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# Collaborative Applications of Internet of Things in various spheres of life: Past, Present and Future

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**Abstract**—The Internet of Things (IoT) connects and establishes communication between physical objects from creatures to machinery over the Internet without human involvement that is embedded with sensors, actuators, software, and various other technologies linked together through wired or wireless networks. In the foreseeable future, the application fields of the Internet of Things will increase continuously and dramatically. This paper considers the current progress of the Internet of Things in the real world and presents various tangible applications of IoT in field of agriculture, industries, smart retails, automated systems, smart buildings, automotive IoT, wearable items, transportation, covid - 19, e-health, security and intrusion detection. The paper also provides overview of the collaborative applications of the Internet of Things with Big Data, Artificial Intelligence, Machine Learning, Wireless Sensor Networks, Cloud Computing, Data Management, Cryptography and Blockchain to disseminate its applications for a better understanding of the research community to apply IoT in further innovative fields.

**Keywords**- Internet of Things, IoT, Applications of IoT

## I. INTRODUCTION

In 2023, it is anticipated that India's IoT industry would generate US $ 27.31 billion [1]. In 1999, Kevin Ashton came up with the term "Internet of Things." In order to promote RFID technology, the word Internet of Things was created, and after 10 to 11 years, it began to acquire traction.The Internet of Things (IoT) is a network of physical objects that consists of tools, gadgets, cars, buildings, and other items with electronics, circuits, software, sensors, and network connectivity. These objects can collect and share data using technology. IoT immediately integrates the physical world into computer-based systems and makes it possible for objects to be sensed and controlled remotely through the already-existing network infrastructure. This increases efficiency and accuracy. IoT can communicate without a human being present. Some early Internet of Things applications have already been developed for the healthcare, transportation, and automotive industries. There have been some recent developments in the linking of physical objects to online sensors, even though the fact that Internet of Things (IoT) technology is still in their infancy. [2]The creation of the IoT entails numerous challenges, including communications, interfaces, standards, protocols, and infrastructure.

## II. LAYERED ARCHITECTURE OF INTERNET OF THINGS

The three-layered architecture, which includes the network layer, application layer, and sensor (perception) layer, has long been the most popular paradigm for IoT applications.

The three-layer architecture has somewhat limited scope do the architecture of Internet of Things is classified into four layers namely, Sensor Layer, Gateway and Network Layer, Management Service Layer and Application Layer as illustrated in “Fig. 1” [3]

### *A. Sensor Layer*

The sensor networks, embedded equipment, RFID tags and readers, and other soft sensors are various types of sensors— make up this layer of the IOT architecture, which is the lowest one. These sensors have RFID tags for identification and information storage, as well as sensor networks for information gathering.

### *B. Network and Gateway Layer*

This layer is in charge of sending the data gathered by sensors to the subsequent layer. It should be able to transport data from heterogeneous devices (different types of sensor nodes) via a scalable, adaptable, and universal protocol. This layer ought to have a strong network and excellent performance. Additionally, it ought to enable autonomous communication between different organisations.

### *C. Management Service Layer*

This layer serves as a bidirectional bridge between the application layer and the gateway and network layer. Large amounts of unstructured data must be collected, and useful data must be extracted from both stored and real-time data. It is also in charge of managing devices and information. Data privacy and security must be guaranteed.

| Application Layer |
| --- |
| Management Service Layer |

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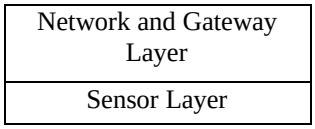


Figure 1.Layered Architecture of IoT

*D. Application Layer*

This is the IoT layer that offers a user interface for accessing different applications to different users.

## III. APPLICATIONS OF INTERNET OF THINGS

*A. Agriculture Using IoT*

In the field of agriculture the various applications of IoT may include **water management** [4]for efficient management of water in agricultural lands so that the crops may be provided with water in case of drought and can be protected from damage during floods by using remote monitoring , **smart greenhouse farming** that increases cultivation by controlling the environmental parameters, **agricultural drones** that can help in the field and plant monitoring, **precision agriculture** to make farming more accurate and controlled, **agricultural automation and robotics** that will help in decreasing the labor cost and time consumption and **smart livestock monitoring** so as to track the location as well as well being of animals. IoT can be combined with Artificial Intelligence, Computer Vision, Machine Intelligence, Wireless Sensor Networks, etc. for more advancement in the field of agriculture as shown in "Fig. 2".

