A Detailed Study on the Applications of the Internet of Things

Nithya sukumar*[1], Nithya dorairaj[2] ,Pavithra Devi rameshbabu[3],Monisha kumar[4],Ramya madhavan[5]

[1,2] Associate Professor,Department of ECE, Panimalar Engineering College, India

[3,4,5] UG Students, Department of ECE, Panimalar Engineering College, India

Abstract

Technology plays an important role in today's world due to the recent rapid development of embedded devices and artificial intelligence. The internet has infiltrated every other program. One of the most important inventions of the decade is the Internet of Things (IoT) is a network of connected gadgets. The Internet of Things is critical to the advancement of agriculture, commerce, and healthcare. It is crucial for the future growth of technology and society. It is inextricably linked to today's digitalized world. This paper seeks to provide a thorough examination of IoT integration in society and its application in a variety of fields involving complex networking. The paper concludes with adequate knowledge of IoT architecture, application, benefits, drawbacks, and its future scope.

Keywords: Agriculture; Industrial automation; Health care; Smart grid; Internet of Things.

1. Introduction

The ever-changing technology has forever changed everyone's existence. The Internet is one of the most profound tools ever devised. IoT (Internet of Things) is described as it is, with 'Internet' indicating interconnectedness and 'Things' defining physical objects connected via the Internet. Over the years, the development of IoT has brought about spectacular advances in science and technology. The Internet of Things laid the foundations for the detection, observation, and examination of extant infrastructures, resulting in the formation of a tangent between the physical and virtual worlds [1]. IoT is a development resulting from the massive growth of embedded system development. It has the potential to be extremely helpful in terms of efficiency, data latency, and security [2].IoT is a paradigm that depicts a system of connected devices that interchange data over a communication network. Internet of Things (IoT), the term itself was conceived by Kevin Ashton in 1999[3]. The proposition behind IoT is that “It is the incorporation of people and technology with connectable devices and sensors to enable remote monitoring and analysis”.Pertaining to an article on the future of IoT by the Times of India[4], thetally of connected devices all over the worldwouldbe22 billion by 2025. IoT is used in the sectors of agriculture, and healthcare. IoT does not have any unique description or architecture reference. Some define IoT as a model that consists of all wireless communication technologies such as sensors, and actuators. Each component is called a thing and they communicateutilizingRadio-Frequency Identification (RFID) to perform a specific task [5]. IoT is harnessed by individuals as well as professionals. For a professional, IoTis of tremendous use in the supply chain, logistics, and analytics. For an individual, IoT plays a major role in their healthcare, smart learning, and home automation [6].Section 2 of this paper describes the architecture of IoT. The various applications ofIoT are described in section 3. The future scope of IoT is discussed in section 4.

2. Architecture

The IoT architecture was not predetermined in a consistent manner but changed as IoT development progressed. Article [7] divided the architecture into software-defined network-based architecture and general architecture. Application, transport, and sensing are the three layers of the overall architecture. The application layer is accountable for utilizing intelligent computing techniques to retrieve data from the processing unit and serves as a user-to-IoT interface. Network activities are handled by the transport layer, and information gathering is done by the sensing layer. Z. Qin et al. developed an IoT architecture based on software-defined networks (SDNs) [8] aiming to provide a high-level quality of service (QoS) to the various IoT jobs in diverse wireless network environments. Article [9]'s author, in contrast, declares at the beginning that it has three layers: the perception, network, and application layers. They are the same as the layers listed above. The network layer and transport layer are analogous to perception and sensing, respectively. A five-layer IoT design was then established, consisting of levels for perception, transport, processing, applications, and business layers as time went on and the three-layer IoT proved ineffective. The additional layers processing and business layer are in charge of processing and functioning the entire IoT system respectively.

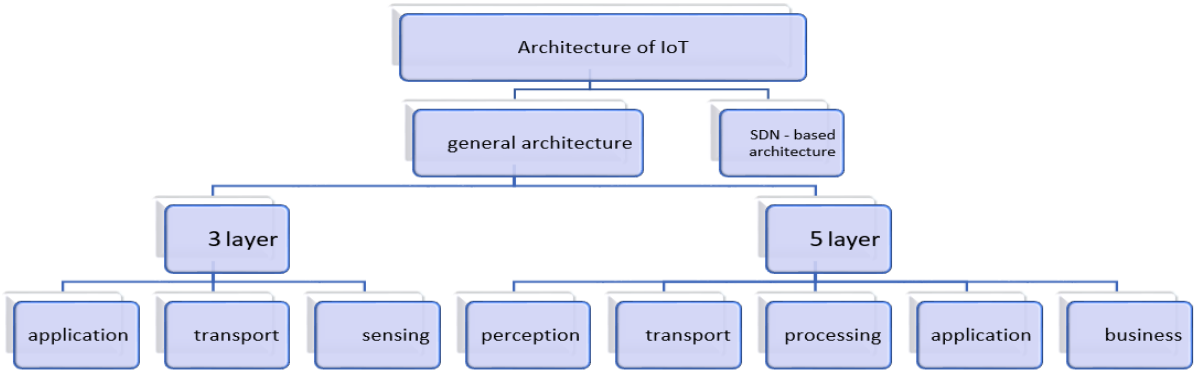

Figure.1: ArchitectureofIoT

3. Applications

Although IoT is still under development, several valuable ones have already found usage in a variety of fields [10]. Those fields are categorized as

1)ConsumerIoT, such as wearable.

2) Enterprise IoT, which encompasses agricultural and industrial automation.

3) Public IoT applications including smart grids, smart cities, and health care.

This article gives a detailed review of these applications.

