Application research of 5G/6G cellular network in intelligent Transportation Internet of Things

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Abstract. This study paper's primary goal is to examine the developments and use cases of 5G/6G wireless communication technologies and the Internet of Things (IoT) in intelligent transportation. This paper will delve into the foundational aspects of IoT technology and its integration into intelligent transportation systems (ITS). It will conduct in-depth research on 5G and 6G wireless communication technologies and the critical IoT technologies that play a pivotal role in intelligent transportation. By analyzing these cutting-edge technologies, the paper highlights their significance and potential impact on transportation systems' efficiency, safety, and sustainability. This research will identify and elucidate the major applications of 5G and 6G wireless communication technologies in intelligent transportation. By comprehensively addressing these objectives, the essay will provide readers with an insightful understanding of the fundamental IoT technology, important 5G/6G wireless communication technologies, and their diverse application domains in intelligent transportation and smart cities. Through this exploration, the study aims to shed light on the transformative potential of these technologies in shaping the future of transportation systems and urban living.

Keywords: IoT; 5G/6G wireless communication; intelligent transportation system.

1. Introduction

The standard of living has significantly increased over the last century. Due to inefficient transportation, it is now the second largest contributor to carbon emissions. In addition to harming the citizens' health, it pollutes the city's environment. Therefore, improving traffic efficiency is crucial for intelligent transportation and smart cities. Despite the fact that transportation has greatly improved our lives, a number of important issues, including traffic jams, auto accidents, and automobile pollution, remain unaddressed [1]. At the same time, the wireless communications sector has also grown extraordinarily over the past few decades. Considering how widely wireless technology is utilized, the increasing number of multimedia mobile devices, and the advent of open-source tools that are becoming more and more accessible, user-centered network communication has received more attention and application. Network design and optimization of related services have become more important as fixed telephones have decreased and moved toward mobile cellular cellphones [2]. In recent years, the IoT industry has seen a rise in interest in the growing field of ITS. This is owing to the growth of the wireless communication business.

Cellular systems have transformed from a specialized mobile communication system to a nearly ubiquitous one that can attain coverage anywhere, anytime, and on any device to fulfill the expanding needs of network communication users [3]. Cellular communication networks have gone from the first Generation (1G) to the sixth Generation (6G) faster than expected due to user demand for increased network capacity [4]. The foundational mobile voice feature was developed in the first-generation (1G) mobile wireless communication network to simulate voice calls. Short message communication is supported by the second generation (2G), a digital technology that addresses capacity and coverage difficulties. With a focus on higher data rates, multimedia support, and spread spectrum, the third generation (3G) offers multimedia capabilities, increased data transfer rates, and more capacity. The fourth generation (4G) overcomes the limitations of 3G networks, provides high-quality mobile communication services, and supports low to high-mobility applications. It combines 3G with fixed Internet, supports wireless mobile Internet, increases bandwidth, and lowers transmission costs. The fifth generation (5G) envisions a completely wireless world. The most advanced features are all covered by 5G technology, which makes 5G mobile technology the most potent. In order to attain global coverage, the sixth generation (6G) proposes fusing satellite networks with 5G. The integration of satellite networks and the delivery of data services such as network position identification, Internet connectivity, and weather data to mobile users are the two main objectives of 6G [5].

The 4G/IMT-Advanced standard, in use since 2011, is being replaced by the 5G mobile network. The capacity of 5G (fifth-generation wireless systems or mobile networks) is significantly higher than that of 4G. A larger user density for mobile communications, extremely high reliability, and extensive communication are all made possible by 5G's greater capacity. Additionally, contemporary 5G research focuses on lowering mobile battery usage and communication resource waste while maintaining the same functional efficiency [6]. Although 5G technology has tradeoffs in delay, energy, cost, hardware complexity, throughput, and reliability, there are still several issues with spectral efficiency (SE), coverage, and interference [7]. In order to achieve the strict network specifications (such as ultra-high accuracy, capacity, efficiency, and low delay), 6G will therefore function together comprehensively given the economic, social, technological, and environmental context envisaged in 2030 [8]. The 6G mobile network is a thorough ground-to-space network that enables coverage of the whole surface of the Earth as well as close to outer space. Future wireless systems must be sophisticated and changeable in order to support 6G connectivity. Reusability of system hardware and mode switching should be part of reconfigurability. The rapid advancement of artificial intelligence, including machine learning, necessitates the creation of intelligent 6G systems in order to deliver better services, such as enhancing functionality modifications and environmental adaptation [9].

