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RESEARCH INVENTION JOURNAL OF BIOLOGICAL AND APPLIED SCIENCES 3(2):36-39, 2024

Online ISSN: 1115-6171

Print ISSN: 1597-2879

The Impact of 5G Technology on Autonomous Vehicles

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ABSTRACT

The integration of 5G technology into autonomous vehicles (AVs) represents a transformative advancement in intelligent transportation systems. This paper explores the role of 5G in enhancing the capabilities of AVs, particularly through improvements in Vehicle-to-Everything (V2X) communication, low latency, and high data transmission rates. As autonomous vehicles evolve from conceptual models to real-world applications, the need for a reliable and fast communication network becomes critical. This paper discusses the fundamental features of 5G, its key contributions to AVs, the levels of autonomy in AVs, and the challenges faced in the integration process. Additionally, case studies from South Korea provide insights into the practical applications of 5G in autonomous vehicle deployments. The analysis highlights both the potential benefits, such as improved safety and efficiency, and the challenges, including security vulnerabilities and infrastructural demands, that accompany the adoption of 5G in AVs.

Keywords: 5G technology, autonomous vehicles, V2X communication, intelligent transportation systems, IoV.

INTRODUCTION

The automotive industry has been facing demands from consumers for years and, at the same time, has been leaning towards comprehensive research and development areas for the creation of a new and efficient transportation system. Hence, the concept of Autonomous Vehicle (AV) has emerged from this research since this vision undoubtedly defines the efficiency and performance of an intelligent transportation system. The enhancement of various network capabilities will be accompanied by the spread of the 5G communication network, which is one of the supporting pillars of such intelligent systems. Some latest generations of the mobile communication architecture (e.g., 3G) guarantee only a data transmission rate up to 2 Mbps while 4G assures 200 Mbps; 5G technology is set to provide a significant amount of bandwidth (1000 Gbps) to address difficult communication requirements in automotive applications. Thus, 5G technology could ensure the development of the AV, aimed at obtaining a "zero-fatality" perspective on our streets [1]. In the internet of vehicles (IoV), cars and infrastructures collect and convey information. Vehicles can communicate with each other and with base stations to enhance AV deployment. The fifth generation of mobile communication networks aims to develop wireless networks with larger capabilities for IoT solutions, including AVs. The 5G technology is critical for the cloud-based IoV-Evolution, providing high data rates, low latency, and efficient spectral usage [2].

FUNDAMENTALS OF 5G TECHNOLOGY

5G is currently a hot topic in the world of technology and business, but not many people know how it actually works or how it can facilitate autonomous vehicles. As a 5th generation mobile network, 5G technology is meant to deliver higher multi-Gbps peak data speeds, more reliable connections, lower latency, massive network capacity, and stronger uniform user experiences to more consumers. One of its salient features is the performance of the rapid response and function of automation, which is mainly reflected in five aspects: high speed (longitudinal cruise), connected cars (sensor sharing and cloud connections for path planning and control), remote driving (vehicle operation and control by personnel in the control center through signals and the Internet), park-and-go (carpooling and super-charging), and

mobile office and entertainment (enjoying life during the travel time) [3]. 5G technology improves V2X communication and enhances vehicle intelligence through data obtained from the network. V2X informs self-driving cars of their surroundings, including traffic lights and weather conditions. 5G's V2V communication improves overall traffic awareness. The low latency of 5G enhances vehicle self-awareness, V2V communication, and decision-making. Overall, 5G greatly enhances automated vehicle capability [4].

KEY FEATURES AND CAPABILITIES

LTE is often labeled as 4.5G, or 4.5th Generation wireless communication technology, as it provides a tantalizing prospect of how advanced the next generation of wireless communications will be. 5G wireless technology will be designed and implemented keeping in view the extraordinary challenges by the year 2020 and beyond. Already, several huge companies like Huawei, Nokia, Apple, LG, Ericsson etc. have shown their keen interest in the implementation of 5G technology. New ideas and new technologies are required for this advanced 5G technology. The present 3G technology is not adequate to handle the large volume of multimedia, video, voice, data etc. This is the right time to explore for the new technology. 5G promises significant evolution from the user environment to new access technologies, network architecture, and emerging applications. In this article, a broad overview of 5G technology, discussing the various features, challenges, and prospects of this exciting new paradigm in the evolution of wireless communication [5].