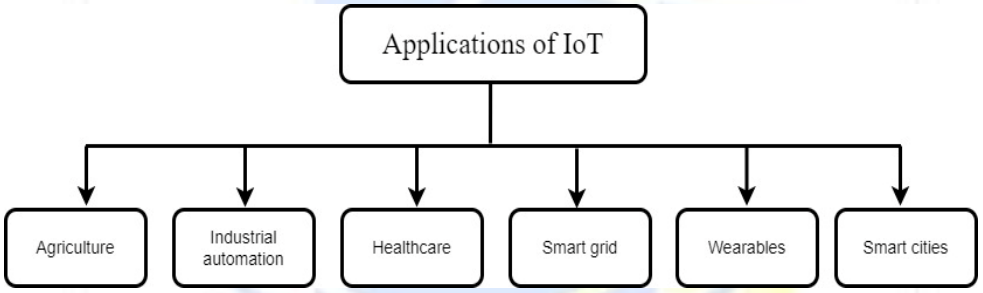

Figure 2: Applications of IoT

A. Healthcare

The use of IoT technology for healthcare purposes is referred to as the "IoT in healthcare." Here, the term "healthcare" refers to the process of enhancing one's bodily and mental well-being through injury prevention, diagnosis, treatment, and cure.In the last three years, there has been a dramatic advancement in the use of IoT in the healthcare industry. These are primarily a result of the current covid pandemic situation. Several IoT applications were more quickly adopted in real life during the pandemic [11]. IoT in healthcare can boost the overall performance of healthcare during the COVID-19 pandemic days as a digitally controlled health management system.

Table 1: Summary of Literature

i)

Ref	Technology	Description
[12]	Smart integrated IoT healthcare system for cancer care	Using cancer care services and business analytics/cloud services, they proposed the implementation of an IoT-enabled medical system for improved treatment, diagnosis, detection, and monitoring of cancer patients, where the business analytics/cloud services serve as enablers for actionable insights, decision making, data transmission, and reporting.
[13]	System for monitoring and supporting the treatment of sleep apnea using IoT and big data	In this work, a unique method to track and direct the treatment of sleep apnea has been put forth by fusing promising technologies including the Internet of Things, fog computing, cloud computing, and big data. The system takes advantage of the various benefits that the integration of these technologies brings.
[14]	Provide accurate information regarding the motion of bones	IoT uses different types of applications to provide motion and related information about the bones It provides daily progress of patients to physiotherapists
[15]	Telemedicine	Healthcare professionals can treat patients through telemedicine while adhering to government directions to remain in one's home and keep a distance from others.
[15]	3D-Printing	A rapidly evolving sector called three-dimensional printing can help with the design of healthcare devices and more readily and cheaply supply necessary materials.

Implementation of IoT in healthcare

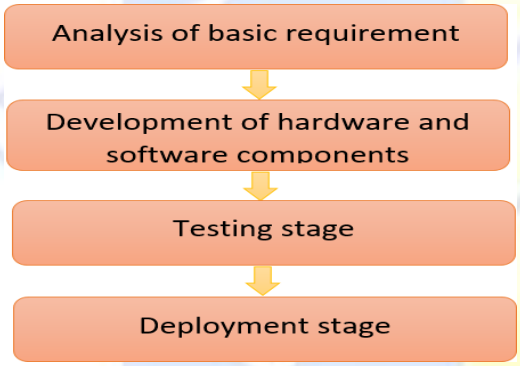

Figure. 3:IoT implementation in healthcare

ii) Advantages of IoT in healthcare

a) Scalability: With a mobile application, the patient's health can be tracked and saved on a cloud platform that can be accessed from anywhere using the internet.[16]

b) Storage: Big data technology allows for the storage of enormous amounts of clinical data. [17]

c) IoT for Smart Medical Implants: IoTeHealth holds great potential for implantable medical devices, which are highly advanced, portable, and trustworthy systems put inside the body to improve or restore human functions.

d) IoT medication: Combining wearable acoustic sensors, smart pill bottles, and categorization techniques allows for a highly accurate assessment of medication adherence.

iii) Challenges in healthcare [16]

a) Data management: Since each application's acquired data must be stored in a different format, managing the data volume requires obtaining the data from the hardware and processing it for the storage format. As a result, a fog administrator manages the data flow between the fog and cloud computing.

b) Security and privacy: Every IoT device has security and privacy as a massive hindrance, but in the healthcare industry it is slightly more sensitive due to the fact that it affects people's lives.[17]

B. Smart Grid

The term "Smart Grid" describes a new era of electricity that generates, delivers, and consumes electricity using information technology. Smart grids can benefit from Internet of Things (IoT) technology by connecting various system functions for energy production, transmission, storage, and distribution, as well as usage. This is done by integrating cutting-edge gadgets to aid interconnection, computerization, and tracking [18] but the definition of a smart grid varies from article to article.[19]

i) Key Technologies

Key communication technology is one of the necessary technologies for the implementation of a smart grid utilizing IoT. Information linked to smart grid devices is sent and received via this [20].The protocol for IoT communication uses 5G, z-waves, Zigbee, Bluetooth, NB-IoT, WirelessHART, GLoWPAN, and LoRAWAN, among other technologies [21].The other technologies include interoperability, intelligence, integration[22], Smart Sensor Technology (SST), and Information and Communication Technology (ICT) [23]

