The Perspective of Vehicle-to-Everything (V2X) Communication towards 5G

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Abstract

At this modern age, wireless communication is affecting every aspect of life and its current advancement is incorporating the vehicular operations. The flourishing wireless communication, especially the cellular services, with its onward growth towards 5G, envision radical changes in the transport system. Safety and congestion, two of the major issues in transport, can be the best examples, to which the vehicular communication has started to contribute. Thus, vehicular congestion and accidents, which are still regular events of our daily life, will be addressed greatly before long. The general form of vehicular communication, referred to as vehicle-to-everything (V2X) communication, allows communication between vehicle and another vehicle, vehicle and pedestrian, vehicle and roadside infrastructure, and so forth. Despite the stupendous potentiality, many different aspects of V2X communication is hitherto unclear among some researchers and professionals. This is partly due to the fact that the standards of V2X communication have been developing very fast. A clear understanding of various aspects of V2X communication should be made available immediately in order to help smooth progress of this technology towards 5G as well as early deployment. This paper aims to clearly depict the most important aspects of V2X communication, namely, modes of operation, network architecture, spectrum used, specifications, applications, system requirements, security, and privacy. It also derives a detailed comparison among competitive standards for V2X communication, namely, Cellular-V2X (C-V2X), Dedicated Short Range Communication (DSRC), Cooperative Intelligent Transport Systems (C-ITS), Advanced ITS, and Association of Radio Industries and Businesses (ARIB) development.

Keywords:

V2X communication, Device-to-Device (D2D) communication, Cellular-V2X (C-V2X), Dedicated Short Range Communication (DSRC), Cooperative Intelligent Transport Systems (C-ITS).

1. Introduction

In this fast developing world, the cities are getting more congested due to the increasing population. Vehicular crashes and long traffic jams are a burning issue of modern time. Millions of working hours are being wasted in the roads due to congestion and in some case, severe accidents are making lives much harder. According to the World Health Organization (WHO) report [1], 1.25 millions of road traffic deaths occurred in the year 2013. Traffic jam also causes a tremendous waste of time and fuel leading to huge economic loss [2], [3]. These major problems can be well addressed if drivers or smart vehicles are updated timely with the current traffic conditions. This sort of promising applications can be offered by Vehicular communication, presently referred to as V2X communication. In this case, the different user equipment (UEs) form a network among themselves and share data, for various purposes, for example, to help each other to take the correct decision at the current moment. Its advantages can include ensuring efficient traffic flow, improving vehicular safety and optimizing traffic congestion and accidents.

Two of the major standards for V2X, developed in recent years for information exchange, are Dedicated Short Range Communication (DSRC) in the US and the Intelligent Transportation System (ITS), the G5 standard of European Telecommunications Standard Institute (ETSI) [4]. Both these standards stem from the IEEE 802.11p standard, which is an amendment of the IEEE 802.11 standard. The specifications for Vehicular Networks (VANETs) were developed based on these standards. But in practice, it has been found that the standard has various limitations in supporting mobility and quality of service (QoS) provisioning. However, on the other hand, at present, the fast commercialization of cellular network has made them suitable for vehicular communication. Very few populated areas of the world remain without cellular coverage. Therefore, the Third Generation Partnership Project (3GPP) has been developing standards for Vehicle-to-Everything (V2X), known as cellular-V2X (C-V2X), aiming to offer more effective solutions to vehicular communication. In this case, Long Time Evolution (LTE) and the 5th Generation (5G) cellular technologies are actual candidates. In contrast to IEEE 802.11p, C-V2X can provide better QoS and huge coverage with higher data flow rate for mobile vehicles. The Device-to-Device (D2D) communication or Proximity Service (ProSe), a feature of LTE-Advanced, allows the UEs to communicate with each other directly, instead of hopping through the eNodeB. The channel structure used in the air-interface to realize the D2D communication is referred to as sidelink (SL) and it can ensure low latency and high reliability. Thus, the D2D sidelink (SL) has been specially adopted as the basis for C-V2X standards [5].

