IoT Resources and Their Practical Application, A Comprehensive Study

Kumar Saurabh[1], Manish Madhava Tripathi[2], Satyasundara Mahapatra[3]
[1]Research Scholar
Department of Computer Science & Engineering
Integral University, Lucknow, U.P., India
e-mail: kumar.saurabh00@gmail.com
[2]Professor
Department of Computer Science & Engineering
Integral University, Lucknow, U.P., India
e-mail: mmt@iul.ac.in
[3]Professor
Department of Computer Science & Engineering
Pranveer Singh Institute of Technology Kanpur, U.P., India
e-mail: satyasundara123@gmail.com

Abstract— The Internet of Things (IoT) has become a paradigm shifter, connecting an enormous number of smart devices and facilitating seamless data exchange for a diverse array of applications. The availability and effective use of the IoT ecosystem's resources are key factors in determining how its practical applications will develop as they mature. The IoT resources and their practical application across several areas are thoroughly explored in this paper. The paper begins by classifying and describing the various sensor types, their applications in various fields, and IoT resources, highlighting their contributions to real-time data collection, processing, and transmission. It then goes on to demonstrate a wide range of real-world uses for these resources, such as smart cities, education, agriculture, business, healthcare, environment monitoring, transportation, and industrial automation. However, utilizing IoT resources effectively is not without difficulties. Critical difficulties such as resource allocation, scalability, security, interoperability, and privacy concerns are identified and discussed in the paper. Furthermore, the paper also highlights future directions and emerging trends in IoT resource management, including edge computing, cloud computing, human machine integration, and compatibility with other systems. These developments aim to increase the dependability of IoT applications in diverse settings and optimize resource allocation. This paper's conclusion highlights the crucial role that IoT resources play in advancing real-world applications across a variety of areas. Researchers, practitioners, policymakers, and other stakeholders may collaborate together to effectively leverage the full potential of IoT resources to build intelligent, effective ecosystems that meet the needs of contemporary society by solving difficulties and utilizing developing trends.

Keywords- Internet of Things (IoT), resources, practical applications, sensors, automation.

I. INTRODUCTION

The Internet of Things is described as an interconnected computing system. These systems may be computing devices, machines, different objects, or living beings. Such objects are provided with unique identifiers so that they can transfer data over a network without any human-to-human or human-to-machine intervention. It is an ecosystem of interconnected physical objects that are within reach of one another through the internet. IoT encompasses any object with an IP address that can automatically collect and transmit data over a network without any human intervention. Smart devices and their objects are connected to a network and function more efficiently, so they can be accessed remotely. In 1999, Kevin Ashton coined the term "Internet of Things (IoT)". In 2005, this term was formally introduced by the International Telecommunication Union (ITU) [1]. Henceforward, this term is localized, and a lot of work has been started by numerous researchers, developers, and industries in this field. IoT is the next big development in internet technology. It is a rapidly growing network that will have the potential to transform human lives if it is allowed to thrive.

II. REVIEW

Developing-country governments are now focusing on smart activities in their countries. The first step to making a country smart is to make every city smart, which requires making every home, farm, and business premises smart as well. Smartness describes how a house, farm, or business premises interacts automatically with human behavior. This automation is only possible with the help of sensor-based devices. A growing number of devices are expected to become part of the Internet of Things, including home appliances, medical infrastructure, medical devices, consumer goods, mobile phones, wearables, and different sensors [2]. As a result, innovations are being created that improve the quality of life of people and organizations by enabling novel interactions between things and people and enabling the development of smart infrastructures, cities, and services [3]. Over the course of time, on a worldwide scale, the industrial sector has been marked by disruptive innovations that have resulted in significant transformations in production and its associated procedures [4, 5]. In fact, three industrial revolutions known as Industry 1.0, 2.0, and 3.0 have occurred and are still occurring in various industries [6].

