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Adoption of Iot In 5g And Wifi-6 Technology Towards Smart Cities

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Abstract *- In future years, 5G cellular technologies and IoT are intended to make effective implementation. 5G will have some initial deployments in urban areas. A bandwidth demand for various smart city applications is considered the significant driver for enhanced mobile broadband-based 5G services and the new generation of IoT applications with 5G. In addition to this, WiFi-6 plays a greater role in the data communication and services in mobile-based technology with the implementation of smart cities. This paper discusses the importance of 5 G-based IoT applications in smart city environments, such as enhancing public utilities, infrastructure, and services.*

Keywords - *IoT, adoption of 5G and WiFi-6, smart cities*

I. INTRODUCTION

The IoT (Internet of Things) technology is considered a basic block for smart cities because it plays an important role in different domains such as transportation, urban planning, automation, and health care. So, it becomes an important feature of smart cities as an internet-based technology by interconnecting virtual things such as computing technology, communicating, and embedded sensing to physical things at rapid growth. Physical objects like buildings, vehicles, or any other appliance connected with network connectivity, software, and embedded sensors can communicate with each other, with or without human intervention, by using IoT [1]. By using IoT, we can control pollution, traffic, and infrastructure in a better way. By 2050, the world's total population is expected to double, which will increase the demand for smart and sustainable environments to improve the quality of life [2]. Numerous smart city services will be running over 5G and WiFi technology. There will be pushing forward the integration of 5G and IoT in the application of smart cities. This paper highlights an overview of adopting IoT and 5G technology in smart cities.

II. RELATED STUDIES

This literature review focus on related studies of adoption of IoT, 5G technology, and WiFi-6 in smart cities.

A. IMPORTANCE OF SMART CITY - The population in urban areas has been increasing for the past few decades because of its rapid growth. To increase residents' quality in cities, smart city technology is important so that cities can operate more effectively and efficiently. We can improve public safety and provide a healthier environment for people [3]. Four important features in smart cities are as follows:

a) Road traffic

Different types of sensors and GPS data are used in smart traffic technology, which is used to find the vehicle number, location, and speed for road safety. According to the traffic situation, lights can be altered automatically by using smart traffic lights to prevent congestion. The Cloud management platform is used to store data so that historical data can be easily retrieved, and it is used in smart solutions for traffic management to prevent potential congestion.

b) Street lighting

Smart lighting is used to switch on, switch off, brighten or dim the streetlights according to the circumstances. So, streetlights can be easy to maintain and cost-effective. The lighting schedule can be framed by integrating the streetlights with sensors and linking them with cloud management technology. It can be updated by the movement of people and vehicles, illuminance, etc., [2].

c) Waste management

Predefined schedules of the waste collection led to extra fuel consumption by garbage trucks and unproductive usage of waste containers. We can convert that into an effective approach by tracking waste levels to optimize the waste-collecting schedule by IoT. By placing sensors in each waste container, the garbage truck driver will get a notification in his mobile app once it reaches the threshold level [4].

d) Environment

Two major qualities that prove whether the environment is healthy or not are air quality and water quality. IoT technology in smart cities is used to maintain them at an optimum level. A smart water meter is used to check the parameters such as temperature, flow rates, quality,

pressure, etc. For example, if the composition of water changes, the maintenance team gets an alert automatically by water quality management solutions, then the field workers will fix the issue. A network of sensors is placed across the cities to monitor air quality to gather data about the pollution rate. It monitors the air pollutants in the atmosphere such as nitrogen dioxide, carbon monoxide, etc. This data is used to take preventive measures for controlling air pollution [2].

e) EVOLUTION OF 5G

Mobile wireless communication has witnessed a lot of development in the last few decades, from 1G to 5G. In 1G, first-generation telecommunication technology, data were transmitted through analog signals through circuit switching techniques. By this technique, we communicate by establishing a dedicated path. Different countries used different standards for their communication, which includes Advanced Mobile Phone System (AMPS), Nordic Mobile Telephone (NMT), Total Access Communications System (TACS) with a speed of 2.4kbps. The main disadvantage of this generation was poor voice quality and security issues, which led to the growth of next-generation technology, i.e., 2G.

