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5G: The Future of Improved Road Safety and Autonomous Vehicle

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Digital Revolution caused the telecommunication network to reshape the current telecom technology and provide good foundation for the development of connected vehicles. Currently, the Release 16 of 5G shows that around the world, Vehicle-to-everything (V2X) testing is being conducted on a large scale. In comparison with 4G, the 5G network provides multitude of potential and opportunities for V2X applications and autonomous vehicles.

The purpose of this thesis is to study the concept of evolution of 5G, their historical background, and their architecture. The 5G technology can be used in vehicular communication devices to minimize the road casualties. The goal of this thesis is also to clarify the benefit of 5G technology in the driverless driving sector.

The thesis introduces V2X capabilities with 5G to prevent unnecessary road accidents. The description of 5G architecture and features are carried out with two types of V2X communication technologies, Short-range communication (DSRC) and Cellular-V2X(C-V2X) are explained. Description of the major applications of V2X along with advance use cases and the security of 5G in detail are given at the end.

Keywords	4G,5G, V2X, DSRC, C-V2X

Contents

List of Abbreviations

1G	First Generation
2G	Second Generation
3G	Third Generation
4G	Fourth Generation
5G	Fifth Generation
5GAA	5G Active Antenna
3GPP	Third generation partnership project
AR	Augmented Reality
AGPS	Assisted Global Positioning System
AVL	Automatic Vehicle Location System
AMF	Access and Mobility Management Function
CUPS	Control-User Plane Separation
C-V2X	Cellular-V2X
DSRC	Short-Range Communication
D2D	Device-to-Device
DSP	Digital Signal Processor
eNB	eNode-B
eMBB	Enhanced Mobile Broadband

ETSI	European Telecommunications Standards Institute
GPS	Global Positioning System
GLONASS	Global Navigation Satellite System
GIS	Geographic Information System
IoT	Internet of Things
IP	Internet Protocol
ITU	International Telecommunications Union
IEEE	The Institute of Electrical and Electronics Engineers
ITS	Intelligent Transport System
IV	In-vehicle
LTE	Long Term Vision
LOS	Line of Sight
MIMO	Multiple-Input Multiple-Output
mMTC	Massive Machine Type
NLOS	Non-LOS
NSA	Non-Standalone
OFDMA	Orthogonal Frequency-Division Multiple Access
POI	Points of Interest
ProSe	Proximity Service

QoS	Quality of Service
RAN	Radio Access Network
RF	Radio frequency
RFID	Radio Frequency Identification
SMF	Session Management function
SA	Standalone
SDN	Software Defined Network
UI	User Interface
VR	Virtual Reality
VCN	Vehicular Communication Network
VANET	Vehicular ad-hoc Network
V2X	Vehicle-to-Everything
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2N	Vehicle-to-Network
WiMAX	Wireless MAN-Advanced

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1 Introduction

In today’s world, 5G can be considered as the digital revolution for wireless technology, providing faster speeds and low latency (duration it takes for the message to travel from sender to receiver and vice-versa). 5g brings improvements in new applications (video, autonomous vehicles) along with the expectation that it will finally be able to enable wireless to compete against the wired connection that is in our home and offices (fixed wireless vs cable internet). In recent years, 5G promises to be an upgrade to the carrier networks, in similar ways the upgrade from 3G to 4G that had occurred.

Currently, 4G and LTE have already occupied the world with its full benefits. However, some drawbacks did not allow IoT devices to function properly to their full potential. Currently, 4G had hit the roadblock and can’t keep up with the ever evolving digital devices such as innovation mobiles, smart home devices, etc, which requires higher speed, flexibility, and functionality in order for smoother operations. This led to the need to use the most advanced wireless networking system which omits the flaws of the present technology in the vehicular communication system. 5G with its bigger potential shows desired performance with smart devices such as smart home devices, connected vehicles, wireless sensors, intelligent road systems, mobile wearables, and other cutting-edge technologies.

The focus of this project is to study the working methodology of 5G and using it in vehicular communication devices to track the vehicle's movement for the safety of people on roads and to avoid the possible casualties and how it operates. Its objective is also to provide the benefits of the technology and its future possibilities like autonomous driving.

The 5G network also allows for collaboration with old networks, making it easy to operate without replacing the old vehicle tracking technology. With the implementation of 5G technology, the use of autonomous vehicles is expected to increase. In terms of transport, it will bring about a new era. It is expected that vehicles on the road will communicate and learn from each other, thereby improving safety. It is a new technology in radio systems which will be the building block for the future network by retrofitting existing platforms (e.g., 2G, 3G, 4G, and Wi-Fi) for increased cell and device coverage, accessibility, and increased network density. The idea behind 5G networks is not only to provide faster connection speeds but also to improve reliability.

2 Problem Statement

Humans are always creative in nature. Through sheer creativity and effort, humans have built the roads, cars and other technological advancements to better their lives. Through the development process, lots of unforeseen challenges are seen. Among them, Road safety is one of the major issues in several countries around the world. Advanced technologies are in place to reduce road hazards. They are somehow able to reduce the number of casualties. But still, due to human actions, they are not completely mitigated. To address such a situation, human activities need to be removed from the road equation. Hence, the intelligent transportation system is built. Automated vehicles (AV) can be considered a major role players in the current intelligent transportation system.

The potential advantage of AV's include, but are not restricted to

(I) increased road space and reduced traffic jam,

(II) Improved lives by making better use of traveler travel for work or leisure

(III) Automation Improves traffic flow resulting in lesser fuel consumption and emissions.

(IV) Easier means of transportation for the sick person, older adults, disabled person, and other mobility-restricted individuals,

(V) Increased highway safety while driving after removing human driving error, assuming that AVs are system failure and abuse proof.

Moreover, the implementation of AVs will represent a step-change in how vehicles operate on the transportation network. Traditional models of driver behavior and response to behavioral stimuli may not apply, and consequently our understanding of how traffic and transportation systems work must be readdressed.

However, it is still very hard to get information on the condition of the vehicle. In urban areas, the number of vehicles is very high, as the number is high there is a huge problem in traffic management. Drivers riding the vehicle at high speed in dense areas often lead to accidents.

The above-mentioned problem could be minimized by tracking the vehicles more efficiently with advanced technologies. Autonomous vehicles are even promising way to reduce road accidents and the safety of pedestrians. With the present technology, acquiring full access and assuring the safety of drivers and people with driverless driving is controversial. Due to the lack of extensive investments in the progress of machine learning models for interpreting traffic and infrastructure for low-latency wireless networks, it is very difficult to make the reality of autonomous vehicles to improve safety.

3 Tracking System

3.1 Introduction of Tracking System

A tracking system can be defined as the device which provides an overview of the location where the tracked vehicles have been. Modern car tracking systems typically use GPS and GLONASS software to locate cars, but other forms are also possible. For the sake of road safety, urban public transit companies are increasing the use of tracking devices in public vehicles. There are various types of vehicle tracking devices categorized as "passive" and "active." GPS position, heading and speed, are recorded by passive devices. Passive devices are generally attached to the monitored vehicles. Once it reached its determined destination, the device is removed and analysed for evaluation by downloading the data into the computer. However, Active devices are similar to the passive device but with the feature of data transmission in near-real-time to a computer or server using the cellular network for evaluation.

Historically, tracking of the vehicle was carried out through the installation of a box into the vehicle, which either was automatically operated using a battery or was wired into the power system of the vehicle. This is still the predominant method for detailed car location and tracking, but many companies become more interested in emerging mobile phone technologies that track a variety of businesses, both a salesman and their vehicles. These systems also provide call tracking, text tracking, web-use and offer a broader range of options [1].

3.2 Current Scenario and Future Prospects

Some technologies have minor effects, and some are causing rebellions in recent generations. The latter category includes device tracking technology. The effective ways in which tracking device technology currently used are [2]:

- GPS Technology
- Assisted Global Positioning Systems (AGPS)
- Automatic Vehicle Location (AVL) System
- Radio Frequency Identification (RFID)

3.2.1 GPS Technology

Today, on every smartphone, GPS technology removes the need for such run-around and saves a lot of time for on the go individuals. The problem is, however, that common sense becomes a lost art as GPS technology could place our basic thinking on the autopilot on our smartphones. The figure 1 below demonstrates the model of vehicle tracking system via GPS technology. The modern vehicle tracking system, GPS-based tracking has three major constituents they are:

- ❖ GPS tracking: The unit is installed in the vehicle, monitors the GPS location and sends additional vehicle information at a regular interval to the main server. Additional vehicle information can contain information about different components of the vehicle such as engine temperature and condition, battery status, altitude, tire pressure, fuel condition, headlights status and a lot more. In general, the capacity of these devices dictates the final capacities of the whole tracking system; in addition to providing location data, many vehicle tracking devices have a long range of communications ports that can be used to incorporate other on-board systems to monitor or automate activity [3].

