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Analyzing the Applications and Recent Trends of Internet of Things (IoT) Enabled in Smart Cities

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Abstract

These days, smart city is an emerging concept, and every government is planning to make their cities smart. Smart cities integrate ICTs in almost all aspects of daily life. These technologies provide better performance at affordable costs to improve quality of life and deliver interaction between such sources. Internet of Things (IoT) is one of the most emerging technologies to be deployed for smart cities. These days, IoT is applicable in virtually every side of life, such as roads, health, lights, waste management, buildings, transportation, and other aspects of IoT to change the verge of development in every element of smart cities.

Objective: To secure the environment, IoT devices are very vital in different technologies. This paper is aimed to discuss various recent trends and applications of IoT in smart cities and deployment in real world.

Methodology: To fulfill these objectives, this study is based on secondary data collected from various relevant studies and online sources.

Findings: The IoT devices use sensors that are connected to Bluetooth, Wi-Fi, and RFID for data collection. These connected devices make the world smarter and evolves smart environment as smart cities, smart buildings, and smart homes. These services are improving transportation and infrastructure systems, providing waste management, minimizing traffic congestion, and improving quality of life of citizens to transform cities.

Keywords: ***Bluetooth; IoT; Internet of things; IoT devices; RFID; Smart cities; Smart buildings; Smart home; Smart environment; Waste management***

1. Introduction

The Internet of Things is a game-changing communication technology that brings ahead an innovative and unforeseen framework to connect plenty of digital devices over the web. It is designed to provide more immersive experience in using the internet [1]. The IoT market is constantly growing and enjoying momentum as vendors, manufacturers, operators, and

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companies are going to recognize emerging opportunities. Smart city is a complex ecosystem which is defined with the intense use of ICTs in order to make cities more sustainable and attractive and there is a different place for entrepreneurship and innovation [2].

Some of the major stakeholders of IoT are service providers, developers, public service providers, governments, and citizens. In addition, smart city cycle includes several development platforms, ICT technologies, sustainability, and maintenance apps for social, technical, and economic "key performance indicators (KPI)" for evolving citizens [3]. At the same time, IoT devices will be vital in deploying heterogenous and large-scale infrastructures. FIG. 1 illustrates applications of IoT in smart city.

