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ORIGINAL RESEARCH PAPER

Blockchain-Based Internet of Vehicles in Green Smart City: Applications and Challenges and Solutions

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ABSTRACT

The ever-increasing growth of the population and their concentration in cities has destructive and often catastrophic effects on natural habitats and human life and exposes cities to painful crises, including environmental and human destruction, which has caused humans to turn to technologies emerging to reduce environmental risks. Blockchain is a new and revolutionary technology in the world's management systems. The blockchain network allows individuals, governments, and organizations to implement any transaction securely on this network. With the Internet of Things expansion and the emergence of the Internet of Vehicles, green smart cities, and integration of these technologies with the blockchain network, human life quality has increased. However, new technical and environmental challenges have emerged by combining IoV applications with the blockchain network in expanding green smart cities. This article examines the concepts and advantages of the blockchain network, and then the applications of IoV in green smart cities are analyzed. Then the technical and environmental challenges of IoV are discussed, and finally, solutions for the environmental and technical challenges are presented.

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1. Background

Blockchain technology is strongly associated with digital currencies; however, it provides several other potential use cases related to energy and sustainability, the Internet of Things (IoT)(Pourrahmani et al. 2022; Salami, Khajehvand, and Zeinali 2023b), green smart cities (Alayi, Sobhani, and Najafi 2020; Hosseinimand et al. 2021), smart mobility, and more. Blockchain can provide the security of electric vehicle (EV) (Ghodusinejad, Noorollahi, and Zahedi 2022) transactions in the Internet of Vehicles (IoV) (Salami and Khajehvand 2020), allowing electricity trading to be decentralized, transparent, and secure. Also, blockchain provides necessary functions for developing decentralized IoV applications, such as data exchange, digital personal identity, collaborative economy, mobile tourism programs (Ebazadeh, Alayi, and Kiani Sakaleh 2021), and optimal energy models(Alayi et al. 2022; Al Anazi et al. 2023; Mohammadiun et al. 2022).

In addition, blockchain technology has the potential to significantly increase energy efficiency, reduce management costs, and ensure the effective use of energy resources. Therefore, its application in the concept of IoV provides secure, autonomous, and automated energy trading between electric vehicles (Abdelmaboud et al. 2022).

The IoV is considered one of the most active research areas in ITS (Intelligent Transportation System), which integrates VANET and IoT. IoV combines two scientific perspectives: (a) vehicle connectivity and (b) vehicle intelligence, focusing on the integration of objects such as people, cars, networks, and environments (Contreras-Castillo, Zeadally, and Guerrero-Ibañez 2017; Salami, Khajehvand, and Zeinali 2023a). The combination of communication and information technology in IoV, is beneficial for handling traffic and driving problems, contributing to passengers' safety and overall driving experience (Saad et al., 2023). Researchers proposed an architecture consisting of four layers based on multiple technologies in the IoV ecosystem (Salami and Khajehvand 2021; Sharma and Kaushik 2019; Fazeli et al., 2019; Gazijahani et al., 2017; Hadi Bonab et al., 2020; Hosseinzadeh et al., 2013).

- The first layer consists of all the sensors inside the vehicles that collect data and identify specific events of interest, such as driving patterns, vehicle location, etc.
- The second layer activates different modes of wireless communication. The communication layer ensures that existing and future networks are always connected.
- The third layer is responsible for storing, analyzing, processing, and making decisions about different situations in the IoV network.
- In the fourth application layer, the highest level of IoV may provide a wide range of vehicle services to consumers.

Figure 1 shows an example of the combined architecture of blockchain and IoV.

1.1. Organizing paper

The paper's organization is as follows: The related work is discussed in the second section, and the third section discusses blockchain networks. Provides applications for IoV in the green smart city in the fourth section. In the fifth section, challenges and proposed solutions are stated. The discussion is presented in the sixth section, and the conclusion is in the seventh section.

2.1. Contribution

In this paper, we have examined the blockchain, its types and features, and then we have examined the applications of IoV and the technical and environmental challenges in the green smart city, and we have provided solution for each challenge.