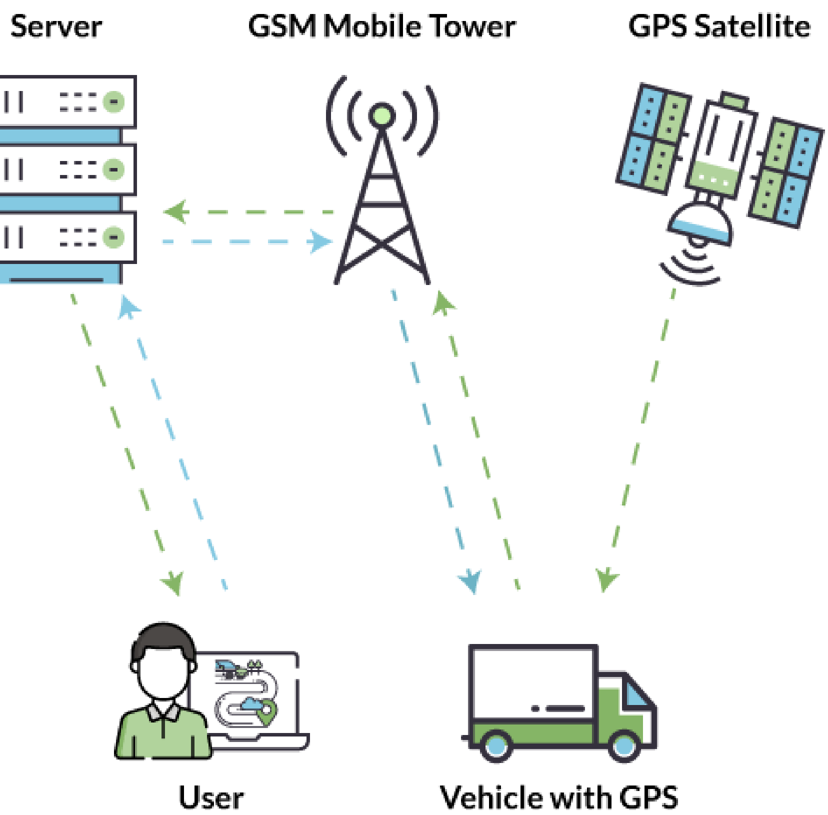

Figure 1. GPS based vehicle tracking system [30]

- GPS Tracking Server: This server operate three purposes namely receiving the data from the GPS devices, storing the data in an encrypted manner if necessary and providing the information to the concerned operator.

- User Interface: The interface allows the user to view the vehicle information using the graphical interface.

3.2.1.1 Analysis of Current GPS Tracking System

We have seen the popularisation of GPS technology in recent years and a wide range of applications. Applications include defence, national security, and the judiciary, personal security and comfort. For instance, in many countries, the criminal justice system uses GPS-based wearable tracker bracelets in the body, which are sometimes required for different types of crime; some fleet operators can monitor worker driving habits, parents can monitor their teen drivers; special tracking systems for people and parts of their bodies are available to track movements. There are several devices like sensors, chips, and receiver which provides the functionality of real-time systems for tracking people and vehicle. All of them must have:

- Software that manages the system – receive data from the hardware, store it, regulate and exchange that data.
- Hardware device (receiver) – receives signals from a satellite or base station.
- Communication network, which enables the exchange of data between different devices in the system.

In tracking objects, people or vehicles, the network plays a vital role. The fourth generation (4G) is currently being used for telecommunications, streaming, and much more. 4G is preferred to use for vehicle tracking as compared to other older generations such as 3G, 2G, and 1G because it provides faster and better networking, high data transfer rate, high speed, and improved safety. Even though 4G network is the best one to work within every IoT devices yet some flaws need to be considered.

3.2.1.2 Advantages of GPS tracking system

GPS tracking has several advantages in tracking the vehicles and the object which will allow users to make relevant decisions [4]. Some of them are:

1. Real-Time Tracking

The ability to track fleets in real-time is one of the main features of GPS systems today. When it moves from one stage to another, you can track your vehicle's progress on a digital map. It helps to navigate the path quickly in the event of challenges and to handle the accident quickly if something like this occurs. You will also be able to see the speed of the vehicle along with the specifics of its position, status (whether parked or moving), etc. Therefore, the role can be used for multiple vehicles without effort.

2. Trip History

It can track all the journeys made by the vehicle. Using GPS devices, vehicle owner or concerned party can get information such as kilometres driven, location it stopped, average speed and engine performance. These data are the utmost necessity to the business personnel.

3. Alerts

Many fleet owners prefer real-time warning tracking systems. Alarm systems include a start time alert, a route change alarm, a speed alert, an unnecessary stop warning, etc. Some alerts received also by a car tracking system, additional features like maintenance alerts, theft alerts, etc. can be added to a specific system.

4. Access

In today's digital age, one can get access to all the information regarding their vehicles using just the smartphone and the internet. With tracking devices, one can easily monitor from anywhere, without any inconvenience.

3.2.1.3 Disadvantages of GPS Tracking System

1. Rare Inaccuracy of GPS

The tracking mechanism for a vehicle works by acquiring the signal from several satellites and interpreting the system. Signals can be disrupted because of several factors, such as hurricanes, large buildings or other obstacles. The ever-trustworthy GPS is soft and unreliable. This can cause damage when the driver is unsure of the roads when driving to new places.

2. Invasion of Privacy

3. Signal or battery failure

4. Commercial exploitation

Ordinally, sophisticated and advanced versions of GPS based vehicle tracking systems provide data storage and its retrieval at later stages for analysis. Consequently, the technology is fast growing and has found superior versions since its first appearance. As mobile advertising becomes the future of advertising, GPS technology will continue to expand. The new technologies will allow advertisers to choose potential customers with accurate likings and geographical locations. In the future, there are many more new features that will be unlocked. Some of them are [5]:

1. Automated Driving

   The future is for driver-less cars. GPS based vehicle tracking systems can ease the task by entering the coordinates of the destination and determine the best possible route of travel while the person might be busy with doing conference presentations or simply taking nap to energize.

2. Augmented Reality

   No human is immune to fatigue and stress. Frequently, drivers forget signals to pedestrians and fellow drivers while on the road. The GPS-based vehicle tracking system allows sensors to detect pedestrian presence near the car, signal alarms to signal the speed, signaling the entry of the vehicle within a limited space, etc., which turn driving into a pleasant experience. GPS tracking device provides directions for drivers to ease the driving.

3. Automated Payment at Tolls and Parking Lots

The location system can be used to calculate the amount that must be charged in the toll booth according to the distance traveled and deducted from the owner's account automatically. In the same way, car park payment can be automated based on the vehicle stop period calculated from GPS position data.

4. Vehicle Sharing for Efficient Utilization of Assets

In some cases, the fleet may be smaller and cannot deliver services to remote locations. Even if services are provided, the holders of the vehicle may have to pay the costs of the return fare twice the distance journeyed. An integrated approach between multiple fleets may promote the mission by sharing passengers with individual cab services. Two or more passengers can also share the cab on the same road and the fare can, therefore, be cheaper. The smartphones and applications allowed by GPS provide an enormous amount of support for the successful implementation of vehicle sharing.

5. Geo Fencing

Using the geo-fencing feature, a person can set limits in the workplace and, once a vehicle crosses this boundary, immediate warnings are issued. The approved GPS tracking device is used for calculating areas and marking geographical boundaries. Many systems use the Google Map while others use the latitude and longitude specified by users to base their calculations. For future references, this user-defined points on the routes can be called POI (Points of Interest). In the safari car, it can also be used to precisely monitor animal spotting at certain locations and any behavioural changes can be detected as soon as possible [6].

3.2.2 Assisted Global Positioning System (AGPS)

In AGPS, a terrestrial radio frequency (RF) network is used to upgrade the performance of GPS receivers by providing information about the satellite constellation directly to the GPS receivers. It is used to locate accurate positioning data using cellular and mobile networks. With unassisted GPS, receiving the data, locating the satellites and verifying the accurate position may take several minutes. AGPS is used to overcome some limitations of GPS [6]. This system uses GPS satellites to track the vehicles. In the car, a GPS receiver is always in contact with four satellites (three determining satellites geo positions (latitude and longitude) along with land increment and the last satellite offer time details). The system provides atomic time (Accurate Time Assistance). The limitation of this system is the cost involved in GSM network to transfer data from the vehicle to the base station [6].

3.2.3 Automatic Vehicle Location (AVL)

AVL system is a highly developed method for tracking and monitoring the unit which receives and sends signals through GPS satellites to any remote vehicle. AVL includes the Global Positioning System (GPS) and the Geographic Information System (GIS) to provide the vehicle's actual geographical location. The system consists of a tracking system interface (GUI for dispatching), a radio system, GPS receiver on the vehicle and GPS satellites. There are two types of AVL: GPS-based and Signpost-based on which GPS-based system is widely used. The GPS receiver on the vehicle receives the signal of its position and sends the data, plus speed, direction and so on, via a radio system to the base station [6]. The limitation of this system is, it is not able to get complete and accurate data in the case of densely populated areas or the presence of natural obstructions.

3.2.4 RFID Systems

The RFID system is an automated form of identification that uses devices named tags to stock and remotely extract data. It consists of three components: tag, reader (antenna) and software. The RFID tag contains microelectronic circuits that send the vehicle information to a remote RFID reader. A reader uses radio waves to send and receive the data from RFID tags. A microprocessor controls the RFID scanner, which is essentially a radio frequency (RF) transmitter and receiver. RFID reader with an antenna attached reads RFID tag data. Then for further processing, it sends the information to the processor. The RFID system's limitations are short-range and available only over short distances [6].