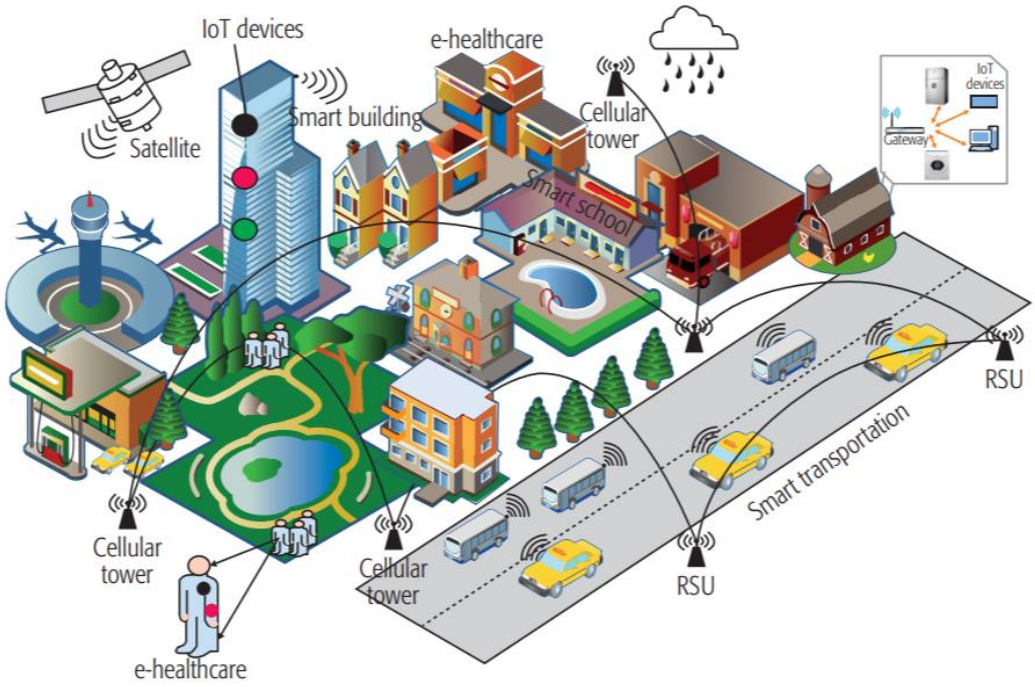

FIG. 1. **Applications of IoT in Smart City [4].**

These days, lifestyle of various people is being changed and they are shifting to cities from villages and small towns. Around 70% of the population relies on urban environment [5]. Hence, some of the systems enabled with IoT sensors are helpful in developing smart cities. Smart city is the concept which consists of innovative ways to develop more IoT devices in healthcare, transport, homes, environment, and buildings. The IoT is pointed out as emerging technologies to access the network. The term "Internet of Things" simply means a device or object connected to the web to exchange and collect big data. The "Things" consist of various devices and objects connected to the "Internet" [6]. There are different sensors used in IoT devices like software, wireless sensors, and other computing devices. These devices are helpful in sharing and transferring useful data over the web without human intervention.

1.1 Background

Over the years, IoT has been developed significantly and still one of the most promising technologies worldwide. Wireless sensor networks are widely used to generate data with these IoT devices. These networks have been developed in several industries like transport, home appliances, smart lighting, parking management (to minimize congestion), smart environmental

monitoring, water quality management, emergency services, waste management, crowd monitoring, etc. These days, IoT devices have been deployed in several sectors with interconnection between several mobile technologies like wired and wireless mobile networks, Bluetooth, GPS, and others. IoT devices are widely used with “Radio Frequency Identification (RFID)” to exchange data [7].

These IoT devices can make cities smarter by improving a lot of features. The above applications in several segments can develop smart environment and cities. It needs QR codes, RFID identification, sensor networks, desktop, and mobile communications [8]. This paper is focused on applications of IoT devices in smart cities which play a vital role in development. There is no need to have a device with huge storage and super computer to work smarter. Proper connection is needed to make such devices smart.

The device can receive or send data with proper internet connectivity. Getting connectivity all the time is the major use of IoT in smart technologies, so that these devices can make decisions on their own. Kevin Ashton was the first to coin the term “Internet of Things” in 1999. The IoT is aimed to unfold the future where objects will be connected to the web and communicate without human intervention. This paper discusses the applications of IoT devices and deployment in real world.

1.2 Literature reviews

A lot of research attempts have been made to connect smart city and IoT. For example, Zanella et al. [9] came up with a complete survey of protocols, architectures, and effective technologies for IoT framework in a project to develop Padova smart city. The deployment of “proof of concept” with several tech solutions can track quality of air, street lighting, and detection of various serious issues. A survey was conducted on basic IoT elements to realize the concept of smart cities by Jin et al [10] and they used case study on “noise monitoring”.

Mitton et al [11] shown a different aspect of smart cities where IoT devices were known to be service providers like cloud-based solutions. They found higher abstraction level to deploy ubiquitous and innovative applications by removing barriers between the cloud service providers and IoT devices in the world. Ganchev & O’Droma [12] have proposed a top-down smart city architecture in which service providers can serve as “central information unit” connected to several IoT-based services while offering acceptance and convergence of several IoT technologies.

Mullner & Riener [13] have come up with an efficient way for management of street lighting. Traditional street lights are usually online at night even when there is low traffic of public in several areas. It causes wastage of energy. Flexible lightings with IoT, i.e., “Smart Street Lightings (SSL)”, can save power to a great extent. Around 95% people use smartphones. With the deployment of IoT, street lights can track signals and position of pedestrians and smart devices. It is very vital in areas which have low traffic. It may not be so efficient in busy streets.