The key features of 5G technology include:

a. It has an integrated service network, that is, it can provide any service, any time, anywhere. It is definable by the users.
b. It provides an integrated global total mobile and cellular network solution for all the advanced technologies.
c. It uses the service primitives in the transfer of reliable data rates and ramp networks. The quality of service is better than what is delivered by the present existing systems. The system offers more services at a lower cost, it can be told as "best value for the lowest cost".
d. As the data rate increases in 5G technology, the power-saving product also increases. The greater the data rate, the more it can save power [6].

AUTONOMOUS VEHICLES

Autonomous vehicles, also known as driverless or self-driving cars, are automobiles that use sensors, machine learning models, and software instead of human action to perceive the surrounding environment, map a path, and navigate to one or multiple destinations without causing an accident. These vehicles integrate different components that perform specific tasks. The perception includes cameras to capture images and videos, lidar sensors to measure distances, radar to determine the object's velocity, and Global Positioning Systems to determine the location latitude and longitude of an object in the world. Sensors embedded in vehicles perceive the surrounding environment to classify different objects as being human, vehicle, animals, or moving obstacles. Autonomous vehicles use planners' software to generate a map of the environment, exact location of a short or long duration [7]. 5G technologies extend beyond IoT and other applications. They ensure 50 billion connected devices within 25 meters of each other. They speed up processing in various transportation networks and enable automation in manufacturing, logistics, and healthcare. 5G infrastructure also allows for enhanced human interfaces. Fifth Generation Network Technology has a radio signal that can be used for robotic control, unlike LTE [8].

LEVELS OF AUTONOMY

There are various concepts of autonomy in the automobile industry. It is therefore important to know the different levels of autonomy as per the SAE document. The Level 0 is where there is no automation taking place. The driver controls every aspect of the vehicle. This is what we find in the manual type of automobile. With Level 1, it means some of the functions are being done by the vehicle. This is the assist type of the cruise control found in some vehicles. With Level 2, it means that all the things that the vehicle must do like steering and speed control for stopping and moving are done by the vehicle. The driver is there to take over if necessary. This is what we mean by partial autonomy in this report. Fully autonomous or what we called driverless is Level 5, in which there are no occupants of any type in the vehicle. For the literature that is available now, the emphasis is usually on Levels 4 and 5 [9]. In general terms, whether in Level 3 or 4 or in a car with only partial autonomy, if a driver does not take over technological functions, then that driver is not paying full attention to the road. For motivations or any other reasons for the death of the driver in these vehicles, our technologies are in Level 3. Nothing has come from Level 4. In most discussions, what occurs for what type of 5G modules to be installed in a 3 or a 4 is not yet fully discussed. The consensus is that a Level 4, due to the implications of the absence of the

driver, is supposed to have a richer 5G module that is intelligent and can detect all types of intruder technologies such as powered devices [10].

INTEGRATION OF 5G AND AUTONOMOUS VEHICLES

From the introduction of the design of the autonomous vehicle systems, researchers have been considering other potential synergies with modern technologies. The prominent interest in integration between autonomous vehicles and 5G technologies is derived from the previous achievements in this area. The mixed system, which works with the exerted signals by 5G, was fulfilled using the Cellular Vehicle-to-Everything (C-V2X) as platform support. The primary research resulted in the positive demonstration of helping CORning Automated Vehicles and Infrastructure (CRAVITS), which aids emergency services with "platoons" that help in carrying out the search or rescue course of action. Corona is unique in respect to previous literature in being merely about support to first responders [3]. The use of 5G technology in autonomous vehicle systems has attracted attention from researchers. Integration focuses on 5G and its applications such as GPS, smart cars, telecommunications for intelligent transportation systems (ITSs), and real-time edge computing. Reliable communication is crucial for autonomous cars, and virtual machines in cloud services can ensure quality of service (QoS). Autonomous cars have become a separate product with widespread application possibilities [11].

