Progress Report

Unveiling the Road Ahead: Assessing the Landscape of C-V2X Technology and Its Journey to 6G Networks

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I. Introduction

Research efforts from both industry and other sectors have been massive in improving communication abilities in vehicles and transportation systems. They are focusing on V2X communications, which cover Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and Vehicle-to-Pedestrian (V2P) connections [1]. These developments hope to improve transportation safety and efficiency. By combining with existing vehicle sensors, V2X can enhance safety features, entertainment for passengers, and optimize traffic flow. It also supports various functions such as warnings for passing, collisions, queues, parking, and speed warnings [2]. These communications rely on exchanging messages among infrastructure, vehicles, and pedestrians using technologies like dedicated short-range communication (DSRC) and cellular networks.

II. LTE

DSRC-powered V2X communications bring benefits such as quick connections, flexible communication, and standardized protocols. But they also come with challenges, such as limited range, delays in accessing channels, and hefty upfront costs [2]. That's why, despite deploying DSRC-based V2X prototypes in the U.S., both researchers and industry folks are now turning their attention to cellular technology for V2X communications.

Cellular technologies like long-term evolution (LTE) offer widespread coverage and robust support for high vehicle mobility and density within a cell. This progress has interested organizations like the 3rd Generation Partnership Project (3GPP) to explore LTE's usability for V2X communications. Currently, 3GPP is actively developing cellular-based V2X services with the goal of offering a range of V2X capabilities [3] . Through Releases 15 and 16, LTE-based V2X services have emerged as a prominent feature alongside other advancements like license-assisted access and massive multiple input multiple output (MIMO) technology.

III. 5G and its specs

While LTE-based V2X communications made huge leaps over previous efforts, there were still several hurdles to overcome. Challenges such as physical layer structure, synchronization, MBMS (Multimedia Broadcast Multicast Service), resource allocation, and security were significant drawbacks for LTE V2X communications purely due to lack of research in the area.

Over time, we pivoted towards 5G based V2X communication. One of the features of 5G is that the network has many macro, micro, and nano cells. So, as the cell size decreases, we can increase the network capacity. However, the problem with this was that when the user was in motion, handover between cells was becoming increasingly difficult because it was a huge load on the network. Also, handover involved many parameters which were difficult to map. One solution to this is to have dual connectivity where the vehicle is simultaneously connected to 2 base stations [4].

Massive MIMO involves using multiple antennas at the base station. Ideally, this should have helped cope up with the increasing demand. However, the problem with this was that it was increasingly difficult to obtain channel state information to prevent interference and increase gain. In the vehicular communication case where most users are in a constant state of motion, the length of the pilot is very low because of short coherence time [5]. This implies that the reuse distance of the pilot between cells is much less. So, there will be interference when users are at the borders of 2 cells. In [6] , it is proposed to use transmit-diversity and quadrature phase shift keying(QPSK) when the channel is bad and to use spatial multiplexing and 64 quadrature amplitude multiplexing(QAM) when the channel is good. This helps improve the gain in different scenarios.

One of the new buzz-words going around is cloud computing. It basically refers to processing data "on the cloud" or on the internet. This can also be applied to processing information recieved from various sensors on a car. This is called Vehicular cloud computing(VCC) [7] . The drawback of this, very obviously is that the amount of data collected is too large and when we consider the total number of vehicles that would potentially be using this, it is infeasible to even store this data, let alone process it. A very general approach to tackle this is something called Vehicular Fog Computing(VFC) [8] . VFC involves processing data close to where it is generated such as the vehicle itself, nearby infrastructure and sometimes other vehicles as well. This improves reliability and reduces latency.

IV. Security: Key considerations

Security and privacy are critical considerations in cellular V2X (C-V2X) communication networks, spanning multiple domains and perspectives, including end-to-end, virtualized infrastructure, and virtualized network views. Common security threats in the 5G context, such as denial-of-service attacks and compromises of Software Defined Network (SDN)/Network Function Virtualization (NFV) controllers, pose risks to C-V2X networks. Additional security objectives, such as authentication and authorization, are necessary to ensure proper behavior and permissions for V2X actors. Considerations for liability and differentiation between regular and special vehicles, such as police or emergency vehicles, are crucial for the security of C-V2X [9].

Weak spots in vehicle architecture, such as complex embedded systems and interconnected electronic control units (ECUs), pose significant security risks. Similarily, ensuring strong isolation between network segments and cloud infrastructures is essential to prevent unauthorized access and data breaches. In terms of privacy, regulatory frameworks like the General Data Protection Regulation (GDPR) in the European Union require strict adherence to data protection principles. V2X protocols must support pseudonymization techniques to prevent the identification of individuals or vehicles, while also minimizing the collection and storage of personal data.

V. Future Considerations

One key factor that never really goes away is security consideration. In today's day and age, the need for security is proportional to how fast any technological development happens. While not easy, vehicular communications and autonomous vehicles are susceptible to attack by various parties. With the evolution of 6G, the security of communication will have a great focus since it can also have applications in various other domains. While we continue to increase connectivity in the most remote parts of the world, there are many partial coverage areas which have limited connectivity. Therefore, in case a user is in such an area, there will be synchronisation problems for basic functioning of the vehicles. While GNSS can be used in such scenarios, we believe that this has huge potential for research and we will try to address this further in our future work.

One last approach we would like to highlight is the use of mobile phones to act as processing centers. When dealing with issues like Vulnerable Road User(VRU), the users mobile phone can be used to relay or obtain any information such as the VRU's intention to cross the road or pedestrian safety issues. However, a challenge arises when the VRU doesnt have a cellular device with them. This also has potential to be explored further.

VI. Progress

Our group has made significant progress in our project thus far, focusing primarily on the extensive review of literature to identify relevant sources for our upcoming report. While we have encountered a wealth of materials, we have also noted the challenge posed by the complexity of the papers. Despite this hurdle, delving into the content has proven intriguing and worthwhile. One of the key challenges we have faced is delineating a clear scope for our project. We are aware of steering clear of overly broad topics, while also being wary of delving too deeply into specific aspects given our time constraints. Admittedly, we did commence our research a bit later than ideal. However, we are confident that we are now on the right path to effectively manage our time and resources.

Moving forward, our plan entails unifying the wealth of information we have gathered from our sources into the final report. Our aim is to craft a concise paper that maintains a coherent thread across its various sections.

VII. Outline of Final Report

In our final report, we will go over some of the drawbacks of using 5G in vehicle communications and expand further on some of the topics mentioned in Section IV and V of this report. We would also like to go into some detail about how the development of 6G will help mitigate some of our problems discussed earlier and its limitations due to lack of standardization.

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