Table 2: Key Technologies of IoT in smart grid

Ref	Application	Protocol	Key technology
[23]	Monitoring of Power Transmission and Distribution	1. wide-range IP protocol/TCP 2. wireless IEEE 802.15.4 Zigbee	1. Smart Sensor Technology (SST) 2. Information and Communication Technology (ICT)
[24]	Microgrid	Network interconnection (IP)	Contains embedded technology to communicate and sense or interact.
[25]	Smart Energy meter.	1. 802.11/ WiFi and variance. 2.802.15.4 PAN for resource – constrained devices. 3.ZigBee. 4.6LoWPAN.	1. Sensing technology. 2. Communication technology. 3.Information technology

ii) Challenges in IoT in the smart grid

a) Energy supply[26]: The integration of IoT in SG as well as energy supply for a variety of devices linked to the network have been viewed as a colossal task ever since the IoT technology was first proposed.

b) Security [26]: The integrity, validity, availability, and secrecy of the protocol's layers are often taken into account when incorporating security risks.

c) Big data management [27]: IoT-SG requires the handling of massive volumes of data, which necessitates a dynamic server. The size of the grid, the variety of connected devices, the need for synchronization and coordination, the management of devices, the interpretation and analysis of data corresponding to various components and devices, and the limitations on data storage are just a few of the management challenges that energy systems must overcome. Utilize energy-saving techniques and tactics.

d) Standardization [28]: In IoT-SG, the various components of the electrical grid get access to embedded sensors that enable them to generate a range of data. To have integrated management, all of the produced data must comply with a single standard. Due to the existence of several operating systems supported or included by numerous large companies, such as Microsoft, Samsung, EBM, etc., it is now challenging to reach an agreement for a global standard

iii) Advantages of smart grid

The Internet of Things and additional digital technologies are used by the smart grid, an enhanced energy network, to increase the efficiency, dependability, and sustainability of power generation and delivery. The following are some benefits of incorporating IoT into a smart grid [29]:

a) Real-time monitoring: IoT sensors can be positioned all over the grid to track energy use, spot possible difficulties, and react swiftly to outages or other problems.

b) Increased energy efficiency: By automatically adjusting the energy supply to match the demand, smart grids powered by IoT technology may help cut waste and boost overall efficiency.

c) Improved dependability: IoT sensors may identify and diagnose possible equipment breakdowns before they occur, enabling maintenance personnel to handle issues proactively and lowering the chance of outages and other disturbances.

d) Better integration of renewable energy sources: By controlling the intermittent nature of renewable energy sources like solar and wind power, smart grids can guarantee that electricity is available when it is needed.

e) Savings: Smart grids can help decrease energy costs for both customers and utility businesses by optimizing energy use, cutting waste, and simplifying operations.

f) Power lines or gas leaks, enabling quick action. The smart grid, an upgraded energy network, uses the Internet of Things (IoT) and other digital technologies to promote efficiency.

C. Agriculture

The term "agricultural Internet of Things" (IoT) refers to a network in which various virtual "objects" in the agricultural system, including physical ones like plants and animals, environmental elements, production tools, and so on, are interconnected with the internet using special agricultural information perception equipment in order to exchange and communicate information. It aims to make agricultural processes and items intelligently identifiable, positioned, tracked, monitored, and managed [30].

i) Major Components of Ag-IoT

a) Sensors: For physical values to be detected and converted into electrical signals that the controller can understand, sensors are essential [31].

b) Platforms and the primary control panel for sensing.

c) IoT protocols and communication technologies.

d) Services and cloud computing platforms.

Table 3: Types of sensors used in Ag-IoT

Ref	Type of Sensor	Function
[32]	Soil moisture sensor	This sensor is used to measure the soil's moisture content.
[33]	PH sensor	This sensor detects the soil's acidity and alkalinity. Which is also used to identify nutritional deficits.
[34]	Sensor for wind speed	This sensor would be employed for the application of Pesticides, and crop harvesting.
[34]	Rainfall sensor	Rainfall and rainfall rate are measured by this sensor.
[35]	NPK sensor	It informsthe farmer when to add fertilizers to the farm.
[36]	Hyper spectral camera	The 400 nm to 700 nm visible, infrared, and UV light spectrums are captured using a hyper spectral camera.

ii) Uses of IoT in Agriculture

a) Scalability [37], Controlling self-driving vehicles and robotics [38], manned and unmanned aircraft [39], and watering systems [40].

b) Forecasting using traditional models [41], models based on ML [42],

c) Tracing: gadgets [39], sensing technology [44], and the supply chain [43]

d) Monitoring is done for ecosystems [45], construction [46], gadgets [47], the climate [48], regulating water [49], the ground [50], and agricultural products [51].

iii) Key challenges and open issues [52]

a) Startup funds.

b) Computing.

c) Cross-cooperative.

d) Network.

e) Reliability.

f) Credibility.

g) Expandability.

h) Governing..

i) Sensor perception technology

iv) Levels in the agricultural IoT architecture [52]

a) User level

b) Application level

c) Transmission level

d) Perceptive level

e) Objective level

v) *Key technologies of agricultural IoT [53]*

a) Sensor perception technology

b) the technique of information transfer technology for information processing

c) Radiofrequency identification

d) 3s technology

D.Wearable Technology

Electronic devices that are physically worn by people in order to track, analyze, and communicate personal data are known as wearable technologies, or simply "wearables."

The most researched wearable IOT application clusters are [54]:

a) Health

b) Fitness

c) Surveillance

d) Welfare

Memory assistance, auto insurance, police and security, personal training, outdoor pursuit navigation, and health care (body temperature, sleep quality assessments, heart rate monitoring, etc.) are only a few of the uses for the data providedbywearabletechnology[55].

