Abstract—The Automotive Vehicle to Everything (V2X) technology is one of the most important innovations that the world will see in the years to come. This paradigm will support many advanced services such as object detection and recognition, risk identification and avoidance, car platooning. These services will require several keys among them, the high data transmission rates of the order of gigabits per driving hour, and high reliability, and high speed for transition of data, which may be available through the capabilities of the new architecture for the next generation of wireless communications 5G and the wide bandwidth of the millimeter wave (mm Wave) which is deemed to be a real solution for the V2X requirements. However, the challenges related to the reliability/latency and security of the V2X system and nature of mm wave communication require several solutions either for natural challenges such as High path loss propagation, penetrating disability or for the technical challenges. This paper provides an overview of the V2X communication technology investigates the V2X challenges including the mm wave and and finally presents some efficient solutions.

Keywords—Smart cities, 5G cellular; mm Wave; Directivity; propagation; Beam forming; vehicles (V2V).

I. INTRODUCTION

Vehicle to everything (V2X) is a new generation of advanced services of information and communication technologies that connects vehicles to everything, in which is broadly classified into four different types: vehicle to vehicle (V2V), vehicle to infrastructure (V2I), vehicle to network (V2N), and vehicle to pedestrian (V2P), for aim to enhance road safety, less traffic congestion, and less environmental impacts and lower capital expenditure, and fuel consumption, and support infotainment applications [1]. The emerging autonomous and cooperative driving services needs many key parameters for Vehicle to everything (V2X) communication, high-throughput in which may provide the required link capacity, and reliability, low latency and accurate position determination use cases. In this regard the emerging 5G technologies including the mm Wave frequencies and Massive MIMO, small cell, interference management, beam forming, spectrum sharing are highly promising due to broadband bandwidth and due to the most radical changes in the architecture of the network [2].

Give birth to several technical challenges that need to be addressed. These challenges include latency/reliability and challenge of safety/security and challenges related to the difficult propagation characteristics of high frequency channels and the dynamic topology of vehicle scenarios, which affect the reliability of communication. Currently, there are two main types of communication technologies used for V2X [3]: Dedicated Short Range Communication (DSRC), which provides a nominal coverage range of about 1 km, with achievable data rates in the order of 2-6 Mbps, and Long Term Evolution for V2X (LTE-V2X), makes use of connectivity below 6 GHz, enabling a data rate of up to 100 Mbps in high mobility scenarios.

The overwhelming majority of current communication systems will not be able to support the massive demand for high data rates that is expected to be required by the next generation of automotive applications, which will include advanced services based on a number of sophisticated sensors and cameras, exploiting visible or infrared spectrum. This is due to the fact that these techniques operate at frequencies below 6 GHz. Therefore, the millimeter wave (mm wave) band has been proposed to cover a range between 10 GHz to 300 GHz, that can be considered as a possible answer to this growing demand for ultra-high transmission speeds in vehicular networks. But in other hand, the increased carrier frequency makes the propagation conditions at mm Waves more challenging, which must be overcome, such as high propagation loss atmospheric losses due to water vapor and oxygen absorption, directivity, and sensitivity to blockage, and Penetrating disability [4].

Therefore, finding solutions to the mm wave limits and challenges is an urgent and critical requirement to take advantage of this huge spectrum in applications of V2X.

The structure of this paper is as follows: Section 2 provide an overview of vehicle to everything (V2X) communication technology, in section 3 analyze the V2X challenges (latency/reliability and security), in section 4 we provide a roles and uses of mm wave communication in V2X, in last section we present the new approaches for V2X communication and the most important designs and solutions proposed to implement the V2X system and to make it highly efficient in terms of safety and reliability.

II. OVERVIEW OF VEHICLE TO EVERY THING (V2X) COMMUNICATION TECHNOLOGY

V2V communications are designed to exchange basic information among the vehicles to enable advanced automotive services, what makes it distinctive in terms of deployment scenarios and traffic characteristics. Was categorized V2X
services into 4 main classes namely: Road safety, Traffic management, Infotainment V2X services, and the Autonomous driving platform [5]. In this regard, the 3rd Generation Partnership Project (3GPP), in its Release 15 [6] has recently categorized different performance requirements for next-generation vehicular systems supporting enhanced V2V applications, as follows:

**Road safety:** It aims to achieve zero tolerance to road accidents and fewer driving fatalities in the near future. It provides collision avoidance and road work, detection of mobile and fixed obstacles on the road and dissemination of weather information. Other road safety use-cases includes emergency electronic brake light, post-crash notification, and road hazard notification among others.

**Traffic management:** This class of V2X will optimize traffic flow, which results in more predictable, fully coordinated and productive driving experience, and also reduces air pollution from vehicle emissions.