BENEFITS AND CHALLENGES

The use of 5G technology in autonomous vehicles allows for efficient processing and decision-making. It transforms vehicles into data and decision centers, reducing traffic accidents with its low latency. Smart technology can directly impact decision-making through V2X communication [12]. However, the integration of 5G technology with autonomous vehicles also poses numerous challenges. In the first place, from a purely technical point of view, we must emphasize the existing and potential vulnerabilities of 5G technology. It suffices to point out the limitations of the SIM/USIM/ISIM databases and the security auditing and deployment question to underline the likely weaknesses that abundant traffic could produce across 5G architecture in general, and the H-PLMN/HA-PLMN communication for intramobility in particular. In a scenario the trace of which within the framework of 5G is still diffuse, this raises issues, such as the design of a solid, lightweight and secure system architecture, the associated challenges in the transfer of decision-making and intermediate computing to the cellular control network, the security and confidentiality safeguards of 5G, and their implications in good practice for the laboratory. Finally, the connectivity scenario on which we have just focused did not consider the effect of datasets or management, routine software updates and the installation of patches, and scanned image streaming computers hosted in Intelligent Controlled Environments on the access and service networks [13].

CASE STUDIES

Case studies, primarily carried out in South Korea as part of 5G test beds, have been conducted on how 5G will function as an enabler for autonomous vehicles. These case studies aim to show how 5G technologies could address some of the key challenges associated with autonomous vehicles highlighted in the previous sections [14]. Case study in the city of Sejong, South Korea: This case study was conducted as part of a KT (Korea Telecom) 5G test bed situated in Sejong, the administrative and provincial capital city of Choongcheongnam-do, South Korea. Between July and September of 2019, a portion of the urban test bed was used to investigate scenarios for the use of 5G as an enabler for autonomous vehicles. The write-up of the case study discusses the potential impact of 5G on the free flow of vehicles in urban environments alongside a competitive analysis for what is termed the 'evolution of smart transportation 5G' [15]. The case studies highlight how 5G technology benefits autonomous vehicles in various settings, including urban and rural environments, roads, and healthcare facilities. It enables improved map updating, data sharing, vehicle-to-vehicle and vehicle-to-infrastructure communication, and enhances system reliability in poor connectivity. However, challenges exist with deep indoor coverage and wider organizational issues. To address these critiques, the case study recommends a non-5G compatible V2X access network operating on 4.9G spectrum [16]. In general, the case studies approach autonomous vehicles as a small and unrepresentative part of automated vehicles. Case studies have also been conducted exploring automated buses [17].

CONCLUSION

The deployment of 5G technology is a critical enabler for the advancement of autonomous vehicles, offering enhanced communication capabilities that are essential for the safe and efficient operation of AVs. The high data transmission rates, low latency, and improved reliability provided by 5G are key factors in the development of advanced AV systems, enabling better decision-making, real-time data processing, and enhanced vehicle-to-vehicle and vehicle-to-infrastructure communication. However, significant challenges remain, including addressing security vulnerabilities and ensuring robust infrastructure to support widespread adoption. Case studies, particularly from test beds in South Korea, demonstrate the

feasibility and benefits of integrating 5G with AVs but also highlight the need for continued research and development to overcome existing obstacles. As the technology matures, the combined potential of 5G and AVs promises to revolutionize transportation, contributing to safer, more efficient, and intelligent mobility solutions.

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CITE AS: Nzeyimana Eric Titus. (2024). The Impact of 5G Technology on Autonomous Vehicles. RESEARCH INVENTION JOURNAL OF BIOLOGICAL AND APPLIED SCIENCES 3(2):36-39.