Smart wearables have increased the market for wearable technology, shrunk the size of electronic gadgets and sensors, and sped up the creation of low-power mobile networks.

i) Nano-integrated wearable biosensors are [56]

Tear-based wearable devices, sweat-based wearable biosensors based on exercise, epidermal-based wearable biosensors, Biosensors with saliva sensing capabilities include implantable biosensors, microfluidic biosensors, and biosensors based on iontophoresis.

ii) Challenges in wearable biosensors

Wearable biosensors that provide comprehensive data about a person's health and physical activity will eventually be used on a daily basis.Several mechanical sensors that stretch or deform, as well as wearable chemical sensors, struggle with stability. Continuous exposure to biofluids can cause biofouling, chemical alterations, or irreversible non-specific adsorption on the transducer surface in chemical sensors.

Table 4: Various types of wearable technology that are now in use or under development [56]

Types of wearable	Description
1.Wrist-mounted wearable	Smart watches, fitness tracker, and armbands are examples of wrist mounted devices.
2.Head-mounted technology	It consists of tiny projections or displays that are put on hats, helmets, or spectacles.
3.Smart Clothing/e- textiles	It is made up of conductive devices and garment material that can sense various ambient conditions and react to changes in temperature, pressure, or chemical composition.
4.Chest-mounted devices	Chest-mounted gear that connects to a remote center makes it simpler to distinguish between the body of a fall and routine motions.

E.Industrial Automation

IIoT(Industrial Internet of Things) utilizes sensors and actuators that are connected over the internet, it analyzes data and extracts meaningful information which can be exploited to achieve advancement in production, industrial processes, and business development. IIoT finds its application in various operations of the industry. It plays a pivotal role in maintenance, diagnostics, and calibration. IIoT itself is a vast subject that includes various other divisions that play a predominant part in the functioning of our society. The IIoT architecture comprises 5 statuses. It is based on IEC 62443 Industrial Automation and Control Systems (IACS). Sensors and Actuators are at level 0. Level 1 represents the Automation control level, while Level 2 represents the Supervision control level. Level 3 represents production control, while Level 4 represents administration [57].

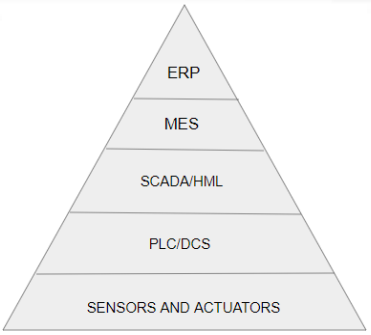

Figure4: Architecture of Industrial Automation

i) Types of Service by Industrial Internet of Things

There are numerous uses for IIoT. According to an article by IoT World Today, there are 9 most popular types of use for IIoT [58]. Here some of them are mentioned below:

a) Supply Chain: It is the tracking of products and assets. For the most part, it's location. This helps the customers in validating their safety and helps keep track of the route of their orders. This also assists the vendors and producers in removing knock-offs, keeping an inventory, and trying to adapt to changes in demands quicker [59].

b) Automation of Manual Processes: Using IoT with machines and artificial intelligence to accomplish tedious tasks. The usage of IoT in the industry makes it easier to process big data and this provides great

Critical environment. As aforementioned it ensures a good Quality-of-Service (QoS) with low latency that is of foremost importance to reinforce real-time applications [60].

c) Predictive Maintenance: This is the evolution of traditional management and is predominantly involved in predicting and analyzing future malfunctions in order to plan preventive measures. This has been adopted by many organizations as a way to safeguard against unexpected failures that may lead to massive losses. Predictive Maintenance is intimately incorporated with sensor technology, which has a significant role in IIoT [61].

d) Resource Allocation: The increasing usage of wireless networks. The IIoT device utilizes fog computing which is a model for distributed computing. This decentralizes the traffic and directs the data to distinct nodes that process it and forwards it to the client. This form of resource allocation provides better latency [62].

e) Data Intelligence to do Strategic Planning: To overcome the disadvantages of traditional diagnostics. The humongous Data collected with the help of sensors are analyzed with the AI and ML techniques and Obtained diagnosis is used to predict future faults leading to efficient management. Provides significant insight into investigation and decision-making. Enhances productivity, and innovation. Accelerates operational processes and efficiency [63].

ii) Key Technologies [64]

I. Edge Computing:As aforesaid Edge also known as Fog Computing reduces traffic dramatically and improves Quality-of-Service tremendously. It provides better resource distribution, scalability, and interoperability.

II. Software-Defined Networking: It works as an interface between the client and the server that facilitates easy communication and thereby reduces traffic in the network. It divides the network into sectors and dynamically manages it by using load-balancing techniques.

III. Blockchain: This is based on decentralized, distributed systems that keep a ledger on transactions that took place over the internet anytime, anyplace. Hence reinforcing data transparency. No third-party organizations have power over the transaction process or the ledger.

IV. Machine Learning: As a consequence of the massive number of connected hardware over the internet, there is a presence of data transparency that is subject to security threats. ML, which is a sub domain of AI, has several techniques which provide the best solutions to these issues of security.

V. 5G Technology: 5G is inclusive of all the above-mentioned applications, as its architecture is built on a distributed network with edge devices connected over the network. It makes use of a Software-Defined Network for dependable communication over the network. 5G is utilized in industries for remote monitoring, smart manufacturing, and more.

VI. Wireless Sensor Network: It is Sensors connected over the internet. The data obtained is used for processing, analysis, surveillance, and data mining. It provides real-time data that alerts in case of faults and failures. It finds applications anywhere such as hospitals, roads, and home automation..

