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5G mobile communication systems application in smart cities

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Abstract. 5G, the fifth generation of mobile communication systems, is expected to bring about a revolution in the world of wireless communication. Its key features include high data transmit rates, low latency, and high system capacity, which make it ideal for supporting a range of advanced technologies and applications. One of the most promising areas of application for 5G is in the development of smart cities. In this article, we provide an overview of the development of mobile communication systems from 1G to 5G, highlighting the key features and benefits of each generation. We also explore the specific features and applications of 5G that make it an ideal technology for building smart cities, including smart driving, smart healthcare, smart energy, and more. Additionally, we explain why 5G is critical for meeting the requirements of smart cities, such as the need for high-speed and reliable connectivity. Finally, we discuss the importance of 5G in constructing smart cities in the future, and the potential benefits that it could bring to society as a whole. With the potential to transform the way we live, work, and interact with our environment, 5G is set to play a critical role in shaping the cities of tomorrow.

Keywords: mobile communication, 5G, smart cities.

1. Introduction

There is a large number of technological advancements from 1G to 5G. In 1G, the Frequency Division Multiple Access (FDMA) schemes were used. In this scheme, the frequencies are divided into different channels and each user will be allocated to one channel at a time [1]. In 1990s, 2G appeared, and it used digital ratio signals rather than analog signals, which increased data rate capacity. The 3G was developed in late 2000s, using Code Division Multiple Access（CDMA）. 3G increased data capacity and communication quality compared to previous generations, and its data transmission rate significantly improved. The high data transmission rate allowed 3G to achieve multimedia transportation of information. Mobile communication started to include images and videos. Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) were 4G's most important technology. And 4G was totally on the basis of Internet Protocol (IP), which makes it stood out from prior generations the most. And it made High Definition (HD) video which are directly from the Internet and 100 Mbps Internet connection possible [2].

The 5G system is powered by technological developments that will alter the structure of mobile communication systems. 5G will make many different application situations possible through implementing an entirely new system model. To promote widespread use of immersive solutions, new technologies such as Artificial Intelligence (AI) and Mobile Edge Computing (MEC) will have a significant impact. Applications that need nearly immediate processing and decision-making depend on MEC in a significant way. Network delay is decreased by MEC's ability to handle data close to its place of origin. The deployment of 5G technology emphasizes core technologies such as fresh radio connections, MIMO, mixed high-density denaturation and waves in the length of millimetre (mmWave) [3]. Compared with traditional mobile communication technology, 5G has a high data transport rate, low time delay, and high spectral efficiency. For example, the data transport rate of 5G can reach up to 10 Gbps which is about 10 times to 100 times of 4G [4].

The format of this essay is as follows: In this paragraph, the development of mobile communication is introduced, and 5G's advantages are also mentioned. In addition, the importance of 5G network is also highlighted. In the next section, the idea of smart cities is introduced, and how 5G network can help construct smart cities is focused. In fact, the 5G can make a difference in almost all the fields of smart cities. Among these fields, transport, healthcare as well as media and entertainment are highlighted in this section In the third section, various ways of achieving smart cities are mentioned and discussed. The advantages and disadvantages of each method will be highlighted. And these methods are put together to compare in the last part of the third section. The last section, this section is mainly to conclude previous sections and the conclusion is mentioned in this section. In addition, some important points will also be included in the last section.

2. Theoretical analysis of 5G network in smart cities

2.1. Definitions and explanations that a smart city should depend on

*2.1.1. The definition of smart city.*The smart city is defined as the product of the Internet, cloud computing, Internet of Things(loT) and other new information technologies combined with traditional cities. And it uses information techniques and communication techniques to sense, analyze and manage livelihood, environmental protection, industry, commerce, public safety and urban services and other information. In addition, it can smartly respond to various requirements to achieve smart city management [4].

2.1.2. Effective wireless sensor networks (WSN). The sources of perceived information and their supporting wireless network and forms a WSN in order to function are required in smart cities. To gather dynamic time-current data, detecting and collecting data must be done as frequently as necessary. Not only would the information gathered need to be up-to-date, but also promptly evaluated and transmitted to the relevant target nodes., where They would be utilized to totally comprehend the significant factors and their connections and make wise selections.

