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CHALLENGES AND OPPORTUNITIES OF THE INTERNET OF THINGS INTEGRATION FOR SUSTAINABLE MANUFACTURING IN INDUSTRY 4.0

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Abstract

The term "Industry 4.0" refers to the fourth iteration of the industrial revolution, which is characterized by the fast rise of information technology and the processes of industrialization, which are the key causes behind the birth of the fourth industrial revolution. The term "Industry 4.0" was coined by the Boston Consulting Group in 2013. These are the key factors that have contributed to the development of the fourth industrial revolution. This revolution incorporates several technological developments, including physical-cybernetic systems, the Internet of Things, cloud computing, and industrial integration, to name a few. Because of the development of these technologies, it is now possible to create "smart factories," which have the potential to be networked, adaptable, and efficient, in addition to being sensitive to changes in both the requirements of consumers and the environment in which they function. However, businesses that want to be a part of this paradigm change will have to overcome substantial obstacles since there are not yet enough tools and processes available to properly capitalize on the opportunities presented by Industry 4.0. This implies that there are considerable obstacles for companies who wish to participate. We see this as an opportunity since IoT represents a potential opportunity for the industrial industry. We take a look at the present state of the art, determine the most significant problems and possibilities, and provide some suggestions for the path that future research should take. In addition, we examine the implications that the inclusion of the Internet of Things could have on a variety of elements of environmentally responsible manufacturing, such as the reduction of waste and energy consumption, as well as improvements in product quality, safety, and social responsibility. Specifically, we focus on the reduction of waste and energy consumption in the production process. Specifically, these are the topics covered in this particular portion of the article. As a consequence of this investigation, we have been able to define the primary obstacles and openings that will be involved in further research, as well as the potential routes along which following research need to go.

Keywords: *Industry 4.0, Internet of Things, Sustainable Manufacturing, Smart Factory, Challenges and Opportunities, Layer Architecture*

Introduction

The idea of the Internet of Things (IoT) first emerged in 1982 with the design of a vending machine that sold primarily goods and beverages and was connected to the Internet to track how many drinks or soft drinks were in the machine and in what form they were at any given time. Later, in 1991, Mark Weiser put forth the idea of ubiquitous computing, which is the term used to define the paradigm that enables the provision of computing services through a network, typically the Internet. Using any device, anywhere, and in any format can lead to ubiquitous computing. The phrase "Internet of Things" was first introduced by Kevin Ashton in 1999 to refer to a network of connected gadgets. The goal for Doucek & Maryska(Acaro Imaicela)

The Internet of Things (IoT) heralds a future in which communication focus will shift from person-to-person or person-to-device communications to machine-to-machine communication (M2M), a pervasive global network where all people and all devices will be connected via the Internet. The IoT is continually changing and is one of many research subjects that academics and businesspeople are very interested in. The prospects are thought to be limitless because the only frontier is our imagination. Developing smart devices where actors can participate as designers, producers, end users, and recycling operators is one opportunity for academics and businesspeople(Aldulaimi, Abdeldayem et al. 2023).

Every day, the number of devices that use Internet services continuously grows, generating a powerful source of information within reach of all or many (Shen & Liu, 2011). The interaction established between intelligent machines is considered a cutting-edge and emerging technology. However, the technologies that make up the IoT are not necessarily new but allow the convergence of data obtained from different sources consisting of devices or things to some platform in the cloud, which presupposes an innovation in the exploitation of said information(ALIOUI and ISMAILI 2023).

The main and basic idea of the IoT is to allow and facilitate the exchange of data and useful and autonomous information between uniquely identifiable real-world physical devices embedded in various devices and powered by innovative communications technologies such as RFID (Radio Frequency Identifications) and wireless sensor network (WSN) that are detected by various sensors and processed to perform data analysis and thereby make decisions with the to executein an automated manner. The number of devices connected to IP networks will be more than three times the world population by 2023 ("Cisco Annual Internet Report - Cisco Annual Internet Report(Almazán-López and Osuna-Acedo 2023).