4 Network

4.1 4G LTE

4G refers to the currently used generation of wireless standards for mobile communication systems, the replacement to the 3G network and fourth generation technology. The highest speed of the 4G standard should be 100 Megabyte per second for a moving body connection (e.g. car) and 1Gigabyte per second for non-moving connections (wired network). The 4G network offers fast and secure internet connections for all the devices such as laptops, smartphone, IP TV, IP telephone and highly popular internet service such as gaming along with other facilities.

4.2 Wireless 4G Networks

In today's technology-driven society, 4G networks are important benchmarks of progress and change. Fourth-generation network is created to enhance cellular, network and visual engineering capability. The market for advanced technologies is expected to grow as the networks continue to thrive.

4.2.1 Opportunities

4G Networks developers depend heavily on state-of-the-art technology and increased speed to make the network reliable. It is understood that, for the 4G network, "multimedia communication systems, including video services, need to be significantly upgraded to accept an upcoming generation. This requires data transfer speeds of at least 100 megabits per second, while a high-speed user operates with a single gigabit per second at a fixed position [7].

a) Features and competences

The opportunities for 4G networks are endless since they are more feasible than ever for high-speed transmission and associated capacities. It endorses the belief that demand for more complicated networks and associated capability is more robust than ever since the promise of improved networks like 4G continues to be purchased by more customers. 4G networks may establish solutions that meet customer and business standards, with the appropriate combination of resources 4G developers must, therefore, look at appropriate safety actions and encourage high-speed network-wide data transmission and should also look at how reliability and data quality can be maintained to achieve the most reasonable outcomes. 4G's ambitious goal is always and everywhere to access the Internet. 4G is IP-based, as opposed to 3G, which is an IP address for every device with a web connection. It enables the convergence of all existing network infrastructures and therefore promotes access to services and applications for users. 4G also provides higher bandwidth, data rate, and less overhead authentication and ensures that the service is provided continuously without interruption to the user. Users can select the desired level of service reliability, radio configuration, etc. 4G Network access is available directly through wireless devices like PDAs, cell phones and laptops.

b) Quality And Affordability

With respect to 4G Network quality and affordability, utilizing the 4G network provided a great platform for every organizations as well as customers as they were able to get higher bandwidth and a truly wireless and broadband environment with higher stable data speed, data integrity and wider areas [8].

4.2.2 Challenges

a) Security Threat and Privacy

To be exchanged as safely as possible when implementing 4G networks, security measures must be developed for information. In general, "The 4G centre deals with travel, security, and quality of service (QoS) by reusing existing structures while trying to deal with some issues of flexibility and handing over" [9]. For this purpose, the organization needs to develop an active software series that endorse full 4G protection measures to protect information from hackers and other safety violations that are transmitted across the web. Due to the complexity of the 4G network, security breaches are more likely to occur and therefore several levels of security are required for securing information and data that are transmitted across the network, including enhanced encryption requirements. One of the key objectives of 4G networks is to provide seamless connectivity to a very large geographical area. Smaller networks can run various operating systems in the local area. The diversity of these WLANs, which share various data types, makes security and privacy issues more difficult. In contrast, the cryptographical and decryption techniques used for previous networks are not suitable for 4G networks, as for the first time in 4G networks, new devices and services were added. There are two ways to mitigate the issues. The first one is to change present methods of security and privacy to include heterogeneous 4G networks. A further solution is to develop new flexible structures that can be reconfigured, modified and lightweight when the current methods are not adaptable to 4G networks [10].

b) Quality of Service

About network quality, most telecom suppliers expect that coverage will improve, and the data quality that is transmitted throughout the network. Major advantage over the 3G network is that consumers can surf the internet even when they are travelling. This is all due to 4G Technology. The technology offers Quality of Service (QoS) features capable of prioritizing certain users and traffic flows. Currently, 4G networks serves all phone types. The integration of service delivery mechanisms for non-IP and IP-based devices is one of the most critical challenges 4G networks faced [11, 12].

c) Complicated Architecture

➢ Multimode End – User Terminals

4G network devices should be able to work on a different network to reduce operational costs. But the simultaneous connection to various wireless networks is one of the major challenges 4G networks. This problem is overcome by one mechanism that has been proposed is “multi-mode devices”. It can be accomplished utilizing a software radio which can be adjusted to different wireless network interfaces on the end user computer. The figure below illustrates an example of such a solution.

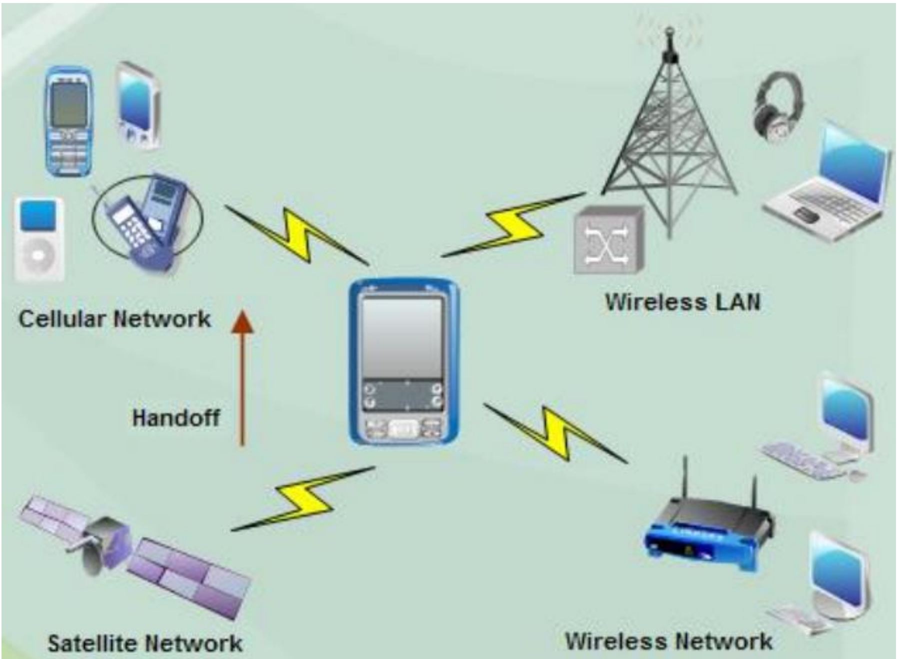

Figure 2. MMU Architecture allows access to multiple networks and services. [13]

➢ System Detection and Selection

Wireless tools can accommodate signals sent from the various systems, locate existing services, and link to specific providers of services due to the diversity of 4G networks. Different service providers have their protocols that cannot be mutually and incompatible with the device of the user. This problem could complex the procedure of choosing the most suitable software based on time, location and demand, thereby impacting the service quality offered to end-users. One solution to this problem is called "Discoveries initiated by the system." With this process, the computer module based on the user-connected wireless system can be automatically downloaded [14]. The overlay networks are another approach to this problem. In this case, a network of overlay links the end user to various networks. The overlay network accomplishes all activities, including protocol translation and service quality negotiations as shown in Figure 3.

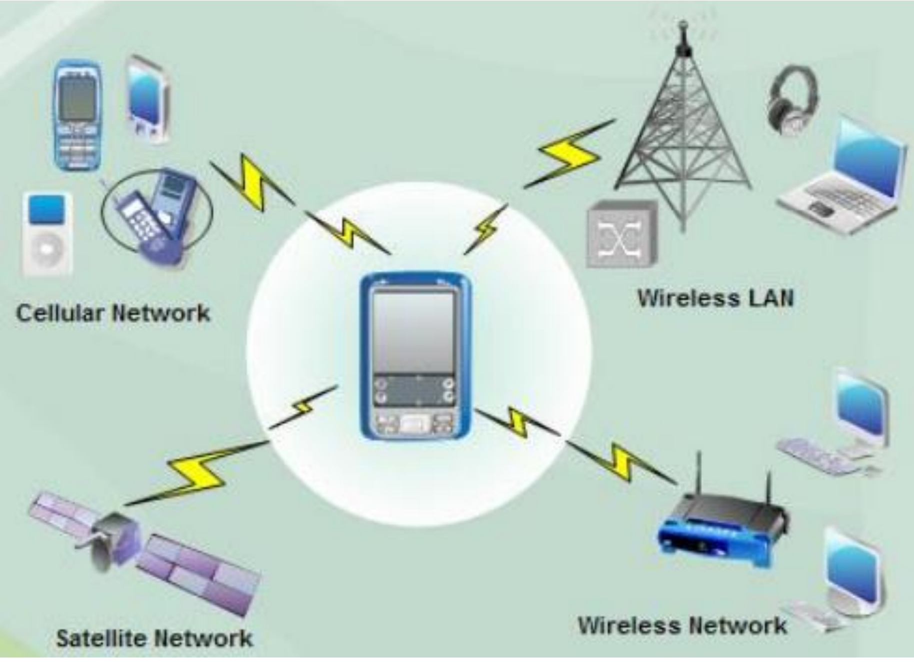

Figure 3: Automatic system detection. [13]

- Service and Billing

The 4G networks have made it much more difficult to control and pay user accounts. This is mainly because 4G networks are Heterogeneous and service providers frequently interact. The research community addressed this issue and suggested various mechanisms to control account information for consumers and users [15, 16].

d) Network Conditions and Architecture

Service performance provided by network varies across different network elements such as bandwidth, jitter, and delay. It is necessary to deal with how a mobile user handles changes in network circumstances and retains the quality of service while crossing heterogeneous wireless networks. 4G is an integration of heterogeneous wireless networks that heavily relies on various network architectures and procedures for transport, routing, mobility management and so on [17].

e) Latency

Latency refers to the user experience delay that takes place in the network when the data moves from source to destination and vice versa. It measures the time taken in milliseconds (ms) for the data to make one complete round trip from source to destination. 4G's development has been an important achievement for mobile technology, for smartphone and tablet development. It is important for an application like as autonomous vehicle, intelligent road transport system, where response time plays a critical role in determining the outcome. In autonomous vehicles, a quick decision can trigger a reaction to avoid an obstacle in real-time. With 4G networks, there is a latency of around 50ms and high latency could be fatal for real-time reactions which leads to negative consequences.