2.1.3. Robust, stable and secure communication networks. To perform incredibly well in the area of low time delay and high capacity for terrific throughput when applying the WSN functions, an exceptional network is required. One more fundamental aspect for the network is stability, which ensures that it is always accessible. Data must not, under any circumstances, including by a malicious entity, be accidentally altered while being collected and sent for decision-making. This could result in data being altered or information (especially sensitive information) slipping into the hands of the wrong people, which could lead to erroneous interpretations of the data they convey. Thus, another crucial consideration is the safety of the information data acquired.

2.2. Relationship between 5G network and smart cities

When wireless communication technology advances, smart cities, and the IoT come to fruition. Users should be able to access virtual reality and augmented reality implementations, smart transportation, smart healthcare, smart grid, and smart manufacture thanks to 5G mobile networks. Smart cities are examples of IoT applications, and 5G networks can be seen of as a key enabler for IoT. Therefore, there is a natural connection between 5G and smart cities. As shown in Figure 1 [4], 5G can be used in managing smart cities for its features and using cases, and 5G is a suitable tool to conduct efficient WSN.

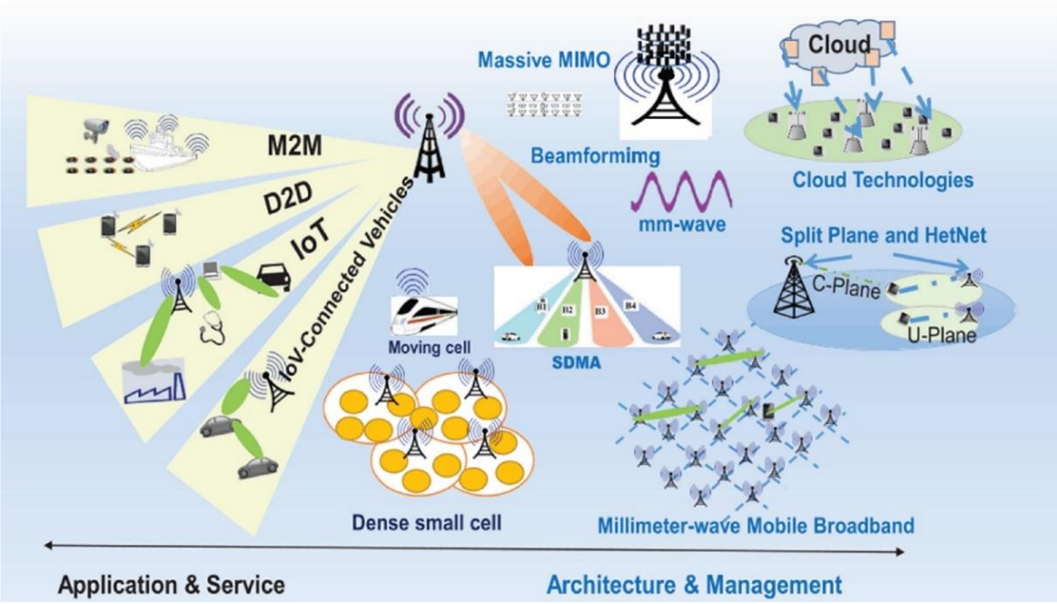

Figure 1. 5G's applications and features.

2.3. Commercial model for 5G use in smart cities
Various stakeholders are related to using 5G in smart cities. Several stakeholder categories with diverse roles, duties, and considerations may be present depending on the business architectures employed in a smart city [5]. Software controls the transport network, enabling flexible rearranging of all network elements adopting the Flexible Ethernet (FlexE) specification, which makes the physical layer visible to the service layer and enables flexible usage of the link's capacity.

2.4. Use cases of 5G networ
A slice is a group of functionally tailored network functions that help meet the communication service needs of certain applications or business strategies. Based on the abstraction of the features of the applications they enable, network slices are divided into many forms. There are four network slice types defined by the 3rd Generation Partnership Project (3GPP) which are as the follows. Enhanced Mobile Broadband (eMBB): Increased rates of data and improved coverage requirements apply to this slice type. This slice type typically contains a lot of gadgets packed into a tiny space. Ultra Reliable Low Latency Communication (uRLLC): This slice type has the name of crucial interaction. Devices with strict time delay and stability requirements are typically supported by this. Vehicle To Everything (V2X) communication: This slice type facilitates interaction between the surroundings and the vehicle.