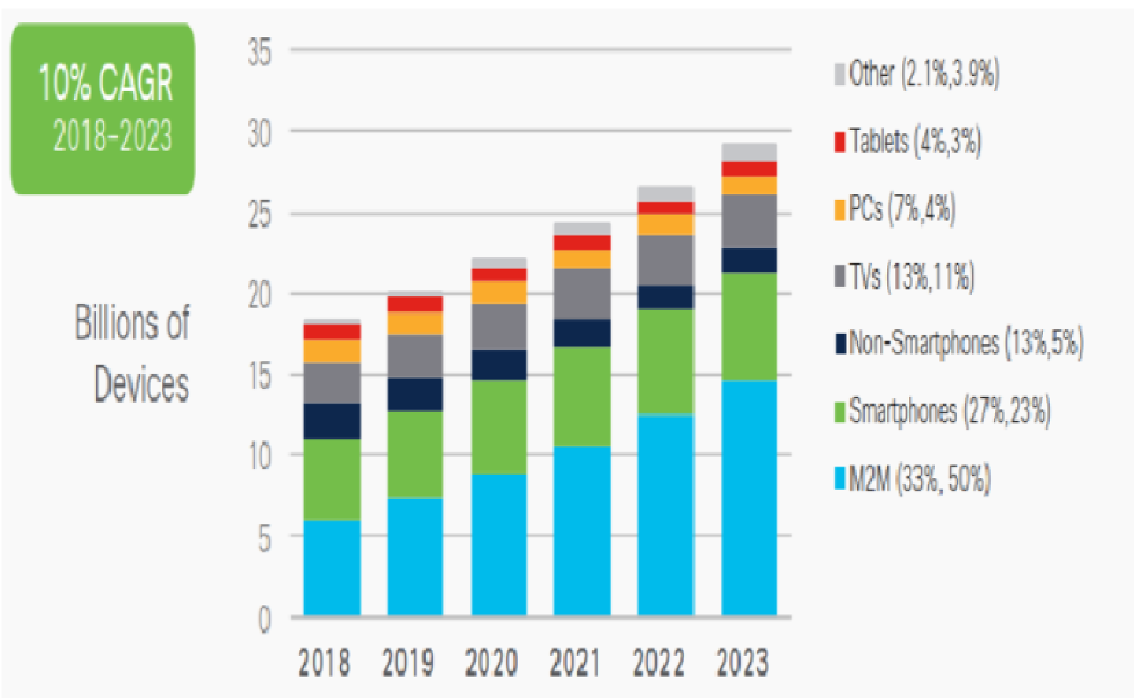

Figure 1. Global growth in device interconnect Source: Cisco Annual Internet Report, 2018–2023

To understand I4.0 or 4RI, it is necessary to understand concepts originating from multiple disciplines related to cloud services and platforms, intelligent systems, flexible manufacturing and in places close to the end user, the interconnection of devices, the geolocation, big data, robotics, 3D printing or additive manufacturing, among several additional concepts, as well as emerging technologies, with trends towards a smart factory. The objective is to integrate the administrative, operational and production processes in companies using the information generated in real-time through sensors to make automated adjustments, exchanging information autonomously between the different interconnected devices(Ávila-Camacho and Moreno-Villalba 2023).

The concept of the smart factory that derives from Industry 4.0 was developed by the German government at the Hannover Fair in 2011 to describe how to make all the processes of a factory interconnected through the Internet. The interaction between machinery, equipment and all manufacturing resources with artificial intelligence systems and models speaks of the intelligent digitization of industrial processes that will allow the development of innovative business models(Avinzano, Sánchez et al.).`

Industry 4.0 requires the integration of various disciplines to achieve a wide range of solutions that impact the market and allow customizing both the products and the services offered to customers from the smart factory. This concept then describes end-to-end digitization, from production to consumption, including automated manufacturing, as an autonomous production chain integrated with final distribution and delivery, generating a new organizational concept and an innovative value chain. Intelligent(BARRÓN HERNÁNDEZ 2023).