The researchers and professionals, contributing to the area of V2X communication, need to have a lucid idea about its various aspects. As a new but promising technology, V2X

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communication merits an organized explanation of all these various aspects. In this paper, an in-depth overview of V2X technologies, with a focus on C-V2X, has been presented, while covering the necessary aspects as well as performing useful comparisons among competing options. Thus, this discussion can be expected to help people both in academia and in industries to delve into V2X communication and contribute better. Thus, both research and practical deployment can be benefited.

The remainder of the paper is outlined as follows. Section 2 discusses different modes of operation for V2X communication. Section 3 depicts its network architecture. Section 4 discusses the spectrum that can be used for V2X. Section 5 discusses the development of relevant specifications. The various applications of V2X are discussed in Section 6. Its system requirements are discussed in Section 7. The security and privacy of V2X communication are discussed in Section 8. Finally, the whole paper is concluded in Section 9.

2. Modes of Operation

There are mainly four modes of operation currently deployed in V2X. They are Vehicle-to-Vehicle Communication (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Pedestrian (V2P), and Vehicle-to-Network (V2N) [6]. These four modes can be used simultaneously for safety, autonomous vehicle control enhancement by using data from nearby sensors and accident prevention. These four modes are discussed below.

1. *Vehicle-to-Vehicle (V2V):* V2V allows vehicles at proximity to form a mesh network and exchange data, which helps to make better decisions through information exchange among the existing nodes. This is done by subscribing into a network operator and gaining authorization. V2V applications work by transmitting messages carrying V2V application information, such as traffic dynamics, the location of the vehicle, vehicle attributes, etc. The message payloads are kept flexible for better communication. Besides, 3GPP messages are predominantly broadcast. Thus, ensuring the one-to-many transmission of data with minimum latency involved, which is a prerequisite for V2V [7].

2. *Vehicle-to-Infrastructure (V2I):* V2I application information is transmitted through a Remote Switching Unit (RSU) or locally available application server. RSUs are roadside stationary units, which act as a transceiver. RSUs or available application servers receive the broadcast message and transmits the message to one or more UEs supporting V2I application. V2I can provide us with information, such as available parking space, traffic congestion, road condition, etc. Due to the high cost and lengthy deployment time, its application or installation is more challenging. A remedy to this problem is V2N, discussed afterward [7].

3. *Vehicle-to-Pedestrian (V2P):* V2P transmission occurs between a vehicle and Vulnerable Road Users (VRUs) like pedestrians, bicyclists, etc. The UEs carried by the drivers and pedestrians will be able to receive and send messages and alerts [8]. Vehicles can communicate with VRUs even when they are in Non-Line of Sight (NLOS) and under low visibility cases such as dark night, heavy rain, foggy weather, etc. The sensitivity of pedestrian UEs is lower than vehicular UEs because of the antenna and battery capacity difference. So V2P application supported UEs cannot transmit continuous messages like V2V supported UEs.

4. *Vehicle-to-Network* (*V2N*): V2N transmission is between a vehicle and a V2X application server. A UE supporting V2N applications can communicate with the application server supporting V2N applications, while the parties communicate with each other using Evolved Packet Switching (EPS). V2X services are required for different applications and operation scenarios. It will help mobile operators to communicate the tasks of the RSU over its network, reducing time to market, cost and eliminating the complexity of designing and running a purpose-built network for V2I as it could include communication between vehicles and the server via 4G or even 5G network. It does not need to be as precise as V2V but reliability is crucial.

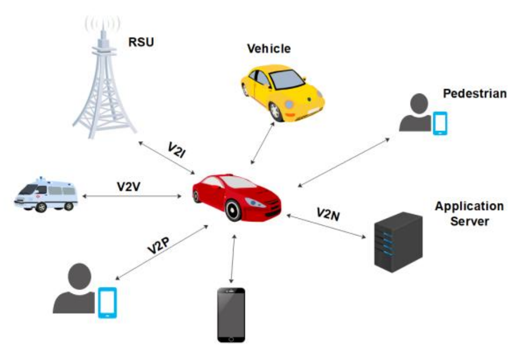

Fig. 1 Different types of V2X applications in 3GPP

3. Network Architecture

V2X is basically an important application of D2D communication. Thus, it uses the PC5 interface, which ensures one-to-many communication and also enables the use of LTE-Uu, which is the radio interface between UE and eNodeB [9], [10]. The transmission can be unicast or multimedia broadcast, which is also known as Multimedia Broadcast or Multicast Service (MBMS). A UE can use these two modes of operation independently for transmitting and receiving data. It is not obligatory that both the operations are supported by the UE. Moreover, V2X messages can be transmitted through LTE-Uu unicast downlink and received by a UE. Different operation modes over PC5 and LTE-Uu are described below.