In the context of 5G networks, four types of network slices have been identified, each catering to specific use cases. The first type, eMBB, builds upon current 4G networks and provides higher data rates and enhanced user experiences for metropolitan regions with high population density. The second type, mIoT, enables cost- and energy-efficient mass sensing, monitoring, and metering with a low device complexity and 10-year battery life. It supports 30,000 devices per cell and is ideal for applications that require small data volumes. The third type, uRLLC, enables highly stable and low time delay communications and finds potential applications in various fields such as smart energy, smart transport, factory automation, and remote surgery. Enabling uRLLC requires meeting two important requirements: latency and mobility. The fourth type, V2X, provides vehicular communication between vehicles, roadside units, and pedestrians, which is critical for the intelligent transportation system.

2.5. Features of 5G network

As the fifth generation of mobile communication, the 5G has some significant features to distinguish it from other generations. And these features, such as millimeter wave, ultra-dense networks and small cells, also make 5G a better way to be used in conducting smart cities.

Small wavelengths found in 5G systems increase data transmiting rate and limit the range of 0.1 millimeter to 100 meters, necessitating the use of numerous small cells.

Base stations having a smaller size are known as small cells, which consume less energy to operate and can be positioned at a distance of 250 meters. To prevent dropped signals, a city could install thousands of these stations. As a result, a dense network would be created that functions like a relay team, transmitting signals and directing data to users wherever they may be. The goal of small cells is to lower energy consumption for circuit power, enhance attainable data rates, and decrease access time. Because of the close proximity between the receiver and the transmitting equipment it can accommodate a large number of user devices in the small cell and prevent interference as well as reduce the pathloss. Key components of 5G networks include emerging small cell technologies and the Massive Multiple Input Multiple Output (M-MIMO) system. Small cells and M-MIMO can be used together to improve Quality of Service (QoS) and system capacity and minimize the Additive White Gaussian Noise (AWGN) [6].

3. Application of 5G in smart cities

3.1. Brief introduction of the application of 5G in smart cities

Because of its high data transfer rate and low delay, 5G may be used in so many facets of smart cities that it can be considered one of their primary factors. For example, the automatic car won’t be available to the public without using 5G. In a smart city, 5G applications can generally be classified into a number of dimensions known as distinct industrial verticals [7]. Furthermore, every vertical industry may have a variety of use cases and many of them are not only brand new technologies but also services that we are familiar with.

3.2. 5G in smart transportation

The number of automobiles on the road has been steadily increasing. This is partially a result of global urbanization, as the UN predicts that by 2050, cities will be home to 21% of the world's population, compared with only 12% in 2013. The latter highlights significant issues that must be addressed, such as the rising number of fatalities in road accidents and the deteriorating global natural environment. In order to prioritize applications that have the potential to increase security, driving effectiveness and travelling convenience, the idea of Intellectual Traffic System (ITS) is essential to solving the challenges of transportation utilizing Information and Communications Technology (ICT).

3.2.1. Automobile communication. Recently, modern car has become a sensor platform that recognizes environmental data. An onboard computer processes this data, which is subsequently applied to navigation, pollution prevention, and traffic management. However, an extremely powerful onboard computer is required to achieve fast data processing. This explains why luxury cars with driver assistance systems are so expensive. With the Internet, it's supposed to be feasible to upload the data onto the cloud to carry out high processing burden in order to avoid employing expensive equipment. In order to supplement the data already gathered by vehicles, IoT can help traffic management centers obtain extra information. The Vehicular Cloud Computing paradigm is a difficult environment to evaluate upcoming 5G abilities with this presumption [8]. Vehicles may communicate with one another and exchange information, and the same is true for any component of a smart city, including the roadside infrastructure, the Internet, pedestrians, and other elements. This term is called V2X which refers to all of these vehicle communication methods, shown in Figure 2 [9].

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Figure 2. Vehicles and the city share information with each other.

3.2.2. Advanced driving. Advanced driving technology allows for partially or entirely automated driving. In this case, longer intervehicle ranges are permitted. Each car exchanges sensor data with other surrounding vehicles so that they can synchronize their driving patterns. Safer transportation, fewer collisions, and better traffic flow are benefits of advanced driving. With advanced driving communications, two vehicles may need to communicate in the following situations. The first is end-to-end communication at the maximum of 10 ms latency for collision avoidance that is cooperative between User Equipment that apply to V2X application. The other one is end-to-end communication latency should be less than 100 ms for information sharing for autonomous driving between applications that support V2X for cars with a minimum range of 700 m for the lowest level of automated cars and 360 m for the highest level of automated cars.