Table 5:*Advantages and Challenges:*

Ref	Application	Advantages	Challenges
[71],[70]	Supply Chain	Adequate Transparency and Customer Satisfaction.	The structure of the supply chain is extremely complex and Highly dependent on individual tasks, which makes it difficult to manage the supply chain.
[68],[67]	Automation of Manual Processes	Rapid completion of complex tasks and Reduces human error.	Requires high funding and has to Train users to use automation efficiently.
[61],[66]	Predictive Maintenance	Reduces energy consumed. This does not influence the regular operations of a system.	Data can be misconceived leading to false alarms. It may not be inclusive of surrounding factors.
[64],[69]	Resource Allocation	High scalability and Effortless communication .	Absence of flexibility while working on miscellaneous tasks. Harder to work within a cloud environment.
[63],[65]	Data Intelligence to do Strategic Planning	Helps in identifying various different attacks on the network and provides a rational analysis of big data.	The massive personal data shared over the internet. may lead to privacy issues. It requires complex networking which is quite expensive to build.

F.Smart Cities

Smart City is a term used to describe built-up cities that use ICT to improvise and grow, business and livelihood. The growth here represents the development of better transportation facilities, economy, and social infrastructure. Smart City development is so popular and in demand that several companies have taken up the mantle in improvising compelling new products that are useful in building flourishing smart cities. Some of them are CISCO, IBM, Microsoft, and Oracle. A society is predominantly connected through the internet and IoT comes into play here by connecting the internet with sensors that monitor and maintain records of social conditions. The Smart City consists of components that make up its basic infrastructure[72].

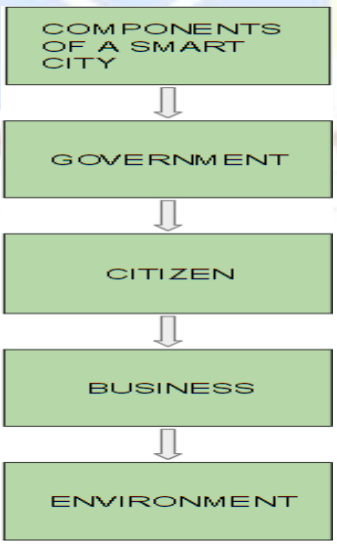

Figure 5: Basic Infrastructure for smart cities

i) Basic infrastructure for smart cities

a) Government

- Surveillance - monitoring crime, and pollution.
- Disaster alerts and response - inducing preventive measures in case of emergency. Public service - providing basic services like water and electricity.

***b)* Citizen**

- Transport - efficient services for traveling easier and quicker.
- Healthcare - providing basic medical amenities in case of emergency.
- Smart traffic - configuring better routes and methods to prevent traffic.

***c)* Business**

- Supply chain - helps customers in tracking their products step by step.
- Agriculture - introducing sensors for the betterment of food production.
- Transaction - safer and quicker transactions via the Internet.

***d)* Environment**

- Smart grid - conservation and efficient use of energy.
- Construction - building smart homes and roads for societal advancement.
- Waste and Pollution control - monitoring pollution and wastes for environmental protection and prevention of degradation of the environment.

Table 6: Key technologies for smart city implementation using IoT *[73]*

Vendors	Solution
Cisco	Provides remote monitoring technology for surveillance.
Streetlight Data	Extracts information on location through GPS and connected systems and displays the anticipated traffic in its platform.
Enlightened	Utilizes sensor technologies to reduce the consumption of power.
FLASH	Helps monitor parking infrastructure and provides parking solutions.
Locus view	Provides a Digital Construction Management platform to manage capital. Thereby helping with planning, revenue, and more.
Optibus	Supplies consumers with an AI-based platform that helps in planning and scheduling massive public transportation.
Enevo	Primarily focuses on waste management and assists in reducing waste-related costs.
Clarity Movement	It utilizes machine learning and data analysis in detecting air quality and helps in further preventing air pollution.
Telensa	Provides a control system that is connected with sensors for easy installment of smart street lights.
Sensus	Connected through a network of sensors, Is of utmost use in implementing smart water systems that monitor temperature, moisture, pressure, and more.
SmartRetail	Its service is based on video. The data it collects is used to find solutions in places like supermarkets and retail shops. It gives an analysis of shopping patterns according to age and gender.
Citymapper	is Useful to consumers in finding better routes in case of traffic and provides easy solutions for better mobility and transportation.
ParkWhiz	Helps people find empty parking lots for immediate use and provides information about any other garages that could be utilized at the moment through a parking pass.
Embue	It provides a cloud-based platform that is used to store data about temperature and moisture. This helps in building smart apartments and smart homes.

ii) Advantages and Challenges [74]

a) Advantages*:*

- Better communication and connectivity.
- Improve transportation facilities.
- Efficient customer service.
- Inflation of the economy.
- Increment in job opportunities.

b) Challenges:

- Lack of control
- Requires highly complex networking.
- Lack of privacy.
- Difficult to implement practically.
- Requires exclusive training.

4. Future scope of IoT

The Internet of Things is an influential technology that has metastasized all over the world. IoT uses AI and MLtechniques. That being so, IoT's application has found its way over multiple domains.As we discussed above, the internet of things has many scopes in various fields like agriculture, health care, smart cities, wearable, smart grid, etc. IoT is anticipated to introduce more novel technologies and applications in the future, such as autonomous vehicles, advanced manufacturing, predictive maintenance, and augmented reality..IoT is crucial in case of emergencies and it helps in scrutiny of various parameters that has incredible use in detection and diagnostics of life changing accidents [75]. According to estimates, there will be over 75 billion IoT devices in use by 2025, producing trillions of dollars in income. The ability to deploy, automate, orchestrate, and protect a variety of use cases at hyper-scale will enable the industry to advance more quickly.IoT devices are anticipated to increase from about 9.7 billion in 2020 to 29 billion worldwide by 2030. With an astounding CAGR of 11.49 from 2022 to 2027, the internet of things market is anticipated to reach US$33.74 billion by that year.