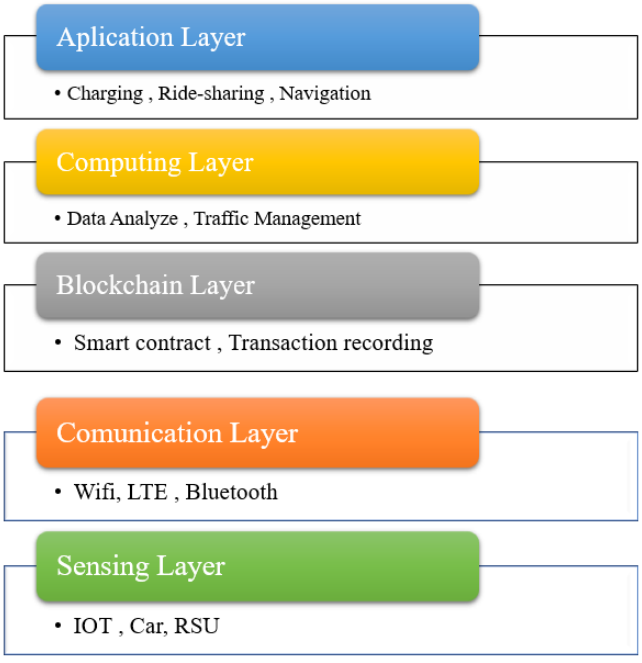

Fig 1. Blockchain and IoV architecture

2. Related work

This section provides a comparison of related work.

Vehicular Internet applications with blockchain was proposed in 2023 by Gao Et al. to describe the application of vehicular applications in blockchain (Gao et al. 2023). However, this paper does not cover green smart city, challenges and solutions. In 2023, Biswas et al. proposed a secure and reliable blockchain-based communication framework for the IoVs, which aimed to securely communicate vehicles with other surrounding environments based on blockchain (Biswas et al. 2023). However, this paper does not support green smart city, applications, challenges and Solutions. Ullah et al., 2023 proposed the application of blockchain in sustainable smart cities, which explained the main purpose of this application of blockchain network for smart cities (Ullah et al. 2023). However, this plan does not support IoVs, Challenges and Solutions. Application of blockchain in the Internet of Vehicles IoVs: Current challenges, contributions, and limitations in 2021 is presented by Kapassa et al. (Kapassa et al. 2021). However, this plan does not address these challenges and green smart city. In 2021, Azam et al. presented the blockchain-based approach for secure communication in the IoVs scenario review (Azam et al. 2021). This paper focuses more on secure communication through the blockchain network, so it doesn't support green smart city, applications, challenges and solutions.

In 2020, the IoV equipped with blockchain for collaborative positioning with a deep neural network approach was proposed by Song et al. (Song et al. 2020). This plan could not support green smart city, applications, challenges and solutions.A survey of blockchain-based applications in the IoVs was carried out by Mendiboure et al. (Mendiboure, Chalouf, and Krief 2020). in 2020, this scheme focuses more on blockchain network applications, so they cannot support green smart city and challenges and solutions. Table 1 shows a comparison of related work.

3. Background

This section provides information about blockchain, its types, and features.

Blockchain is a distributed database with parallel versions in different network nodes. Blocks are added one after the other in a chain so that each block is related to the previous block's hash value. The root block in the blockchain is known as the development block. Each block of the blockchain contains the block version, the hash value of the previous block, the time stamp value, a random nonce value, and the number of transactions within the block. After the block is formed, each node verifies the block, and the verified block is added to the blockchain and linked to the previous block by the parent hash value. Therefore, any block added to the chain cannot be tampered with, and no block can be added between two added blocks. This way, the records stored in the block are simultaneously open and safe. Blockchain technology can be divided into three categories: public, private, and consortium (Bagga et al. 2022).

Table 1. Comparison of related work

Works	Blockchain	Internet of Vehicles	Green Smart City	Applications	Challenges	Solutions
(Gao et al. 2023)	Yes	Yes	No	Yes	No	No
(Biswas et al. 2023)	Yes	Yes	No	No	No	No
(Ullah et al. 2023)	Yes	No	No	Yes	No	No
(Kapassa et al. 2021)	Yes	Yes	No	Yes	No	No
(Azam et al. 2021)	Yes	Yes	No	No	No	No
(Song et al. 2020)	Yes	Yes	No	No	No	No
Proposed	Yes	Yes	Yes	Yes	Yes	Yes

Public blockchain

Also known as the permissionless blockchain, Bitcoin works in an open environment like Ethereum, where anyone can join and write shared blocks. Each participant in the public blockchain has the same privilege of creating consensus in the consensus mechanism. Public blockchains fully comply with features such as non-repudiation, transparency, and traceability (Yang et al. 2020).