Mohamed [14] has discussed the future of street lighting system powered by IoT. Sometimes, streets are not too busy and there is low traffic of vehicles, especially during late night and early morning. He proposed a system which turns off street lights automatically when streets are vacant and turns on automatically few seconds before when it detects a vehicle is approaching.

The “Vehicular Ad-hoc Networks (VANET)” is used to detect the speed, presence of vehicles, and their real-time locations. It saves a lot of energy and improves lifespan of street lights.

Abhishek Y& Srikanth [15] have focused on IoT and technological aspects. They explored the unnecessary power usage because of street lights which are left turned on unnecessarily in areas which don’t need them. A new model has been proposed to save energy with great efficiency and management. They used ZigBee protocols for several sensors and LEDs. It is an effective way to control street lights in remote locations. They used LEDs for power saving and proper illumination and promised to save up to 75% of energy to improve the lifespan of lights.

Kumar [16] discussed smart roads at highly populated and traffic areas in cities. Smart roads are powered by Piezoelectric material to produce energy from the stress or pressure due to vehicle’s movements. The Piezoelectric effect is the main concept behind this. It will be highly beneficial in renewable resources. Gubbi et al [17] proposed cloud-based vision on IoT. They presented realization and challenges in “Cloud-centric IoT”. They found interaction of clouds for more scalability and flexibility in cloud computing.

Schaffers et al [18] discussed future digital devices and smart cities and taken IoT as user-driven and open innovation. They discussed how partnership can be sustained among strategies and environment. They took contribution of several EU and national actors, ICT businesses, and researchers. Samaras et al [19] discussed improvement of social networking with sensors. They focused on people-centric services and used “SEN2SOC” method to connect sensors and social media. Their main concern was privacy which is not safe in these networks and need proper security. However, this system can provide better information about smart cities where people live and technological improvements over the years.

1.3 Research gap

Internet of Things (IoT) is itself a broad concept which has various applications in different industries. There is still lack of information about emergence of IoT in smart cities. This paper is focused solely on its use cases and applications in smart cities.

1.4 Research objectives

- To discuss various applications and recent trends of IoT in smart cities
- To explore its deployment in real-world scenarios

2. Research Methodology

In order to fulfil above research objectives, this paper is based on secondary data collected from various sources like research papers, relevant news articles, journals, and others.

2.1 Research method & design

Worldwide forecasts indicate that the size and population of cities will increase further. This immense growth will put a strain on resources and pose a major challenge in many aspects of everyday life in urban areas, such as the quality of services in the

medical, educational, environmental, transportation, public safety, and security sectors, indicatively. Thus, novel methods of management must be put in place for these cities to remain sustainable. The accepted papers cover a wide range of research subjects in the broader area of smart cities, including service delivery, service recommendation, user privacy, crowdsensing, and vehicular networks. To alleviate these problems, the authors propose a hybrid service recommendation prototype utilizing user and item side information for use in the Ubiquitous Consumer Wireless World (i.e., a novel wireless communication environment that offers a consumer-centric and network-independent service operation model, allowing the materialization of a broad range of smart city scenarios).

2.2 Research approach

The Internet of Things (IoT) is an emerging paradigm that enables the communication between electronic devices and sensors through the internet in order to facilitate our lives. IoT use smart devices and internet. Moreover, it takes advantage of quantum and nanotechnology in terms of storage, sensing and processing speed which were not conceivable beforehand [2]. Extensive research studies have been done and available in terms of scientific articles, press reports both on internet and in the form of printed materials to illustrate the potential effectiveness and applicability of IoT transformations. It could be utilized as a preparatory work before making novel innovative business plans while considering the security, assurance and interoperability. In whole, IoT is an innovation that puts together extensive variety of smart systems, frameworks and intelligent devices and sensors (FIG. 2). Moreover, it takes advantage of quantum and nanotechnology in terms of storage, sensing and processing speed which were not conceivable beforehand [2]. Extensive research studies have been done and available in terms of scientific articles, press reports both on internet and in the form of printed materials to illustrate the potential effectiveness and applicability of IoT transformations.