**Infotainment:** This category aims to improve user experience by providing enhanced in-vehicle entertainment features such online gaming, point of interest notification, on-board high speed broadband connection.

**Autonomous driving:** V2X is the key technology enabler to improve advanced driver assistance systems (ADAS) and paving the path to attain fully autonomous driving vehicles in the near future. This will be achieved through wireless connectivity between several on-board sensors and roadside infrastructure. V2X supports a unified connectivity platform for the connected entities. Also, it allows road entities to transmit information such as their current speed, position, and direction to their fixed and moving neighboring entities, then they use this information to make intelligent decisions, e.g. road side units (RSUs) and nearby pedestrians can be supported by various short and long range radio communication technologies, such as DSRC, LTEV2X, which are considered the most common, which are briefly described below.

DSRC (Dedicated Short-Range Communications) is a wireless communication technology that enables vehicles to communicate with each other and other road users directly, without involving cellular or other infrastructure. Each vehicle sends 10 times per second its location, heading and speed in a secure and anonymous manner. All surrounding vehicles receive the message, and each estimates the risk imposed by the transmitting vehicle. Risks are defined as “safety applications” such as Left Turn Assistance (LTA), Intersection Movement Assistance (IMA) and many others. The technology was developed specifically for V2V applications requiring critical latency of ~ 100 ms, very high reliability and security authentication with privacy guarantees. The DSRC standard was finalized in 2009 and has been extensively tested by car manufacturers and selected large-scale tests. Stakeholders completed work on using the DSRC to protect vulnerable road users [7]. At the physical layer and the medium access control (MAC) layer, DSRC uses the 802.11p protocol, which simplifies authentication, associated processes, and data transmission before sending data, enabling vehicles to broadcast relevant security information directly to neighboring vehicles and pedestrians. The network architecture and security protocols are defined in IEEE 1609 WAVE. At the application layer, SAE J2735 defines the message format used for communication, and the J2945/x family of standards defines various scenarios of V2X communication and its performance requirements [8].

DSRC provides a key foundation for V2V and V2I safety by enabling connectivity between road users that have, until now, never been linked in large scale. DSRC can ensure a common interoperable safety standard for vehicles, regardless of size, make and model, to help avoid crashes, optimize traffic flow, and reduce congestion.

Cellular V2X was developed within the 3rd Generation Partnership Project (3GPP), to replace the US promoted Dedicated short-range communications (DSRC) and the Europe originated Cooperative Intelligent Transport Systems (C-ITS). As such standards are decisive steps towards the target autonomous driving and clues to market influence [9]. The Cellular V2X mode for communication relies on a distributed resource allocation scheme, namely sensing-based semi persistent scheduling which schedules radio resources in a stand-alone fashion in each user equipment (UE).

The 3GPP Release 14 LTE standard completed includes support for use of V2X cell phones (C-V2X), allowing cellular technology to become an additional option for most V2X applications. With LTE Version 14, direct device-to-device communication improves latency and ensures operation in areas with no network coverage and at high speeds, while network delivery capabilities can help meet other V2X requirements. In addition, the ability to leverage the existing cellular infrastructure, with its broad coverage, would reduce costs and accelerate the realization of the benefits in terms of security and efficiency of V2X communication.

Study and analysis were done [10] to compare the effectiveness of direct communication technologies between LTE-V2X PC5 and 802.11p from the perspective of accident avoided and reduction in fatal and serious injuries. The study shows that LTE-V2X achieves higher level of accident avoidance and reduction in injury. Also LTE V2V has superior coverage compared to DSRC, and indicates LTE-V2X performs higher percentage of successful packet delivery and communication range.

### III. V2X Challenges

V2X communications support several services such as road safety, traffic efficiency, user experience and supporting autonomous driving, by enabling the exchange of information between vehicles, infrastructure and pedestrians, using different wireless communication technologies, but to achieve these services, several challenges must be addressed most notably reliability and low latency, and security, in which may not be achieved as required by the technologies currently offered and can be achieved through the proposed mm wave technology, therefore, these challenges must be discussed to find a real solution.
A. Latency / Reliability

5G will support a wide range of non-V2X use cases including mobile broadband (eMBB), large Internet of Things (mIoT) and critical services. These use cases have various requirements, including high data rates for eMBB, low power consumption and high scalability for mIoT, and very low latency and high reliability (URLLC) communications for critical services in which Network performance is critical for applications requiring low latency and reliability [11].

A new radio interface will support a set of advanced V2X features in which these features will provide a radio interface with much lower latencies, improved reliability, higher spectral efficiency, and higher data throughput. With fewer vehicles, DSRC has lower latency and increased reliability, but its performance is opposite in a dense vehicle environment. The latency of LTE-V2X is relatively stable and the communication delay based on the PC5 interface, which can provide a predictable delay and less interference, is less than 100 ms [12].