1. *PC5 Based Communication*: V2X messages are transmitted via PC5 and are received by UEs through PC5 and MBMS. With PC5, V2X messages are received by an RSU serving as a UE. Afterward, the RSU forwards the processed message to a V2X Application Server using the V1 interface. V2X Application Server processed messages are distributed to UEs through MBMS [11]. In this mode, the cellular network can deliver information from extended range. It enables advanced driving assistance applications.

2. *LTE-Uu based and PC5 based V2X Communication without MBMS*: This mode supports communication of UE-type RSUs via PC5 for both transmission and reception of V2X messages. V2X application servers can communicate with the RSU through a cellular network. For instance, LTE-Uu is used to communicate V2X messages beyond the direct PC5 communication range. Based on such hybrid use of LTE-Uu and PC5-based V2X communications, MBMS broadcast of downlink data transmissions could be negligible [9]. This operation mode has got three components

   i. To ensure adequate coverage to the available traffic, stationary infrastructures like UE-type RSUs are incorporated. This RSUs and UEs communicate with each other for V2X over PC5. The V2X Application Servers can also communicate with the UE-type RSUs.

   ii. UE-type RSUs obtain V2X messages from other UEs via PC5. The V2X application of the RSUs evaluates whether the message should be routed to the V2X Application Servers over the LTE-Uu connection or not, in case of a larger target area (i.e. larger V2X communication coverage over PC5). The target area and the size of the area are determined by the V2X Application Servers, where the V2X messages are distributed. In the process of determining the coverage area, V2X Application Servers can communicate with each other.

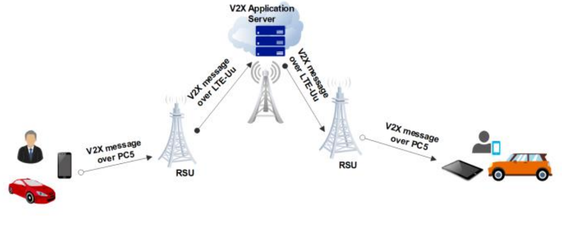

Fig. 2 V2X message transmission and reception over LTE-Uu using PC5

   iii. V2X downlink (‘Sidelink' in terms of D2D Communication) messages are sent by V2X Application Servers to the available RSU in the target distribution area. Afterward, the received message is broadcast by RSUs over PC5. UEs available in the same region are free to receive those broadcast data. In this process, vehicles operate using V2V/V2P services. When the UEs are employed as RSUs, they operate in a hybrid mode with simultaneous V2X communications over PC5 and LTE-Uu. These hybrid operations are also performed by UEs when they are unable to obtain a V2X signal directly from distant UEs via PC5.

4. Spectrum Used

The spectrum use of V2X services based on LTE sidelink is described in this section. 3GPP specifies the RF requirements based on adjacent coexistence of LTE based V2V operation in different regions, as shown below.

1. *ITU Region 1*: In Europe Intelligent Transport Systems (ITS) are regulated in the ETSI within the band 5.855 GHz to 5.925 GHz [3]. ECC Decision (08)01 defined the spectrum utilization conditions within the band 5.875 GHz to 5.905 GHz. It aims for non-safety ITS and proposes CEPT frequency with sub-band 5.905 GHz to 5.925 GHz for the spread of ITS spectrum. ECC Recommendation (08)01 states that spectrum utilization should be within the range 5.855 GHz to 5.875 GHz for non-safety ITS. For safety-related ITS applications, 5.875 GHz to 5.905 GHz is considered in the Commission Decision 2008/671/EC.