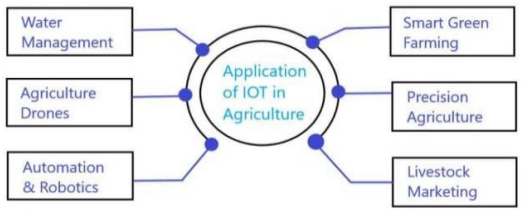


Figure 2.Applications of IoT in Agriculture

*B. Iot in Smart Retails*

Various retailers have implemented market using IoT for retails in various applications as shown in "Fig. 3". For smart retails the applications of IoT may include **automated checkout** which provides a facility to charge to the customers automatically as well as reduce human error and staff charges, **smart shelves** in which IoT sensors are built that can collect data from tags or packaging of items and display it to customers as well as in store, **smart robot employees** that can be implemented by collaboration of IoT devices, Internet and robots so as to provide several benefits, **supply chain management** to coordinate goods from initial manufacturer to retail sale using monitoring technology, **enhanced customer experiences** by item monitoring, pinpointing each customer desires, sending personal messages, etc.

*C. Industrial IoT*

The acronym for Industrial IoT is IIoT (Industrial Internet of Things) which is expected to grow in upcoming years has many applications as illustrated in "Fig. 4". Some of the major technical IIoT applications include **tracking & monitoring of assets** which is helpful in proper asset utilization and maintenance as well as reducing theft, **industrial automation** by the combination of IoT sensors and AI which help in the collection of data, create new architecture and streamline the process of manufacturing. By the use of IoT, more granular monitoring ability can be applied for **smart energy management** of lights, room's equipment, ventilators, air-conditioners, etc. which help in reducing bills as well as operating costs, **predictive maintenance** that can help in fixing assets before failure, and **supply chain optimization** so as to establish a network between customers, retailers, and suppliers.

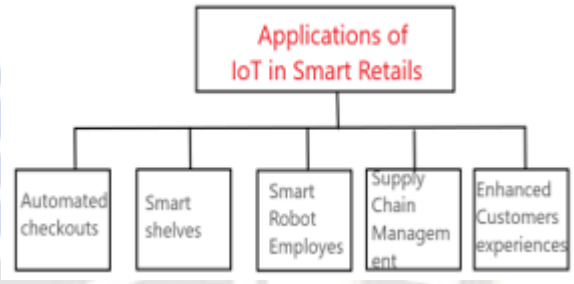


Figure 3.Applications of IoT in Smart Retails

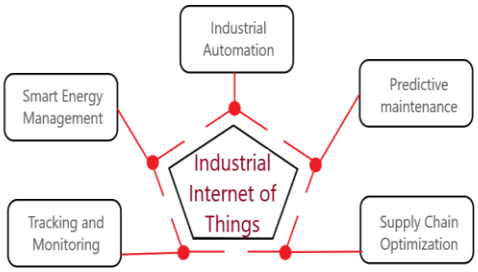


Figure 4.Industrial Internet of Things

*D. Automated systems using IoT*

The applications of IoT in the field of smart infrastructure may include **smart parking** that can be established by interconnecting IoT sensors with Cloud-based servers in each parking space, **traffic management** for analyzing the traffic pattern and signaling the vehicles to divert towards the route having less traffic [6], **smart electrical grid** so as to monitor and control the entire electrical system by providing the internet connectivity to the power grid, **trash collection** by using the sensors attached to the bins to track the waste and composition which can prove

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itself helpful to customers as well as management in several ways, and **water management system** so as to measure and control various measurements such as water level, temperature, water flow, pressure, etc. of a water system in a smart way as illustrated in "Fig. 5".

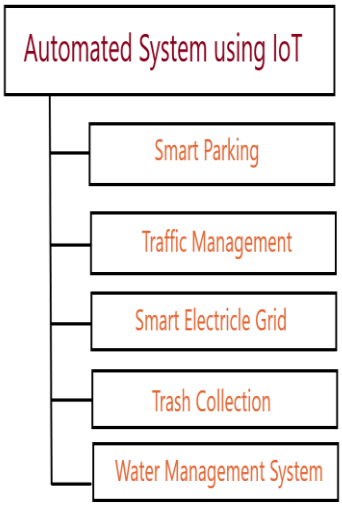


Figure 5.Automated Systems using IoT

*E. Smart Homes and Buildings*

Internet of Things will be applicable for buildings in tremendous ways shown in "Fig.6" such as for **air quality** by predicting the presence of various harmful compounds or pollutants and altering it by using various interconnected devices, **energy efficiency** by analyzing and saving energy consumption using IoT sensors, **occupant comfort** to monitor comfort-relevant traits of a building and change them as per their desires, **security** by coordinating, monitoring as well as adjusting a variety of elements and sensors present in a building, and **predictive maintenance** by monitoring the condition of the building and its types of equipment. [7]