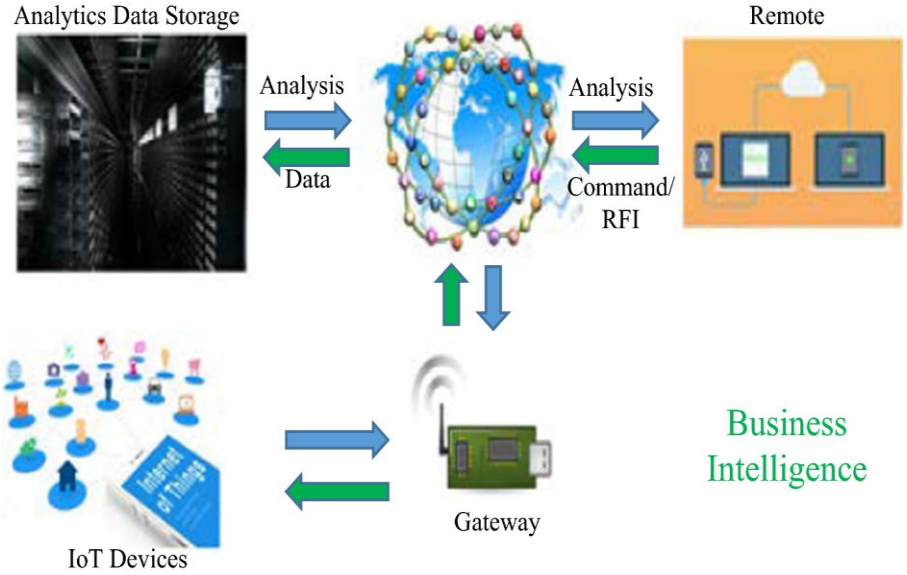

FIG. 2.

3. Analysis of Study

There are endless applications of IoT as it is an emerging technology which can redefine the daily lives of people. In this section, we will discuss the applications of IoT in smart cities.

3.1 Applications and recent trends of IoT in smart cities

In future, the smart cities are going to rely completely on IoT devices which can be accessible to everyone across the nation. Smart cities will rely totally on connected devices and self-driving vehicles. Novel approaches in public transport will lead to the development of smart bus and flying taxis. Network connectivity will be the key to access those technologies. The smart buildings are also the part of smart cities to work efficiently and save energy for organizations. Here are some of the major applications of smart cities.

3.1.1. Smart vehicles

When it comes to smart vehicle, India has strong standing in marketing 2-wheelers across the world. In 2016, the sales of 17.8 million vehicles were recorded in India, surpassing China in marketing of 2-wheelers [2]. Around 211,844 2-wheelers were stolen in India itself, according to the "National Crime Records Bureau (NCRB)". Only 46,436 vehicles were recovered out of those vehicles and others were still missing. The IoT-enabled smart vehicles can avoid such incidents. The IoT and smart security system will provide automatic controlling of the vehicles while accessing and managing them. It can be made possible only with smartphones and IoT devices (FIG. 3).

This system can provide data of the vehicle, positioning of the vehicle, time of incident, and alert the vehicle owner through SMS. These days, mobile apps can make it possible. These apps control the vehicle with IoT and secure vehicles remotely. This application is very helpful for users, drivers, delivery partners, and organizations. This system also consists of vehicle performance, low battery alert, emergency alert, fuel leakage, fuel level, and low tire pressure alert with analytics.