The first industrial revolution, which began near the end of the 18th century, was characterized by mechanical production facilities powered by steam and water [7]. Industrial products exploded in quantity and diversity during Industry 2.0, which lasted from the turn of the 20th century until the 1980s [6]. Since the 1970s, the third industrial revolution has been in progress. This revolution led to a significant digitization wave and described the use of electronics and information technology (IT) in factory automation. Processes in Industry 3.0 were automated using data and logic processors. There is still a human element involved even though these processes frequently operate for extended periods of time without human intervention. This digital tsunami thus paved the way for Industry 4.0, or the Fourth Industrial Revolution, to begin in the year 2011 [8, 9]. The concept of Industry 4.0 as a whole was first introduced by the German government's initiative to change industrial production paradigms toward a digital future and increase the manufacturing sector's competitiveness [10, 11]. Industry 4.0 uses state-of-the-art Information and Communications Technology (ICT) to increase the degree of digitalization and automation of production, industrial operations, and manufacturing. The primary objective of this initiative is to effectively oversee the entire value chain process, enhance operational productivity within the manufacturing sector, and deliver goods and services of superior quality [12, 13]. This global movement involves a number of technologies: cloud computing, big data, augmented reality (AR), additive manufacturing, cyber-physical systems (CPSs), autonomous robots, 3D printing, simulation, system integration, and electric vehicles are some of the concepts that fall under the umbrella of the IoT [14]. The connectivity of objects and people as well as their information exchange are made possible by IoT technologies, which are among the most well-liked and frequently used for building smart environments based on RFID, sensors, actuators, and mobile phones [12, 15].

The concept of Industry 4.0 encompasses the integration of the virtual and physical realms, alongside the implementation of the IoT. CPSs, which combine computational and physical processes, allow for this unification [16]. With CPSs, it accelerates the digitalization of production along whole industrial value chains. These interconnected networks of people and robots cooperate and communicate while exchanging and analyzing information [7]. The promised production paradigm has been particularly detrimental to the automotive and industrial sectors because of Industry 4.0 [17].

IoT accounted for 13% of all business in 2014, but it was predicted that by 2019 it would account for 25% [18]. According to a report released in November 2019 by Statista Research Development, there will be 75.44 billion connected IoT devices worldwide by 2025, a five-fold increase over the current estimate discussed in [18]. McKinsey estimates that in 2025 IoT will have a gross economic impact ranging from $2.7 trillion to $6.2 trillion, according to its report on IoT [18]. According to research, the IoT will generate $11 trillion in annual revenue and operational savings by 2025, which is equivalent to about 11% of the global economy and one trillion IoT devices deployed by the aforementioned users [3]. In their efforts to make daily life for their citizens better, governments are embracing Industry 4.0 and other forward-thinking technologies. IoT can be crucial in these sectors because it enhances process monitoring, produces insightful insights and recommendations for decision-making, and even starts actions through actuation. The emphasis on data-driven manufacturing practices in Industry 4.0 has had a big impact on the manufacturing environment [19]. Transportation, healthcare, manufacturing, and retail are just a few of the sectors that have used IoT devices, and the list of sectors keeps expanding [19].

III. WORKING OF SENSORS AND ITS CLASSIFICATION

A. Sensor

IoT connects all objects, both living and nonliving, and leads to revolutionary changes. IoT's primary goal is to make the user's life more convenient and dynamic. Numerous intelligent things, objects, and devices are linked together using various types of network media, which has significantly increased the number of these objects in the IoT space and enabled them to act intelligently. The utilization of numerous tools and technologies [20], such as sensors, radio-frequency identification (RFID), near-field communication (NFC), and various embedded computing devices, has enabled objects that can be enabled with IoT technology to be embedded with smart competencies. The advent of IoT technology has enabled individuals to enjoy pervasive connectivity and intelligent services. At present, there exists a broad range of intelligent application deployments, which in turn presents a diverse array of economic opportunities. [20]. IoT is made up of a variety of components, such as the cloud, mobile devices, AR-VR, sensors, RFID, NFC, and AI [21]. Additionally, IoT-based networks provide a range of cognitive services, which is what gave rise to cloud-based IoT networks [22]. RFID (Radio Frequency Identification Devices), a rapidly developing technology that enables automatic identification of goods with RFID tags, is used by a variety of resource-constrained devices in IoT to interact in the network. An antenna-equipped integrated circuit makes up these RFID tags. Fig.1 demonstrates how IoT functions by utilizing multiple technologies, such as RFID, which detects and records data

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about objects. In order to identify physical changes in objects, sensors gather and process data. Smart technology increases network strength by expanding network capabilities, while nanotechnology allows tiny entities to communicate and collaborate with other network nodes [23].