6G networks also feature improved security and reduced costs due to their integration of satellite and 5G wireless mobile systems to provide worldwide coverage. With 6G technology, satellite networks offer wireless devices extremely fast Internet speeds of up to 11Gbps. In addition to using high-speed optical fiber lines to amplify and safeguard point-to-point wireless communication networks that carry data from the transmitter to the destination, various sites will be outfitted with nanoantennas made specifically for 6G [10]. In recent years, smart transportation initiatives have been executed in various urban areas thanks to the emergence of 5G/6G mobile cellular data. Cutting-edge cellular data technologies make connectivity, transportation, traffic management, flow monitoring, and autonomous cars possible.

2. The primary technology in intelligent transportation system

2.1. 5G/6G cellular network

2.1.1 Crucial technology of 5G

Table 1. Summary of Current Technique

Ref.	Technique	Common Term	Key Concept	Solution	Drawbacks
[11]	Multi-access Edge computing (mec)	Core network.	Supply mec capabilities on a per-packet basis.	Dus and a mec agent.	How service replication through edge nodes.
[11]	Network function virtualization. (NFV)	Intent–based networking.	Intent for 5G networks.	Wireless controllers and the wired backhaul controller.	Telemetry, path restoration, and VNF migration
[12]	Software defined networking (sdn)	Network architecture	Decoupled, programmable.	Provided simple programmable network devices.	Require greater memory and a faster processing speed.
[13]	Enhanced Mobile Broadband (embb)	Broadband	Sufficient digital capacity, low latency, and high quality.	MIMO and millimeter-wave spectrum.	More functionality and stability
[11]	Ultra reliable low latency communication (URLLC)	5G functions.	5G testbed E2E configuration.	Framework function in 5G testbeds.	Choose a case for a different KPI

The MEC, NFV, SDN and network slicing are some of the important technologies employed in the 5G design, as illustrated in Table 1. SDN allows software applications to centrally and intelligently control network traffic routing. The major benefits of SDN are centralized control, network programmability, and abstraction. NFV is a concept for encapsulating network operations like routing, load balancing, and firewalls into software programs that may be executed on generic and commodity hardware. The issue of the close linkage between network functions and specific hardware components can be resolved using NFV, which is a major barrier in developing such network services. The main goal of MEC is to give edge networks access to cloud computing, which will ease backhaul network congestion and improve the optimization of resources, customer service, and overall network efficiency [14].

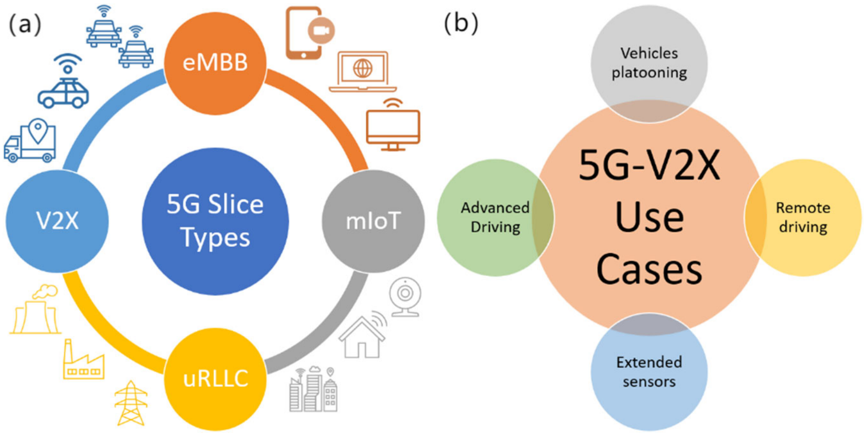

Fig. 1 (a) Slice types supported by 5G [15]. (b) V2X use cases based on ITS [15]