Vehicle networks mainly offer safer and more comfortable driving and driving efficiency. However, if we do not guarantee the reliability (probability of error) of a system supported by a physical layer (PHY), the benefits of vehicular networks cannot be exploited. We need to study the characteristics of the PHY layer of LTE V2X and DSRC and the millimeter wave to evaluate their BLER performance. 3GPP versions 15 and 16 will enable even more V2X services with longer range, higher density, higher throughput and reliability, very precise positioning and extremely low latency.

B. Safety / Security

The network security is an important part of V2X technology and the threats faced by V2X are divided into four aspects: mobile terminal security threats, V2X service platform security threats, V2X communication security threats, vehicle network data and privacy threats [11].

The V2X cloud platform contains data about vehicles, roads, and pedestrians. If these data are leaked, they could cause significant losses. Owing to the high-speed mobility of vehicles, identity authentication and establishing a trusted connection with the cloud is a difficult problem. Because of its wireless transmission properties, the V2X network is particularly vulnerable to attacks. Therefore, communication security is very important. The security attributes include authentication, availability, data integrity, confidentiality, non-repudiation, real-time constraints, and attacks against these security attributes.

What is needed is to ensure that the cellular network can support the relevant message transfer, protocols and mechanisms, between devices and between devices and the network. It also must support third party servers such as vehicle manufacturers’ certification authorities. With the complete of the standard specification for V2X in 3GPP and the DSRC family of standards designed an extensive system architecture that ensures no single entity can correlate the identifiers used and track a vehicle [13].

IV. mm Wave Communication For V2X

Vehicle to everything (V2X) system rely on Dedicated Short-Range Communication (DSRC) standards, such as IEEE 802.11p/DSRC and ITS-G5/DSRC. Even though these technologies operate in a licensed band and ensure low communication latencies, their maximum realistic data rate hardly exceeds 6 Mbps [12], also the Long Term Evolution-Advanced (LTE-A), which can guarantee higher communication rates. Nevertheless, the maximum supported data rate is limited to 100 Mbps and end-to-end latencies cannot go below 100 ms. As a result, both DSRC and LTE-A cannot always meet the communication constraints dictated by delay and bandwidth sensitive services that will be offered by future V2X technology as shown in [10].

As a result, researchers are looking to use a bandwidth that meets the stringent requirements of V2X, the millimeter has already attracted researchers’ attention as a competent and good solution for applications of V2X, considering that the available global spectrum bandwidth allocation for all cellular technologies does not exceed 780 MHz, where each major wireless provider has approximately 200 MHz across all of the different cellular bands of spectrum available to them, makes the emergence of new applications is not possible such as communication between vehicles (V2V) and between vehicles and infrastructure (V2I), with an example cameras, exploiting visible or infrared spectrum, could be used to detect speed limit signs and to improve the automotive driving experience. therefore a new bandwidth with a higher frequency bandwidth has to be proposed, for this purpose, mm wave with a bandwidth of 30-300 GHz that offers the promise of orders of magnitude greater bandwidths combined with further gains via beam forming and spatial multiplexing from multielement antenna arrays, in term to overcoming the rate and latency and reliability limitations of existing technologies.

The approved band offers approximately 1.5 GHz bandwidth between 27.5-31.5 GHz, a second 7 GHz band that will operate in the 57-64 GHz range is already used for some Wi-Fi equipment. Finally, the so-called “E-Band” band is composed of three bandwidth segments totaling 12.9 GHz she is also unlicensed [14]. In fact, because of the development of semiconductor technology for millimeter bands currently commercialized mm Wave systems can already ensure up to 7 Gbps and latencies smaller than 10 ms.

In view of the new requirements of V2X technology, the use of the mm Wave frequencies for future V2X applications is imperative given the features that are rich in mm Wave frequencies, including the large bandwidth and the large amount of available spectrum, which may ensure higher
transmission rates and higher productivity, and also improve the safety of wave transfer due to narrow transmission range and the directionally use of this type of waves. Although this, there are many concerns about the characteristics of microwave waves that make it difficult to create new technologies which supports these applications and poses significant challenges [4], among them:

A. High path loss

It is well known that wireless signals at millimeter frequencies mm Wave suffer from high path loss, which limits their range. In particular, the diffraction and penetration losses are greater, which makes the signals reflected and dispersed all the more important. Typical penetration losses of building materials range from a few dB to more than 40 dB. There is also an absorption by the atmosphere which increases with the frequency, but also the attenuation of the rain and the atmospheric and molecular absorption characteristics of mm Wave limit the range of mm Wave communications. Therefore, mm Wave communications are mainly used for indoor and backhaul environments with cell sizes of the order of 200 m. The large-scale fading F (d) can be modeled as follows:

\[ F(d) = PL(d_0) + 10n \log_{10} \frac{d}{d_0} - \sigma \eta, \]

Where \( PL(d_0) \) the path loss at reference distance is \( d_0 \), \( n \) is the path loss exponent, and \( \sigma \eta \) is the showing loss. \( \sigma \) is the standard deviation of \( \sigma \).