4.3 Evolution of 5G

5G networks refer to the fifth generation of internet connectivity which provides a higher speed rate, larger area, and constant bandwidth. This is all about making the best use of the radio frequencies available and making a larger number of devices over long range to access the internet. 5G devices communicate with a local antennas array and a low-power audio transceiver within the cell from the common frequency pool via radio waves. Local antennas connect through a high bandwidth optical fiber to the mobile network and the internet. Like existing mobile phones, when an operator passes from one cell to another cell, the new cell automatically” shifts” their mobile device seamlessly to the antenna.

The new 5G wireless devices also have 4G LTE capability, so that it can switch the network capability to 4G in case there is no 5G communication. It can handle up to one million devices per square kilometre, whereas 4G can only support 4000 devices per square kilometre.

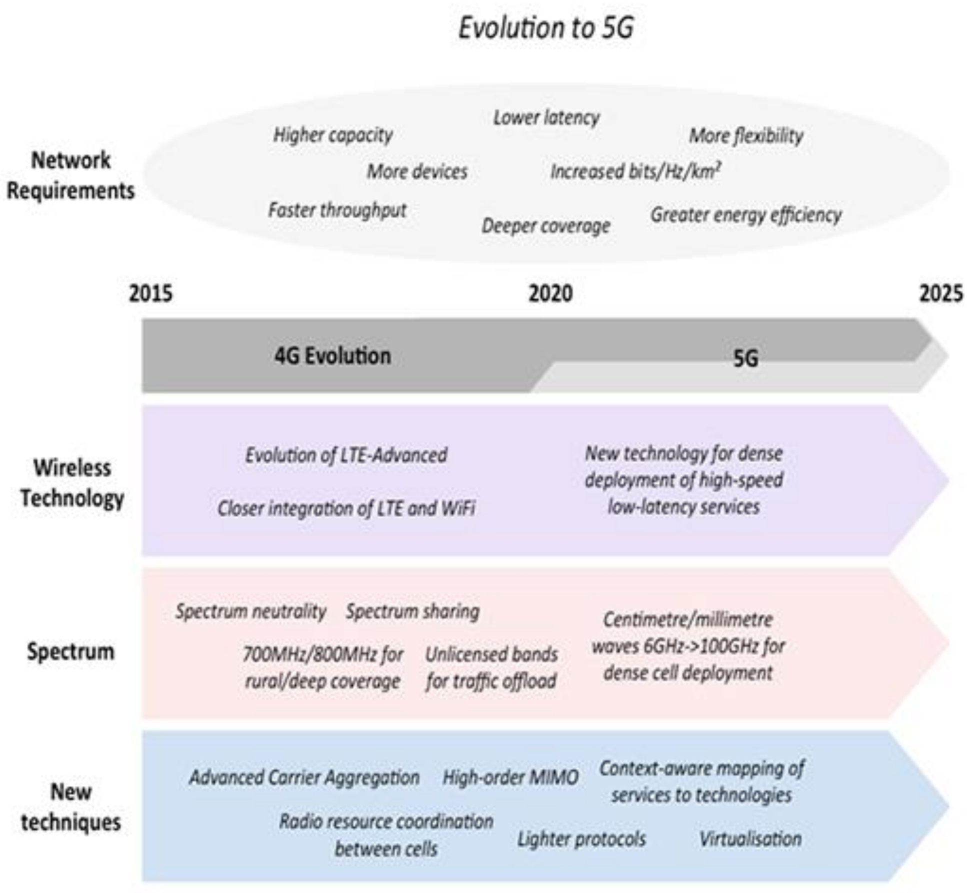

Figure 4. Close Comparison of 4G Network and 5G Showing its Evolution via Block Diagram. [18]

5G is currently undergoing active development as a new generation of mobile communication technology. The above figure 4 illustrates the comparison between 4G and 5G and gives a close view of how 5G is evolving. In wireless technology, 4G has a close integration of LTE and Wi-Fi whereas 5G is looking for new technology for the dense deployment of high-speed and low-latency services. Similarly, 4G has spectrum neutrality and spectrum sharing which has a frequency of 700-800MHz for deep coverage. For better coverage and low-latency, 5G operates in the frequency of 6-100GHz. The final goal of 5G is to cover the massive area with high availability and connectivity. The world is getting more populated due to which serving every person with good quality data with 4G seems difficult but with 5G, it works with a high bandwidth (1000x) per unit area which provides super speed and dense coverage. 5G technology serves in real-time which allows different IoT devices to connect, receive and send data without latency (<1ms).

The massive connection with IoT devices leads to low usage and low energy consumption which ultimately allows communication devices to have a better battery life (up to 10-year).

4.4 5G Core Network Architecture

According to the SA2 group of 3GPP, the architecture 5G core network can be depicted in figure 5 [16]. Several key technologies such as system architecture, network slicing, and control-user plane separation (CUPS) are being implemented to support 5G core network infrastructures. The CUPS provide the user's network surfaces to decentralization so that it can be organised flexibly within the core network (central data server), giving us a distributed network. The 5G core network control plane can be divided into two groups, they are AMF and SMF, where AMF (single) handles access and mobility management, while SMF is responsible for session management functions. There are two types of reference points (which can be understood as the interaction between two specific functional blocks) in the 5G core network: one is traditional point-to-point communication based which are illustrated in red colour and another one is the service interface-based which is represented using blue colour [19, 20].

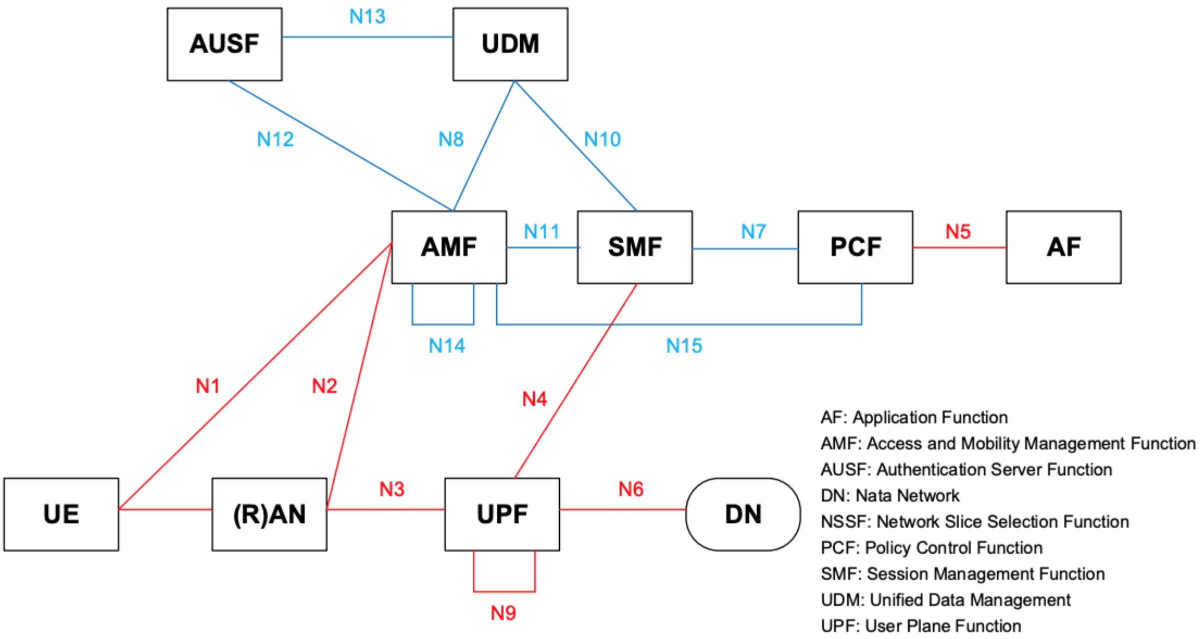

Figure 5. 5G core Network Architecture. [21]

To deploy the 5G network in the existing network and minimizing the cost overheads, most users will take a two-phase method to deploy 5G. Figure 6 illustrates this type of deployment.