Within this range of disciplines necessary for integrating the smart factory, the Internet of Things or IoT, for its acronym in English, is the pillar for the automation of various production processes through the interconnection of devices, equipment, and good machinery for the implementation of processes(Vargas, Mora et al. 2023, Viera Vallejo 2023).The present work is organized into 5 sections. In this first section, the panorama of Industry 4.0 was described as the reason for the technologies necessary for the generation of new business models; section 2 describes the main vision of the IoT, section 3 describes the most common architecture for the IoT, section 4 explains the technologies that make up the IoT and section 5 concludes the work describing the challenges faced by companies to venture into Industry 4.0(BAUER, MERLO et al.).

2. Main Vision

The ubiquity of the Internet has brought the world into an era of greater connectivity where a wide variety of devices and accessories are and will increasingly be connected to the network. What makes this era the era of the Internet of Things? As mentioned in the previous section, various authors have defined the term in different ways (It .defines the Internet of Things as a simple interaction between the physical and digital worlds through sensors and actuators(Castillo-Vergara and Araneda 2023). What constitutes a paradigm in which computing and networks are embedded or embedded in objects and devices? In common terms, the Internet of Things refers to a different world where almost all the devices and accessories used daily are connected to the network, and it is possible to use them collaboratively to fulfil tasks that even require smart actions. Accomplishing these smart tasks requires in addition to sensors and actuators, processors and microcontrollers, as in the case of ARM systems. That is why the Internet of Things is not made up of a single technology; it is an integration ofa set of technologies that operate and work together to form a solution(Belman-López, Jiménez-García et al. 2023).

In this sense, the main vision of the Internet of Things describes an environment where objects or things can communicate(Torres-Rivera , Saavedra-Neira and Hernández-Barba 2023, Sarsembayev, Sarsenova et al. 2023, Urban Veloz 2023), perceive the environment through various sensors, and perform actions within that environment using actuators. Actuators are devices that convert energy into movement and are used to apply force, carrying out environmental actions. The data collected by the sensors are stored and intelligently processed to execute tasks or generate some inference using machine learning or machine learning(Diaz Guerra 2023).

The storage and processing capabilities of an IoT object are restricted by the available resources, which are reduced and bounded given the limitations in size, energy, power and computational capacity of the device, so the processing is normally done on a remote server, and a pre-processing of said data is carried out in the devices. An important research topic is to ensure that the correct data type is obtained with the desired level of precision. Communication between IoT (Royo Sánchez and Lambán Castillo , Mala, Pratikto et al. 2023, Patricia Malagón-Suárez and Arturo Orjuela-Castro 2023, Ramírez Molina, Herrera et al. 2023)devices occurs mainly wirelessly since they are installed in geographically dispersed locations, so the communication channels can generate noise that distorts the signals and thus appear unreliable. In this sense, the problem is to obtain highly reliable data without too many retransmissions, which is also an important study topic in IoT devices(Fuentes-Gavilánez, Erazo-Castillo et al. 2023).

After processing the received data, some actions should be carried out due to the generated inference. These actions can be several, the physical world can be directly modified through the actuators, or an action can be carried out that involves sending information to other smart devices. Changing the physical world will depend on the state of the device at a given time, known as context awareness; each action considers the context since each application can react differently in different situations. Contexts(Gutiérrez Botello 2023).

To establish a framework or work environment for the IoT, it will be necessary to have an intermediate layer or middleware that allows connecting and managing this entire range of heterogeneous devices, so standardization is required for this wide spectrum of IoT devices.The various applications of the Internet of Things in the sectors of health, education, training, energy conservation, environmental monitoring, manufacturing, transportation systems, and home automation, among others, will significantly reduce human efforts and improve the quality of people's lives(León García and Madinabeitia 2023).