2G digital signal transmission was used for data transmission, and instead of a dedicated path, dynamically allotted different paths were used for communication. It was achieved through packet switching along with the circuit switching technique. 2G was based on the standard Global System for Mobile communications (GSM) with an increased speed of 64kbps. It further underwent some development which led to 2.5G and 2.75G. The standard used in 2.5G was General Packet Radio Service (GPRS) with a speed of 115kbps, and the standard used in 2.75G was Enhanced Data rates for GSM Evolution (EDGE) with an increased speed of 384kbps. 2G provides facilities like SMS (Short Message Service), MMS(Multimedia Message Service), Email, WWW(World Wide Web), etc., and it has better voice quality than 1G. A major drawback was that it provided limited data services.

3G was an improved version of 2G with an increased speed of 2Mbps, comparable to broadband connections. It provided services like video conferencing, live streaming, navigational map, etc. Due to the demand for higher speed in the market, 3G undergoes further development of 3.5G, 3.75G, and 3.9G. Power consumption is high in 3G. 4G differs from the previous generation by implementing only a packet switching technique. It provided a speed of 100 Mbps to 1 Gbps using a frequency of 2 – 8 GHz [5].

4G supports different services like High-Quality Live streaming, Video Chat, Mobile Television, and High Definition Television (HDTV) content. Even though it has a higher speed, the latency of 40ms to 60ms is not acceptable for real-time applications. It led to the research of next-generation technology, which is 5G [6]. The 3 important features in 5G technology are high speed, low latency, and connecting with multiple devices. It has a 10Gbps speed with 1ms latency, which is 10 to 50 times efficient than 4G-LTE. So, the 5G technology leads to the evolution beyond mobile internet to IoT [5].

f) EVOLUTION of Wi-Fi 6

Wi-Fi technology is developed to offer wireless communication by transferring data using electromagnetic waves. Wi-Fi 6, also known as 802.11ax, is the next generation of the WiFi standards proposed by the Institute of Electrical and Electronics Engineers (IEEE).

In 1999, the first WiFi standard 802.11a was made available to worldwide users, and then the WiFi standards and frequencies have evolved over the decade. The 802.11b runs at a frequency of 2.4 GHz covering 150ft with a maximum speed of 11Mbps. The 802.11a WiFi standard uses electromagnetic waves that run at a 5 GHz frequency and provide a speed of 54Mbps.

In 2003, the 802.11g was launched with better advancements to support higher bandwidth, ranges, coverage, and power. In 2009, the demand for a more efficient and high-speed wireless connection was raised after the launch of smartphones. Hence, Wi-Fi 4, also known as 802.11n, was built to offer a high-speed wireless connection of 300Mbps. It can run at both 2.4 GHz and 5 GHz frequencies, and by adding more antennae, it can also provide a speed of 450Mbps.

In 2014, Wi-Fi 5, also known as 802.11ac, was introduced to provide a high-speed connection ranging from 433Mbps to various Gbs per second. This technology can run at 5 GHz frequency and allow multiple streaming to multiple clients simultaneously. In 2018, the 802.11ad version was introduced to run at 60 GHz frequency and provide high speeds up to 6Gbps [7].

Wi-Fi 6, also known as 802.11ax, is an improved version of 802.11ac mainly developed to work with next-generation IoT applications. Wi-Fi 6 can operate in the dense environments created by the IoT applications and support more concurrent users. This technology can expand the frequency bandwidth from 80 Mhz to 160 Mhz for a faster connection between the router and the device [7]. The 802.11ax standard utilizes the communication technologies such as Multi-User Multiple Input Multiple Output (MU-MIMO), BSS Coloring, and Orthogonal Frequency-Division Multiple Access (OFDMA), and Target Wake Time (TWT) [8]. The advantages of using OFDMA in Wi-Fi 6 include advanced data transmission between devices, greater network efficiency, greater power, improved latency, improved devices' battery life, and faster communication between router and devices [7].