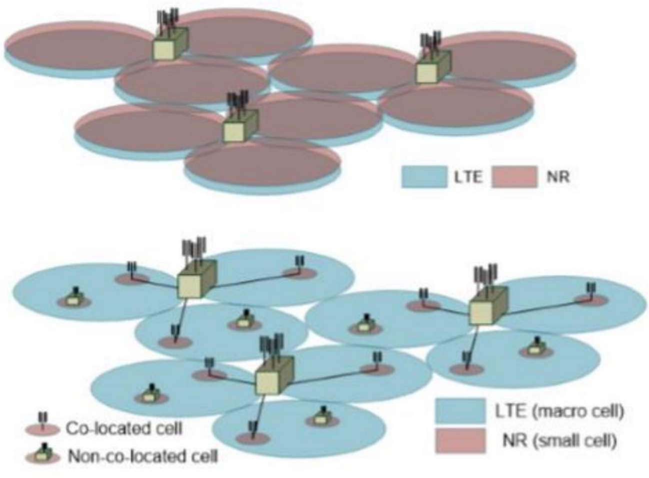

Figure 6. Co-existing 5G NR Cell and LTE Cell Coverage. [22]

Some key technologies for 5G wireless communication networks are briefly described below.

1) Multi-Carrier Technology

Multiple-carrier systems can handle and increase the spectral efficiency of radar signals. By determining the bandwidth between carriers, the carrier control can be completely used. Besides, a filter is also needed to address the drawbacks of wireless technology when sending information [20]. The addition of the inserted prefix into the sub-carrier allows the orthogonality between the sub-carriers to be disconnected which can minimize data interferences and eliminate the sub-carriers synchronization phenomenon and thus take full account of its advantages.

2) Full Duplex Technology

It enables dual communication simultaneously with the same frequency signals. For wireless communications networks, there are many forms of self-interference factors.

If bidirectional communication is not utilized by a similar frequency, a huge amount of energy will be discarded. The use of this technology will increase performance and use resources for signal processing effectively, thereby improving the use of a mechanical device. When using full duplex technology industrially, employees must constantly reduce signal interference and increase signal transmission and receiving power [20]. It is also necessary that asset networking and distribution must also be dealt with efficiently.

3) Device-to-Device (D2D) Technology

D2D communication shares cell resources to allow client cells to communicate within the cellular system within a certain area. In this communication method, the data traffic does not need to travel through the communication centre and core network area saving communication delay and external interference. This results in reducing the network load, increase network throughput and system performance as well as reduce the data transmission costs. Meanwhile, research is needed to ensure real-time connectivity and the management of unregulated resources to facilitate the fast development of the 5G wireless communication network to completely maximize the value of D2D technology.

4) Massive Multiple-Input-Multiple-Output (MIMO)

MIMO technology can enhance bandwidth multiplexing and transmit power so that wireless communication networks maximize their performance. MIMO also has been greatly improved with the constant development of its level of technology that not only can carry out single-point to single-point but also single-point to multi-point operations. Also, MIMO technology is introduced to the new systems with the application of the cloud wireless access network, to further boost 5G performance [20]. The benefits of MIMO technology include increasing the resolution of 5G communication systems, using spatial tools to their full potential and achieving simultaneous communications with the base station, thus enhancing efficient 5 G mobile communication network deployment effectively. Therefore, the data beams in a certain space can be focused so that external disruptions are not affected.

5) Diversified Ultra-Dense Networks

5G technology, especially in communication, is evolving towards the path of diversification. With the advancement of human society, the demand for data traffic increases slowly and the mobile data volume exceeds the pre-set limit. The use of diverse high-intensity networking technology will solve these problems. It can minimize the gap between nodes and endpoints, this increases the versatility between the business and the overlay layer and allows for more dynamic network delivery and more efficient frequency reuse to maximize the network spectrum and power [20]. Although the above-stated advantages come from the heterogeneous ultra-dense network, the increasingly dense implementation of the network is making the topology of the network complicated, and intercell interference is now an important factor limiting the growth in systems ability.

4.5 Potential Use Case of 5G Technology

The ITU-R has defined three main uses types to enable 5G expected capability. They are Enhanced Mobile BroadBand (eMBB), Ultra-Reliable Low Latency Communications (URLLC), and Communications of Massive Machine Type (mMTC) [8]. The 5G Wireless Standard provides a unified connectivity fabric, bringing enormous improvements to mobile broadband services today. Mobile networks can support a wide range of devices and services with 5G. As 5G networks arise in 2019, there is increasing speculation about possible use cases. For instance, 5G finally gives IoT the connectivity it demands.

The following are the categories that cover the hyped topic of use cases of 5G [23]:

<u>Early Use Cases of 5G</u>

Fixed Wireless: Fixed wireless access by using 5g will be the major achievement of implementing 5G. It will provide Internet access in due time to houses using wireless network technology to replace the currently in use fixed cables. 5G concepts such as millimetre wave (mmWave) spectrums and beamforming to bolster wireless broadband services will be used by fixed wireless.

Enhanced Mobile Broadband: In the next era of cloud-based and immersive experiences, the 5G standard offers quicker standardized information rates at lower latencies and lower per-bit costs. With fast, constantly connected Internet links with real-time responsiveness, the 5G standard will bring mobile computing efficiency to the next level. The aim is to achieve peak throughput of up to 20 Gb/s and 1Gb/s throughput in high mobility [6]. With evolving technology such as augmented reality and Virtual reality, there is a high need for high-speed internet with real-time response.

Later Use Cases of 5G

a) Massive Machine-Type Communications: One of the most expected 5G applications is the ability to seamlessly connect integrated sensors to virtually everything. By 2020, the sector anticipates enormous numbers of potential IoT devices in service – up to 20.4 billion. Industrial IoT is one area in the 5G sector that will allow smart cities, asset tracking, intelligent services, agriculture, and safety infrastructures to play their significant part.

b) Ultra-Reliable Low -Latency Communications: Latency has always been the huge issue for new technologies such as autonomous cars, smart grid control, and critical infrastructures. 5G provides such services that will revolutionize the industry.

Future Use Cases of 5G

Once everything is linked through 5G, the use of scenarios with the emergence of fresh services and apps will improve enormously. Check for vertical sectors and domestic priorities, for revolutionary transformation–from healthcare and intelligent towns to remote industrial machinery operation and online sports participation.

5 5G Assisted Vehicular Communications and Networking (5G-VCN)

Vehicle communications and networking (VCN) has been gaining growing interest since the end of the last decade as one of the main supporting techniques for the next generation of ITS and IVs. VCN requires low latency and high-reliability communications to promote multiple apps including vehicle safety, transportation effectiveness, and entertainment. To effectively support VANETs, the dedicated short-range communications (DSRC) standard based on IEEE 802.11p [24]and IEEE 1609.x [25, 26, 27] has gained the support and promotion of the federal government in the United States [28]. In the European Union, China, and Japan, systems based on DSRC and alternative technologies have been created and standardized [28]. Since VANET needs important front-end investment in infrastructure, it is still in the field trial phase and has not yet been implemented extensively.

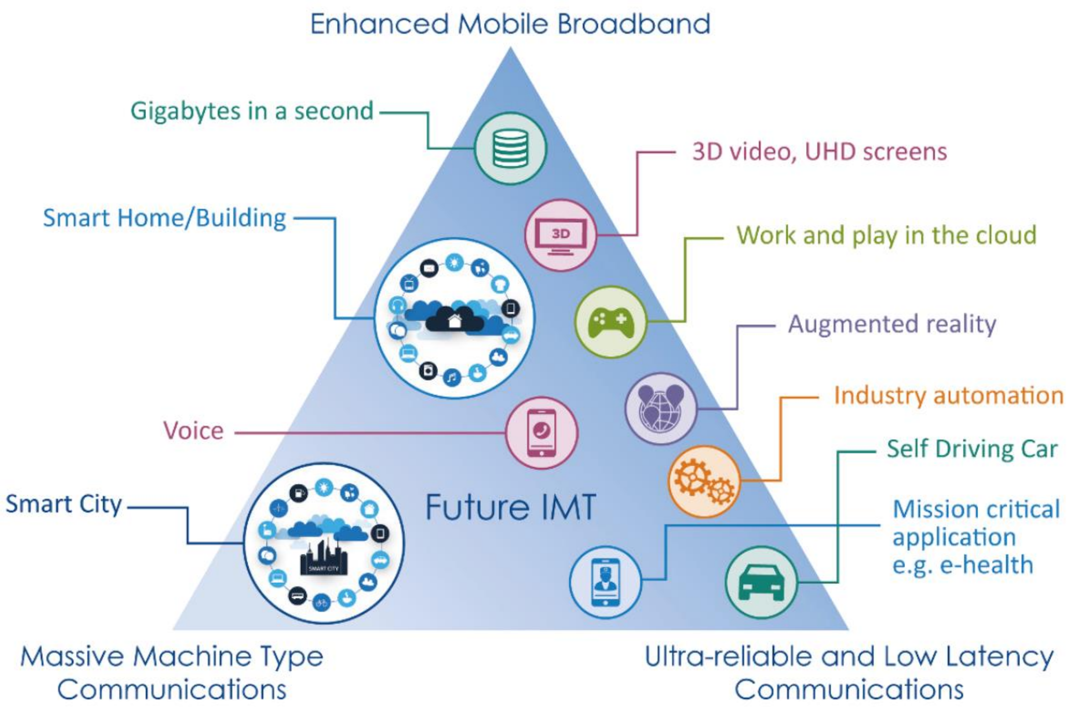

Figure 7: 5G application scenarios. [29]