3. Architecture

There is no consensus yet to define a traditional architecture that is universally accepted, and several authors have proposed different architectures. However, as shown in Figure 1, around 30 billion devices connected to the network are expected by 2023, which represents a large number that will undoubtedly not be supported by the current Internet architecture based on the protocol. TCP/IP, so an open architecture that can support various quality of service (Quality of Services) incidents will be necessary, as well as support for current applications using open protocols. Additionally, to ensure the adoption of the IoT, the security and reliability of the information must also be guaranteed, as well as the privacy of the data(Al-Amin, Hossain et al. 2023).

Various architectures based on multiple layers have been proposed to support the current and future development of the IoT. Wang Chen proposed a three-layer architecture, while Hui Suo et al. presented a four-layer architecture. Miao Wu proposed a five-layer one using the Telecommunication Network Management Model (TNM) characteristics. In the same way, Minghui Zhang et al. proposed a six-layer architecture based on the hierarchical structure of networks that has perhaps been the most widely implemented(Al-Khatib 2023).Figure 2 shows a comparison between the 3-layer architecture and the 5-layer architecture.

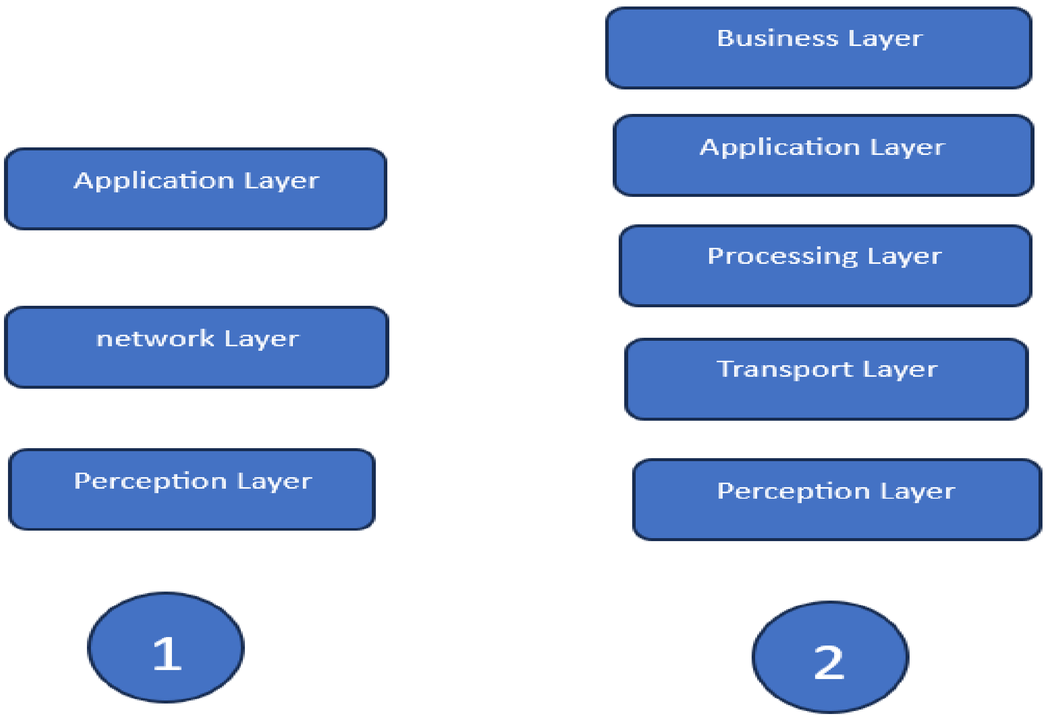

Figure 2. IoT architectures. (1) three-layer architecture, (2) five-layer architecture

In the three-layer architecture (1), the perception layer, the network and the application layers are shown. When the concept of IoT emerged, one of the first architectures proposed was the three-layer architecture. The input layer is the perception layer, and it is the layer where the sensors that perceive the environment and collect the information by reading physical parameters are located. In this layer, the data of other objects is also identified. The next layer is the network layer responsible for connecting with the network and other devices to process and transfer the data collected by the sensors(Almazán-López and Osuna-Acedo 2023).