3.1.2. Smart lighting

It is one of the widely researched topics in IoT domain. These systems can detect human motion and activities of vehicles to light up the streets. In addition, they can adjust lighting whenever needed. Ultimately, this technology helps improve the lifespan of lighting equipment and save energy, which is good for the environment. There are sensors which control this technology.

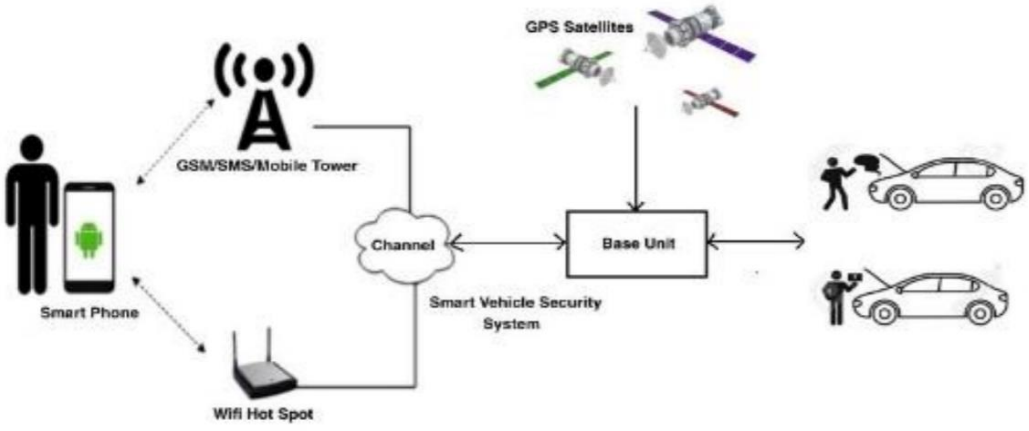

FIG. 3. **Application of IoT in Smart Vehicles Source [5].**

3.1.3. Smart building

Smart building should not be confused with smart home. Smart buildings can be industrial, residential or any commercial building. The multi-storey apartments, office complexes, and offices are buildings with various sizes and shapes. Smart buildings use a lot of smart home technologies like centralized air conditioning, smart lighting, smart security, and automatic switch on/off. IoT systems provide high efficiency, better security, customer satisfaction, low production cost, and reduced workload of humans. The smart grid is widely used to interact with various smart devices. Smart grid has great connectivity with smart buildings. It is possible to monitor building maintenance with this technology and ensure low power consumption and high efficiency. In addition, one can handle smart systems safely and quickly. Room temperature can be monitored by sensors automatically and air coolers are adjusted as per weather conditions. Proper monitoring of elevators, lighting systems, and ventilation can be made possible with smart devices.

3.1.4. Waste management

This process manages waste from origin to disposal to avoid the spread of waste. There are several stages involved in this process, such as identification of waste, i.e., non-biodegradable or biodegradable waste, so that proper method can be decided for waste disposal. There are also dry and wet wastes. IoT devices can be used to identify different types of waste and communicate. IoT devices include various sensors like ultrasonic, infrared, etc. to distinguish various types of wastes. IoT can also help in advancement of municipal operations. IoT can be applied in waste collection too. The garbage bin can be equipped with sensors to identify dry and wet waste and whether the tank is full, so that garbage collection truck can come and collect the garbage (FIG. 4). Workers do not have to check the system and garbage bins on their own. They can get the information on their devices to avoid foul smells and toxic gases. It also helps save time by separating wastes, maintains workers' hygiene, and save environment and fuel in garbage trucks. It will be a lot easier to identify wastes and dispose of. It is also vital to detect biological and toxic waste as they cannot be disposed of as other wastes. It can be hazardous to the environment, workers, and people nearby. Such kinds of wastes need special treatment. With proper isolation, much of the waste can be reused and recycled. IoT can play a vital role in recycling of waste. Digital codes can be inserted into packaging while manufacturing goods and define whether the material is reusable. It would be easier to identify the reusable product using that code. E-waste is very common currently. A new technology arises every day, making older one even more obsolete. IoT should also be used to manage e-waste.