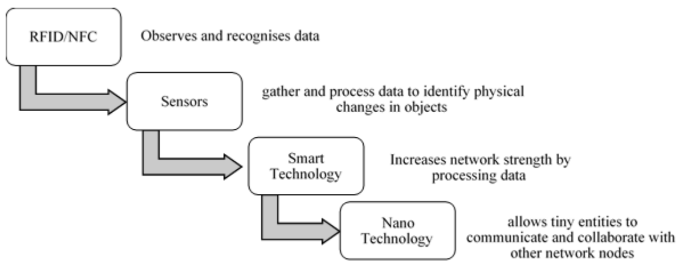

Fig 1. IoT functions utilizing multiple technologies

B. *Working and classification of Sensors*

A sensor is defined as a mechanical, modular, or subsystem entity that is designed to perceive alterations and events within the surrounding environment. These updates are then communicated to a wide range of devices, the majority of which have some type of computer processing. Every sensor requires an accompanying electrical device.

To find out if a certain physical quantity exists, the sensor takes a physical parameter and turns it into a signal that can be analyzed. (e.g., mechanically, optically, or electrically) [24]. Fig. 2 shows the working of Sensor.

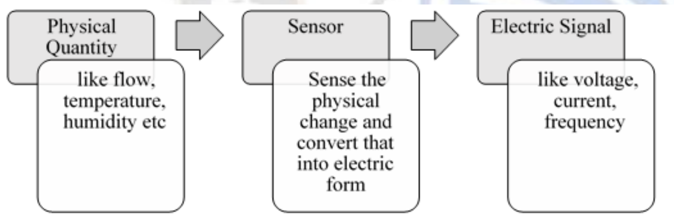

Fig 2. Working principles of sensor

Sensors are classified in various ways by experts and academicians. The first categorization separates the sensors into Active and Passive groups; the second categorization separates the sensors into Analog and Digital groups; and the third categorization separates the sensors into Scalar and Vector groups [25].

Classification of sensors

- Passive and Active
- Analog and Digital
- Scalar and Vector

Passive Sensor: Passive sensors do not need any additional power supply/energy source, and they produce their own electric signal directly or makes an electric signal in reaction to a stimulus from the outside. Example: Electric field sensing, thermal sensors, and metal detection sensors [25].

Active Sensor: Active sensors require an external excitation signal or power signal in order to function. Example: laser altimeter sensors, sounders, and radar [25].

Analog Sensor: An analog sensor's response or output is a continuous function of one or more of its input parameters. Example: analog pressure sensor, LDR, temperature sensor, and analog hall effect [25].

Digital Sensor: A digital sensor exhibits a binary response. Digital sensors are specifically engineered to address the limitations associated with analog sensors. In addition to the analog sensor, the device incorporates supplementary electronic components for the purpose of bit conversion. Example: digital temperature sensor (DS1620) and passive infrared (PIR) sensor [25].

Scalar sensor: The scalar sensor exclusively detects the input parameter by considering its magnitude alone. The response of the sensor is dependent on the magnitude of a specific input parameter. The direction of the input parameters does not affect the output.

Example: gas, temperature, color, strain, and smoke sensors [25].

Vector Sensor: A vector sensor's output is proportional to the input parameter's magnitude, direction, and orientation. Example: gyroscope, accelerometer, motion detector, and magnetic field sensors.

IV. TYPES OF SENSORS AND THEIR USES

A. *Types of Sensors*

1) *Smoke Sensors*

A smoke sensor is capable of detecting the presence of smoke and calculating its concentration in the air. They have been there for a long time since they are linked to a system that instantly notifies the user of any concerns that arise across different industries, but thanks to the growth of the IoT, their effectiveness has increased considerably. Smoke sensors are commonly employed in various industrial sectors, lodging facilities, ventilation systems, and construction sites for the purpose of detecting potential safety hazards. Due to its overall superior performance compared to earlier ones, it protects those who operate in dangerous locations [26, 27, 28].

