and Access Gateway

The information gathered by sensors is transferred to the following layer by this layer. It must make possible a uniform protocol for data transfer from heterogeneous devices that is scalable, flexible, and standards-compliant. [12] A strong network and excellent performance are expected for this layer. Additionally, it ought to facilitate autonomous communication between various organisations.

2.3 Management Service Layer

This layer acts as an interface in both directions between the gateway/network layer and the application layer. [13] It is responsible for managing sensors and details in addition to collecting a sizable amount of raw information and extracting relevant information from stored and real-time data. Privacy and data security must be ensured.

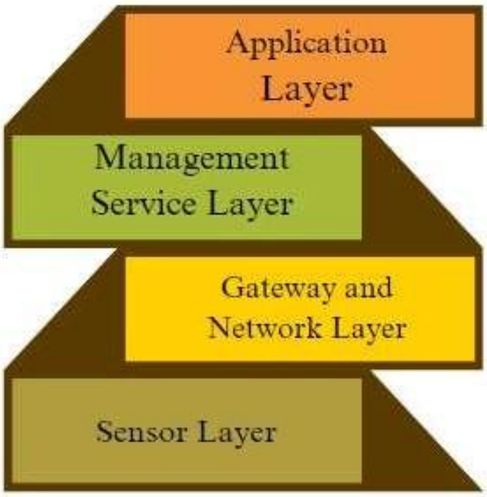

Fig. 3 IOT's Layered Architecture

2.4 Application Layer

This is the highest tier of the Internet of Things, offering diverse users an interface to access different applications. [14] Numerous industries, including healthcare, transportation, supply chain management, retail, agriculture, and government, can make use of the applications.

3 Iot Application Domains

Numerous fields can benefit from the many applications of this technology. IoT has the power to be used in the following ways to address everyday issues. But there are a tonne of more uses for it.

TABLE I: Relationship between IoT and sensor networks

Senor Network	IoT
A sensor is a device, which collects data.	Devices or objects are made smart objects, which are connected to the internet.
Data is collected using sensors.	Data is collected, later it is processed and decisions are taken
Sensors are part of IoT.	IoT is the combination of sensors, networks and people
Sensors are used to monitor space, objects, and human beings.	Here daily life objects are made intelligent, which alerts when something is wrong.

3.1 Smart society Smart home

These days, homes and businesses use IoT devices. [15] Different technological gadgets and HVAC systems are equipped with actuators and sensors to ensure that energy is used efficiently, to monitor and regulate the amount of heating, cooling, and light in a room, to detect the presence of people and turn on the lights when you enter, to sound alarms when a fire or smoke is detected at home, to add more comfort to life, and to reduce costs and increase energy savings.

3.2 Smart home automation

Your home's appliances can be programmed and controlled remotely thanks to the Internet of Things. It may help identify and prevent thefts.

3.3 Smart City

IoT technologies can be used more broadly to increase the efficiency of cities. Utilising the Internet of Things (IoT) to enhance traffic management, track parking availability, These days, homes and businesses use IoT devices. Different technological gadgets

3.4 Smart Traffic

The management of traffic is currently a major problem in urban areas. It is now nearly hard to manage them manually. It then gives drivers a traffic update, enabling them to choose a more efficient route. In addition to showing the user where to pick up and drop off of cabs in real time, this also makes it easier for them to reserve a cab without making a phone call.

3.5 Smart parking

Parking spaces will have sensors installed in them to determine whether or not they are available. When drivers park their cars, they glance at an application that shows them the closest parking spaces that are available, as well as the cost of parking based on data gathered and processed by smart sensors, which saves them both time and gas..

3.6 Smart waste Management

A trash can equipped with sensors that will notify the authorities when it has to be emptied since it is full.

3.7 Smart Street light

Street lights will be equipped with sensors that can detect and interpret contextual information, such as the time of day, weather, and season, to automatically turn on or off the lights and adjust their dimming levels.

3.8 Smart water supply

In order to guarantee that residents and businesses have sufficient access to water, smart cities must keep an eye on the water supply. By detecting leaks and informing users of water loss, wireless sensors enable more precise monitoring of water piping systems, saving both money and natural resources.