As Fig. 1, the Internet of Things, smart cities, intelligent transportation systems, and Industry 4.0 are the four primary concepts put forth by 5G technology. The massive bandwidth and extremely low latency capabilities of 5G will save costs and improve service quality for numerous businesses, which enables massive Internet of Things (mIoT). Consequently, the pattern of intelligent transportation is anticipated to change due to 5G technology. Besides, Vehicle-to-Everything (V2X) is also an example of 5G types that can improve ITS performance in various ways. 5G aims to make urban automatic transit systems more secure and effective than present by developing Cooperative Intelligent Transport Systems (CITS). Through the real-time exchange of sensor data and the numerous connections required to communicate with a number of vehicles, information sensors along the route, and other adjacent wireless equipment, 5G technology enables autonomous driving. Additionally, 5G can improve signal coverage, deliver high-performance, dependable, and stable communications, and lower the risk of accidents in both urban and rural locations. The 5G Automotive Association (5GAA) has conducted research that concluded that offering an intelligent transportation system over a cellular network is substantially less expensive than providing Roadside Units (RSU) [15]. However, massive connectivity is one of 5G's main obstacles. One of the causes of data traffic is the network's rapid increase in user numbers. So the ability to handle enormous data volumes and high data bit rate connectivity per device is a key requirement for 6G wireless communication [16].

2.1.2 Primary technology of 6G

Intelligent transportation systems (ITS) and the Vehicular Internet of Things (VIoT) are both being fundamentally altered by advancements in 6G technology. Using large-scale massive machine type communication (mMTC), 6G cellular network technology enables V2X connectivity. As shown in Fig. 2, in a VIoT network based on 6G, several vehicles can send a payload of short-duration vehicle information without human contact. V2X characteristics are considered a tradeoff between scalability, dependability, and latency to achieve this. As a result, features like slots of time and hashing operations are modified to reduce the likelihood of false positives in order to optimize the VIoT network architecture. Additionally, deep learning uses its capability for multidimensional adaptation to simulate channels for vehicle telecommunications and enable network management, providing intelligent support for 6G-based VIoT. Deep learning technologies, which can automate the scheduling of data transfers by utilizing three methods—learning under supervision to estimate data rates, geospatial uncertainty detection in the estimation model using unsupervised learning, and reinforcement learning (RL) for automatically coordinating data transfers based on expected efficiency of resources—are also focused on intelligent vehicles. In multi-objective VIoT, the integrated solution is anticipated to achieve optimization and maximization from resource allocation to data rate. Because each vehicle is considered a physical linked vehicle system with full self-control and recognition in 6G, the communication performance of Vehicle-to-Vehicle (V2V) networks is crucial. In this context, cooperative driving refers to coordinating moving vehicles through information exchange. This foundation allows deep learning to naturally offer quick V2V communication prediction solutions to achieve intelligent control performance boundary distances between vehicles [17].

Fig. 2 6G-based VIoT for ITS [18]

2.2. Principle and application of ITS

Fig. 3 Vehicle to infra communication [1]

As shown in Fig. 3, sensors that exchange data, IoT devices and wireless networks are the core components of intelligent transportation systems. Vehicle sensors gather field data and provide dynamic data to the driver via a short message service regarding the car's position, navigation, and speed, allowing the autonomous vehicle to travel safely to its intended location without human intervention. While sensors at the roadside are installed at regular intervals to collect information on traffic patterns in the area and can automatically establish an interconnectivity platform with surrounding IoT devices, smartphones connected to in-vehicle networks can also provide real-time information to correct traffic information. Because the car has to exchange data with another vehicle, the sensor along the roadway serves as the ideal middleman. Roadside sensors offer an intermediary connection to a particular range of values. The sensor sends the owner an alarm with vehicle details in the event of unlawful vehicle access to avoid an accident [1].