In addition, DSRC-based VANET's achievable rate and network configuration cannot meet the rapid and ever-increasing communication demands of vehicle applications, particularly for autonomous vehicles soon. Furthermore, IEEE 802.11p showed bad scalability and lacks guaranteed delivery of service in large-scale network deployments. Unlike VANET, the mobile network is mature, business model and extensive standardization growth. At present, the 4G scheme of long-term development (LTE) has been extensively created and fully marketed. In support of vehicular communications, LTE for the car (LTE-V) [30] becomes an increasing star for VCN, and it is broadly deployed LTE. Currently, LTE-V is under effective growth for standardization and marketing. The 5G is already being developed as the next generation of the cell network. 5G for the first time lists the VCN as one of the representative application scenarios as shown in figure 7. 5G-enabled cars and networking (5G-VCN) calls for greater efficiency and reduced information latency transmission to help prospective further apps linked to future cars, such as smart and autonomous vehicles. The study and layout of 5G-VCN are therefore very difficult and very careful.

5.1 5G-VCN: Key Features

5G is presently under active growth as a new generation of portable communication technology. The 5G apps designed to assist ultra-high data rates with extremely low latency and highly trusted efficiency provide a successful enabler for self-driving IVs. In addition, to be a crucial supported technology of the IVs and an integrated part of the IV-system, 5G's distinctive characteristics such as Proximity Service (ProSe), a software-defined, data-controlled network (SDN), versatile network architecture and configuration, cloud/fog computing and processing, and application-oriented development are also important [28]. A significant characteristic of 5G-enabled communications is the proximity service (ProSe) developed from D2D communications [31].

ProSe's current purpose is to raise consciousness using local data to discover equipment and facilities. For many of the spontaneous relationships or communication possibilities within a given vicinity, ProSe is especially important in the 5G-VCN context [32]. The location data and interaction patterns in social networks are essential to ProSe-based apps. More importantly, ProSe can be used as a communication platform for government security situations to explore and interact without an infrastructure.

The SDN features data access separation in 5 G network architectures [33]. This is possible by implementing a central control of personal network devices in an external entity to deal with the network control issues. The increase in SDN in IVs could improve the latency of the network with self-driving activities on the centralized control level. SDN makes the remote control of IVs by 5G-VCN a practical possibility. Moreover, 5G-VCN can perform IV data storage and handle on three stages, that is, cloud, fog and onboard, due to the coexistence of the integrated Cloud network and distributed fog/edge networks [34, 35]. 5G-VCN can organize its storage and handling in a versatile way, depending on information features and latency conditions of various IV services. 5G-VCN can use the available use of multi-IV information more effectively and efficiently based on cloud and fog systems to enable different teaching features and therefore to achieve self-drive habits, which better imitate or outweigh human driving. The hierarchical coexistence of heterogeneous networks is another important feature of 5G. In this context, the heterogeneity is not only concerned with cells of distinct dimensions but also with distinct operations and standards. This allows 5G-VCN to improve the stability of IV's high-speed network connectivity. For instance, macrocell base stations with large-area coverage could maintain IV control messages to ensure the stability of highly mobile connectivity, and to guarantee low latency and high reliability, the interchange of bulk data can be made possible through micro- and femtocells by the advanced data dissemination system and the D2D technology.

5.2 V2V and V2X

The automobile industry is during a transition to more environmentally conscious cars. For numerous years, it has been the goal to ensure that vehicles can communicate with not only other vehicles (V2V) but also with local infrastructure (V2I). These use cases are jointly referred to as vehicle-to-everything (V2X) connectivity [16]. V2V (vehicle-to-vehicle) communication refers to vehicular communication through an in-vehicle terminal. The vehicles can also form an interactive platform to exchange information in real-time. Intelligent transportation systems (ITSs) refer to services to enhance traffic safety and boost efficiency. For instance, platooning, in which several trucks drive close by and join the first truck in the platoon to minimize fuel and CO2 pollution [36]. For real-time information systems, V2I is mostly used for communication while V2P (vehicle to pedestrians) refers to traffic groups using user equipment to communicate with in-vehicle devices.

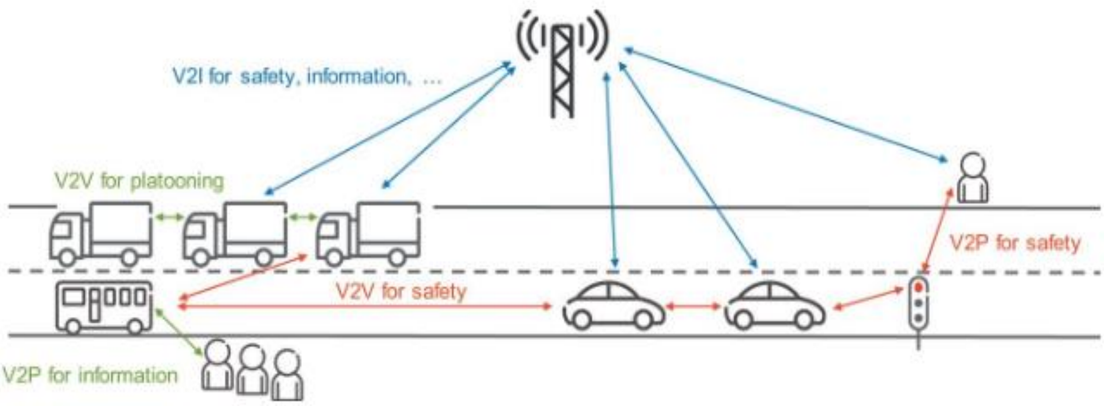

Figure 8. Illustration of V2V and V2X. [36]

In figure 8, it demonstrates RSU is sharing and collecting information from its surroundings and making communication between vehicles and humans. Autonomous cars must be able to share their driving intentions in fast, two-way communication to allow complicated vehicle manoeuvres. Such interactions allow vehicles to function as intelligent clusters instead of individual inert units. In Europe, a large consortium led by Ericsson is designing a 5G system architecture that offers all-round (V2X) connectivity with an integrated end-to-end device.

Based on the usage of various fundamental technologies, two types of V2X communication technology have been proposed, which are cellular-based and WLAN-based V2X [20].

5.2.1 Short-range Communication (DSRC)

In the V2X connectivity, Wi-Fi is used and operates straight from V2V to V2I. The norm for this form of V2X is known as short-range communications (DSRC). DSRC uses IEEE 802.11p to provide wireless access in vehicular environments [20]. It enables low latency communication between vehicles and on-road infrastructure of basic safety messages. The DSRC's highest protocol stack is designed according to the IEEE 1609 standard. Instead of the TCP / IP protocol used by WIFI, the V2V Information Interaction uses the

WAVE Short Message Protocol [20]. The V2I and V2N data exchange are based on the TCP / IP protocol.

5.2.2 Cellular-V2X

Initially, C-V2X (Cellular – V2X) is defined from LTE in 3GPP Release 14 which is aimed to apply in V2N and V2I. In 3GPP Release 15, the functionalities of V2X are expanded to aid 5G. Like 802.11p, C-V2X direct communication support broad-band coverage connections, improve safety by identifying and exchanging data using high reliable transmission in the 5.9GHz ITS band [20]. C-V2X now transitions from information service applications to traffic safety and efficiency applications, enabling autopilot communication through a full range of connections and efficient information exchanges between people, vehicles, roads and cloud platforms [20].

Release 16 C-V2X will have 5G NR development characteristics that allow new automated driving case applications with higher demands. 5G NR-based C-V2X provides increased performance, reduced latency, and improved reliability. To support both Unicast and Multicast, 5G NR C-V2X is further improved concerning broadcast communication. It also allows wideband coverage and positioning to ensure accurate location (e.g. submeter). Through using vehicles as moving sensor nodes, 5G C-V2X will become a new type of sensor with extremely long and very precise measurements. For instance, in a typical “see-through” use case scenario, a vehicle with limited visibility in case of rain or obstacle can receive high-quality, real-time video feeds from cameras installed on the trunk or other nearby vehicles to gain visibility [16]. Besides improved visibility and accuracy, this new C-V2X system also gives vehicles with less-capable on-board sensors access to high-quality sensor data and enhances road safety further.