Wi-Fi 6 offers high network security by including advanced security protocol WPA3, which can provide 192-bit security for wireless connection networks. The current unencrypted and open wireless connection networks are replaced by utilizing Opportunistic Wireless Encryption (OWE) in the WPA3 security protocol. OWE offers individualized encryption to open networks and protects users against eavesdropping.

Wi-Fi 6 is an evolutionary innovation that can provide four times the strength of Wi-Fi 5 (802.11ac). It is developed to support a wide range of future IoT applications and devices from the enterprise environment to smart homes. This standard provides a better experience with more devices served by a single wireless router. Wi-Fi 6 protects

data and improves security on public wireless networks [7].

g) ADOPTION OF IoT TOWARDS SMART CITIES

In simple, the Internet of Things (IoT) refers to the physical devices connected to the internet, which can be controlled anywhere from the world. IoT fills a gap between the real world and the digital world. It operates by collecting and sharing data. For example, a small pill or jet engine of an airplane. It is about extending the power of the internet beyond computers and smartphones to real-time applications [9].

The concept of adopting IoT within homes to use intelligent technology seems convenient. But, the same concept does not apply to the adoption of smart technology within a city's infrastructure. The adoption of IoT towards smart cities needs to focus on important objectives such as providing security to enhance the safety of residents, improving the management and maintenance of city infrastructure, reducing the cost and energy consumption for a greener environment, and improving the residents' life quality [10].

IoT technology can deploy sensors in roads, bridges, and railway tracks to detect the decaying infrastructure of smart cities. IoT technology improves the security and safety of smart cities through face recognition and biometric applications. The remote sensors of IoT technology can detect weather changes and alert the smart cities for emergency preparedness [10], [11]. A smart corridor refers to a specific area that is highly integrated with smart technologies that offer adaptive capabilities, including adaptive traffic signals, real-time weather updates, and more. The most important benefit of adopting IoT technology in smart cities is improved traffic flow management and congestion prevention [10].

h) IMPLEMENTATION OF SMART CITY SOLUTIONS WITH IOT

The most important thing that needs to be considered while implementing a smart city platform is that if a municipality plans to expand its service, it should be easy to upgrade the existing structure without rebuilding it. There are different stages to implement efficient IoT architecture for a smart city. The first stage is designing an IoT-based basic smart city platform with sensors and actuators. Sensors and devices can act by actuators by collecting data and passing that data to the central cloud management platform. The collected data must be processed and filtered before passing it to the cloud. A filed gateway can do it for secure data transmission. A data lake is used to store data in its raw state. The valuable and structured data is stored in a big data warehouse.

The second stage is monitoring and analyzing data to perform a particular task. The third stage is Deep Analytics which uses advanced techniques like statistical analysis and machine learning to identify hidden correlations and patterns in data. It is used to create a predictive model and identify trends by analyzing historical data collected in a big warehouse. This model sends signals to actuators of IoT devices to act. The fourth stage is smart control. We can control applications by two methods which are rule-based, and Machine Learning (ML) based. Rule-based are predefined manually, while ML-based use a predictive model.

The fifth stage is the interaction with citizens via user applications. For example, in traffic management, sending a notification to the driver in the area about traffic jams and encouraging them to take a different route. Also, sending congestion alerts to traffic control employees for managing the traffic. The final stage is integrating several solutions such as controlling air quality and traffic parallel in traffic monitoring. Well-designed IoT-based smart city solutions lead to a healthier environment, safer cities, and reduced energy costs. It helps to connect cities with its services in an efficient way [9].