2) *Level Sensors*

A level sensor measures how much fluid, liquid, or other material is flowing in a closed or open system [29]. These sensors have applications throughout various sectors. Industries that are involved in the handling of liquid substances commonly employ these sensors, which are widely recognized for their ability to accurately measure liquid levels. Industries that deal with beverages, juice, oil, and other liquid materials use these sensors to monitor their liquid assets [30]. As sensors always gather relevant data, they can streamline processes. Dams, water reservoirs, sea level detection, high or low tide, tsunami warning, medical equipment, liquid levels in containers, beverage, juice, oil, and pharma industries are the best use cases [30].

3) Infrared (IR) Sensors

An infrared sensor either emits or detects infrared light in order to identify specific characteristics of its surroundings. Additionally, it is able to detect the heat emitted by objects. Now a days, these sensors play a vital role in a variety of IoT devices in the healthcare industry as they can monitor blood flow and blood pressure in body easily. These sensors can also be used in home automation [31], waste collection System [32], smart security [33], smart watches [34].

4) Proximity Sensors

By utilizing a proximity sensor, it is possible to swiftly identify the presence and location of nearby objects without the need for direct physical contact. The detection of an object is accomplished by examining any variations in the reflected signal subsequent to the emission of electromagnetic radiation, specifically infrared. Numerous types of proximity sensors, including photoelectric, inductive, capacitive, ultrasonic, magnetic, and others, are available and are used for various purposes and use cases. The utilization of this sensor is predominantly observed in applications that prioritize both efficacy and safeguarding measures. One prominent and firmly established application pertains to automobiles. The proximity sensor serves to alert drivers of vehicles during the process of reversing when an obstruction is detected. This sensor has several other applications too, including detection of objects, measuring rotation, placing objects, counting nearby objects, detecting materials, calculating movement direction, and determining the parking spaces accessible at venues like shopping centers, stadiums, airports, and similar establishments [35, 36, 37].

5) Water Quality Sensors

The importance of water is universal. These sensors are crucial because they are used to monitor the quality of the water for a range of applications and are used for ion monitoring. There are several reasons why these sensors are utilised in water delivery systems, Concerns that need to be resolved are, for example, that in low pressure areas, leaking pipes allow contaminated water to seep into the water supply, contamination from cross-connections with non-potable water, or microbiological development in the distribution network [38, 39]. Researchers in [40] introduced a novel framework that monitor the water quality in an IoT setting for detecting dissolved oxygen, temperature, PH, turbidity, and conductivity, all at reduced cost.

6) Pressure Sensors

In many different devices, liquid or other types of pressure are utilized. The sensors enable the realization of IoT systems for monitoring pressure-driven systems and equipment. The system administrator is notified of any issues that need to be fixed whenever there is a deviation from the established range of pressure values. Due to the ease with which pressure changes or drops can be detected, these types of sensors can be used in the healthcare industry [41, 42].

7) Temperature Sensors

Temperature sensors are used in various forms in various sectors, like in the agricultural sector, where soil temperature plays an important role for proper crop growth [43, 44, 45], while in the healthcare sector, various types of temperature sensors are used, for example, body temperature sensors, and various atmospheric sensors are used to maintain the required temperature of various devices in ICU and critical care units, equipment, and medicines, while the manufacturing sector also requires such sensors as a defined temperature is required to maintain for the operation of machines, furnaces, and the storage of products [46,47].

8) Chemical Sensors

Chemical sensors are used to measure the composition of various chemicals or chemical changes in the environment. These sensors respond by sensing the presence of any chemical, a chemical reaction, or a mix of chemicals. In smart cities and coastal areas, a network of wireless chemical sensors is used to monitor the release of harmful chemicals in rivers, various other water bodies, and the sea. [48, 49] These sensors are widely used by pharma industries, labs, pathologies, and international space stations, to detect the release of harmful chemicals [50].

9) Gas Sensors

Gas sensors, akin to chemical sensors, serve the purpose of monitoring air quality and detecting the existence of diverse gases within the atmosphere. [48]. Various sectors like mines, rubber, petrochemical, paint, and plastic manufacturing units use this sensor to identify the presence of hazardous, toxic, or combustible gases [50, 51, 52].

10) Humidity Sensors

Humidity sensors measure air moisture, these sensors are widely used in sectors like agriculture [45], pharmaceuticals, hospitals, cold storage, and the preservation of archaeological items in museums. These are used to sense the quantity of water vapor present in the atmosphere, so that the system can control heat, air conditioning systems, and ventilation [53, 54].