5. Conclusion

As a whole, the IoT is a rapidly expanding sector with several applications in numerous sectors. We have examined some of the most important IoT applications in this paper, including smart cities, healthcare, the smart grid, industrial automation, wearable technology, and agriculture. We have seen how Internet of Things (IoT) devices and sensors can deliver real-time data and insights that can be used to improve operations, efficiency, and the user experience as a whole. We have also discuss some of the obstacles to the mainstream adoption of IoT applications, such as interoperability problems, security and privacy difficulties, and the requirement for standards. Despite these difficulties, the potential advantages of IoTare too great to ignore, and we believe that this sector will keep growing and developing in the years to come. To fully utilize the IoT's potential and enjoy its benefits, it is crucial for both organizations and consumers to be informed about the most recent advances in technology.

References

[1] PradyumnaGokhale, OmkarBhat, SagarBhat, “Introduction to IoT”.International Advanced Research Journal in Science, Engineering, and Technology ISO 3297:2007 Certified Vol. 5, Issue 1, January 2018.

[2] Sharma,N., Shamkuwar, M., & Singh, I. (2018).” The History, Present and Future with IoT. Internet of Things and Big Data Analytics for Smart Generation.”Internet of Things and Big Data Analytics for Smart Generation [1st ed.] 978-3-030-04202-8, 978-3-030-04203-5

[3] https://timesofindia.indiatimes.com/education/news/future-of-internet-of-things-iot-in-dia/articleshow/93969472.cmsTNN / Sep 5, 2022, 04:00 IST

[4] Bob Violino,”Top IT Vendors reveal their IOT strategies”https://www.networkworld.com/article/2604766/top-it-vendors-reveal-their-iot-strategies.htmlNetwork World 15 September 2014

[5] Omar Said, MehediMasud, "Towards the Internet of Things: Survey and Future Vision".International Journal of Computer Networks (IJCN), Volume (5): Issue (1): 2013

[6]K. Shafique, B. A. Khawaja, F. Sabir, S. Qazi and M. Mustaqim, "Internet of Things (IoT) for Next-Generation Smart Systems: A Review of Current Challenges, Future Trends and Prospects for Emerging 5G-IoT Scenarios," in IEEE Access, vol. 8.January 2020, IEEE Access PP(99):1-1

[7] Yaqoob, I., Ahmed, E., Hashem, I. A. T., Ahmed, A. I. A., Gani, A., Imran, M., &Guizani, M. (2017)." Internet of Things Architecture: Recent Advances, Taxonomy, Requirements, and Open Challenges." IEEE Wireless Communications, 24(3), 10–16. June 2017

[8] Z. Qin et al., "A Software Defined Networking Architecture for the Internet-of-Things," 2014 IEEE Network Operations and Management Symp., May 2014, pp. 1–9

[9] Rasmeet Kaur, B.L.Raina, and Avinash Sharma," Internet of Things: Architecture, Applications, andSecurity" Concerns]Journal of Computational and Theoretical Nanoscience Vol. 17, 2469–2475, 2020

[10] https://www.visionofhumanity.org/what-is-the-internet- of-things

[11] JOral BiolCraniofac Res.(2021) Apr-Jun; 11(2): 209–214 "Internet of Things (IoT) enabled healthcare helps to take on the challenges of COVID-19 Pandemic" Published online 2021 Jan 30.

[12] Onasanya, A., &Elshakankiri, M. (2019). "Smart integrated IoT healthcare system for cancer care. Wireless Networks."1-16

[13] Yacchirema, D., Sarabia-Jácome, D., Palau, C. E., &Esteve, M. (2018), "System for monitoring and supporting the treatment of sleep apnea using IoT and big data, Pervasive and Mobile Computing in article researchgate(2018).

[14] Haleem et al. "Journal of Clinical Orthopaedics and Trauma, Internet of things (IoT) applications in orthopedics" 11 (2020) S105eS106.

[15] TsikalaVafea, M., Atalla, E., Georgakas, J. *et al.*"Emerging Technologies for Use in the Study, Diagnosis, andTreatmentofPatients with COVID-19". *Cel. Mol. Bioeng.*13, 249–257 (2020).

[16] Farahani, B., Firouzi, F., Chang, V., Baharoglu, M., Constant, N., &Mankodiya, K. (2018). "Towards fog-driven IoTeHealth: Promises and challenges of IoT in medicine and healthcare. Future Generation Computer Systems", 78, 659– 676.google scholar

[17] Selvaraj, S., Sundaravaradhan, S. "Challenges and opportunities in IoT healthcare systems: a systematic review".SNAppl. Sci. 2, 139 (2020).

[18] M.O. Qays, I. Ahmad, A. Abu-Siada, et al."EnergyKeycommunication technologies, applications, protocols, andfuture guides for IoT-assisted smart grid systems: A review"Reports 9 in journal ScienceDirect (2023) 2440–2452.

[19] Abeer Akkad, Gary Wills, AbdolbaghiRezazadeh,"An information security model for an IoT-enabled Smart Grid in the Saudi energy sector",Computers an Electrical Engineering, Volume 105,2023,108491,ISSN 0045-7906,https://doi.org/10.1016/j.compeleceng.2022.108491.

[20] N.S. Madhuri a, K. Shailaja b, DebasmitaSaha c, Revathy P d, K.B. Glory e, M. Sumithra f "IIOT integratedsmart grid management system for effective energymanagement." In journal ScienceDirect(https://www.sciencedirect.com/science/article/pii/S2665917422001222)AnushreeRamanath,"Technical Article Key Technologies for Applying the IoT to the Smart Grid" October 23, 2021.