The application layer is in charge of applications that offer or consume user services and specific services that are part of the application or use, such as medical diagnostics, smart homes, smart cities, smart manufacturing, etc. The three-layer architecture is not very specific or detailed, although it describes the general idea of the Internet of Things. For this reason, it causes the emergence of new proposals such as the 5-layer architecture, also shown in Figure 2, which adds two additional layers and divides the network layer, the new layers proposed by the 5-tier architecture include the processing layer and the business layer. The processing layer is an intermediate layer that works as a middleware to store and process the data it receives from the transport layer. This layer can also manage and provide services to and from the lower layers. To do this, it can use various complementary technologies connecting to database servers, cloud computing services, and big data services. The business layer manages the entire IoT system, as it includes applications, business models and rules, as well as the rules for user privacy(Almela 2023).

The transport layer is just a layer that transfers the sensor data coming from the sensing layer and is delivered to the processing layer. The transport layer uses a network scheme and interconnectivity to perform this task, and the network scheme can be wireless, GSM, 3G or 4G, wired network, Bluetooth, RFID or NFC. On the other hand, Ning & Wang. propose a six-layer architecture, which is based on the processing scheme of the human brain, which generates the ability in human beings to think, remember, feel, make decisions, etc., according to the reactions caused by the environment or physical environment. This six-layer architecture is organized into three parts. The first, analogous to the human brain, is data processing and management. The second part is the backbone, similar to a network of nodes that perform distributed processing and smart gateways. The third is a nervous system comprising network components, including sensors(Bigliardi, Bottani et al. 2023).

4. Technologies

The IoT was initially inspired by members of the RFID (Radio Frequency Identification) community who considered the possibility of discovering information about tagged objects by scanning internet addresses or entries in a database related to particular RFID or NFC technologies. Given the ubiquity of computing, where digital objects can be uniquely identified and are also capable of interacting with other objects to collect data and automate actions that require a combination of technologies, among which the key technology is RFID that, allows the creation of uniquely identifiable objects, additionally, given their size and cost, makes it feasible to integrate or embed them in objects. The architecture defined in the IoT based on a service-oriented architecture (SOA) will allow defining of each of the different technologies used within one of the 4 layers defined in the IOT to understand how the enabling technologies and the technologies are related difficulties in each layer(Chen, He et al. 2023).

In the context of IoT and SWOT architectures, the perception layer of SWOT is similar to five sense organs that interact. It is responsible for perceiving all kinds of physical events and then sending this data to the control plane for further processing. A number of technologies can be used to define IOT, but the four main technologies that can be understood as IOT are the following

1. (RFID) Radio Frequency Identification

2. (NFC) Near Field Communication

3. (MtoM) Machine-to-Machine Communication 4. (VtoV) Vehicle-to-Vehicle Communication

4.1. Radio Frequency Identification (RFID)

The data stored on the RFID tag is used to identify the object it is attached to. This identification process is done through the use of a unique identifier, which is usually a number or a code. This number is used to identify the object and allows the interrogator to access the stored data on the tag. There is a possibility for the characteristics associated with the "things" in a database to be stored and updated in real-time to meet the needs of different applications regarding data management. (Garcés-Giraldo, Patiño-Vanegas et al. 2023).

Most RFID systems consist of tags that are attached to the objects that are required to be identified. Labels can be read-only or rewritten depending on their internal memory and the type of application for which they are designed. The label can store information about a product, such as the serial number, the date of manufacture or some other important information(George and George 2023).

An RFID reader generates high-frequency electromagnetic fields with a range that activates the tags of objects within that range. As a result, communication is established between the system's main components, the tags and the reader. This generates large amounts of data controlled through filters that supply chain companies use to route to back-end information systems(Govindan and Arampatzis 2023).