Private blockchain

Works in a closed environment where all authorized participants in this process are well-known. The private blockchain is also known as the commercial blockchain (Yang et al. 2020). Public and private blockchains differ in how they allow users to access, store, change, send and receive transactions. Public blockchains are open to everyone, meaning anyone can access the blockchain, but in private blockchains, only trusted entities are allowed to access the blockchain, thus forming a trusted network.

Blockchain consortium

A hybrid approach that combines both public and private blockchains to achieve consensus in a peer-to-peer network is called a blockchain consortium. Access in the consortium blockchain is given to a set of pre-defined nodes. Any new node that wants to join the network must be authenticated and authorized (Zavolokina et al. 2020). Figure 2 shows the advantage of blockchain. Blockchain technology embedded with IoT has several advantages as follows.

Transparency

For a public blockchain, any user can participate in the blockchain to add or validate a block. Similarly, any transaction or block added to the blockchain is accessible to all users. In a private blockchain, data is only open to authorized private users. It is also easy to trace the transactions made by an entity even when its true identity is secure (Francisco and Swanson 2018)

Fig 2. Blockchain advantages

Immutability

This means that once a block is entered into a public or private blockchain, it is impossible to change later. Since the blocks contain the previous block's hash value, any value change in the block will affect the validity of all consecutive blocks. In addition, there is a copy of the blockchain for each user of the network, so conflicts in the copies can be easily identified (Hofmann et al. 2017).

Traceability

Verification and traceability of the data stored in the blockchain are possible due to the presence of nance and the mapping of the data to the timestamp value (Demestichas et al. 2020).

Interoperability

The IoT consists of heterogeneous devices, so they face a significant challenge in interacting.

The decentralized nature of the IoT makes data exchange challenges. Blockchain allows different systems and devices of the IoT to communicate with each other through data exchange (Belchior et al. 2021).

Reliability

The data stored in the blocks of a blockchain are valid. They can be trusted because various cryptographic techniques, such as hashing, and encryptions, form the fundamental basis for storing data in the blockchain (Lo et al. 2020).

Decentralization

Traditional database systems depend on a third party or institution for validation. At the same time, blockchain technology is unique and operates independently using a distributed ledger that verifies transactions across nodes without consulting or requiring a third party. Using decentralized blockchain technology in IoT network reduces the overall communication costs and makes appropriate use of the shared resources in the network (Balcerzak et al. 2022).

4. Applications

This section examines the applications of IoV in the green smart city. Figure 3 shows the applications of the green smart city.

Intelligent transportation

Intelligent transportation applications for IoV and vehicle-based systems offer a broad, renewed, and innovative market. Researchers have proposed and tested APIs (application programming interfaces) for congestion avoidance, traffic safety, in-vehicle entertainment, and mobile services for locating, unlocking, and reading vehicle odometers across brands.

Fig 3. Green smart city applications

Research initiatives related to transportation applications for vehicular systems provide different contributions and mainly involve the IoV processing layer along with the IoV security layer for security and privacy purposes. Blockchain-based platforms are used for intelligent car parking services, car rental, training and learning of autonomous vehicles, and establishing reliable multilateral insurance (Yuan et al. 2022).

Energy

In the intelligent cars (i.e., fully autonomous or driverless cars and EVs), significant efforts have been made to enable electric and energy service providers to digitally monitor, manage and control their customers' electric cars. The primary tasks of researchers in the industries include retrieving the charge status and remaining range of EV batteries, scheduling and remote control of charging and discharging-charging processes, optimizing relative pricing costs, and building EV management dashboards. A typical application among existing energy studies in IoV is for smart charging or refueling services in vehicle-dependent networks using blockchains (Kapassa and Themistocleous 2022).