[22] Shu-wen, W. (2011). "Research on the key technologies of IOT applied on Smart Grid." 2011 International Conference on Electronics, Communications, and Control *(ICECC).*

[23] N A Hidayatullah1, A C Kurniawan2 and A Kalam3"Power Transmission and Distribution Monitoring usingInternet of Things (IoT) for Smart Grid" InternationalSymposium on Materials and Electrical Engineering(ISMEE) 2017 IOP Publishing

[24] Z.I. Dombrovskyi, A.O. Sachenko, I.M. Zhuravska, M.Z. Dombrovskyi, G.M. Hladiy, M.P. Musiyenko, Y.M. Krainyk,E.V. Brezhniev, M.O. Kolisnyk "Internet of Things for Industry and Human Applications Internet of Things for SmartEnergy Grid.

[25] Rind, Y.M.; Raza, M.H.; Zubair, M.; Mehmood, M.Q.; Massoud, Y. Smart Energy Meters for Smart Grids, an Internet of Things Perspective. *Energies* 2023, *16*, 1974. https://doi.org/10.3390/en16041974

[26] Z. Davoody-Beni, N. Sheini-Shahvand, H. Shahinzadeh,and Intelligent Systems (ICSPIS), Shahrood, Iran, 2019, pp.1-8.

[27] Jaradat, M., Jarrah, M., Bousselham, A., Jararweh, Y., &"networks and big data management for smart grid"Procedia Computer Science,Volume 56,2015,Pages 592-597,ISSN 1877-0509https://doi.org/10.1016/j.procs.2015.07.250.(https://www.sciencedirect.com/science/article/pii/S1877050915017317)

[28] R. Morello, C. De Capua, G. Fulco and S. C. Mukhopadhyay, "A Smart Power Meter to Monitor Energy Flow in Smart Grids: The Role of Advanced Sensing and IoT in the Electric Grid of the Future," in IEEE Sensors Journal, vol. 17, no. 23, pp. 7828-7837, 1 Dec.1, 2017, doi: 0.1109/JSEN.2017.2760014.

[29] Md. OhirulQays, Iftekhar Ahmad, Ahmed Abu-Siada, Md. Liton Hossain, Farhana Yasmin, "Key communication technologies, applications, protocols, and future guides for IoT-assisted smart grid systems: A review, Energy Reports", Volume 9,2023, Pages 2440-2452, ISSN 2352-4847.

[30] Melanie McCaig, DavarRezania, RozitaDara,Framing the response to IoT in agriculture: A discourse analysis,AgriculturalSystems,Volume 204,2023,103557,ISSN 0308-521X,https://doi.org/10.1016/j.agsy.2022.103557.,2016

[31] B. Sinha, R. Dhanalakshmi," Recent advancements andchallenges of the Internet of Things in smart agriculture: A Survey",Futur. Gener. Comput. Syst.126 (2022) 169–184.In journal Future Generation Computer Systems (2022)

.[32] M.A. Zamora-Izquierdo, J. Santa, J.A. Martínez, V. Martínez, A.F. Skarmeta, "Smart farming IoT platform based on edge and cloud computing, Biosys".Eng.177(2019) 4–17.

[33] K. Paul, S.S. Chatterjee, P. Pai, A. Varshney, S. Juikar,V. Prasad, Bhadra, S. Dasgupta, "Viable smart sensors and their application in data-drive agriculture,comput, Electron, Agric."198(2022)107096.

[34] N. Chamara, M.D. Islam, G. (Frank) Bai, Y. Shi, Y. Ge, "Ag-IoT for crop and environment monitoring: Past, present, and future, Agric. Syst."203(2022)103497.

[35] S. Ratnaparkhi, S. Khan, C. Arya, S. Khapre, P. Singh,M. Diwakar, A. Shankar, "Smart agriculture sensors in IOT: A review", Mater. Today Proc. (2020).

[36]U. Shapira, I. Herrmann, A. Karnieli, J.D. Bonfil, "Weeds detection by ground-level hyperspectral data, in Theory to Pract." XXXVIII, 2010, pp. 27–33.

[37] B.H.D.D. Priyanka, PamulaUdayaraju, Chandra SekharKoppireddy, AlluriNeethika,Developing a region-based energy-efficient IoT agriculture network using region- based clustering and shortest path routing for making sustainable agriculture environment,Measurement: Sensors,2023,100734,ISSN 2665-9174,https://doi.org/10.1016/j.measen.2023.100734.

[38] A. Bechar, C. Vigneault,"Agricultural robots for field operations:Concepts and components, BiosystemsEngineering" 149 (2016) 94–111.

[39] A. Villa-Henriksen, et al.,"Internet of Things in arable farming:Implementation, applications, challenges and potential, Biosystems engineering 191 (2020) 60–84.

[40] A.Goap,etal.,"AnIoT-based smart irrigation management system using Machine learning and open source technologies, Computers and electronics in agriculture." 155 (2018) 41–49.

[41] G. Severino, et al., "The IoT as a tool to combine the scheduling of the irrigation with the geost atistics of the soils, Future Generation Computer Systems"82 (2018)268–273.

[42] G. Alfian, et al., "Improving the efficiency of RFID- based traceability system for perishable food by utilizing IoT sensors and machine learning model, Food Control" 110(2020) 107016.

[43] F. Bibi, et al., "A review: RFID technology having sensing aptitudes for the food industry and their contribution to tracking and monitoring of food products, Trends in Food Science & Technology"62 (2017) 91–103.

[44] S. Khanal, J. Fulton, S. Shearer," An overview of current and potential applications of thermal remote sensing in precision agriculture, Computers and Electronics in Agriculture."139 (2017) 22–32.