Another specific use of intelligent transportation systems is to register vehicle data to roadside sensors and set the destination the vehicle is to reach. The system gathers traffic data and assesses the best driving route option by linking roadside sensors in one location with sensors in another. The first route is offered if the solution is practical. If not, take into account the subsequent route, and so on, to provide the car the best possible route that will lessen city traffic. Utilizing the traffic data that is now available, this system enhances parking space processing safety, efficiently manages pointless travel delays, lessens traffic issues, and generates a generally calm traffic environment in contemporary cities [1].

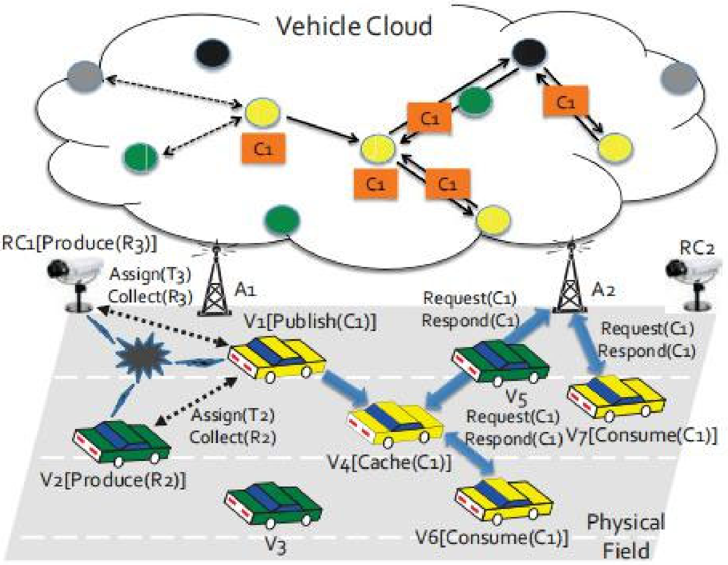

Fig. 4 Autonomous driving schematic based on VC and V2X platforms [19]

ITS will face additional difficulties when cars transition from being operated manually to autonomous vehicle (AUV). AUVs with scaled-up sensor deployment and the enormous amount of data they may gather from their surroundings present some of these problems. The AUV itself also creates additional difficulties: the AUV can act quickly in an emergency while the driver may be preoccupied with side tasks and inattentive.

From a collection of device systems, V2X will grow into an internet with features like driverless cars. V2X will have the same communication, storage, intelligence, and learning capabilities as other IoT instances to predict customers' intentions. Vehicle cloud (VC), the automotive version of the Internet cloud, will become the principal foundation system, and the primary beneficiary of cloud architecture will be self-driving vehicles [19]. Like Fig. 4, the AUV may perform autonomous driving duties when connected to the VC and V2X platforms and can make decisions based on information about the vehicle and its surroundings.

IoT can lessen the likelihood of auto accidents and collect on-the-spot data about urban traffic and navigational features from cloud storage. This system can make dynamic judgments on real-time information traffic management and efficiently control urban traffic thanks to the installation of intelligent devices across the city, numerous sensors, and high-speed wireless Internet connection. Certain fundamental technologies, like autonomous driving and intelligent parking systems, are required for an effective traffic management system. When autonomous cars are used in smart cities, traffic accidents, transportation expenses, and traffic congestion can all be properly managed to allow for the fastest driving speeds throughout the city. Additionally, in-vehicle information can show the location of vacant parking spaces nearby to cut down on time spent looking for spaces in city traffic. Additionally, it increases fuel efficiency, which can considerably lower greenhouse gas emissions [1].

