INTERNET OF THINGS: REVOLUTIONIZING CONNECTIVITY AND AUTOMATION

Abstract

An emerging standard termed the Internet of Things (IoT) has transformed the traditional way of operation into one that makes use of cutting-edge technology. The IoT brings about changes in smart manufacturing, smart homes, smart cities, and intelligent transportation systems. Numerous significant research investigations and queries have been conducted in order to advance technology using IoT. Multiple challenges and issues need to be overcome in order for IoT to completely deliver on its promise. These issues and worries need to be examined from a variety of IoT angles, including applications, testing, enabling technologies, ecological and societal ramifications, etc. The main aim of this review article is to provide a comprehensive technical and social study. The article identifies a number of challenges and important issues with the IoT, architecture, and sizable application industries. The article also emphasizes recent research and demonstrates how it supports different IoT components. From, this article, the readers and scholars will have a better understanding of the Internet of Things and how it interacts with the physical world.

Keywords: IoT (Internet of Things), IoT definitions, IoT functional view, architecture, characteristics, future challenges.

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I. INTRODUCTION

With the advent of the Internet of Things (IoT), electrical devices and sensors are now able to talk to one another through the web, streamlining our daily lives in the process. The IoT is a solution to worldwide commercial, governmental, and public/private sector problems that combines internet-connected smart devices with innovative problem-solving methodologies. In many parts of contemporary life, the IoT is becoming increasingly essential and pervasive. The IoT is a technical breakthrough that brings together several interconnected computing systems, networking protocols, and high-tech sensors and gadgets. Storage capacities, sensing capabilities, and calculation speeds are all greatly enhanced by quantum and nanotechnology, which were previously thought to be impossible. Numerous studies have been undertaken to show the potential effectiveness and applicability of IoT changes, and the results have been published in academic journals and news reports that can be found online and in print [1]. It might serve as a reference point for the development of novel, imaginative business ideas that include assurance, security, and interoperability.

The future of the Internet is the IoT. It gives society, governments, communities, and people the chance to connect and get services through the Internet, from anywhere and at any time. The IoT improves Internet-based connectivity between both people and objects. Through the Internet of Objects, everyday interactions between people and applications on computers are expanded to include objects. Things are items, either in the real (physical things) or virtual (virtual things) worlds [2]. Things have the ability to be recognised and included in networks of communication. Physical objects may be detected, operated, and linked to the Internet, including industrial robots, items, and electrical systems. A physical entity is more precisely defined as a physical item that is outfitted with a device that enables it to be connected to the Internet. A device in the IoT is defined by the International Telecommunication Union (ITU) as a piece of machinery having the required capability of telecommunications and an optional enhanced capability of sensing and actuating [3]. On the other hand, virtual objects aren't necessarily tangible or real. They may exist independently of any connection to a physical object. Multimedia material and web services are examples of virtual items since they can be stored, processed, shared, and accessed online. Despite this, a virtual object may also serve as a representation of a real-world object. For instance, themajority of computer applications and databases used today make use of objects or classes, which are virtual representations of real-world items. As a result, communications in the IoT may take place entirely between objects as well as between people and things. This comprises communications between "physical objects" and "virtual objects," as well as communications between "physical objects" and "virtual objects." The Internet may now be connected to anything, anywhere, at any time because of the diversification of telecommunications. As a consequence, the IoT is anticipated to be present everywhere and in a wide range of application domains, including, but not limited to, manufacturing, urban planning, agricultural activities and production, monitoring the environment, smart dwellings, and several service industries.

The IoT may be seen from the standpoint of networking as a diverse network that incorporates various wired and wireless networks, such as low-power cellular networks as well as local area networks, with an ever-evolving architecture. A variety of devices are connected via this heterogeneous network [4]. It includes gadgets that link to the Internet through a range of wireless and LAN technologies, including ZigBee, RFID, Bluetooth, Wi-Fi, and 3G or 4G, among other rapidly developing communication technologies.

Today, the IoT has evolved from RFID tags to a worldwide infrastructure of interconnected objects [5]. The IoT has expanded in scope due to recent technological advancements, which now include additional technologies like sensor networks. The IoT now has more opportunities to provide a platform for scattered objects to collaborate intelligently across local wireless and wire-connected networks, as well as over a larger region of heterogeneous and linked networks like the Internet. This draws inspiration from both the advancement of technologies for wireless communications and their broad range and minimal power consumption characteristics, as well as from the commercialization of RFID technology.