11) Optical Sensors

Optical sensors are capable of detecting light rays and subsequently converting them into electrical impulses. These are often employed in IoT applications, such as in digital cameras, because they are passive to many kinds of electrical interfaces. These sensors are used in various sectors like energy, healthcare, aerospace, chemicals, oil, and gas [55].

12) Accelerometers or Velocity Sensors

The velocity sensor figures out quickly how position values change at predetermined intervals. A device's speed can be measured using an angular velocity sensor and a linear velocity sensor. The angular velocity sensor is responsible for detecting the rotational movement of the device, whereas the linear velocity sensor is designed to quantify the speed of an object along a straight path. These sensors are used for vehicle monitoring [56] and road surface monitoring [57]. They have become so widespread that they can even be found in smart phones and other mobile devices like watches, smart pedometers, and fitness bands. They are used in various sectors like automotive, health, sports, consumer products, aviation, and flight to detect movement, vibration, vehicle control, free fall detection, and smart city traffic control [58].

13) Gyroscope Sensors

Gyroscope sensors measure the angular velocity to determine the object's angular movement. Its main use is to track an object’s orientation. It is widely used in vehicle navigation systems, gaming, sportsperson training, mobile phones, camera devices, robotics, and drone or UAV controls [59, 60].

14) Image Sensors

Once optical images are converted into electrical signals by image sensors, they have the capability to either show or store these signals. In digital cameras, the image sensor also acts as the focusing mechanism. Applications for image sensors include digital cameras, imaging devices for use in medicine and night vision, thermal imaging devices, radar, sonar, biometrics, IRIS systems, etc. [61, 62].

15) Motion Detection sensors

A motion detection sensor is capable of perceiving physical motion within a given space and subsequently converting the resulting kinetic movement into electrical energy. It can detect any type of movement where no movement should be observed, and these sensors just make this invigilation simple by detecting any type of motion if it occurs, capturing movement, and uploading images and videos on the server. Security agencies are heavily dependent on them [63]. These sensors are very common now in household security, for business premises, sports [64] and for detecting the presence of cattle in farm fields [65]. Automated sinks and flushes, hand dryers, lights, parking, toll plazas, boom barriers, etc. are the most common examples now.

B. Uses

TABLE I. USE OF IOT SENSORS IN VARIOUS IOT APPLICATIONS

IoT Applications	Type of Sensors
Smart Home	Light, temperature, motion, infrared, proximity, Biosensers, chemical, smoke, humidity
Smart Premises	Light, Accelerometer, chemical, water quality, chemical, air quality, smoke, image
Smart Security	Light, IR, optical, motion, Accelerometer, proximity
Smart health & fitness	Chemical, pressure, IR, Temperature, Biosensers, proximity, position, gyroscope
Smart Agriculture	Light, smoke, chemical, gas, humidity, level, image, motion, optical, water quality
Smart Irrigation	Smoke, Gas, humidity, IR, water quality
Smart Environment	Humidity, Gas, Temperature, Bio sensors, Chemical, optical, water quality
Smart Transport	Gyroscope, Motion, Pressure, proximity, smoke, Temperature, Accelerometer, Image
Smart City []	Accelorometer, Light, optical, image, smoke, gas, water quality, temperature, IR, humidity
Smart education	Optical, image, motion
Smart business	Biosensors, Light, temperature, optical, image
Smart factories	Light, Smoke, gas, chemical, humidity, water quality, IR, temperature, gyroscope, motion
Smart shops	Light, optical, image, motion, proximity, temperature
Smart disaster management	IR, gyroscope, accelerometer, smoke, chemical, gas, optical, motion, image, bio sensors
Smart financial institutions	Biosensors, Light, motion, optical, image, IR
Smart administration	Chemical, light, gas, optical, accelerometer, motion, image, gyroscope, bio sensor
Smart surveillance	Accelerometer, Gyroscope, proximity, light, GPS, Bio sensor, Motion, LiDAR

V. IOT APPLICATIONS AND THEIR USE CASES

The Internet of Things (IoT) is the most comprehensive representation of the interconnected network of devices that have the ability to collect and distribute information. These devices often engage in communication with each other using the internet protocol (IP). Now IoT is extended as the Internet of

Everything (IoE) to connect network devices along with data, peoples, and processes. The next extension is the Internet of Nano Things (IoNT) which uses NanoTechnology to connect objects at nano scale. Disaster management, Rescue operations, battlefields, and other critical missions uses Internet of Mission-Critical Things (IoMCT), is the next evolution thereof, and the devices equipped with integrated mobile sensors establish communication among themselves through the Internet of Mobile Things (IoMT) [66].