B. Low signal penetration

While low frequency signals can penetrate buildings more easily, mm Wave signals do not penetrate most solid materials. Certain materials, such as the exterior brick walls of buildings, cause severe loss of penetration. The wall insulation effects prevent outdoor base stations from covering indoor users, which motivates the deployment of small cells and distributed indoor antennas.

As a result, the movement of obstacles and reflectors, or even changes in orientation of the handset relative to a body or a hand, can cause the appearance or the rapid disappearance of the channel. Recent studies show that, with increasing distance between transmitter and receiver, path loss increases up to 20 dB / decade in line-of-sight propagation, but decreases to 40 dB / decade more an additional blockage loss of 15 dB for non-visibility[4].

C. Beam directionality:

\( \text{Mm} \) Wave links are by nature trend. With a small wavelength, electronically orientated antenna arrays can be manufactured in the form of metal patterns on a printed circuit board. Then, by controlling the signal phase sent by each element of the antenna, the array of the antenna electronically transmits its beam in any direction and enables a large gain in this direction, with very low profit in all other directions.

In view of all this, several experiments have been conducted to determine the characteristics of the \( \text{mm} \) wave and impact of the high free space propagation losses at these frequencies together with the high noise levels because of the larger bandwidths. The result was that to low signal to noise ratios, unless directional antennas arrays are used and Beam forming technology and small cell deployment.

V. NEW APPROACHES FOR V2X COMMUNICATIONS

Several recent papers on the role of \( \text{mm} \) Wave have been written as a solution to the requirements of V2X systems, but most of this literature point to the challenges that were previously analyzed at low frequencies in 60 GHz wireless network scenarios and the nature of their propagation. Therefore, the need to find solutions specifically designed to meet the future V2X systems requirements has emerged. We refer to some of them:

Because of conventional technologies, such as DSRC and 4G cellular communication, do not support the gigabit-per-second data rates that would be required for raw sensor data exchange between vehicles. This article [16] makes the case that \( \text{mm} \) Wave communication is the only viable approach for high bandwidth connected vehicles in which a high-level solution to one key challenge — the overhead of \( \text{mm} \) Wave beam training — is proposed and its main feature of this solution is to leverage information derived from the sensors or DSRC as side information for the \( \text{mm} \) Wave communication link configuration. Examples and simulation results show that the beam alignment overhead can be reduced by using position information obtained from DSRC.

Due to mobility, some vehicular antenna elements might be subjected to full or partial blockages from a plethora of particles like dirt, salt, ice, and water droplets. These particles cause absorption and scattering to the signal incident on the array, and therefore distorts the radiation pattern of the array mostly and decrease in gain, in this paper [17] propose a blockage detection technique for \( \text{mm} \) wave vehicular antenna arrays that jointly estimates the locations of the blocked antennas and the attenuation and phase-shifts that result from the suspended particles, without proposed technique does not require the antenna array o be physically removed from the vehicle.

Numerical results show that the proposed technique provides satisfactory results in terms of block detection with low detection time provided that the number of blockages is small compared to the array size.

In [18] V2V millimeter wave radio channel characterization and modelling To see the wideband effects, such as the power delay profile and delay spread, in which an experimental characterization of the 38 GHz and 60 GHz radio channel is
presented. In this paper [19], the design of a high-speed telecommunications network and the identification of core link budget measures. In particular, a new theoretical model was presented that calculates a typical scenario where heavy vehicles (such as buses and trucks) by mmWave basic stations (BS) are deployed along the way, showing that reducing the horizontal beam width from 90 degrees to 30 degrees sets the minimum probability of interruption SINR, and it is still possible to achieve the probability of a SINR breakout smaller than 0.2, for a small BS density (ie one BS per 500 m).

VI. CONCLUSION

MM Wave is one of the most important components of the fifth-generation architecture, as its characteristics are excellent in solving the problem of capacity and the increasing demand for huge data transfer. In this paper we have provided an overview of vehicle to everything (V2X) communication technology, as well as investigated the V2X challenges (latency/reliability and security). Then, we have analyzed the performance of using mmwaves in V2X communications and discussed several solutions to enhance both safety and reliability in V2X networks.

REFERENCES