Many sectors will undergo a transformation due to the IoT, which will also improve online communications. The IoT presents many options [6]. IoT services provide the user with a wide range of capabilities and services. The most apparent ones are the capability to remotely manage and keep an eye on real-world conditions through networks of communication. The ability to remotely shut a door or get smoke warning messages through the Internet are common examples. However, when objects and collections of objects are linked, technology undergoes a revolution [7]. The Internet of Objects (IoT) may be made smarter and more ubiquitous by connecting more objects, which not only enables items to interact with one another but also the network of interconnected things, in conjunction with backend systems engaged in various user and other thing collaboration endeavours, cloud platforms, internet services, big data, and location-based services, among others, will renovate not only online communications but also the countries. The IoT will make it possible for information to be shared across domains, which will improve service quality overall. For instance, the capacity of nurses, physicians, and chemists to communicate health information with one another would improve the standard healthcare system. As a result, it is anticipated that the IoT will permeate several sectors [8]. It is viewed as an emerging era of technological advances that will benefit not just the average user but also numerous enterprises by providing them with exciting commercial prospects.

This chapter will go on to discuss some of the most anticipated applications for the Internet of Things and the effects that the IoT may have on numerous facets of life. Some of the most significant IoT potentials are examined. Since the possible uses given by the IoT are many and only limited by our imaginations, the chapter focuses mostly on a few exciting applications for the IoT rather than attempting to survey many projected IoT applications. For instance, the IoT has the potential to change the healthcare industry. The goal of integrating the IoT into the healthcare industry is to improve the delivery of medical treatment and services, thereby preserving more lives. Other industries that will benefit from the use of the IoT include nursing homes, remote monitoring of health, smart housing, smart water, robotics, industrial production, and transportation. Nevertheless, the IoT will be used in numerous fields to improve service quality, productivity, and security. In particular, vehicle-to-vehicle connectivity and smart roadways that monitor and manage the flow of traffic are exemplary examples of such applications that help to increase road safety and the effectiveness of transportation systems, particularly in crowded cities

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II. THE ARCHITECTURE OF IOT

The linked structure of elements that constitute IoT networking systems is referred to as "Internet of Things architecture." These components include sensors, actuators, cloud services, protocols, and layers. It is often segmented into layers that allow managers to evaluate, monitor, and maintain the network's dependability. Data is transported from connected devices to the cloud for analysis, modification, and storage in a four-step procedure known as the IoT architecture. The IoT is only going to become bigger and better over time, giving people all sorts of new opportunities.

1. **Different Layers of IoT Architecture:** The Internet of Things (IoT) is a popular technological advancement with several applications. The architectures and designs of Internet of Things applications, across a wide range of use cases, determine their functionality. However, the division of work is not uniformly organized in the same way everywhere. Various architectural layers and degrees of complexity are used as needed for various business tasks. The standard and most frequent layout are a four-layer structure.

2. **Layers of IoT Architecture**: The following illustration in Figure 1 shows that there are four distinct levels, labeled "perception," "network," "processing," and "application. [9]"

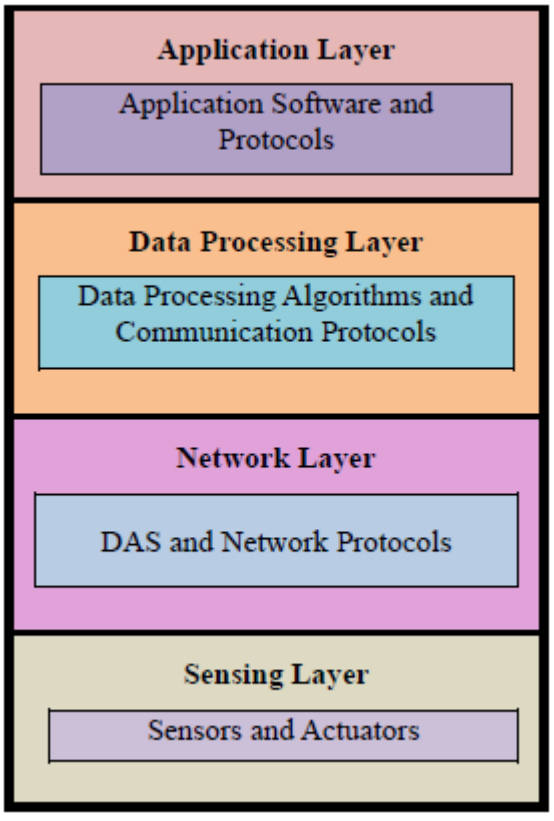

Figure 1: Layers of IoT

3. **Sensing or Perception Layer:** The first layer of any IoT system is comprised of "things" or terminal devices that serve as a bridge between the physical and digital worlds. The sensors and actuators that have the capacity to collect, receive, and analyze data across the network are all part of the physical layer, which is termed as "perception." The