Different types of sensors, actuators, and microcontrollers are used to build up an IoT environment, Various scientists are developing new sensors and different devices every day, and various researchers are developing new ideas to use these devices to make the environment smart than smarter by integrating IoT devices with various other technologies like blockchain, Artificial Intelligence, Machine learning, cloud computing, etc. and by applying new algorithms to boost performance and utilize these devices more efficiently. In this section, we present some of the applications.

- *Smart Home*
    - Intelligent Electrical Appliances
    - Daylight harvesting sunroofs
    - Water and electricity usage reminders
    - Intruder detection
- *Smart Premises*
    - Premises access control
    - Air quality monitoring
    - Unauthorized access of restricted zones
- *Smart Security*
    - Hazardous gas leak detection
    - Radiation level detection
- *Smart Health and Fitness*
    - Smart band to track patient health
    - Control medical devices
    - Sleeping habits
    - Workout positions
- *Smart Agriculture*
    - Soil quality indications
    - Weather station networks
    - Green house networks
    - Motion based cattle identification
- *Smart Irrigation*
    - Smart Tank occupancy system
    - Sprinkler Systems
    - Humidity maintenance system
- *Smart Environment*
    - Air pollution indicators
    - Ground water harvesting system
- *Smart Disaster Management*
    - Forest fire detection
    - Landslide, river flood and earthquake alarm
- *Smart Transport*
    - Road quality
    - Breakdown and SoS service
- *Smart City*
    - Smart traffic management
    - Vehicle positioning system
    - Smart metering system
    - Smart waste management
    - Smart parking
    - Smart lighting
- *Smart Factories*
    - Autonomous production units
    - Worker safety
- *Smart Education*
    - Automated attendance system
    - Safety in Premises
- *Smart Shops*
    - Customer centric habit based advice
    - Discount offers

A. Smart Home:

To establish a smart environment at home, sensors are attached to various objects. This allows for the intelligent on/offing of appliances, reminding people to limit their use of water and electricity, as well as the detection of intruders. This is accomplished through providing warnings, which lead to a better way of living.

An intrusion detection system was presented by the authors in [67] that sends the owner a notification when it detects motion at the door.

B. Smart Premises:

Sensors and alarms provide the capability to establish an intelligent boundary surrounding designated regions, so facilitating access control for premises, monitoring air quality, detecting smoke and fire hazards, and alerting against the presence of unauthorized individuals in restricted zones.

C. Smart Security:

In order to uphold environmental security, the installation of sensors might be implemented across several sites. Sensors may be cleverly used to detect things like elevated amounts of hazardous gases or radiation levels, and leaks. Where there is a risk of leaking, such as in factories, workshops, mines, and industries [67, 83].

D. Smart health and fitness:

In the context of smart health or e-health, patients can wear sensors at home, at work, or when they are in hospitals. These sensors track a person's health and, in the event of any abnormalities, transmit notifications to the appropriate parties.

Nowadays, at hospitals, doctors use smart bands worn by patients to aid treatment. Sensors can be used to monitor elderly patients' vital signs, administer vaccines, control medical devices, and monitor organic substances. Individuals may receive cautionary advice regarding their detrimental behaviors and health conditions.

The wearable sensor proposed by the authors in reference [68] is designed to monitor physiological parameters. A NIGHTCare platform is suggested by [69] to track patients' nightly anomalous events while they are receiving treatment in a hospital. A wearable smart shoe insole was suggested in a study in [70]. It measures the wearer's body temperature and humidity through the shoe insole. A low-cost model for suburban regions and rural areas health care monitoring is given in [71].

E. Smart Agriculture

Sensors are commonly employed in many agricultural applications for a variety of functions, such as automatically applying pesticides and water to crops, keeping track of weather patterns, and measuring soil moisture levels to determine how much watering is necessary based on the temperature and air humidity.

