A Comprehensive Survey: 6G for V2X Scope, Use Cases, Challenges and Enabling Technologies

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Abstract: As the number of consumers and network tools in a wireless environment are growing by each passing epoch accompanying the exercise of Internet of Things (IoT), the demand for extreme data rates and services is likewise growing. 6G was imported accompanying the aim of extreme data rates, energy efficiency and reliability. Integrating 6G accompanying Vehicle-to-Everything (V2X) surroundings will provide aids to more consumers in addition to reconstructing the reliability and adeptness of the network. The role of V2X is for the most part to prevent sudden interruptions in the consumer connectivity and still improves privacy. 6G-V2X will help transform conveyance holes by enhancing the connectivity, security and effectiveness of the vehicular communication networks.

1 INTRODUCTION

5G technology was invented to support high data rates (upto various Gbps) and upgraded capacity in addition to combining various IoT (Internet of Things) devices and users. It has a theoretical data rate peak at 20 Gbps and again pledged lower latency that completely improved the mathematical occurrences like wager, video conferencing and self-compelled vans. The introduction of 5G technology heralds a revolution in communication engineering by providing unseen changes to improve efficiency, performance, and connection in many fields (R. Khan and Liyanage, 2020). The various technologies that guide 5G are Millimeter-wave communication, High-band spectrum, Massive Multiple Input Multiple Output (Massive MIMO) technology etc. The implementation of these technologies accompanying 5G ensures embellished data rates, energy effectiveness, upgraded throughput and ultra-low latency.

In future, V2X communications will have a vital role in the manufacturing of smarter and autonomous vehicles. Extensive research is being conducted in these networks as they have the capability to enhance the driving experience and safety of road users (De Saint Moulin, 2024). . Fig 1 displays the differing progresses in Vehicular communications, Vehicle-to-

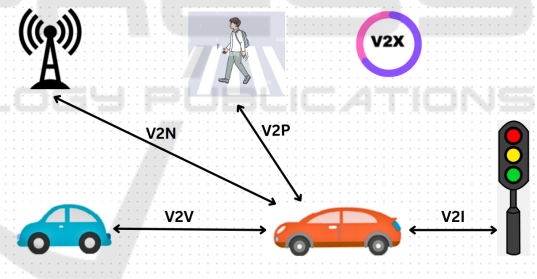

Figure 1: Various vehicular communications

Pedestrian (V2P), Vehicle-to-Vehicle (V2V), Vehicle-Infrastructure (V2I) and over a natural network (V2N) communications (M. Z. Chowdhury and Jang, 2020). V2X communications finds its applications in various infotainment, safety and non-safety services. The aim of safety aids is to search out underrate accidents.When each car that is linked to the Internet in the network is viewed as a node, the network is called IoV (Internet of Vehicle), which is the integration of the Internet of Things (IoT) in automobiles. IoV, which blends IoT and vehicular networks, is regarded as a few of the most lately investigated fields. This capability positions V2X communications at the core of intelligent transportation systems (ITS) for connected vehicle environments (Sunuwar and Kim, 2024).

Two fundamental radio access technologies—one

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based on cellular (C-V2X) and the other on Wi-Fi (IEEE802.11p)—are ultimately enable V2X communications (A. Alalewi and Cherkaoui, 2021). Vehicular routes established by V2X demand extreme reliability, depressed latency and extreme throughput. Therefore, 5G-V2X was grown as a resolution to the necessities of V2X systems for information exchange. It supports device-to-network communication that considerably helps in the growth and variety of V2X requests. The various methods that help in the exercise of 5G-V2X are enhanced Mobile BroadBand (eMBB) and Ultra-Reliable and Low-Latency Communications (URLLC). 5G-V2X poses challenges in allure arrangement in miscellaneous surroundings, system distribution, freedom and privacy. Moreover, the 6G network may be used to combine the various miscellaneous atmospheres.

Inorder to meet the necessity of 6G inside Artificial Intelligence (AI), Blockchain, Intelligent Reflecting Surfaces (IRS), Quantum Computing (QC), Convolutional Neural Networks (CNN), Terahertz (THz) and Visible Light Communication (VLC) spectrums maybe valuable. Blockchain may be implemented in a well delivered network surroundings and further supports enough security. QC aims at providing greater computational competence and security. THz spectrum ideas determine intensely extreme throughput and range for the network. As 6G aims at providing aids in various surroundings, then integration of cloud computing and edge computing is favored for faster computing, enhanced security and low operational cost.