*F. Wearable Items using IoT*

The electronics industries of smart wearables have already surpassed $10 billion. Applications of IoT for wearable items include **pets wearable** that are equipped with biometric sensors and GPS so as to track location and behavioral data, **assistive technology** increases the data requirements by sensing and relying data to individual, **healthcare wearables** can track a large amount of information about human body by monitoring human biometrics, **sports wearable** have ability to monitor every movement of an athlete, and **remote controlling** allow a person to control all the assets that are connected to a single device such as wrist watch as demonstrated in "Fig. 7".


Figure 6.IoT for Smart Homes and Buildings


Figure 7.Wearable Items using Internet of Things

*G. Automotive IoT*

Automotive IoT implies automatic vehicle technology by the help of interconnected devices. Applications of IoT for automatic vehicle technology include [9] **automotive driving** by the collaboration of IoT with various interconnected components such as computers, sensors, GPS navigation in which vehicles require no drivers, **biometrics** in cars can be used for locking-unlocking doors, prohibiting drunk drivers & many more, **infotainment** provides navigation, entertainment as well as diagnostics to the passengers by using various hardware and software, **predictive maintenance** can be performed by collecting data via sensors and detecting the failures using cloud-based modeling and vehicle-to-vehicle communication can be established using sensors for accurate sharing among the vehicles as shown in "Fig. 8".

*H. Transportation using IoT*

The applications of IoT for smart transport is demonstrated in "Fig. 9" that includes **fleet management** which is a coordination of a number of vehicles that are automated by adding computers, RFID systems, scanners to IoT devices, **smart trains** by enhancing the performance of monitoring, signaling, level crossing, interlocking, **drone delivery** by the interconnection of cameras, batteries, remote piloting that are time-saving as well as cheap, **public transit management** that establish and monitor a connection between customers and systems, and end-to-end visibility to monitor vehicles is obtained by coordinating IoT devices with Bluetooth, RFID tags, GPS and many more.

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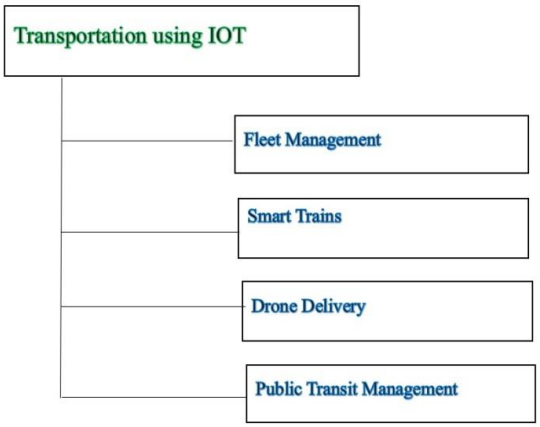


Figure 9.Transportation using IoT

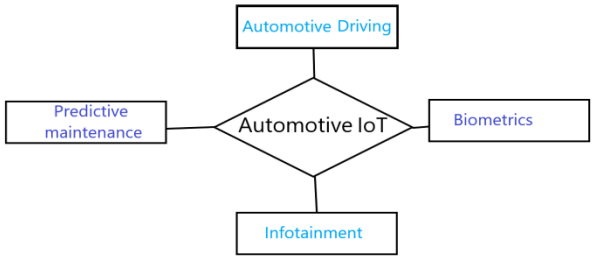


Figure 8.Automotive Internet of Things

*I. Cities and Public Places Automation*

The advanced urban areas that are built by the collaboration of IoT with interconnected technologies such as sensors, Radio-Frequency Identification (RFID), cameras, WSN, etc. can be termed as smart cities. The applications of IoT as illustrated in "Fig.10" for **smart cities** include smart homes that are automated houses that are usually controlled by the house owners using various devices, **smart parking** that will help the drivers to find a place to park [11], **vehicular traffic** so as to keep track of the routes traveled, **surveillance systems** purposefully designed for security by doing proper monitoring and many more. These applications will affect various factors of human life.