connection between actuators and sensors may be made via either wireless or wired connections. The breadth of the architecture's components or where they are placed is not constrained.

4. **Network Layer:** The network layers provide a high-level view of the programme's data flow. At this layer, there are Internet/network gateways and data acquisition systems (DAS). A DAS performs data collection and transformation tasks (such as gathering and combining sensor data, converting analog data to digital data, etc.). It is necessary to send and process the sensor devices' data. The network layer is in charge of handling the networking task. It paves the way for these devices to interact with other servers, smart devices, and networked devices. It also controls the flow of information between all of the gadgets.

5. **D. Processing Layer**: The "brain" of the Internet of Things ecosystem is the processing layer. Before being delivered to the data centre, data is normally analysed, preprocessed, and stored here. Data is retrieved by programs that process it and plot the following actions: This is where "edge analytics" or "edge IT" comes into play.

6. **Application Layer:** The application layer is the point of user engagement, and it is responsible for delivering application-specific services to the user. One example is a dashboard that shows the state of all the instruments in an orchestra, while another is a smart home app that allows the user to turn on the coffee maker with the press of a button. The Internet of Things has a wide variety of potential applications, some of which include smart homes, smart cities, and smart healthcare systems**.**

III. USE CASES FOR THE INTERNET OF THINGS

1. **Smart Home:** IoT devices monitor and control the electrical, electromechanical, and electronic systems used in many different types of buildings, including both private and public, commercial, institutional, or domestic [10]. House automation is the practice of employing different control system approaches to automatically operate house equipment. A variety of control mechanisms [11] may be employed to regulate the electrical and electronic equipment used in homes, including fans, lighting, exterior lights, alarm systems, kitchen alarms, etc.

   - Ways to monitor tenant behavior and reduce energy use by monitoring home equipment in real-time

   - The incorporation of smart devices utilizing IoT in structures and potential uses for them in future, the most popular IoT-related search term on Google is "smart home."

   IoT firms creating items to make your life simpler and more practical are nothing to be astonished by. It is projected that in the near future, smart houses will overtake smartphones as the innovative ladders for achievement in residential areas [12]. Time, energy, and financial savings are promised by IoT-enabled smart home goods [13]. Smart home firms like Nest, Eco Bee, Ring, and August will establish themselves as household names and promise a revolutionary user experience. The concept of smart home is simply depicted in Figure 2.