3.9 Smart Environment

Detecting pollution and natural disasters is a critical use case for the Internet of Things. In order to reduce air pollution, researchers have the ability to track emissions from vehicles and companies. Water pollution can be stopped by tracking the discharge of waste and dangerous chemicals into rivers and the ocean. We can also monitor the quality of the water that is made available for consumption. By spotting tremors, we can issue earthquake and tsunami alerts. To be prepared for floods, we can monitor the water levels in rivers and dams. With the use of this technology, forest fire detection is also feasible.

3.10 Monitoring of Air Quality

By including sensors that gather context data, such as the ambient temperature, humidity, sound levels, and concentrations of CO and NO2 in the air. This gives constant context-related information, which makes it easier to take appropriate action if it deviates from the norm.

3.11 Smart Water Quality Monitoring

When installed or circulated in water, sensors that sense context—such as flow,water quality, speed, temperature, and pollution—can be used. This aids in the management and analysis of the water resources that are accessible for use in real time.

3.12 Smart sewage water management

By continuously supplying information about the amount of waste water contained, embedded sensors in sewage tanks aid in the control of waste water overflow. With this information, the service team can schedule the water treatment procedure and avoid sewage overflow.

3.13 Monitoring of Natural Disasters

It is possible to forecast natural calamities like earthquakes, landslides, forest fires, volcanoes, floods, etc. by utilising wireless sensing sensors. These discoveries alert the relevant authorities to the need to take preventative measures before the calamity strikes.

4. Agriculture

4.1 Smart Farming

The owner is informed about the need for water, pesticides, manure, fertiliser, or therapy for the sick plants based on the sensors' collection and analysis of contextual data, which includes soil moisture conditions, current temperature,solar radiation and leaf wetness.

4.2 Healthcare Health tracking

Through applications, the Internet of Things is employed in the healthcare sector to enhance human life quality by helping with daily chores that humans must complete. Patients' health monitoring devices may have sensors installed on it. IoT devices can also be used to track a patient's existing pharmaceutical regimen and assess the potential for allergic responses and unfavourable drug interactions when a new prescription is prescribed. To monitor an individual's blood pressure, heart rate, body temperature, and other vital signs by utilising sensors and the technology mentioned above.

All of the information gathered by the sensors will be used to notify the patient and their personal physician in the event of an emergency. People with disabilities who live independently and senior persons will find great value in this method.

4.3 Pharmaceutical products

In order to protect patients' health, pharmaceutical product safety is vital. The benefits of using sensors to monitor drug status and attach smart labels to medications include preserving storage conditions and preventing the transportation of expired medications to patients [12].

4.4 Sustainability of food

The food cycle involves several processes that packaged food must go through, including harvesting, production, distribution, and transportation. In order to keep food from rotting, sensors are employed to monitor context such as humidity, temperature, heat, light, etc. These sensors precisely notify the variation and notify the necessary parties.

4.5 Supply-chains

The supply chain is tracked by the Internet of Things at every point, including the producers' purchases of raw materials from production, suppliers, storage,distribution, after-sale services and product sales. This will contribute to the maintenance of the inventory needed for ongoing sales, which raises customer happiness and boosts revenue [12]. Over the next ten years, supply chain and logistics will produce $1.9 trillion from IoT, according to Cisco's economic analysis[13]. We can also determine whether the machines need maintenance and repairs by using this. A hundred smart towns are to be developed by the Indian government as well, addressing some of the IoT uses already mentioned.

5. The Profits And Fallout From Iot

5.1 Benefits of Communication

IoT allows for device-to-device communication, allowing physical equipment to remain connected and providing complete transparency with reduced inefficiencies and improved quality.

5.2 Control and Automation

Machines are automating and managing enormous amounts of information without the need for human intervention, producing results more quickly.

5.3 Monitoring reduces costs and saves time.

IOT saves money and time by using smart sensors to monitor many elements of our daily lives for a variety of applications. Our everyday lives are made more comfortable and well-managed by IoT-based applications, which raises our standard of living.

5.4 Fresh chances for business

Generates new IoT technology businesses, which boosts economic growth and employment creation.