[45] Y. Tsang, et al., "An IoT-based cargo monitoring system for enhancing operational effectiveness under a cold chain environment, International Journal of Engineering Business Management." 9(2017) 1847979017749063.

[46] M. Abdel-Basset, L.A. Shawky, K. Eldrandaly,"Grid quorum-based spatial coverage for IoT smart agriculture monitoring using enhanced multi-verse optimizer, Neural Computing and Applications."32 (3) (2020) 607–624.

[47] R. Badia-Melis, P. Mishra, L. Ruiz-García,"Food traceability: New trends and recent advances. A review, Food Control", 57 (2015) 393–401.

[48] P.P. Ray," Internet of things for smart agriculture: Technologies, practices and future direction, Journal of Ambient Intelligence and Smart Environments."9(4) (2017)395–420.

[49] Z.Zhang, et al.,"Survey on water-saving agricultural internet of things based on wireless sensor network, International Journal of control and Automation ."8 (4) (2015) 229-240.

[50] J.J. Estrada-López, et al.,"Smart soil parameters estimation system using an autonomous wireless sensor network with dynamic power management strategy", IEEE Sensors Journal 18 (21) (2018) 8913-8923.

[51] P.P. Jayaraman,etal.,"Internet of things platform for smart farming: Experiences and lessons learned", Sensors 16 (11) (2016) 1884.

[52] VivekRamakantPathmudi a, Narendra Khatri a,*, Sandeep Kumar b,AntarShaddadHamed Abdul-Qawy c, Ajay Kumar Vyas d."A systematic review of IoT technologies and their constituents for smart and sustainable agriculture applications."

[53] Artificial Intelligence in Agriculture.http://www.keaipublishing.com/en/journals/artifici al-intelligence-in-agriculture/ in Progress Jun 2023

[54] F. JOHN DIAN,(Senior Member, IEEE), REZA VAHIDNIA,,AND ALIREZA RAHMATI."Wearables and the Internet of Things (IoT), Applications, Opportunities, and Challenges: A Survey."20 April 2020 'IEEE Access'

[55] Wang Huifeng a, SeifedineNimerKadry b, EbinDeni Raj c,"Continuous health monitoring of sportsperson using IoT devices based wearable technology."2020 in journal "Computer communications"

[56] DaminiVerma, Kshitij RB Singh, Amit K. Yadav, VanyaNayak, Jay Singh, PratimaR. Solanki, RavindraPratapSingh."Internet of things (IoT) in nano-integrated wearable biosensor devices for healthcare applications",may 2022.

[57] Abdu Idris Omer, M.M Taleb, "Architecture of Industrial Automation Systems."31 January 2014 'European Scientific Institute, ESI.'

[58] https://www.iotworldtoday.com/iiot/the-9-most-popular- types-of-iiot-use-cases.

[59] Jack Davies and Yingli Wang," Physically Unclonable Functions (PUFs): A New Frontier in Supply Chain Product and Asset Tracking." IEEE Engineering Management Review Volume: 49, Issue: 2, 01 Second Quarter, June 2021.

[60] Chegini, H.; Naha, R.K.; Mahanti, A.; Thulasiraman, P. "Process Automation in an IoT–Fog–Cloud Ecosystem: A Survey and Taxonomy." IoT 2021.in MDPI

[61] Selcuk, S. (2016).Predictive maintenance, its implementation, and the latest trends. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of EngineeringManufacture,231(9),1670–1679.

[62] K. A. Abuhasel and M. A. Khan, "A Secure Industrial Internet of Things (IIoT) Framework for Resource Management in SmartManufacturing," in IEEE Access, vol.8,pp.117354-117364.

[63] Nguyen, H.D., Tran, K. P., Zeng, X., Koehl, L., Castagliola, P., and Bruniaux, P." Industrial Internet of Things, Big Data, andArtificial Intelligence in the smart factory: a survey and perspective." July 2019 Conference: ISSAT International Conference on Data Science in Business, Finance, and Industry At Da Nang, Vietnam.

[64] Akseer Ali Mirani, Gustavo Velasco-Hernandez, AnshulAwasthi, Joseph Walsh." Key Challenges and Emerging Technologies in Industrial IoT Architectures: A Review." Sensors 2022, 22(15), 5836.

[65] LenkaVenkataSatyanarayan," A Survey on Challenges and Advantages in Big Data." IJCST Vol.6, Issue 2, April- June 2015.

[66] https://www.ecmsp.co.uk/it-blog/pros-cons-predictive- maintenance-cloud/

[67] J. Frohm, V. Lindström, M Winroth, J. Stahre," The Industry's View On Automation In Manufacturing, IFAC Proceedings" Volumes, Volume 39, Issue 4,2006.

[68] Richard Breton, EloiBosse." The Cognitive Costs and Benefits of Automation."(2003).

[69] M.Kandan, R.Manimegalai."Strategies for Resource Allocation in Cloud Computing: A Review."International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.76 (2015).

[70] Lambert, D. M., & Cooper, M. C. (2000). "Issues in Supply Chain Management. Industrial Marketing Management",29(1),65–83.

[71] Stevens, G.C. (1989), "Integrating the Supply Chain", International Journal of Physical Distribution & Materials Management, Vol. 19 No. 8, pp. 3-8.

[72] Yin ChuanTao, Xiong Zhang, Chen Hui, Wang JingYuan, Cooper Daven& David Bertrand," A Literature survey on smart cities."October 2015 Vol. 58 100102:7

[73] https://builtin.com/internet-things/iot-smart-city- applications.

[74] https://www.aplustopper.com/smart-city-advantages-and- disadvantages/

[75] Elumalai. G,1, Nallavan. G and Ramakrishnan. R,"Smart Industry Monitoring and Controlling System Using IoT."2021.