III. ADOPTION OF IOT IN 5G TECHNOLOGIES AND WI-FI 6 TOWARDS SMART CITIES

In future years, the number of IoT connections will increase drastically. By 2025, the number of cellular IoT networks will be around 2.5 billion, as the cellular IoT growth will be 25% annually. Also, there will be around 30 billion connected devices [10]. A high-speed wireless connection is required for smart homes, smart vehicles, industrial automation, and other IoT applications in the smart city.

A fully functional 5G and Wi-Fi 6 connection placed in every zone of a smart city's infrastructure can provide a high-speed wireless network and increase network strength. More IoT devices and sensors can track conditions and quickly deliver real-time data when the network capacity is increased. The widespread network coverage of 5G and Wi-Fi 6 enables a more impactful IoT technology for the smart cities infrastructure. It can improve the important services of the smart city such as waste management, utility grid, and more [12].

Adopting IoT in advanced cellular and wireless technologies can improve performance, including accurate location sensing, faster speeds, and increased real-time data capacity. Enterprises consider 5G and Wi-fi 6 a significant chance to transform their operations in the evolving smart cities. Wi-Fi 6 technology enables the connection between many more IoT devices on the network to transfer massive amounts of audio, video, and other data in real-time. The three significant attributes of 5G technology are massive IoT device connectivity (mMTC), ultra-reliable low latency (uRLLC), and enhanced mobile broadband (eMMB) [13].

Both the 5G and Wi-Fi 6 technologies ensure significant performance in unique ways. Wi-Fi 6 compliments 5G technology by acquiring cellular traffic to prevent cellular network congestion at peak time [13]. Many outdoor IoT applications benefit from 5G technology as it can support any number of cellular users. Similarly, many indoor IoT applications benefit from Wi-Fi 6 as it can offer high user density and high bandwidth at a low cost. The powerful combination of these two technologies in adoption with IoT technology can improve the efficiency of new smart city applications [12].

The adoption of 5G and Wi-Fi 6 enables the utilization of the full potential of IoT technology that allows large amounts of data flow between devices and people. IoT technology aims to improve efficiency in smart cities by collecting and analyzing massive amounts of data from multiple connected devices. In smart cities, using 5G and Wi-fi 6 in smart vehicles can accelerate the communication between vehicles and transport infrastructure. IoT equipped with these wireless technologies improves the system of real-time traffic monitoring in response to lane openings and current conditions, thereby reducing delays [12].

With the ability to respond in real-time and connect multiple IoT devices, 5G and Wi-Fi 6 can enhance the efficiency of smart corridors. Based on the real-time data, air filters fixed on streetlights will turn on whenever the pollution level gets above a certain point. The noise-canceling technology equipped in noisy places will turn on whenever the sound readings reach a certain point.

The adoption of IoT in 5G and Wi-Fi 6 technologies towards the development of smart cities brings significant benefits such as increased interaction between smart devices and people, increased amounts of real-time data and devices, enhanced developments of smart industries, better use of IoT devices, and improved environmental safety [13]. One of the most advantages of 5G technology is that it offers different features and applications for various requirements [14]. The 5G and Wi-Fi 6 technologies can be a force multiplier for IoT technology and emerging smart cities. The adopters and providers of advanced wireless and cellular technologies can get enormous opportunities over the next few years [15].

IV. CONCLUSION

A smart city is a city with the ultimate aim of connecting every human to devices using innovative IoT technology and high-speed wireless networks. A smart city can establish a smart environment, governance, smart economy, and living by integrating government, society, and technology. IoT builds a connection with the physical objects of the smart city equipped with smart technology and capable of sensing and communicating real-time data. As part of the wireless infrastructure of smart cities, the advanced cellular and Wi-Fi networks work together to enhance the applications of IoT technology. The next generation of wireless technologies, 5G and Wi-Fi 6, play an important role in the current evolution of smart cities. Wireless technologies continue to develop in the future, causing a more prevalent and impactful IoT technology in smart cities. While IoT adoption is not universal yet, its demand is increasing as the important advantages of smart technology in smart cities become more widespread.

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