# Securing the Road Ahead: Blockchain for Enhanced Trust and Security in V2X Communication

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## Abstract

As autonomous and interconnected vehicles continuously grow, the critical necessity for ensuring secure Vehicle-to-Everything (V2X) communication becomes increasingly apparent. However, conventional vehicular networks are inherently vulnerable to cyber threats due to their high connectivity, prompting the need to explore robust security mechanisms, such as blockchain. While recognizing blockchain's potential to bolster security and privacy, significant concerns such as security and scalability still pose challenges to its integration within the future vehicular ecosystem. This paper discusses the integration of blockchain into V2X systems, addresses current challenges, outlines potential future research directions, and identifies opportunities.

## Ⅰ. Introduction

With the rapid advancement in wireless communications and intelligent transportation systems, the deployment of intelligent and autonomous vehicles will be expected soon. Autonomous vehicles are equipped with sophisticated GPS facilities, advanced sensing mechanisms, visual aids, and other advanced features to enhance their capabilities involving data processing and connectivity.

Vehicle-To-Everything (V2X) has emerged as a fundamental building block to enable vehicles to communicate with their surroundings (neighboring cars, pedestrians, infrastructures). It facilitates real-time data exchange among vehicles and enables the exchange of information about road conditions, traffic patterns, and potential hazards. V2X has evolved by integrating cellular 5G and New Radio (NR) access technology; it can meet the evolving application, communication, and service requirements of connected vehicles, such as ultra-low latency, ultra-high bandwidth, ultra-high reliability, and robust security.

However, acknowledging the benefits V2X communication promises for future users to achieve its full potential requires the resolution of several challenges. Foremost among these challenges is ensuring the security and reliability of V2X. The inherent vulnerability arises from the extensive interconnectivity of the vehicles, exchanging a vast data volume within a centralized architecture. This exposes the system to various threats, including malicious attacks, single points of failure, limited scalability, and misuse of personal data affecting confidentiality and integrity, alongside additional privacy challenges [1].

To mitigate the aforementioned limitations, blockchain technology offers a promising solution to enhance V2X. Blockchain is an immutable and distributed ledger based on cryptography, specialized data structures, Peer-to-Peer (P2P) networks, consensus algorithms, and smart contracts [2]. Blockchain can be employed as a security mechanism for V2X by establishing trust among peer vehicular nodes in a trustless environment. It also eliminates the need for a central authority due to its decentralized nature. The inherent security features offer a potential remedy, particularly in providing privacy and security protection to fortify the vehicular nodes within the network against cyberattacks, which guarantees data integrity and confidentiality within V2X, thereby mitigating potential threats.

## Ⅱ. Integration of Blockchain with V2X

To secure the V2X system, blockchain can can act as an intermediate layer between the network and application layer through the means of smart contracts and consensus mechanisms, as shown in Fig. 1. Smart contracts are software programs developed by users to define rules for database modifications. On the other hand, consensus mechanisms facilitate agreements among participants on state changes within the network.

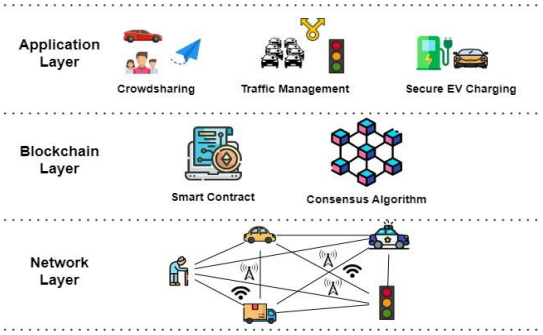


Fig. 1. System Overview of Blockchain-V2X

As a result, applying blockchain to V2X has gained a lot of interest in recent years. Different uses cases have emerged and divided in two main categories: data recording and transactions. For the case of applications requiring data transmission and recording, blockchain can serve as a secure channel for distributing and storing the data (i.e., crowdsensing and traffic management). As for applications involving payments, blockchain can be leveraged to support reliable payments without compromising privacy (i.e., electric vehicle charging systems) [3].

## Ⅲ. Challenges, Future Directions and Opportunities

### A. Scalability:

Blockchain still encounters significant gaps in terms of storage, throughput (transactions per second), and network capacity (high network latency) [2][4]. In blockchain, a massive volume of vehicular transactions is generated, and all the nodes store a copy of complete blockchain transactions, resulting in computational and storage load on resource-constrained vehicles [2]. Also, the throughput is limited due to the additional time required to add a block to the blockchain caused by consensus mechanisms, which are time-consuming processes. Hence, a potential research direction can be directed to developing lightweight and efficient blockchain systems to minimize resource overhead and optimize transaction processing efficiently. For instance, designing lightweight and novel consensus protocols, incentive and penalty mechanisms, hardware mining processes, and smart contract verification standard.

### B. Security and Privacy:

Although the transparency and immutability of blockchain are advantages in ensuring the security of exchanged data in V2X communication, it may still be vulnerable to specific attacks that hinder privacy and lead to insecure transmission. For instance, attacks such as "51% attack", quantum attacks, and attacks on smart contracts, might result in private information leakage, data tampering, or even disrupt blockchain mining operations [2][4]. Therefore, there is a need to design additional security assessment mechanisms, access controls, message authentication, strong cryptographic techniques, and privacy-preserving techniques.

### C. Integration with Emerging Technologies

Applying emerging technologies such as Artificial Intelligence (AI), Mobile Edge Computing (MEC), and next-generation networks such as 5G and Beyond 5G (B5G) networks can significantly impact the performance and improve the security of blockchain-enabled V2X communication. For example, blockchain and Machine Learning techniques can mutually support each other regarding intelligent predictions and real-time decision-making among different entities, i.e., estimation of traffic data to avoid congestion, achieving lightweight consensus algorithms, or handling multiple smart contract transactions [2][4]. Integrating MEC with blockchain can provide flexible, optimized resource management and reduce latency by processing data closer to the source, enabling quicker response times in V2X communication. Furthermore, deploying B5G will require addressing rigorous technical requirements, emphasizing the critical need for robust security measures and privacy protection. Integrating will be vital in enhancing the security of B5G-based V2X communication.

## IV. Conclusion

While V2X communication offers invaluable benefits, security vulnerabilities and privacy concerns persist which underscores the need for robust and secure system. Blockchain emerges as a promising security mechanism that will ensure a robust security layer to prevent attacks from malicious attackers. Although it plays a significant role in the V2X environment, it still suffers from limitations ranging from scalability to security issues, which is not suitable to support the needs of the future autonomous vehicular ecosystem. Hence, combining blockchain with 5G and B5G networks and emerging technologies such as AI or MEC can help mitigate and improve the overall system's security and performance. In summary, this survey emphasizes blockchain's role in fortifying security, ensuring privacy, establishing trust, and enabling a more efficient and intelligent system for the future of vehicular networks.


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