The authors propose a model that measures soil pH, soil moisture, humidity, and moisture in the air in [72]. In [73], drone technology was used for intelligent agriculture. A sensor can be used to identify the presence of cattle in the field [65].

F. Smart Irrigation:

An intriguing topic in developing smart agriculture is intelligently sensing humidity and temperature conditions to avoid the growth of fungus and other microbial pollutants.

The authors in [74] provide a presentation on water sprinkling in IoT agriculture. The quantity of water used is reduced by simply sprinkling in dry areas.

G. Smart Environment:

Environment monitoring is becoming more popular and difficult all across the world. The monitoring and regulation of poisonous and dangerous gas emissions from companies and automobiles can be done with the help of sensors. Sensors can also help in monitoring ground water harvesting. If handled quickly, this can greatly safeguard the environment.

Researchers present a few of these applications in this field in [75].

H. Smart disaster management

It is feasible to identify danger for any landslide or earthquake well in advance by monitoring density in the soil, earth vibrations, and other factors.

It is fundamentally necessary to keep track of the water level in rivers, dams, and reservoirs and how it occasionally varies.

When sensors keep an eye on the conditions that could lead to a preemptive fire and the combustion gases, alert zones can be set up and timely warnings can be issued [75].

I. Smart Transport

The implementation of vibration monitoring techniques can contribute to the enhancement of shipping conditions in terms of quality. GPS-like devices make item tracking simple [76]. The same devices can be used for breakdowns or emergency SOS services.

J. Smart City

Real-time suggestions and route optimization for both drivers and pedestrians are possible using traffic and congestion monitoring on every route.

Vehicle positioning systems can be utilized with GPS-enabled vehicles and monitoring systems [76].

Smart meters can be used to intelligently monitor a variety of characteristics, including energy consumption, oil, or gas levels, and solar energy plants. Monitoring various metrics and adjusting controls accordingly greatly improves performance [77].

Monitoring and carefully parking vehicles in the city by locating appropriate parking places is the responsibility of the smart city's smart parking system.

Depending on the weather and other factors, such as when a car passes through a road, street lights are turned on or off. Utilizing adaptive lighting allows for significant energy savings [77].

By determining the amount of waste in various containers, waste container collection routes can be made more efficient.

K. Smart factories

Within the context of Industry 4.0, a smart factory can be defined as an advanced manufacturing facility characterized by a significant level of automation, wherein state-of-the-art technologies such as AI, IoT, and robotics are employed to enhance quality, productivity, and efficiency.

Smart factories are establishments that use advanced technologies to raise operational effectiveness and productivity [78]. Such factories are highly automated, networked facilities that rely on cutting-edge technology like robotics, IoT, and AI to streamline production processes and boost operational effectiveness [79].

IoT devices can be used to keep an eye on employee safety, ensuring that staff members are adhering to safety procedures and that any potential hazards are found in any machinery or equipment [80, 81].

L. Smart education

The IoT is significantly transforming the education sector and making it possible for educational facilities to become wireless enabled smart learning systems. It is now possible to employ Wi-Fi and sensor technologies to enable intercommunication, total integration, and synchronization processes in new intelligent and smart systems.

Upon students' arrival in the classroom, their attendance can be efficiently documented through the utilization of biometric technology or a barcode system that is linked to their unique identity card number. The likelihood of storage issues or inconsistencies with this method is minimal. [82].

Many educational institutions lack the necessary resources to effectively recognize indicators of abuse, theft, sexual assault, and other related incidents that may occur on their premises. Additionally, these schools often lack a comprehensive emergency response plan. The IoT has the potential to make a substantial impact on addressing these issues. By employing a network system, IoT provides real-time monitoring of camera footage, allowing for immediate response to any detected undesirable actions. This is achieved by displaying the video feed on several screens within the monitored area.

M. Smart Shops

Sensors have the capability to monitor and effectively oversee inventory, transactions, payments, and several other activities within the retail industry. When making a purchase, it is prudent to provide intelligent thoughts and suggestions that are tailored to the individual customer's preferences, behaviors, and other pertinent characteristics [78]. A retail establishment has the capability to transmit promotional discounts or offers to the mobile devices of potential customers by leveraging the proximity of these individuals.

VI. RESEARCH WORK DIRECTIONS

The aforementioned study provides guidance for the upcoming work. The finding supports the assertion that there are still a number of IoT applications in various fields that require additional study. The following list contains a few possible research axes.