*J. Contend with Covid-19 using IoT*

IoT when used during the pandemic period will be an innovative technology for superior monitoring and treatment of the patients. The applications of IoT to contend with corona as illustrated in "Fig. 11" are implementation of **internet-connected hospitals** that will help the patients and hospital staff to respond quickly according to data provided, **telehealth systems** with automatic treatment and medications facilities, **real-time systems** so as to track and help the active cases, **digital data** regarding patients or medications can be captured and stored. **Virtual management** in hospitals must be established so as to minimize the contact of corona-positive people with nurses, doctors, and other working staff. [10]

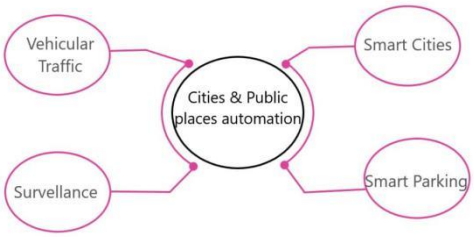


Figure 10.Automation of Cities and Public Places

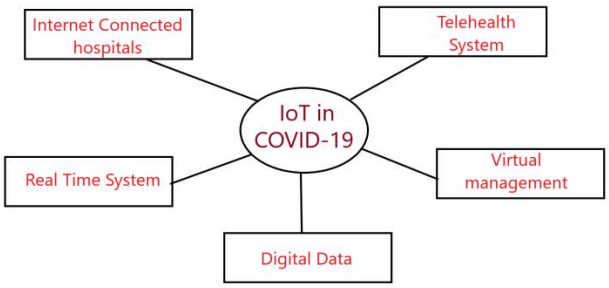


Figure 11.Contend with Covid-19 with IoT

*K. E-health and wellness using IoT*

By using IoT the e-health and e-wellness for a person can be implemented by using various interconnected technologies such as RFID, GPRS, Zigbee, Wi-Fi, Satellites, etc. that help to monitor the patient's health, send the data to and from cloud to the doctors and data centers for analyzing the measurements of patient, provide the prescriptions regarding health to the patients. The monitoring of blood pressure, mood, ECG, oxygen and sugar levels, temperature, and also the management of medications and wheelchair can be done. [8]

*L. Internet of Vehicles*

The Internet of Vehicles (IoV) is the name given to IoT when it is included in the field of smart vehicles. The collaboration of IoV, VANETs, and cloud computing results in the formation of an intelligent transportation system as illustrated in "Fig. 12". Some of the major implementations of VANET along with IoT include **safety-oriented applications** by sending warning messages, assisting vehicles on the road, increasing road safety by reporting about traffic, car accidents, and road construction, **commercial applications** by providing maps, entertainment and making driving easy as well as comfortable, **convenience applications** by facilitating drivers with electronic toll collection and information of parking and route diversions and **productive applications** that involves fuel saving and time utilisation. [5]

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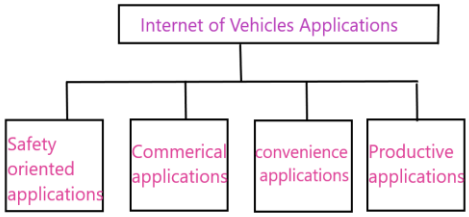


Figure 12.Applications of Internet of Vehicles

*M. Security in IoT*

The external environment communicates and is connected to the Internet with the help of IoT which uses sensors and various other devices. The communication must be secure, verified, and trustworthy. The privacy, authentication, confidentiality, and authorization of the data must be maintained and also various techniques and tools are used for this purpose. IoT security threats may occur in any field and it is a must requirement to protect the devices, networks, and data from attacks namely DoS attacks, malicious code attacks, gateway attacks, etc. The IoT systems and devices can be protected by the use of Public Key Infrastructure (PKI), Network Access Control (NAC), digital certificates, network security, Application Program Interface (API) security, etc.

*N. Intrusion detection in IoT*

Intrusion Detection System (IDS) techniques and approaches are security mechanisms that are used to protect the networks and the information systems. The conventional IDS are not suitable as well as not applicable to handle the security attacks faced by IoT so various other IDS are proposed for IoT networks, attacks, complex patterns ad various intrusion detection. An Intrusion Detection System is required in IoT to protect the IoT-based systems.