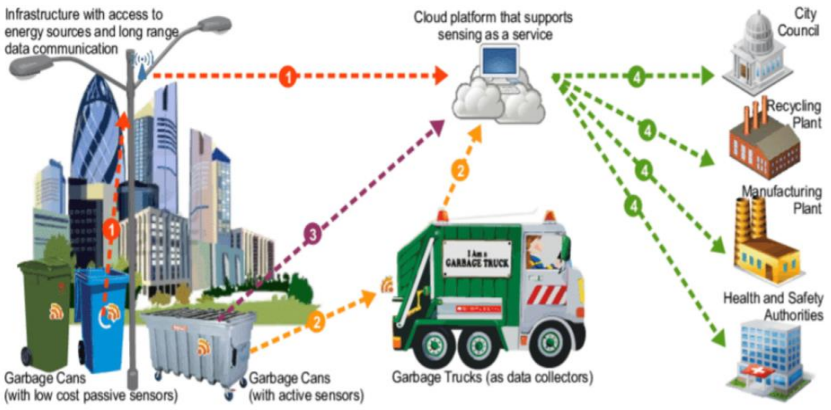

FIG. 4. **Application of IoT in waste management. Source [5]**.

3.1.5. Water quality management

Pure water is a luxury in this world. This generation must ensure that the future generations will be able to access water. Water must be utilized well and IoT can be helpful to ensure proper use of water by common public. People can make the most of water resources with the help of available data from the sensors. One can know the smell and color of sensor from far away by uploading the data to the cloud. Ultrasonic sensors can tell the amount of water available in dams. IoT sensors can help avoid damage when releasing the water from the dam by knowing the height. People cannot track the flow of water everywhere. IoT applications can help monitor the tunnels, pathways, and flows of water. It is also possible to guide the water route to reach its destination by opening valves through sensors from far away. Sensors can also tell the water temperature, turbidity, and pH level of waters.

3.2 IoT in smart cities - use cases

This section discusses some of the case studies from various enterprises, apart from modern IoT synergies to make smart cities possible. It provides a summary of real-world deployments of IoT devices and projects to deal with various issues in cities. TABLE 1 consists of a brief summary of IoT projects deployed in various locations.

TABLE 1. **Brief Summary of Case Studies and IoT Projects.**

Location	Population	IoT Solutions	Key Stakeholders	Authors
Santander, Spain	0.1 million	Smart metering of traffic, temperature, transportation, humidity, and water needs	Telefonica, Ericsson, Telefonica I+D	Lin et al. [20]
Busan, South Korea	3.4 million	Smart, drone-based marine; smart parking; safety for kids/elderly; energy and crosswalk usage	Cisco, KETI, KT, ETRI, and Busan Government	Lee et al. [21]
Milton Keynes, UK	0.2 million	Low carbon emission, smart transportation, water management, and smart energy	Samsung, Huawei, Milton Keynes Council, Cambridge University, CATAPULT	Sicari et al. [22]
Chicago, US	2.7 million	Smart living, smart grid, low crime rate, emergency alert	Chicago Government, IBM, Cisco	Botta et al. [23]

3.2.1. Santander, Spain

This Spanish city is well regarded as “Future Internet Award-winning” smart city. This project was an initiative of 15 leading organizations like Telefonica, Ericsson, and various research groups and institutions in Greece, Spain, Denmark, Australia, Germany, and the UK. The city is powered by around 20,000 smart IoT devices performing various smart tasks like temperature control, position and speed of vehicles, humidity, public transport schedules, traffic intensity, water networks, and air quality.

The sensor data which is acquired is transferred to laboratory and combined by a central computer into a big picture. This digital city has a record of everything [20].