Data management

Intelligent cars and electric vehicles with embedded computers, GPS receivers, short-range wireless network interfaces, and potential access to in-vehicle sensors and the Internet must be able to share and store records of events and sensitive data, such as driver or vehicle identities, encryption keys, local construction, the following predicted route, traffic and road congestion. To avoid the problems of security vulnerabilities and bottlenecks in centralized architectures, sharing and storage should be securely implemented in a fully distributed or semi-distributed blockchain of the IoV network (Devi, Rathee, and Saini 2022).

Health care

Health monitoring through IoV improves communication between medical professionals and patients. Patient monitoring is enhanced with a wireless body sensor network by sending personal health information to the health center. This provides facilities to patients in emergencies; that is, delivering an ambulance from the nearest point takes the patient to the hospital as soon as possible. This information can be sent from the

blockchain network, and you guarantee the security of the data in some way (Shah et al. 2022).

Traffic efficiency and management

Traffic management and productivity applications are intended to prevent road accidents by optimizing traffic flow and preventing congestion. Vehicles are informed about the traffic situation ahead based on different RSUs, and based on this; vehicles may change their route if there is any congestion, and as a result, travel time is also saved. To determine the accuracy of received information, they can use the blockchain network to ensure data security (Elsagheer Mohamed and Alshalfan 2021).

Traffic sign violation warning

This IoV application is based on infrastructure-to-vehicle communication to notify vehicles in case of any hazard, i.e., If the traffic light is red and the vehicle does not stop, it will warn the driver. By placing RSUs together with a traffic light controller, it is possible to receive notification messages because RSUs broadcast traffic light information. Notification messages may include traffic signal status and timing, stop location or signal distance information, road surface, and weather conditions. If the IoV uses the blockchain network, cars can trust the warnings and take risks seriously more confidently (Elsagheer Mohamed et al. 2021).

Avoid collisions at intersections

This application mainly focuses on avoiding intersection collisions to reduce the number of accidents and thereby increase road safety. The authors have proposed a new architecture to avoid intersection collisions based on dedicated short-range communication. The proposed architecture is based on organizing secure links with RSU installed in the intersection area where they share their status information. Establishing safe connections in advance provides advance notices in case of any incident and thus alerts the vehicles to take necessary action. However, cars could have more confidence in the data received from IoV if the proposed architecture was in the blockchain network (Mohamed et al. 2022).

Stop sign violation warning

Drivers are alerted to the vehicle's current location along with the stop sign, which is the primary purpose of this type of application. In addition, the vehicle's speed shows that a high braking speed is needed to stop completely. Weather and road conditions near the stopping place play an important role in estimating the braking distance. The combination of this application with the blockchain network will give the driver more assurance of warning signs because the driver can have high confidence in the received data (Chen and Englund 2015).

5.Open challenges

Traditional database systems outperform blockchain in terms of performance due to its recent peer-to-peer distributed nature. This section presents an overview of the main limitations of blockchain efficiencies prevent for use in IoV interactions. Figure 4 shows challenges of IOV in smart green.

1.5.Technical Challenges

Performance limitations: Performance limitations consist of 3, which are described below:

Operational throughput

Traditional database systems currently have better performance than the operational throughput of blockchain business platforms. However, the efficiency of these platforms should be improved so that the processing of business transactions in the Fog and cloud environment is more efficient and effective (Salami, Ebazadeh, and Khajehvand 2021).

Latency

Due to the blockchain system, which needs to confirm two other blocks, it has a delay, therefore, reducing the processing delay is necessary to maintain security.

Network bottleneck

This refers to any condition under which data flow is limited due to insufficient computer or network resources. Since the number of blockchain systems is increasing, the problem of network bandwidth bottleneck must be solved.

Scalability limitations

Due to the scalability and weak internal connectivity, the development of the blockchain system for large-scale commercial adoption is problematic. First, the traditional blockchain has a sequential data structure. Accordingly, scalability is hindered due to sequential block storage. One solution is to develop a parallel data structure that can accommodate multiple chains. As a result, it becomes possible to add several blocks to the chain simultaneously, which makes the transaction process faster and increases the throughput. However, multiple chains require consensus protocol upgrades to ensure data consistency and correctness.