## IV. COLLABORATIVE TECHNOLOGIES with IoT

*A. IoT and Big Data*

IoT and Big Data work together with each other though they are two independent technologies as the huge amounts of data that is generated by IoT can be easily handled using Big Data. IoT collects the data from the physical World and Big Data enables that the data collected by the sensors is stored, processed, and retrieved efficiently. Usually, the information collected using IoT is unstructured, and then the big data analytics convert the data in a structured form. IoT and Big Data are used collaboratively in various sectors such as industries, social media, agriculture, health, business, transportation, energy conservation, lifestyle etc.

*B. Artificial Intelligence with the Internet of Things*

The amalgamation of AI with IoT has the prospective to change the World. AI in collaboration with IoT has been implemented in robotics that is similar to humans from working to expressing as they include the skeletal system, sensory system, power source as well as brain, smart thermostat to regulate the temperature of our surroundings using interconnected devices, voice assistants that acknowledge and communicate with users to act as a smart personal assistant, and various other applications that are mentioned above such as autonomous devices, vehicles, industries, retail analytics, etc. The alliances of IoT and AI have the potential to provide us with a World that will be responsive, optimized, and intelligent.

*C. Machine Learning in IoT*

Machine learning can help in making the IoT devices more intelligent as it provides intelligent services such as deducing useful knowledge and human requirement, providing security, maintaining privacy etc. The applications of ML in IoT may include automation in fields of industries, homes, manufacturing, hospitals, merchandise, and many more. ML is also applicable for IoT in traffic routing for the prediction of traffic to keep an account of the flow of traffic and movement of vehicles as well as provide a route that is less energy consuming and more time-saving. As a large amount of data is collected by various IoT devices so, by the use of machine learning, data can be absorbed and transformed into a particular format, using various algorithms a model can be developed, then finally the model can be installed on the cloud and various devices.

*D. Wireless Sensor Network (WSN) with IoT*

The major building block for the IoT devices is Wireless Sensor Network (WSN) because IoT provides interconnection between devices and WSN provid-es sensing, controlling, and monitoring services between those interconnected devices. WSN and IoT work collaboratively in the field of smart grid to provide the facility of smart electricity consumption by monitoring and warning systems in transmission lines and networks that helps in reducing power equipment accidents, transportation by sensing the traffic as well as another environment on a particular route, home automation by controlling and increasing proficiency of the infrastructure of buildings and various other applicable collaborations of WSN and IoT may come into action in future.

*E. Cloud Computing and IoT*

With the amalgamation of IoT and cloud computing the accessibility to resources and management of the smart environment and smart things becomes quite easier. The benefits of using cloud computing with IoT are that it provides security, storage, scalability as well as better authentication and privacy facility. The connectivity of cloud computing in IoT can be established using the Internet and the user only has

to pay for the resources being used therefore it is cost-efficient. Cloud computing integrated with Internet of Things can be useful in field of agriculture, healthcare, smart cities, transportation, smart grid, manufacturing, and business which enables the users to perform tasks in an efficient manner.

### *F. Data Management using IoT*

Traditionally the file management system was used for the process of data management but with the advancement of time various other tools and techniques from mainframe-based hierarchical databases, RDBMS, data-warehouses to Hadoop, Spark processing engine, NoSQL, and many more have emerged in the last two centuries. The use of IoT in data management is done because of the massive quantities and varieties of data. The data types in the Internet of Things are RFID data, sensor data, historical data, positional data, and descriptive data that can be collected from all aspects of society.

### *G. Cryptography and Blockchain for IoT*

In an IoT environment, cryptography can provide security to the data from attacks and hackers by implementing encryption and decryption techniques. It helps in the secure transmission and storage of data in an online environment by maintaining the confidentiality and authentication of the data. Cryptography is the building block for blockchains as the blocks (records) in a blockchain are linked together by the use of cryptography. The applications of cryptography and blockchain in IoT are used in the field of the online banking system, agriculture, medications, supply chain tracking, and many more. Blockchain based IoT system can also be used for security purpose [12].

## V. CONCLUSION

This paper examines how the Internet of Things is now developing in the real world and shows a variety of concrete and cooperative applications of the technology in order to better understand how the research community may use it in future cutting-edge sectors. Over the past few years, IoT has grown quickly, and many new technologies have been released. The most recent Internet sensation is the Internet of Things. The world's resources are all growing more intelligent after collaboration with IoT. Research on the Internet of Things has a lot of potential. Several new technologies will develop throughout the ensuing years, raising humanity's level of technological advancement as the future of the IoT is bright.

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