4.2. Near Field Communication (NFC)

NFC technology is a short-range half-duplex communication technique that Philips and Sony developed at the end of 2002 for the purpose of establishing a communication link between sender and receiver with no physical contact between them. NFC technology uses radio signals to transmit data between two electronic devices over a short distance of up to 4 cm. It is widely used in contactless payments and mobile phone-to-device communication. In order to produce good results with this form of wireless communication between the transmitter and receiver, the concept of inductive coupling between the two devices is used as a central organizing principle. NFC communication may also take place between two or more smartphones. In addition, the use of an NFC tag allows for the possibility of communication with other NFC-enabled devices. The reader/writer mode, the point-to-point mode, and the card emulation mode are shown in Figure 3 as three distinct working modes. On the left-hand side of the diagram, you'll see these several modes. When naming each of these modes, it was important to consider the kind of communication that takes place between NFC devices when they are brought into close contact with one another. Through the use of NFC tags, it is possible for communication to be established not only between an NFC tag and a smartphone but also between an NFC reader and a smartphone while operating in this mode of operation. It is also possible for this communication to go in the other way. There is also the possibility of communication going in the other direction, from an NFC reader to an NFC tag. This may take place. In addition to this, it is possible to establish a connection between a smartphone and an NFC reader provided that the reader is equipped with the necessary hardware.(Gupta 2023).

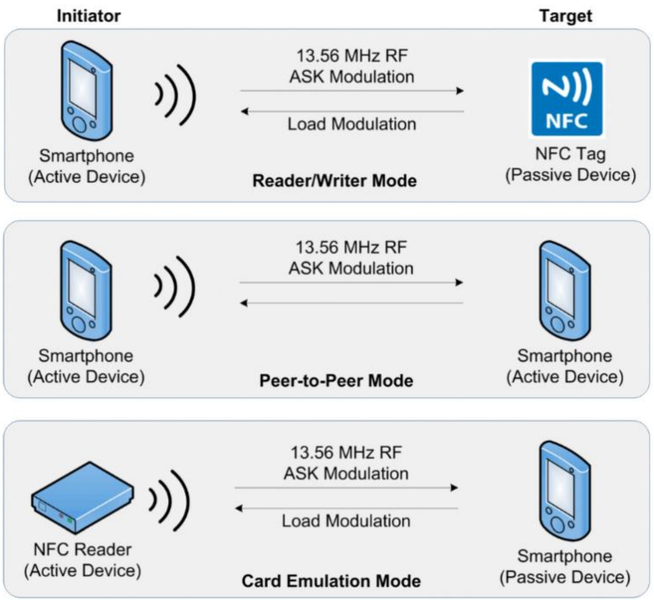

Figure 3 Styles of interaction and modes of operation of NFC

There are 3 communication models for NFC devices

1. Read/Write communication model.
2. Point-to-Point Communication Model.
3. Card Communication Model.

4.3. Communication Model Read/Write

In the read/write communication operating mode, an IoT device initiates communication as an active device and can read and write to an NFC tag. NFC tags are a type of passive RFID tag.

4.4. Point to Point Communication Model

In peer-to-peer communication mode, IoT devices exchange data through a two-way connection. In this way, the devices exchange data collected from the sensors.

4.5. Card Communication Model

In the card emulation communication model, the device is brought close to an NFC reader and behaves like a smart card with the NFC tag, achieving interaction with the SE.

4.6. Machine to Machine (M2m) Communication Model

The Machine-to-Machine (M2M) communication model typically refers to the exchange of information between computers, mobile devices, embedded processors, smart sensors, and actuators, whether or not a human is in the loop(Hayat, Shahare et al., 2023). This model has enabled the emergence of the Internet of Things (IoT) and has enabled a wide range of applications, from connected homes to smart cities and autonomous vehicles. M2M communication can be used to increase operational efficiency, reduce costs, and improve customer experience. As a result of two observations, the logic behind M2M communications can be summed up as follows:

1) A networked machine is more valuable than an isolated one;

2) The precept that the more machines are interconnected, the more autonomous and intelligent applications are generated.