2 COMPARATIVE ANALYSIS OF V2X TECHNOLOGIES

V2X communication technology was introduced as 4G-V2X and it focused primarily on safety-critical applications like collision avoidance and traffic alerts. 4G-V2X was also known as LTE-V2X (Long Term Evolution V2X). Later 5G V2X (Near Radio (NR)-V2X) was introduced which provided improved data rates, reduced latency and also supported autonomous driving and Intelligent Transportation Systems. Recently researchers are focusing on development of 6G-V2X which is expected to revolutionize V2X communications by integrating it with AI, providing ultra-low latency and global coverage through satellite integration. Table 1 illustrates the brief comparison of the above listed technologies.

3 EVOLUTION OF 6G-V2X

Advances in wireless telecommunications today have allowed honest-time facts exchange between vehicle-to-passenger (V2P), vehicle-to-vehicle (V2V), vehicles-infrastructure (V2I), and vehicle-to-networks (V2N). V2X communication networks can be deployed in infotainment, safety and non-safety services. Intelligent Transportation Systems (ITS) use non-secure duties to correct the adeptness of existing relations and enhance traffic management, with lowering traffic impacts to a degree accidents and their impact on the surroundings (M. Z. Chowdhury and Jang, 2020).

5G uses three main strategies at the radio level: more resource utilization, resource reuse, and improved spectral efficiency. For example, Full Duplex (FD) improves data rates, flexibility and reliability of vital range distribution, and enables concurrent broadcast/gathering. NR V2X provides a better act accompanying improved aids. The upgraded acting is achieved through exhaustive assets in hardware and fittings, and adopts a coat with metallic material guidelines and design processes that form the basis of LTE-located V2X. At the same time, the number of driverless machines will be necessary to increase rapidly from now on on account of urbanization, improved behaviors, and mechanics.

Fifth Generation New Radio (5G NR)-V2X was presented in 2018 with the goal of fostering enhanced V2X aids, like driver assistance and remote driving, amid others. Two more significant considerations that affect legal utilization of V2X technology are public consensus and government management. Due to urbanization, raised living guidelines, and mechanics progressing the number of independent tools will increase quickly from now on. Moreover, as the demand for looming duties in Autonomous Vehicles (AVs) is rising, new ideas challenges to the V2X network have arised. 5G NR-located V2X networks are weak and hence 6G-V2X networks must be organized skillfully in order to satisfy a wide range of requirements and use cases.

In addition, there is an increasing demand for more aids for independent cars, from 3D counseling that determines deeper and better perceptibility, to holographic control arrangements, and revised amusement and automobile factual film or tv presentation methods. This will produce new ideas and challenges to V2X networks (F. Tariq and Debbah, 2020), (I. F. Akyildiz and Nie, 2020). All these happenings will harshly limit the potential of existing wireless networks and will cause new research challenges and challenges for transport networks in con-

Table 1: Comparative Analysis of various V2X Technologies

Aspect	4G-V2X	5G-V2X	6G-V2X
Standardization	3GPP Release 14/15	3GPP Release 16/17	Under development (post-Release 18)
Frequency Bands	Sub-6 GHz	Sub-6 GHz,mmWave	Sub-THz,Terahertz (THz)
Data Rate	Up to 100 Mbps	Up to 10 Gbps	less than 1 Tbps
Latency	approx. 30 ms	less than 10 ms	less than 1 ms
Communication Types	V2V, V2I, V2P	V2V, V2I, V2P, V2N	V2X
Key Features	Basic safety applications	High-reliability, low latency applications	AI-driven, highly reliable network applications
Scalability	Limited	Improved	Massive scalability
Applications	Traffic Safety	Autonomous driving, smart mobility	Fully autonomous systems

ditions of data rates, latency, inclusion and transport networks. Energy/cost adeptness, data, cooperation and freedom, etc. and by what method to employ the ruling class.

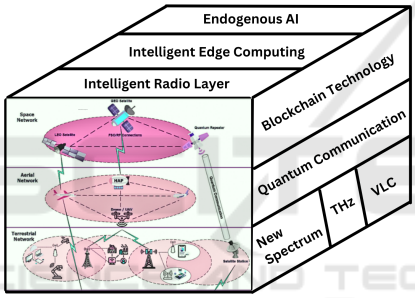

Figure 2: Proposed 6G Technology

Figure 2 shows a 6G-V2X network that supports miscellaneous decision-making requests utilizing vehicular communication networks. For example, drones and depressed-Earth orbit satellites can support V2X communication, serving to better communication conditions by providing seamless connectivity in hybrid locations. Edge/cloud computing help V2X communication networks achieve faster computing, better decision-making, and longer battery life. Visible V2X communications using visible light communications (VLC) interoperate with existing RF communications, for lower cost, lower data power consumption, and improved reliability. To enable reliable and real-time interchange of massive amounts of haptic information, tactile communication entails incredibly fast and low-latency connection (S. Tanwar and Kumar, 2019).