3.2.3. Additional detectors. Additional detectors are used to describe a vehicle's capacity to communicate unprocessed or processed data about items in its immediate area that are not visible to its sensing devices. To help other adjacent vehicles in presenting a full view of the traffic conditions in a given region, other nearby vehicles that are able to identify these elements process and broadcast them. A vehicle's sensor data can include anything from a real-time livestream to a picture of an item that it perceives.

The situational sensitivity and public safety for automobiles and pedestrians are improved by sensor data from diverse sources. Additional features and abilities, such as cooperative driving and the exact positioning required for autonomous driving, are made possible by extended sensors. Vehicles can contact nearby vehicles with messages to notifies them to situations that has poor field of view. These are crucial intersections where the range of the sensing devices is constrained by the weather. The following are some possible communication needs between two V2X endpoints to support extended sensors: The V2X technology supports the sharing of sensor information between use cases for vehicles with varying degrees of automation. The maximum end-to-end communication delay for vehicles which have the lowest proportion of automation is 100 ms, while for those with the highest proportion of automation, it is only 3 ms. Video sharing is also enabled between applications, with a maximum end-to-end communication delay of 50 ms for the least automated vehicles and 10 ms for the most automated ones. The information reliability between vehicles ranges from 99.999% for the least automated vehicles to 99.999% for the most automated ones. Additionally, V2X supports high connection intensity in congested areas, with a capacity of up to 15,000 vehicles per mile at busy interstate crossings.

3.3. Smart energy

In the past a huge central power plant can meet the needs of the final consumers. Yet, as the utilization of alternative energy sources rises, we have unstable relatively tiny power plants to deal with. These

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hundreds of small spread power plants are beginning to displace the massive conventional central power producing systems [10]. As a result, networks for generating and distributing electricity switch to a two-way power flow from a one-way one, allowing customers to produce electricity on their own.

Aiming at the interconnection and supervision of energy and detached power stations that generate electricity across the four elements of the value chain. is the goal of 5G and these elements are generation, transmission, distribution, and consumption. By controlling distributed sources of energy, constructing advanced measuring methods, and boosting the integration of detectors into the infrastructures that generate electricity.

3.3.1. Smart grid. Several sensors will be deployed for network monitoring, preventative analysis, and infrastructure security on a chosen electrical system, in a few auxiliary substations, and on the related reduced voltage lines. To enable new services and manage load and generation assets in new ways, a management architecture that draws inspiration from the blockchain protocol will be created. This will make it easier to integrate diversified generation into networks which has low or medium level of voltages. The building of an integrated network with a crucial element and a variety of connectivity options will be possible with the help of the 5G, which will then give wireless connectivity to the periphery plants.

Because they allow high connection densities and dependability, 5G networks boost connectivity in congested locations and inside buildings. As a result, 5G networks are able to integrate the control and management of multiple energy grid sectors. As a result, utilities and energy customers can use smart energy networks at lower costs. The basis of smart energy, the smart grid, plays a key role in fostering social and economic harmony. By doing so, sustainable development is improved. It makes possible a better quality of life, a more stable society, and a cleaner environment. This helps to improve energy management and enables the switch to electricity and alternative energy.

Moreover, it is projected that renewable energy sources will make it possible for the next generation of electric vehicles (EVs) to be produced, helping the environment and reducing greenhouse gas emissions. Since they emit less noise and pollution, EVs can support a sustainable transportation industry. It eliminates the detrimental effects associated with the issue with internal combustion engines.

3.3.2. Managed distribution of energy. The supply and delivery of more scattered power sources is enhanced in the way of handling resources for distributing energy. With the use of nearly immediate data and sophisticated data analysis, 5G empower the capacity to detect and make reactions to changing requirements of energy in the multiple power system, allowing a better response to maximum consumption and averting potential power outages. Energy providers can put money into 5G technology to develop a smarter, more sensitive electricity system. According to estimates, the utility segment will support to upgrade the existing power grid to a more budget - friendly, dependable, and real-time intelligent grid.

4. Conclusion

This article introduces the mobile communication from 1G to 5G and focuses on how 5G being used in the structure of smart cities. The 5G technology is capable for many areas because of its advantages over the previous 4 generations mobile communications. To build smart cities, a tool which holds the capacity transmit massive information in a short time is required, and the appearance of 5G can fit this requirement. In fact, many parts of smart city are depending on 5G technology, such as smart transport, smart energy and smart healthcare.

Although many applications of smart city are still in theory, some of the applications are put into use with the help of 5G technology. For example, autonomous vehicles have been in the market. It can be predicted that there will be more and more 5G usages in constructing smart city.

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