3.2.2. Busan, South Korea

This ubiquitous city is one of its kind in South Korea. Using cloud infrastructure, the Busan "Green u-City" is one of the lively and modern epitomes of how a smart city should be developed. It uses cloud services to improve the lives of citizens, and efficacy of local businesses and city management. It is a public-private initiative between leading tech providers, KT (largest telco in South Korea), Cisco, and Busan government, with investment of whopping US$452 million. It is aimed to deliver e-healthcare, improved transportation, increased business and job opportunities, and improved accessibility to information with various communication sources and devices [21].

3.2.3. Chicago, Illinois

This smart city project is based on economic growth, infrastructure development, and community engagement to deal with various serious issues of crime, education, transport, and economy in Chicago, US. Over 300,000 smart devices have been deployed in association with IBM for smart grid operations. This project is mainly aimed to save energy to save US$170 million for consumers. Cisco has developed this project on its analytics platform to reduce crime. In addition, the model can predict and avoid infestations by rodents with over 31 variables. Analytics also detect buildings which might be vacant. A lot of apps have been developed with 600 datasets of open city portal to inform citizens on various unexpected situations in the territory [23].

3.2.4. Milton Keynes

This smart city project was aimed to design a data hub in association with "Open University" to manage and collect data from various smart devices. The project has support and control of carbon emissions and sustainable growth without using extra infrastructure. The project is designed in association with Huawei, Samsung, Cambridge University, and CATAPULT to provide innovative solutions. It was aimed to provide smart energy, transport system, and water management solutions and to facilitate education, business, and community activities [22].

IoT devices are basically small and have a lot of sensors. A constant source of energy is needed to handle such devices. Hence, cost and battery life are some of major challenges. The devices should be able to consume less power at low cost to deal with these issues in smart cities. More advancements are needed to make micro-electronics and wireless communication more mature.

4. Results

Along with the given advancements above, there are so many open research challenges that should be resolved for adopting IoT-based smart cities. The following challenges pointed below should be considered for further research path in this area -

- **Connectivity** - There are billions of devices connected and work together in the network in an IoT-based smart city. Smart city can be successful only when it can provide better connectivity to every IoT device available with smart sensing capabilities to deliver precise information. IoT devices can use communication networks like Bluetooth, public Wi-Fi,

satellite, and mobile networks to communicate with cloud center. Here are some challenges in providing connectivity in smart cities -

- Providing connectivity to vehicles and high-speed trains
- Connectivity from device to network and network to device
- Connecting widely deployed devices without communication networks

- **Big Data** - It is one of the major areas for research in paradigm of IoT-based smart cities [24]. Billions of devices are connected in smart cities to provide a huge amount of data and information for analysis. This data consists of information from smart hospitals and surroundings. Smart algorithms and techniques are needed for analytics. It is possible to adopt deep learning algorithms to analyse huge data from local devices.
- **Security** - Every IoT device needs security. Internet connectivity is available to different devices in smart cities, making security a major challenge. Around 70% of IoT devices were vulnerable to attack in a smart city because of poor software protection, insufficient authorization, and weak encryption in communication [23]. Here are some of the issues to address for a successful smart city -

  - Private communication for user data
  - Light, simple, and efficient security solutions for data integrity and authenticity
  - Secure communication between cloud center and IoT devices
  - Proper risk assessment is needed to detect new and existing attacks, threats, and loopholes. ENISA has proposed this kind of risk assessment tool to detect common attacks in ITS [25].
  - Proper and active decentralized trust management program is needed.
  - Strong privacy measures are recommended to ensure users' consent and trust.

5. Conclusion

This paper has discussed the application and use cases of IoT in smart cities for better development of cities. IoT creates new environment to make the lives of citizens easier and businesses and government authorities more efficient. This paper explained how to make cities smart and efficient. This article has also addressed the benefits of using IoT devices in smart buildings and other applications. Proper research directions have been devised for applications in smart city environment by addressing several challenges. IoT can provide various benefits to the society with successful implementation.

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