4 6G-V2X TECHNOLOGIES

To solve the earlier ambitious aims, 6G will demand the unification of a range of causing trouble technologies, containing stronger and adept air interfaces, resource distribution, accountability, and calculating. Different networking strategies for 6G scenarios are needed to satisfy the demands of the network for 6G and its diverse framework of autonomous devices, which will make decision-making for future V2X networks easier (Orrillo H, 2024). There is a number of important advancements that will enable the future of 6G-V2X as a creative, autonomous, consumer-driven relationship and aid platform for ITS. With the help of this novel idea, a network architecture that can be modified and adjusted to suit the needs of various societal and industrial sectors would be feasible. We will present these technologies in the following divisions. We can distinctively categorize these technologies into two parts: one is Advanced V2X technology and other is Evolving the same.

4.1 Advanced Technologies of Sixth Generation-V2X

Here we focus on the hopeful revolutionary sciences accompanying the capability to be utilized in 6G-V2X.

4.1.1 Programmable V2X Network

In usual statistical theory about information processing, the wireless channel is thought-out as an accident and impedance problem, but it is more attainable to limit the channel. One of the most negative attributes is named two-fold channel selection (that is, period and commonness selection), that is

extensive in ideas devices on account of the transmitter capacity and/or recipient movement. Recently, the meddling ideas of technologies called IRS have happened to acquire more and more consideration, that was earlier aimed at designing smart radios by RF transmission waves. More specifically, IRS is an photoelectric meta-surface instrument (containing many small antennas accompanying joined circuits) that can control the amplitude, phase, frequency and also dissemination of wireless equipment to overcome the losses of diffusion environments. RIS offers a cost-effective alternative to traditional approaches by leveraging its ability to reconfigure the wireless propagation environment through the adjustment of phase shifts (and/or amplitudes for active RIS) of reflecting elements (J. Kim and Chung, 2024). Thus, the IRS helps in achieving higher rates, provides continuous assistance and prevents interruption of the connection.

4.1.2 Blockchain-Assisted V2X

The application of V2X networks majorly relies on better security through bulk messaging and authentication. Taking this into account leads to new limitations on resource allocation in V2X networks. For example, while the target important messages need to have highly robust security against malicious attacks or tampering, multimedia information only needs intensive security as it is big data. Both the security systems result in various models, network/communication strategies, and energy/spectrum allocation methods. 6G-V2X can utilize blockchain, which is considered a disruptive technology for secure transactions within a network which involves multiple parties. In contrast to existing privacy and security solutions, the incorporation of blockchain can enable numerous advancements in safety and confidentiality without requiring consent for third parties (D. C. Nguyen and Seneviratne, 2020). Based on the blockchain technology, (Z. Ying and Yi, 2019) provides a dynamic self-driven vehicle platoon monitoring that permits efficient handling of the Join/Leave element and guarantees the platoon leader's profit. Blockchain-based security solutions (such as smart contracts or consensus strategies) in 6G-V2X should not only verify the authenticity of messages, but also protect the privacy of mail (J. Kang and Niyato, 2019), (A. Yazdinejad and Choo, 2019). 6G-V2X can also benefit from the blockchain-based spectrum sharing method, which can provide safer, smarter, low-cost and efficient shared spectrum sharing (Zhang, 2019).

4.1.3 Terahertz-Assisted V2X Networks

Terahertz assisted communication networks operate in the terahertz range (0.1–10 THz) and are considered a hopeful habit to relieve the growing blockage in the reduced-commonness spectrum (I. F. Akyildiz and Nie, 2020). Terahertz transport can influence the chance of ultra-wideband communication with data rates ranging from a great number of gigabits per second to various terabits per second. This raised competition will support various new V2X uses, to a degree high-speed data and vehicular transport. Since terahertz media can transmit data over long distances without the requirement of cables, they can be used in aviation. It is mainly used to characterize and accept terahertz wireless transmissions, especially in miscellaneous V2X networks such as highways, cities, and automobiles. One of the key challenges of 6G-V2X advocating terahertz is the appropriate use of cellular and terahertz communication networks.