3. Application of 5G/6G cellular network in ITS

In 2015, network slicing became available for the first time, and the key 5G network capabilities are seen as being applied in network slicing. By dividing an actual network into many conceptual networks, the idea of network slicing is specifically discussed so that each logical network can specialize in offering particular network capabilities and functions. 3GPP describes network slicing as a technique that "operators can build interconnected networks to provide optimized solutions tailored to different market needs." Seven key tenets—isolation, resilience, automation, programmability, customization, end-to-end, and hierarchical abstraction—form the foundation of network slicing. The following four components of the 5G/6G cellular technology-enabled intelligent transportation revolution can be summed up:

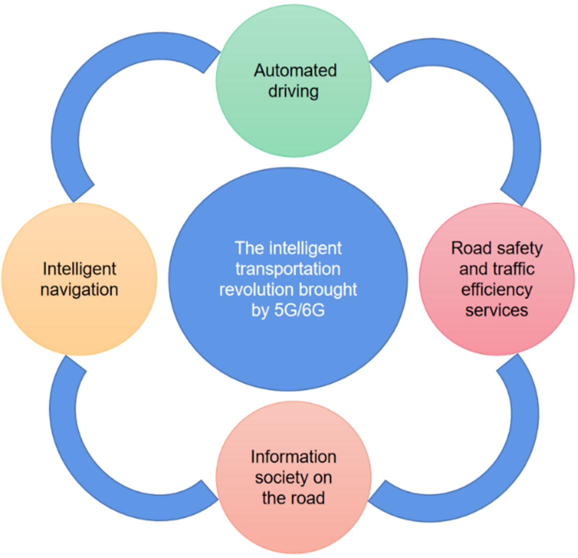

Fig. 5 ITS changes brought about by 5G/6G [1]

Slices of the distinct tasks in Fig. 5 (autonomous vehicles, remote control cars, and remote diagnostic and management cars) have varied network requirements for autonomous driving. The communication requirements of an autonomous vehicle may be satisfied by a portion of the vehicle. An additional component of a remotely driven vehicle can be utilized to control the vehicle in a risky environment remotely or to communicate instantly with the car's maker or diagnostic facility. The IoT is tightly interwoven with numerous areas of transportation in terms of road safety, thanks to the extensive growth of transportation systems.

With advanced driving, semi or fully autonomous driving is conceivable. In this case, longer intervehicle distances are permitted. Each vehicle, or RSU, communicates sensor data with neighboring vehicles so that they may coordinate their driving routes. Safer transportation, fewer collisions, and better traffic flow are benefits of advanced driving. Table 2. shows some basic communication requirements for using V2X in different cases:

Table 2. Requirements for sophisticated V2X usage situations [15]

Usage situation	**Minimum-Maximum Interval (m)**	**Maximum Latency (ms)**	**Data Speed (Mbps)**	**Network Stability (%)**
Automobiles Platooning	80-350	10-500	50-65	90-99.99
Remote-controlled Driving	-	5	1-25	99.999
Additional Sensors	50-1000	3-100	10-1000	90-99.999
Advanced Driving	360-700	3-100	10-50	90-99.999

The V2X, which includes a variety of use cases, including vehicle, pedestrian, infrastructure, and network, places a high priority on communication reliability and latency. Each use case has different requirements for connectivity and services. Hence they cannot be connected using the same network infrastructure. The best option is network slicing, which raises traffic safety while being reasonably priced. New road authorities, automakers, and towns offering a variety of services will take part in the V2X scenario and dynamically alter the functioning of the installed network in the network to enhance traffic efficiency and manage a high density of moving cars. Dynamic network deployment is designed based on the time of day (highs and lows) and area type (cities or countryside) in order to improve the efficiency of network resources [14].

4. Summary

IoT can improve the effectiveness of intelligent transportation when combined with 5G and 6G technology. The safety of autonomous vehicles and the effectiveness of information transmission and interaction can be considerably increased by adopting 5G/6G technology by IoT devices. In the context of intelligent mobility in smart cities, this study focuses on the key technologies, applications, and tendencies of 5G and 6G. IoT systems in intelligent transportation can operate effectively and offer top-notch traffic management, safety, monitoring, and other services by utilizing these technologies. This study also looks into how 5G/6G-based IoT technologies can be used for intelligent transportation. Some applications include deep learning, autonomous route planning, and querying nearby parking information. The adoption of the high speed and high stability of 5G/6G by researchers and industry professionals in the IoT area suggests that more effective IoT applications will be created. The Internet of Things' potential can address the issue of environmental sustainability by enhancing the efficiency and environmental friendliness of smart cities and transportation [20].

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