The impacts of M2M communications will increase continuously in this decade, according to previous predictions (Khurshid, Danish et al., 2023).

Machine-to-machine communications, often called M2M communications, are comprised of three primary components: a cloud, an infrastructure, and swarms of individual devices. It's possible to refer to a big number of machines as "swarms of machines," which is a term that may also be used to describe an ocean that's teeming with various sorts of electronic gadgets. A collection of connected computing devices that can communicate with one another and with a cloud is referred to as a swarm. All of these gadgets are connected to one another in some way. The machines can collaborate on the processing of data and exchange information with one another as a result. Because of this, it is possible to carry out activities in a manner that is more efficient and to have a greater grasp of the environment that is all around you. This kind of communication is acquiring an increasingly significant role in today's contemporary world as a direct consequence of the technological advancements that have taken place over the course of the previous many years. A cloud networking system, which typically uses high-speed wired or optical networks to connect data centers, applications and services servers, as well as gateways to and from the cloud, is a method for connecting data centres, servers, and gateways together. There are two types of infrastructure, wired and wireless, that connect the cloud with the swarm or ocean of machines, which can be wired or wireless(Kliestik, Nagy et al., 2023).

4.7. Vehicle-to-Vehicle Communication (V to V)

Wireless data transmissions are part and parcel of V2V technology, which is used to exchange data between motor vehicles. As part of this communication, vehicles in transit will be able to share data about their current position and speed within a meshed network, thus preventing possible accidents (Mijwil, Hiran et al., 2022).

There are two types of mesh topologies: fully-connected mesh topologies and partially connected-mesh topologies, which are based on a decentralized connection system. Fully connected mesh topologies have each node connected to every other node in the network, creating a single path between two nodes. Partially connected mesh topologies have nodes connected to only some of the other nodes in the network, creating multiple paths between two nodes. In the first case, each node in the network can be directly connected to other nodes in the network. A second case in which some nodes can be connected to all the others, while the rest are only connected to the ones with which they are most likely to exchange data, is where some nodes can be connected to all the others, and so on. A mesh network can take advantage of this network topology by allowing nodes that are directly connected (single hop, in the case of a fully connected network) to exchange messaging and data with neighboring nodes that are directly connected (cluster, in the case of a fully connected network), or can take advantage of the different routing protocols available. When a partially connected network is used, several hops may occur before reaching the destination. The network structure is also more robust due to the topology that is used in this topology. The routes are calculated in the forwarding tables to ensure that they reach every destination in the event of a collapse or temporary malfunction of a node(Nadkarni, Kriechbaumer et al. 2023).

5. Conclusion

The challenges and opportunities that are given by these technologies include becoming adept in IPv6 and RFID technologies, to establish the large-scale and cross-industry applications. These are only few examples of the challenges and opportunities that are presented. In this period, which some refer to as the "fourth industrial revolution," we are of the belief that the Internet of Things will bring about significant modifications and adjustments in the industry. These developments are expected to take place in the near future.

As part of the follow-up work that we want to carry out, one of our goals is to test the viability of the architecture that we have proposed in an actual industrial context. For instance, we would like to test it in a setting that is involved in smart manufacturing or smart logistics. This will be carried out as an integral component of the job we are scheduled to do. This will be done as a part of the follow-up work that we plan to do. To enhance the information processing layer and offer our clients services that are more intelligent and more tailored to their unique requirements, we wish to research more sophisticated data analysis methods such as machine learning and artificial intelligence. Because of this, we will be able to provide our customers with more knowledgeable services adapted to each customer's specific needs. In addition, we aim to investigate the ethical, sociological, and legal repercussions that the Internet of Things will have on the industry, as well as the potential risks and worries that may emerge with regard to the data's privacy and security. To put it another way, the purpose of this research is to determine

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