4.1.4 Quantum Computing-Based V2X

Numerous studies suggest Quantum Computing to be one of the novel technologies for generic 6G wireless communications (F. Tariq and Debbah, 2020), (I. F. Akyildiz and Nie, 2020). It will take several years to reach a consensus, though, as quantum computing continues to be in its infancy. As a result, quantum computing could potentially have an essential role in the development of 6G or even in technologies coming after 6G. However, even though few forms of quantum computing may be applicable for 6G communication, they are not still applicable to V2X networks. Quantum computing is a suitable technology to reinforce the security of 6G-V2X communication networks because it has a security property named quantum entanglement and it cannot be replicated or achieved without tampering.

4.2 Evolving Technologies for 6G-V2X

We outline a variety of newly emerging technologies in this area. Due to substantial research and prior implementation, these technologies have acquired a certain level of maturity; however, continued development is crucial to their use in 6G-V2X.

4.2.1 Hybrid RF-VLC V2X System

The automobile and its passengers are anticipated to receive exceptionally high data speeds and extremely low latency in 6G-V2X (W. Saad and Chen, 2020). However, traditional RF-vehicular communication typically suffers from severe interference, low

packet delivery rates, and substantial latency in extremely crowded networks, hence this cannot be accomplished with Radio Frequency (RF)-assisted V2X communication. By getting beyond the limitations of RF-based V2X communications, VLC can enhance the capability of V2X communication networks. Both radio and visible light waves can be employed as a wireless communication channel in vehicle networks, which might be accomplished via an integrated structure of RF and VLC-based V2X communications. Interoperability and deployment concerns between VLC and RF technologies are among the many unresolved challenges that must be addressed in order to achieve hybrid RF-VLC V2X. Consequently, these problems need to be appropriately resolved prior to using VLC in 6G-V2X systems.

4.2.2 Large-Scale Non Orthogonal Multiple Access

6G-V2X demands large connectivity to guarantee reliability, and availability of V2X messages. This allows affiliated vehicles to steadily learn and interact accompanying their environment for a holistic knowledge and security. One of the possible technologies for 6G-V2X networks that can meet these specifications is NOMA. NOMA exists in two primary forms: energy domain NOMA (S. M. R. Islam and Kwak, 2017), (Y. Liu and Hanzo, 2017) and code domain NOMA (Liu and Yang, 2021). NOMA is used to obtain extreme-low latency for large connectivity while offering large spectral coverage. In fact, NOMA can powerfully complement other 6G-V2X-authorized networks mentioned above for V2V and V2I applications.

4.2.3 Advanced Resource Allocation

Radio Resource Management (RRM) plays an important role in addressing the QoS necessities of 6G-V2X networks, particularly for advanced V2X uses. In a cellular V2X network, the base stations are often in charge of RRM (Noor-A-Rahim, 2022). However, RRM in 6G-V2X networks faces many serious challenges. As said earlier, 6G-V2X networks demand diversified radio networks to specify the necessary QoS. When making RRM decisions, resources for various communication networks must be considered. Smart schemes are required that incorporate multiple capabilities (eg; higher mmWave rates and better dependability below 6 GHz). A modern budgeting system that can be built to support contextual understanding and design processes is needed. For V2V and V2I communications, a hybrid RRM architecture that allocates shared resources and radio to linked cars can be created. Additionally, the problem of future radio channel overload will be made severe by the high volume of data interchange and the growing need for bandwidth (M. Herbert and Bokor, 2020).

5 CONCLUSION

The possible limitations in the deployment of 6G-V2X communication network are discussed in the section. Integrating Artificial Intelligence (AI)- Machine Learning (ML) with 6G-V2X technology introduces the difficulty in selection of datasets for training of the model which will eventually decide the learning technique used. Also the hyperparamters like learning rate need to be selected wisely as it will decide how quickly or slowly the model convergence will take place. Privacy and Security concerns need to be considered before deployment of the communication network. A good ML approach shall include training, testing, and validation phases, as well as dataset protection and confidentiality.

6 CHALLENGES IN DEPLOYMENT OF 6G-V2X

By enumerating the features, applications, and benefits of 6G-V2X networks which surpass those of 5G, we have presented a number of important, cutting-edge, and developing technologies in the proposed work. Major developments, obstacles, and the possible future reach of each advanced and evolving technology are covered. We anticipate that this paper will give professionals and researchers the essential knowledge about 6G-based V2X, which will foster innovation and research opportunities for the technologies involved.

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