2. *ITU Region 2*: The Americas and Greenland are under this region. Here IEEE Working Group 802.11 and 1609 have standardized the V2V architecture and protocols in the name of Wireless Access Vehicular Environments (WAVE), which operates in the band 5.850 GHz to 5.925 GHz. A guard band of 5 MHz is considered from 5.850 to 5.855 GHz. Three types of channels are there in V2X, namely control channel 178, shard channels 172, 174, 176, 180, 182 and 184 and aggregated channels 175 and 181. Aggregated channels have a bandwidth of 20 MHz and are used for multi-channel operations. According to FCC 06-110, channel 172 is reserved for V2V safety communications. Channel 184 is used for higher power and long-distance communication. It is also used for public safety operations.

3. *ITU Region 3*: This region covers all parts of Asia except Middle-East and includes Australia. A revised edition, ITS standardization 2014, was published by the Telecommunications Technology Association (TTA) in South Korea, which supports vehicular communication at a maximum speed of 200 kph. Between 2012 and 2013, the Japanese Association of

Radio Industries and Business (ARIB) has also specified, based on IEEE 802.11, a V2V and V2I communication system in the 700 MHz frequency band.

5. Specifications

There are a few different standards supporting V2X communication and two of them, considered seriously for use in America and in Europe, are known as Dedicated Short Range Communication (DSRC) and Cooperative Intelligent Transport Systems (C-ITS), respectively. Due to parallel development in this volatile field, these two standards have similarities as well as differences. The organizations responsible for developing these standards are known as Standards Developing Organizations (SDOs). In America, they are IEEE and SAE, whereas in Europe they are ETSI and CEN. Different standards are discussed below.

1. *C-V2X*: C-V2X is the cellular counterpart of DSRC, which is based on LTE technologies. The main feature of it is the use of a D2D interface termed as PC5, which supports enhanced V2V use cases with more emphasis on V2X requirements. The 5G system is introduced in 3GPP Release 15, which is completed in 2018. Later 3GPP Release 16 is introduced and expected to be completed within 2019. The 5G radio interface is known as 5G New Radio (NR). 3GPP Releases 15 and 16 will introduce more V2X services by increasing ability to deal with high relative vehicle speed up to 500 km/h, ensuring longer range communication and efficient resource allocation, enhanced services in higher density, very high throughput, high reliability, highly precise positioning, and most importantly ultra-low latency [12], [13]. This system operates in the spectrum between 30GHz and 300GHz. It also ensures data rates higher than 7Gbps, an end-to-end latency less than 10ms and link establishment latency of 1ms. Downlink and uplink access technologies are based on Single Carrier Frequency Division Multiple Access (SC-FDMA) for 3GPP Release 15 and Orthogonal Frequency Division Multiple Access (OFDMA) for 3GPP Release 16. Resource multiplexing across vehicles uses TDM and FDM techniques for 3GPP Release 15 and also possibly for 3GPP Release 16. Data channel coding uses turbo method for 3GPP Release 15 and LDPC for 3GPP Release 16. Modulation supports up to 64 QAM for 3GPP Release 15 and up to 256 QAM for 3GPP Release 16. Both the schemes cover over 450 meters using direct mode and a very large area using cellular infrastructure [8], [14], [15].

2. *DSRC*: These standards are mainly derived from IEEE 802.11-2012 where Physical Transmission (PHY) and MAC are clearly defined though they are adjusted according to the requirements of V2X. As a derivative of IEEE 802.11, it also operates in the 5 GHz frequency band, the difference being the use of dedicated channels instead of the regular WiFi channels. The range of this dedicated channel is 5.825 to 5.925 GHz where the spectrum is divided into 10 MHz channels. The multiplexing technology used here is OFDM [16]. The specialty of the OFDM used here compared to the common usage in WiFi is the use of half clock. This reduces the 20 MHz bands to 10 MHz doubles the OFDM symbol duration with the cyclic prefix. This compensates the Doppler spread due to the high speed of vehicles.

   Various SDOs have defined different aspects of DSRC. For example, IEEE 802.11 has defined the Basic Service Set (BSS), which provides different network topologies with an access point or mesh network. IEEE 1609.4 defines a management extension to the MAC to ensure the best utilization of the allocated multiple wireless channels in the 5 GHz band. Security is defined in terms of authentication and optional encryption, which are based on digital signatures and certificates in IEEE 1602.2. It ensures the privacy of the user in V2X [17].