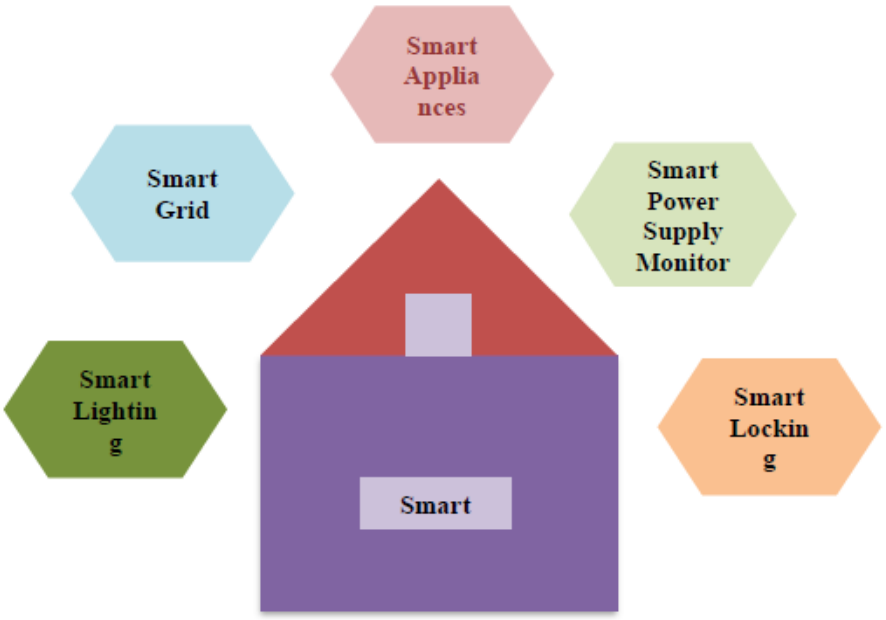

Figure 2: The Concept of Smart Home

2. **The IoT in Agriculture:** Global population growth is continuing, and there is a tremendous need for food supplies. In order to increase food production, governments in every region of the world provide financial assistance to farmers who use innovative agricultural practices and conduct scientific research. The Internet of Things has made smart farming one of the businesses that is expanding the fastest [14]. The monitoring of soil moisture and nutrients, the management of water use for plant growth, and the creation of customised fertilisers are all examples of straightforward applications of the Internet of Things in agriculture [15].

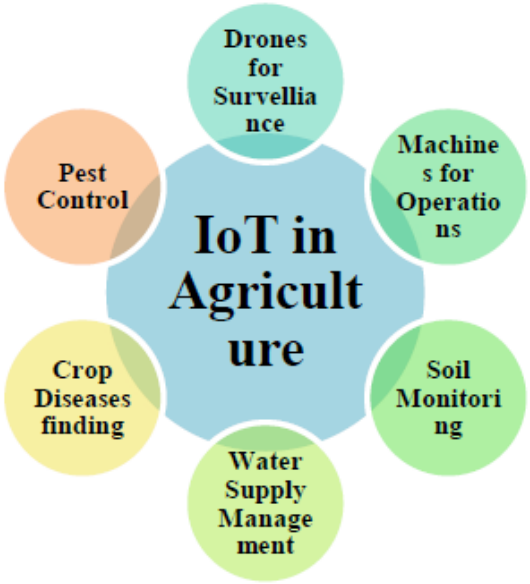

Figure 3: Applications of IoT in Agriculture

The Internet of Things dramatically improves agricultural practices. Farming is one of the first businesses to employ the Internet of Things in this area due to problems brought on by population growth and climate change [16]. The incorporation of wireless sensors in agricultural applications and cloud computing platforms aids in the gathering of crucial data regarding environmental factors related to farming, such as rainfall, temperature, relative humidity, wind velocity, and insect infestation. Making educated choices to increase quality and quantity while lowering risks and waste may all be done using this information to enhance and automate agricultural practices. Figure 3 shows the applications of IoT in Agriculture.

3. **Smart City:** Another effective IoT use case that inspires interest among people worldwide is a smart city. Some examples of applications for the Internet of Things that may be found in smart cities include intelligent monitoring for smart shipping, intelligent systems for managing energy, intelligent systems for water distribution, metropolitan security, and ecological monitoring [17]. The Internet of Things will assist in resolving key issues that are faced by city dwellers, such as automobile traffic, pollution in the air, a lack of available energy sources, etc. Devices with mobile communication capabilities, like those found in Modern Trash, are able to alert municipal officials when a bin needs to be emptied [18]. By installing sensors across the city and using mobile applications that are connected to parking, residents will be able to identify available parking places [19]. The sensors may also pick up on general faults, meter tampering difficulties, and any installation problems in the power system. The Figure 4 shows the applications of IoT in Smart City.

Figure 4: IoT in smart City

4. **IoT in Smart Industry:** Utilizing automation and IoT in industrial processes to continuously enhance productivity is known as smart manufacturing [20]. The secret to realizing the advantages of converting your storage and manufacturing facilities into smart spaces is to use indoor intelligence to precisely monitor assets, support worker safety, boost efficiency, and enhance security on your factory floor. Manufacturing has seen a massive digital shift during the last ten years [21]. Artificial intelligence, IoT connectivity,

predictive analytics, cloud computing, quantum computing, cutting- edge additional fabrication techniques like 3D printing, cyber-physical technology, and a host of additional innovations have all seen the emergence of new applications in industries [22]. These innovations launched a fourth industrial revolution when used together.