6 Application of C-V2X for Road Safety

With an emphasis on allowing vehicle safety for longer-range applications and reliability enhanced applications, reliable performance in congested situations and advanced vehicle communications. C-V2X has many advantages over DSRC, some of them are:

6.1 Consistent Operation Under Traffic Crowding

For a limited period, security messages are usually sent regularly. C-V2X aims to use these quasi-periodic modes of traffic arrival to pre-allocate resources deterministically for subsequent traffic arrivals. A semi-constant scheduling system confirms that traffic resources are accessible when traffic arrives. For subsequent traffic, resource contention procedures are not required, so that C-V2X can keep latency low, even as vehicle density increases. Moreover, C-V2X selects the best resource for the transmission of traffic instead of the first available to boost channel connectivity when the load is heavy. This ranks the radio resource blocks and chooses one of the lowest relative energy levels for transmission. In the presence of other transmitting vehicles, this less energy resource selection system provides enhanced signal quality. The figure 9 (a) below demonstrates a scenario where C-V2X allows vehicles A and B to transmit simultaneously to their respective recipients whereas figure 9 (b) shows the corresponding DSRC scenario when vehicle A is transmitting, and vehicle B backs off to avoid the collision. In the face of congestion, C-V2X makes incremental degradation (decrease in range), while more rapids in packet transmission rate occur over time in DSRC, which in extreme cases leads to a lack of service.

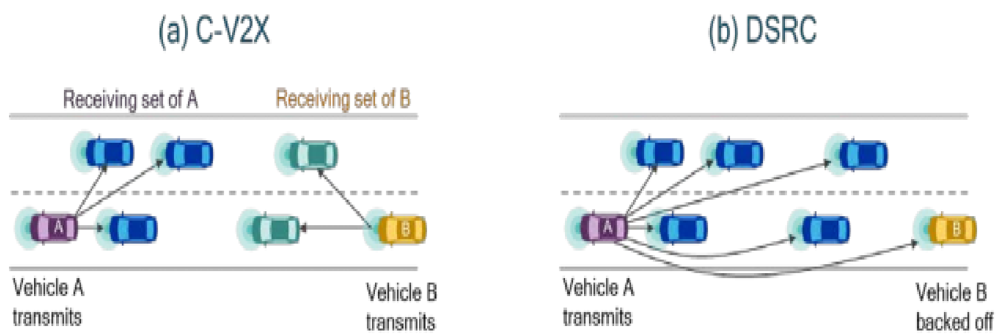

Figure 9. Enabling Efficient Connectivity by The Selection of Minimum Energy Resources. [16]

6.2 Improved Range and Reliability

According to link-level simulation analysis [17], C-V2X can achieve Line of Sight (LOS) and non-LOS (NLOS). V2V ranges of 443 m and 107 m, respectively, compared to 240 m and 60 m, respectively, for DSRC [16]. The longer range can be translated directly into early warnings and better visibility of unpredictable and potentially risky conditions. It makes it possible for cars to travel at greater speeds and yet can stop in time for dangerous circumstances. Figure 10 illustrates a situation in which a damaged vehicle transmits warnings to approaching vehicles in both the icy and normal road conditions behind a blind curve. When the DSRC is in use, an approaching vehicle must maintain a speed below 28 mph and 46 mph to stop in time for an accident after getting the warning, in the icy and normal road conditions respectively. The incoming vehicle receives the warning at a longer distance earlier with C-V2X. Therefore, even when driving at high speed, it can stop before entering the disabled vehicle, (for example, for icy and normal road conditions, 38 mph and 63 mph, respectively).

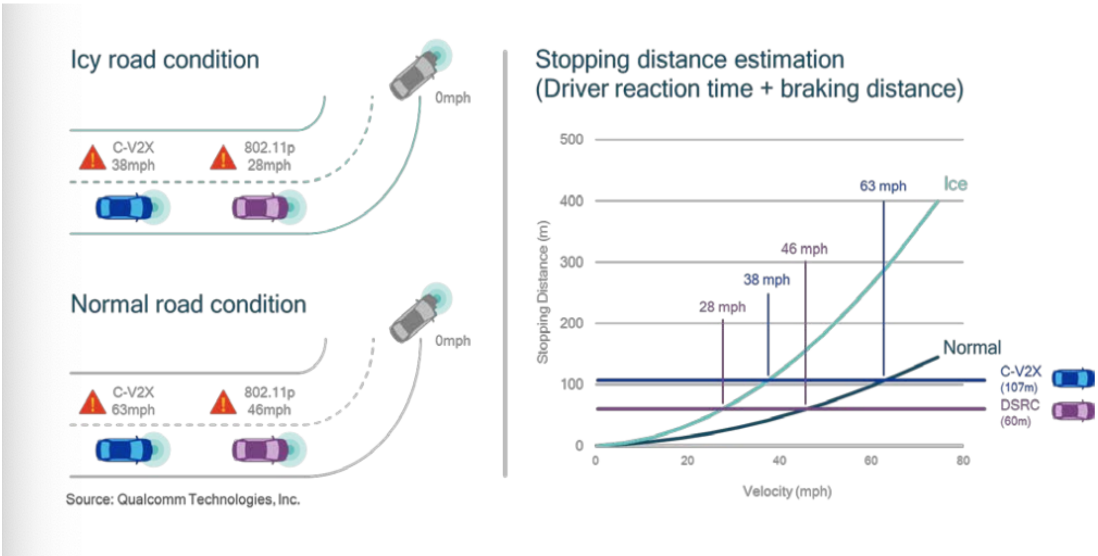

Figure 10. Use Case of Blind Spot. [37]

Figure 11 demonstrates a case scenario for a do – not - pass use when there is limited visibility of the opposite roads in a car trailing the large truck. At the same time, from the adjacent lane, a second vehicle approaches the first. The higher the speed the quicker the two vehicles get together and if the first vehicle chooses to overtake the truck, the more dangerous is the situation.

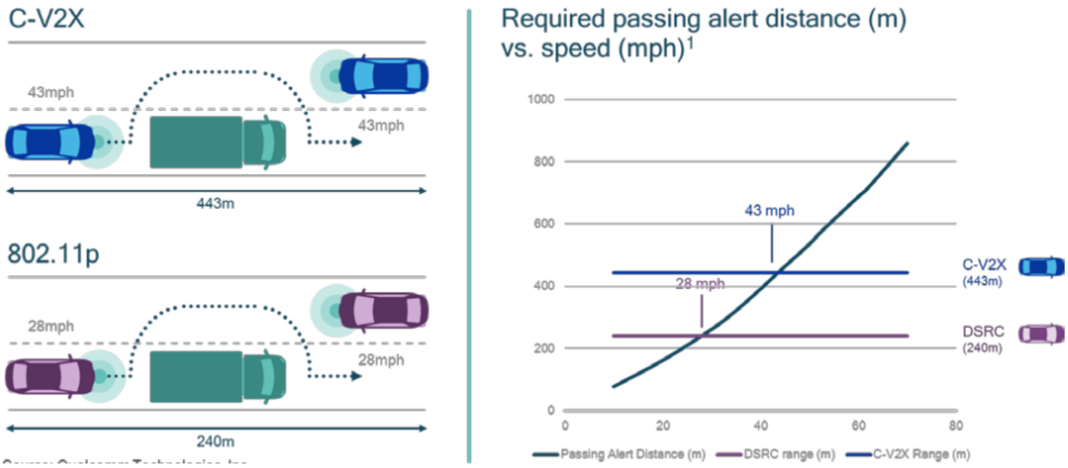

Figure 11. Use Case of Do - Not - Pass Warning. [16]

V2V contact enables the second vehicle to send warning signals and determine whether to drive through the truck, used by the first vehicle. As the first instance above, the longer C-V2X range allows the first vehicle to receive the warnings earlier, thus enabling it to drive over the truck safely even when it drives at a speed higher compared to the case when using DSRC.

6.3 Evolution path towards 5G for emerging applications

DSRC and C-V2X Release 14 support low latency and reliable interchange of information among vehicles and the infrastructure to improve efficiency and safety. However, it is the start of the development of upcoming vehicles with many sophisticated safety and non-safety features that are anticipated more and more autonomous. This evolution will involve additional capabilities for V2X communication including more capacity, extremely low latency, extremely high reliability, extended range, and higher data speeds. For instance, sensor sharing is intended for potential vehicles as an important feature to increase the visibility of vehicles outside their direct visibility (LOS) areas. Sensor sharing includes exchanging large quantities of data between vehicles and even the infrastructure. Often very low latency and high reliability are important to provide the transmission of data with timeliness and accuracy. With the anticipated high-density vehicles in many congested municipalities, the emerging V2X technology is needed to allow sensor sharing, which can aid higher capacity, data speeds, and low latency.

7 Advanced Use Cases

There are some advance case scenarios of V2X for 5G - based communications.

7.1 Improved Driving By Path Allotting

Improved driving allows semi-or completely autonomous driving. Each vehicle and/or RSU shares information from local sensors with nearby vehicles, enabling vehicles to organize their paths or maneuvering. Each vehicle also shares its driving intentions with nearby vehicle. The advantages of this class of cases are smoother travel, better traffic quality, and collision avoidance. The required correspondence prerequisites between two vehicles utilizing propelled driving interchanges are [16]:

- Higher bandwidth to aid bursts broadcast of huge amount of information.
- The latency of 10 ms for automation.
- Information dependability of 99.99 % for automation.