3. *C-ITS*: The European Telecommunications Standards Institute (ETSI) is an independent, not-for-profit, standardization organization in the telecommunications industry [5], [18]. C-ITS is a European development for vehicle-to-vehicle communication [19]. There are some fundamental similarities between C-ITS and DSRC in the sense that, for access technologies, networking and transport, and V2X messages they use the same structure of horizontal layers whereas for management and security entities, the same vertical layers. It also operates in the 5 GHz band, where the spectrum allocation is subdivided into part A to D where ITS-G5A (30 MHz) is the primary frequency band. It uses the half clock OFDM in the physical layer with the added feature of an adapted spectrum mask [16]. Another feature of C-ITS is the use of EDCA with CSMA/CA and access categories to aid in data traffic prioritization. For V2X messages it uses Co-operative Awareness Message (CAM), which is similar to BSS. For spreading safety information, Distributed Environmental Notification Message (DENM) is used, which is not automatic as CAM and needs triggering from an application.

   The aforementioned features along with the other features of C-ITS are indirectly standardized by setting a minimum requirement for three groups of applications, namely Road Hazard Signaling (RHS), Intersection Collision Risk Warning (ICRW) and Longitudinal Collision Risk Warning (LCRW).

4. *Advanced ITS*: Telecommunications Technology Association (TTA) is a South Korea based organization. Advanced ITS is a modified version of IEEE 802.11p, which is deployed in the Republic of Korea [20]. TTA

established four standards for advanced ITS radio communications, as shown below.

i. Vehicle communication system Stage 1: Requirements (TTAK.KO-06.0175/R1)
ii. Vehicle communication system Stage 2: Architecture (TTAK.KO-06.0193/R1)
iii. Vehicle communication system Stage 3: PHY/MAC (TTAK.KO-06.0216/R1)
iv. Vehicle communication system State 3: Networking (TTAK.KO-06.0234/R1)

The advanced ITS radio communications considers the described V2V/V2I communication schemes and its service requirements for international harmonization. In V2V applications, it considers the low packet latency because the life-saving time of safety message is useful in the span of 100ms. Also, it requires a highly activated radio channel when many vehicles try to activate radio channel simultaneously. In V2I applications, it needs to adopt the long packet transmission, which includes a short message, map information and image information to be an order of 2 kilobytes in a packet size in high mobility condition.

5. *ARIB Development*: This technology has been developed in Japan by Association of Radio Industries and Businesses (ARIB). For the use of safe driving support systems, a part of the 700 MHz band (755.5-764.5 MHz) has been assigned in a new spectrum allocation on a primary basis in the digital dividend band. A 9 MHz channel width in the 700 MHz radio frequency band will be used for the safe driving support systems. The data transmission rate is variable based on the selection of different modulation scheme and coding rate. The single channel accommodates both V2V and V2I communications based on CSMA/CA media access control [20].

Table 1: Comparison of Different Specifications of V2X

Parameters	C-V2X	DSRC	C-ITS	Advanced ITS	ARIB Development
Standards	3GPP	IEEE 802.11p	ETSI	TTA	ARIB
Specification completion	Expected to be completed within 2019	Completed	Completed	Completed	Completed
Operating frequency range	30 GHz-300GHz	5.85 GHz-5.925 GHz	5.855MHz-5.925MHz	5.855MHz-5.925MHz	755.5MHz-764.5MHz
RF channel bandwidth	10/20/40/60/80/100…MHz	10MHz or 20MHz	10MHz	<10MHz	<9MHz
RF transmit power	Maximum 33dBm	N/A	Maximum 33dBm	23dBm	
End to end latency	<10ms	<10ms	<10ms	<10ms	<10ms
Link establishment latency	1ms	Very small	Very small	Very small	Very small
Bitrate	>7Gbps	3Mbps-27Mbps	3Mbps-27Mbps	3Mbps-27Mbps	3Mbps-18Mbps
Out of network operation	Yes	Yes	Yes	Yes	Yes
V2P support	Yes	Yes	Yes	Yes	Yes
V2I support	Yes	Limited	Limited	Limited	Limited
V2V support	Yes	Yes	Yes	Yes	Yes