5. **IoT Technologies in Industry 4.0:** Manufacturing is evolving quickly. No one technological advance, nor even a group of technologies, can be used to define Industry 4.0. In the digital age, it represents a radical restructuring of employment [21]. Industry 4.0 is seen by some as being characterized by the fusion of several technologies into adaptable technological environments. Industry 4.0 technologies complement, facilitate, and improve one another as systems, which clearly shows that it is a crucial transformation in the sector. We may use indoor positioning to make interior areas accessible using either the award-winning sensor technology or your current technological infrastructure. Using mobile devices, portable electronics, tracking tags, or other devices, users may precisely locate the location of persons or assets within a building with the use of indoor positioning systems (IPS) [22]. The technology behind IPS detects and tracks information about a device's position using a range of sensors. This may be done either with radio frequency sensors deployed throughout an interior environment or with sensors within and radio receivers in mobile phones and other IoT gadgets that are worn [23]. The system for positioning absorbs the location information and uses it to create precise coordinates that are presented on a digital twin, providing a level of visibility previously unattainable for complex manufacturing operations and the communication environments inside them.

6. **Wearable Electronics:** Intelligent devices that may be stitched into clothing or other things, implanted in the body, or worn as external accessories are known as IoT-enabled wearables [24]. These gadgets have the ability to be linked to the Internet in order to gather, transmit, and receive information as well as data that may be used to make wise decisions. These wearables are developing from being fundamental devices to more sophisticated and useful applications, and they are becoming a more significant component of IoT technology [25]. Smart wearables may interact with a variety of different devices, including smartphones, for various applications in communication and computing [26]. The ability of smart wearable devices to gather and transmit data while in motion and to receive data obtained from the Internet in response is becoming more and more crucial due to the movement of both people and animals. This information aids in making better judgments. Using smart wearables may increase productivity.

IV. THE FUTURE OF THE INTERNET OF THINGS

More exciting is the Internet of Things' potential, where billions of objects will communicate with one another and human interaction will be minimal. The Internet of Things is having an influence in a lot more sectors. The transition to edge computing is one of the biggest themes in IoT. Instead of transmitting data to the cloud for analysis, this entails processing it locally on the device [27]. Edge computing may aid with latency reduction, dependability, and privacy and security enhancements. As a consequence, in the next few years, we may anticipate seeing an increase in the number of IoT devices with integrated edge computing capabilities.

The rising use of artificial intelligence (AI) and machine learning (ML) in the analysis of data from connected devices is another IoT trend. Businesses may acquire useful insights that might aid them in making better choices by applying sophisticated analytics to IoT data. For instance, AI-powered wearables and gadgets are being utilized in the healthcare sector to track patients' health and spot possible problems before they become serious. IoT is also being utilized more and more in agriculture to monitor crops and increase production, in addition to healthcare. For instance, sensors may be used to gauge the temperature, moisture level of the soil, and other environmental elements that influence plant development [20]. Farmers may adjust their fertilization and irrigation methods to increase crop yields and decrease waste by gathering and evaluating this data. Smart cities are a fascinating area for IoT applications. Cities may enhance their infrastructure and citizens' quality of life by integrating a variety of devices and sensors, including waste management systems, environmental monitors, and traffic cameras. Smart waste disposal solutions, for instance, may lower landfill trash and increase recycling rates while also reducing congestion and improving air quality. The use of blockchain technology to improve security and privacy is a new trend in the IoT. IoT device data may be kept in a decentralized, immutable ledger utilizing blockchain, increasing its security and reducing its susceptibility to hackers. By allowing data to be exchanged only with those who have been given permission, blockchain may also help safeguard user privacy.

V. CONCLUSION

The Internet of Things refers to an interconnected network of items that can connect with humans, obtain information from the Internet, and communicate with one another through it. The rise of internet-based applications has drastically altered the world. Without it, interaction appears impossible in all circumstances. Through the facilitation of communication amongst intelligent devices, IoT has the ability to expand its frontiers. IoT is a crucial research area, and it's crucial for science-policy stakeholders to comprehend the direction of the field. The many IoT applications are examined in this study. The analysis's findings indicated that the IoT's primary implications are in smart cities, smart industries, smart farming, and smart house and construction automation. The Internet of Things (IoT) has a bright future ahead of it, with a number of emerging trends and applications that are set to revolutionise a variety of industries and make our day-to-day lives better. The Internet of Things has an almost infinite number of possible applications, ranging from cloud computing and artificial intelligence to the planning of smart cities and blockchain technology. In the years to come, we can anticipate even more interesting advancements as companies and developers keep on innovating and pushing the limits of what is possible.

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