A. ***Energy efficiency:*** IoT equipment needs a continual supply of power, which might be difficult in industries with expensive and scarce power sources. To help minimize energy usage and expenses, future research can concentrate on creating IoT devices, networks, and designs that are more energy-efficient [81].

B. ***Edge computing:*** As opposed to transmitting data to the cloud, edge computing processes data locally. This can facilitate real-time decision-making by lowering latency and enhancing response times. The development of edge computing architectures and algorithms that are more effective and efficient can be the subject of future research.

C. ***Security and privacy*:** Security and privacy are major concerns as more gadgets are connected to the internet. To guard against cyberattacks, data theft, and other hazards, research might investigate fresh methods of safeguarding IoT devices and networks. Future research might concentrate on creating safe and private IoT infrastructures for various domains [83].

D. ***Adaptive bandwidth usage:*** IoT devices if consistently use network bandwidth to remain connected with other devices even when not in use, then they require a lot of power to operate and increase traffic in network too [84]. Future research could potentially prioritize the development of a more adaptive algorithm for network bandwidth distribution, with the primary objective of minimizing resource wastage.

E. ***Machine learning and artificial intelligence:*** The integration of machine learning and AI with IoT devices enables domain-specific systems to achieve enhanced levels of intelligence and autonomy in decision-making processes. Future research may focus on the development of AI algorithms capable of acquiring knowledge from data provided by IoT devices. These algorithms would then utilize this knowledge to make informed decisions that optimize operations within certain domains.

F. ***Decision making:*** IoT devices and sensors are utilized by a variety of industries to collect information on different system components so that precise, real-time decisions may be made. In the IoT-enabled industry, decision-making comprises gathering and analyzing data, putting decision-making algorithms into practice, keeping an eye on operations in real-time, and utilizing human experience to make wise decisions.

G. ***Cloud Integration:*** The integration of cloud computing and the IoT within Industry 4.0 has the potential to revolutionize traditional corporate processes, enabling them to become highly automated, data-centric operations that are characterized by enhanced efficiency, flexibility, and user responsiveness.

H. ***Interoperability:*** One significant challenge is in the absence of compatibility among IoT devices sourced from various vendors. The utilization of open standards, protocols, and application programming interfaces (APIs) holds the potential to facilitate the integration of various devices and systems by manufacturers, hence future research can explore avenues for enhancing interoperability.

I. ***Compatibility with other systems:*** It is imperative for every industry to establish integration with a diverse range of other systems. For example, a production facility must be integrated with CRM system, logistics system, and SCM system. Future studies could examine the most effective ways to combine different systems utilized in a field and how to make sure that information is seamlessly transferred from one to the other. :

J. ***Human-machine interaction:*** Humans continue to play a key role in monitoring and managing diverse processes, even as factories, agriculture, city care, medical, and education sectors become more automated. With the help of technologies like natural language processing, virtual reality, augmented reality, and others, research can examine strategies to enhance human-machine interaction.

VII. CONCLUSION

The importance of this study extends to managing IoT resource usage and promoting global sustainability. Numerous industries are automating a variety of processes using real-time data and connected devices. With the help of these procedures, smart factories are improved and production is optimized. Smart Cities benefit from using adaptive lighting systems, detecting environmental pollution, and sending alerts. In smart agriculture, routine testing of the quality of the soil and water as well as automated green houses are used. These are just a few instances that demonstrate how effectively using IoT can increase system efficiency. The implementation of Internet of Things (IoT) technology has the potential to enhance productivity, efficiency, and safety within the workplace. This is achieved by reducing the reliance on human intervention. Additionally, IoT can facilitate the maintenance of high-quality work standards, minimize waste generation, and decrease downtime in the production process across various industries. The IoT has the potential to provide comprehensive insight across the supply chain, allowing managers to track inventory from its origin, through the manufacturing process, and ultimately to the end consumer. It is possible to utilize IoT sensors to keep an eye on environmental variables like humidity, temperature, and air quality in order to safeguard the well-being and comfort of individuals and the surrounding environment. Overall, IoT has the potential to revolutionize the way people live and handle various day to day tasks in business, service, and production sectors by improving efficiency, increasing productivity, and reducing costs.

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