5.5 Improved surroundings

Strives to create a smarter, greener, and more sustainable globe by protecting natural resources and forests.

5.6 Disadvantages

Interoperability

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- Since the Internet of Things will connect devices from many manufacturers, there is currently no universal standard for interoperability for the tagging and monitoring equipment.

Intricacy

- IoT networks are intricate and multifaceted. There will be dire repercussions for any hardware or software malfunctions. Even a power outage might be quite inconvenient.

Security and privacy

- IoT involves a variety of technologies and gadgets, and it will be observed by a number of businesses. There is a significant chance of losing private data because smart sensors will communicate a lot of context-related data.

- Reduction in the need for menial labour: As a result of technology, everyday tasks are becoming more automated through the use of IoT, requiring less human intervention overall. This reduces the need for human resources. This contributes to the social problem of unemployment.

5.7 Technology Takes Over Humanity

Our lives will be more impacted by technology, and we will become dependent on it. Already, the younger generation is totally reliant on technology. This reliance will permeate user everyday habits and generations as a result of IoT. We must choose the extent to which we are ready to let technology mechanise and govern our daily lives.

6. Challenges And Issues

6.1 Scalability

1. A variety of new smart devices are indiscriminately joining the network. As a result, issues including information management, service management, and addressing should be handled by IoT. It ought to be able to accommodate different size settings as well.
2. IoT devices should be programmed for self-configuration, which eliminates the need for user intervention and allows them to adapt to certain environments.

6.2 Device heterogeneity in terms of interoperability

IoT consists of a large number of interconnected smart things, each with the ability to process, communicate, and gather data on its own. Different kinds of smart objects need have a common communication standard for cooperation and communication.

6.3 Complexity of software

Smart object software systems have limited resources, so in order to administer and support the network's smart objects, a server must run in the background. Software infrastructure is therefore required to support the network.

6.4 Volume of Storage

Smart objects can collect a lot of data or very little, depending on the circumstances and environment. Therefore, storage needs to be allocated according to data volume.

6.5 Interpretation of data

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Interpreting the context that the sensor needs to sense is crucial. In order to produce meaningful information and derive conclusions from the sensor data, context is crucial.

6.6 Security and personal privacy

Ensuring security and privacy inside a network of smart objects comprised of the Internet of Things presents a significant problem. Users in the Internet of Things may prohibit other users from interacting or transacting, or from accessing specific information at specific times, in order to safeguard sensitive data from competitors. As a result, handling everything is a little challenging.

6.7 **Tolerance for faults**

The context of smart devices, or those connected to the Internet of Things, is constantly changing. Nevertheless, the network needs to keep running automatically to adapt to the new situation. IoT design must therefore be fault-tolerant and resilient.

6.8 Data interchange via wireless technologies that is widespread:

Smart device communication is hampered by problems with wireless technology, including congestion, delays in the network, and availability.

6.9 **Energy-efficient solutions**

A network is made up of numerous connected devices, and maintaining the network's activity demands a lot of energy. Therefore, the main component of IoT is energy optimization. Farmers in India have historically followed the following main stages for their crops. They are choosing a crop, preparing the land, choosing seeds, sowing the seeds, irrigation, development of the crop, fertilising, and harvesting. For all of the aforementioned tasks, they were entirely dependent on labour. Nowadays, finding labour has become a laborious chore, and profits have decreased as well. This has caused the proportion of people who work only in agriculture to decline.

7. Conclusion

This article examined the IoT domain in this survey report, taking into account its applications, architecture, and benefits and drawbacks. We noticed that the field of agriculture is still not using a lot of IoT. Therefore, we believe that it is imperative to enhance IoT applications in this sector and teach farmers about them. Doing so will lessen reliance on labour and raise yield, both of which boost the economy.

Abbreviation

SCADA - supervisory control and data acquisition

IOT - Internet of Things (IoT)

M2M - Machine to Machine

Competing interests

The authors declare that they have no competing interests.

Consent for publication

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Ethics approval and consent to participate

Not applicable

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Authors' contribution

Author A supports to find materials and results part in this manuscript. Author B helps to develop literature part.

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