Network coverage support	Yes	Limited	Limited	Limited	Limited
Broadcast support	Yes	Yes	Yes	Yes	Yes
Multimedia services support	Yes	No	No	No	No
MIMO	Yes	No	No	No	No
Throughput	Very high	Moderate	Moderate	Moderate	Moderate
Reliability	Very high	Moderate	Moderate	Moderate	Moderate
Synchronization	Synchronous	Asynchronous	Asynchronous	Asynchronous	Asynchronous
Resource multiplexing across vehicles	TDM and FDM	TDM only	TDM only	TDM only	TDM only
Data channel coding	Turbo coding and LDPC	Convolutional code	Convolutional code	Convolutional code	Convolutional code
Waveform	SC-FDMA and OFDMA	OFDM	OFDM	OFDM	OFDM
Modulation	Supports up to 256 QAM	Supports up to 64 QAM	Supports up to 64 QAM	BPSK, QPSK, 16QAM, Option: 64QAM	BPSK, QPSK, 16QAM
Covering distance	>450 meters using direct mode and very large area using cellular infrastructure	Up to 225 meters			
Coverage	Ubiquitous	Intermittent	Intermittent	Intermittent	Intermittent

6. Applications

V2X can be used for various purposes. Their application can make mobility much smoother and free from danger. The major types of V2X applications are as follows.

1. *Safety Application*: It operates by notifying the drivers and the pedestrians about the current road condition. Drivers and pedestrians are periodically updated about their surroundings. In an intersection, vehicles are warned about the different complexities they might face, thus helping them in decision making [21]. From the information shared by different vehicles, RSUs broadcast it throughout the UEs for better deliberations and maneuvers. This shared information can also be used to distinguish and locate endangered sections of a road [22], [23].

   i. Forward Collision Warning: Forward Collision Warning (FCW) application serves by alerting a Host Vehicle (HV) about a possible collision with a Remote Vehicle (RV). With V2V service, FCW helps drivers to mitigate or avoid rear-end collisions.

   ii. Control Loss Warning: Control Loss Warning (CLW) works by broadcasting a message about the loss of self-generated control. Surrounding RVs are notified about the HV's condition, thus they perform maneuvers to avoid collisions in such conditions.

iii. V2V Use for Emergency Vehicle: A emergency vehicle like an ambulance or fire brigade vehicle broadcast messages, which ask RVs to make a gap for fast mobility.

iv. V2V Emergency Stop Use Case: This operation is performed to keep a vehicle away from any sort of eminent obstruction. This ensures a safer maneuver and collision-free environment.

v. Wrong Way Driving Warning: This use case enables communication between two vehicles moving in opposite directions. In this scenario, the wrong sided vehicle is warned about its wrong heading and a safety behavior is triggered for cars in the vicinity.

vi. Pre-Crash Sensing Warning: Alerts are generated and onboard safety measures are activated in this case. The moment where a crash cannot be omitted, the application warns the driver about the imminent contact and activates all the available safety measures.

vii. Pedestrian Warning: Pedestrians are warned about their surroundings periodically. Alerts are sent to road users to avoid collision with a moving vehicle.

2. *Non-Safety Application*: Non-safety based applications mainly focus on reducing traffic, increasing traffic efficiency, improving traffic flow, ensure improved traffic coordination and provide assistance to the drivers [22], [24]. Moreover, they supply updated information, maps, and real-time data to each other.

i. V2N Traffic Flow Optimization: V2N traffic flow works by managing the speed of the vehicles for smooth driving. The priority of vehicles can be taken into consideration to ensure a harmonious surrounding.

ii. Co-operative Adaptive Cruise Control (CACC): This application focuses on improving traffic efficiency by controlling the navigation vehicles, where a vehicle with V2V capability can leave and join a group of CACC vehicles. This application can provide safety and convenience for CACC vehicles. This application also helps in reducing traffic congestion, thus improving traffic efficiency. The latency-tolerant applications also fall in this category. These applications include discovering unoccupied parking slots, traffic flow control, and cloud-based sensor sharing.

7. System Requirements

The requirements to deploy V2X services can be categorized as hardware requirement and capacity requirement [15], [25]. Both of these categories are discussed below.