7.2 Extended Sensors

Extended sensors denote the vehicle's capability to receive data about events outside its onboard sensors. Other vehicles in the proximity of which these objects are detected and processed, then pass them to other vehicles to help them build a more comprehensive picture of the roads. In general, this provides a more comprehensive view of the traffic environment for vehicles in a city. The ETSI ITS and 5GAA presently operate on this topic. Extended sensors allow the transmission between cars, RSUs, pedestrians and V2X application servers of raw and processed sensor data (e.g., cameras, radars, LIDAR). The availability of sensor information from a wide array of different sources increases awareness and thus improves safety in vehicles and pedestrians. Extended sensors also provide the new features and abilities required for autonomous driving, such as co-operative driving and accurate positioning. For example, vehicles send messages to other vehicles that raise awareness of non-line-of-sight (NLOS). Such intersections/on-ramps are particularly important or when weather conditions (such as rain, fog, snow) affect the range of on-board sensors. In Figure 19, the yellow car is informed by the red car about the cyclist behind it.

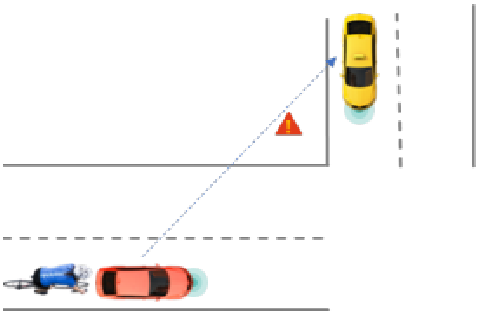

Figure 12. Intersection NLOS View. [16]

For extended sensors, there are possible connectivity requirements between two V2X nodes, they are:

- High bandwidth for enabling large data transfer.
- Latency of less than 10 ms.
- 95 % of high information reliability.
- High connection density (e.g., 14,000 vehicles per mile at a dense intersection) to help congested areas.

7.3 Platooning

Platooning makes it possible to shape a narrowly structured "train" with an inter-vehicle range significantly reduced, which improves road capacity and productivity. It also improves fuel economy, reduces the rate of accidents and increases productivity through the freeing of drivers for other tasks. Vehicles within a platoon should be able to exchange data regularly and send activity notifications such as braking and accelerations (for instance, to share status information such as speed and heading. Platooning is helped in many ways through efficient communications with V2V [16]:

- Announcement and Warning: to signal platoon's formation and existence so that the next vehicles can choose to enter or avoid platoon disruption.

- Entering and exiting a platoon: enable a vehicle always to signal its intention of joining or leaving a platoon during the dynamic action of the platoon and to aid extra signaling to complete the join/leave actions.

- Stable group communication: enabling the exchange of stationary management messages to signify the braking, acceleration, transition, shift in the leading position, etc.

Due to its short, high-speed target inter-vehicle range, V2V communication should be able to aid consistent high-duty cycles and secure information exchanges to ensure effective and harmless driving. Some of the key requirements for V2V communication to support platooning are as follows [16]:

- High communication range control to enhance resource effectiveness due to the various size of the tube and limit the information circulation for reasons of privacy.

- 25 ms end - to - end latency for interaction between cars.

- Broadcasting rate per second of 10-30 messages.

- The relative precision of a longitudinal location of less than 0.5 m.

7.4 Real-Time HD Mapping

The crucial element of automated driving is real-time HD mapping, but the techniques for technical implementation differ. Highly definition maps are mainly for navigation purposes in "maplight" approaches and are overlaid by real-time situation data (e.g. accident reports, road buildings). HD mapping plays a far more vital role in road planning, even to a minimum level of aspect, in' map heavy' approaches [16] . These may also need updates on request if vehicles are moving across the region, and not only are these maps updated regularly without direct user interaction. Deployment strategies that leverage roadside technology and cutting-edge cloud solutions to provide these map updates are critical to reducing costs.

7.5 Remote Driving

Driving remotely makes a person or cloud-based V2N communication to remotely control a car. Some of the different scenarios that can lift remote driving are [16]:

- Offer an autonomous vehicle backup solution. For instance, whenever a vehicle is in an unknown location and has trouble navigating during the initial autonomous vehicle arrangement, a remote operator can take over.
- Enable cloud-driven public and private transportation, all of which are specifically suited for services with pre-defined stops and routes.
- Allow fleet owners to manage their vehicles remotely. For example, moving trucks from one place to another, providing customers with rental cars and remotely operated taxis.

Remote driving can be used in the lower technical requirements for certain users and can help reduce the cost of fully autonomous driving. Some of the potentials of V2X requirements for supporting remote driving are [16]:

- Vehicular speed of up to 250 km/hr.
- 99.99 % of Ultra-high reliability.
- Data rate up to 0.9 Mbps downlink and 26 Mbps at uplink.

8 5G-VCN: Security

5G network is the next phase in the progression of wireless mobile communication. As such, it will need to provide capabilities far beyond what we have today; with new users and new use cases, for billions of devices, and new applications to connect the society at large. This also means we will need new approaches when defining the security for 5G.

The 5G networks will have a unique capacity and latency requirements to meet the efficient needs of different industries, intelligent transport, or smart grid and so on. There will also be machines and sensors connected to the 5G network and new models for how services, networks, and infrastructure are being provided. This also impacts how security for 5G is defined. Some two decades ago, when the GSM systems were being developed, security was designed to protect connectivity: voice, and in later generations also packet data. The purpose has mainly been to gain users trust in terms of privacy. It has worked well, but 5G will also drive other requirements.

Figure 13. Defining Characteristics of 5G. [38]

In figure 13, it shows that the new trust model for 5G is needed. For existing mobile systems, the trust model is upfront, with a device, a subscriber, a home operator, and a serving network user. New devices and different business models will be supported by 5G. With 5G, it will provide new service delivery models. The use of cloud, virtualization, and network slicing highlights the need for secure software, and having multiple applications executing on the same hardware puts requirements on virtualization with strong separation properties. 5G will have an outspoken role as critical infrastructure, and attacks against 5G networks could have severe consequences for society. This evolved threat landscape calls for strengthening security, and shows the need for measurable security, and shows the need for measurable security and compliance.

Given the role of 5G in the Networked Society, there will be monitoring pressure on how the 5G network will operate. It is thought that the 5G network will benefit from a more transparent model of identity management that offers different alternative solutions with the Internet of Things and billions of smartphones. Due to the changing threat spectrum, network attack resistance must be considered, for instance, by means of steps implemented in a 5G radio designing protocol. Network slicing is the key tool to provide independent subnetworks tailored for different user groups and applications. It can, however, also be used from a safety and security viewpoint to meet specific specifications.

9 Discussion and Conclusion

The 5G technology is so diverse and still to be researched more that even a small topic regarding it can be explained to write a book. The concept of connecting IoT devices with 5G technology is not new but the testing and implementation are growing rapidly. The thesis was started with the aim to introduce 5G and its advantages along with its vital role in minimizing the road casualties by explaining the concept of autonomous vehicles. It is also tried to put the light on the present vehicular tracking system. The concept of autonomous vehicles and its implementation has not started yet, but people are highly focused on it and bringing out new theories to make the future of driverless cars. Not only the driverless cars but also the connectivity of more than 50 billion IoT devices will be able to make people's life easier and safe with the advancement of 5G technology. It will be the basis for VR, AR, IoT and many more. Connecting vehicles to make the road safer and autonomous vehicle is the new sector for improvement.

The paper concerns applications of 5G technology for the betterment of road safety with the connection of vehicles to everything. The paper is started with the problems we are facing in our today's life regarding the safety of people on roads. Then when things put into perspective, the types of vehicle tracking systems that are used with its current benefit and the future possibilities are briefly described. After that thing related to networking is written as all the devices need a network to connect. So, about 4G and its challenges which are overcome by the evolution of 5G need to be mentioned. This thesis also gives an idea about the 5G core network and its key technologies. The intention was to make the reader familiar with the current network and on-going development and the potential uses of 5G technology in our lives. The compatibility of IoT devices and 5G will be most advanced due to the characteristics of 5G for the interaction from small cells to millimetre waves that can reuse the frequency and full duplex makes it easier for IoT devices to communicate with each other. 5G provides the low-latency (10 times faster than 4G) which is very crucial for real-time data transmissions between the vehicles and other IoT devices which directly boost the chances for autonomous vehicles.

There is a lot of engagement between the environment and technology that needs new advancement measures with the connectivity. 5G allows us a tremendous amount of low-latency and bandwidth that is very essential to be able to work on some solutions that require huge data to be processed incredibly faster. With the new features of 5G, it allows to flow the data not only faster but also avoids unnecessary data and sends relevant data that are useful to the users which allows them to make better decisions. 5G requires a new communication infrastructure that needs to be deployed in the cities so that the connectivity is available to the citizens when they need it. The arrival of new infrastructure doesn't mean the end of 4G, new devices will also be compatible with 4G technologies. Sensors need to be deployed on the ground, light poles and in key areas where people are interacting to be able to have an exchange between our environment and the individuals who are going through the environment. Infrastructure for 5G is massive as well as data is also an important part of it because of huge information flow and with great power comes great responsibility. There is a high risk of data security and privacy concerns as well which needs to be solved.

Hence, as a result, the thesis explains the evolution of 5G technologies and how it is going to benefit road safety and the future possibilities/potential of autonomous vehicles.

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