1. *Hardware Requirements*: To implement V2X, the vehicle needs to have this hardware incorporated.

i. Cameras: Works as the vision of the system. Data accessed through the camera is used for further decision making.

ii. Radars: Augments the camera in NLOS cases, low sunlight and bad weather.

iii. Lidar: Lidar (Light Detection And Ranging) technology creates the 3D images of the objects nearby, giving the user more information about the surroundings.

iv. Ultrasonic sensors: Ultrasonic sensors use ultrasonic soundwaves and measure the distance by calculating the time between the transmitted and received signals.

v. V2X wireless sensors: These sensors are used mainly to see through objects and to get 360 NLOS view, which aids in the better judgment of overall road conditions.

vi. 3D HD Map: Provides the user with full HD maps in order to navigate accurately.

vii. Global Navigation Satellite System (GNSS): GNSS provides highly precise data on the position of the vehicle. This can be used for deriving accurate speed, accurate heading, and time synchronization.

2. *Capacity Requirements*: As road safety is of utmost concern when planning to implement V2X on a mass scale, the system itself has some strict requirements [26], as shown below.

i. Low Latency: End-to-End delay occurs due to delay in gathering data from local sensors, processing delay in the protocol levels and transmission delay over wireless media. Security mechanisms (signature and certificate verification) add some more delay in the process. In G-V2X, the latency is kept at 300ms [ETSI TS 102 539-1]. But autonomous driving demands more attention to this matter. A very small delay can result in a disaster in autonomous vehicles. Hence, this field requires more attention.

ii. Data Load Control: Smaller inter-vehicular distance and high vehicle-density results in a heavy flow of data. This is amplified by the high message rate and by additional data load for the exchange of control messages. In order to ensure uniform flow of data, utilization of the current frequency spectrum, effective prioritization of messages using Decentralized Congestion Control (DCC) function and strict control of forwarding operations are required.

iii. High Message Rate: In 1G-V2X vehicles broadcast periodically within every 100ms to 1s. Here the data flow is controlled by the dynamics of the generating vehicle and the capability of the wireless channel. But autonomous vehicles need more data with lower latency. They need to know about the neighboring vehicles to make the correct decision. Autonomous vehicles require a complete and real-time environmental model to coordinate maneuvers in a safe manner.

8. Security and Privacy

The security and privacy, in vehicular communication, are addressed as discussed below.

1. *Security*: A major application of V2X is to ensure safety and increase efficiency. These can be achieved by sending real-time alerts to drivers and pedestrians. In doing so, information related to road hazards, congestion conditions, the presence of emergency vehicles, and so forth, are all taken into consideration. As the messages are all related to safety features, it is trusted to be originated from a trusted source.

   As PC5 messages are broadcast, the transmitter vehicle does not have any idea about the number of the receiver. Various kinds of UEs can participate in this network. Thus, the current LTE security and Proximity-based Services (ProSe) security mechanisms are not normally applicable [10]. PC5 operates by transmitting the message from one-to-many. No security mechanism is used in this layer. The data frames include fields relating to group keys. But these fields are set to zero for PC5 based V2X communication. Enhancements in LTE are needed in order to support V2X use cases. In this case, the following security requirements are considered.

   i. The need for direct, ad-hoc, broadcast, secure communication without any a priori configuration of security by the network.

   ii. Management of identities for user privacy from the network or other third parties.

2. *Privacy*: High transparency can affect vehicle-privacy in the case of broadcasting UE messages. Thus, V2X services are operated under regional regulatory law or policy. Thus, it is optional to use the PC5 privacy mechanisms. For V2X communications in the LTE-Uu interface, there are no additional privacy features. However, in the application layer, privacy may be supported by using credentials and identifiers, which are not linked to long term UEs. Besides, these credentials can be periodically refreshed [10], [27].

9. Conclusion

V2X communication technology has been developing fast. Autonomous driving is one the major application of V2X communication and it may cause the first major impact on the lifestyle of people. Similarly, many other vehicular applications will gradually improve transport and other systems, for example, offering smooth collision-free mobility of people and goods. The overview and perspective of V2X communication have been presented in this paper, underscoring its ongoing progress towards 5G. This organized description can be a timely contribution as it can help both researchers and professionals to quickly grasp the relevant aspects and keep pace with the progress of the technology.

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