Energy

Due to the limited energy in IoV, if each transaction needs to confirm two previous blocks in the blockchain, the energy consumption will increase significantly beyond the processing power of IoV (Ghoshchi et al. 2022).

Security

One of the goals of using blockchain is to increase security in IoV, considering the functionality of blockchain, which uses hash functions to create blocks; to confirm a new block, two previous blocks need to prove it through hash comparison. To verify the blockchain system, it must compare the hashes of the previous blocks to confirm if it was the same. Due to the high comparison, the energy

consumption is very high and it is not suitable for the IoV network.

5.2. Technical Solutions

The blockchain system in combination with IoV has three problems: high energy consumption, low scalability and security, which are discussed in this section of the existing solutions.

Energy

Considering that energy is an essential and fundamental factor in IoV, the processes performed in IoV must be proportional to the processing power. However, due to its nature, the blockchain network always needs to confirm its two previous blocks. In this case, confirming two blocks means comparing the string of hash functions, which requires high energy consumption. To solve this problem, we need to design a new lightweight blockchain network to minimize energy consumption and be able to implement it in IoV networks. For energy efficiency, developers of encryption algorithms should design new methods with low complexity and cost so that we can design lightweight blockchains for energy-limited environments based on these methods (Salami et al. 2021).

Scalability limitations

Due to the nature of the blockchain network, it has problems in scalability; for this reason, IoV networks have limitations in terms of scalability. To overcome these limitations, it is necessary to separate the blockchain depending on each part's needs and increase scalability; you can put each piece in fog, edge layers. Considering that layers in fog, and edge are distributed, choosing the best local blockchain to do your work in IoV is possible, depending on the need and proximity. To overcome this limitation, blockchain networks must be designed in a distributed and centralized manner about the environment used. However, this design should be done so that the different use of centralized and distributed blockchains does not damage the integrity of the blockchain network.

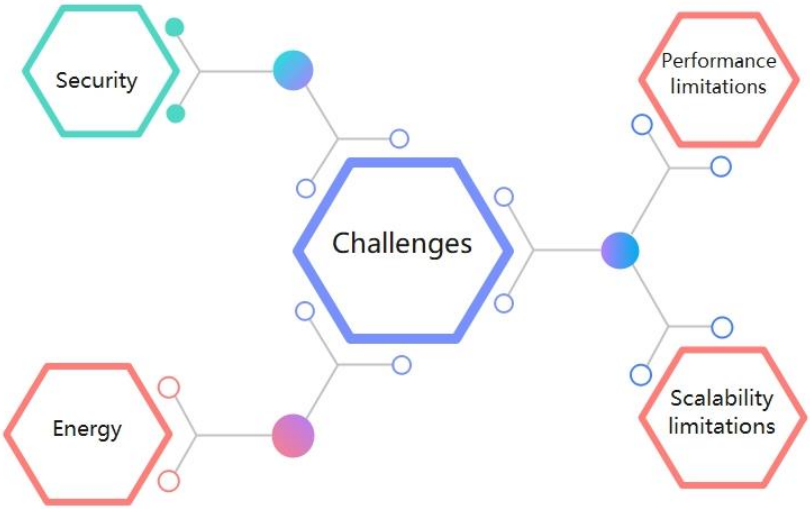

Fig 4. Challenge of IoV in smart green

Security

With the production of lightweight blockchains, it is necessary to use cryptographic algorithms with high-security strength and low computational complexity and type of database in the lightweight blockchain network architecture to solve the challenges of scalability and energy (Salami, Khajevand, and Zeinali 2023). The database should be chosen in terms of distribution and scalability according to the need; in the database style used, distribution and scalability should be considered based on the condition.

Solar Energy

To increase and maintain energy, it is better to use solar and wind energy in the cores and layers of fog and edge simultaneously with the existing energies. This will provide the energy needed by the blockchain network for IoV. If the blockchain network in IoV does not suffer from energy problems, this will make people more confident in applications due to the security of the blockchain. However, there is a need to develop modern cryptographic methods with low implementation costs for energy efficiency to match the limited solar energy.

3.5.Environmental challenge

Since the genesis block, the first block of Bitcoin was mined in 2009, we have continuously witnessed the presence of new miners and the development of mining process technologies.

Since cryptocurrencies are not a cash and therefore cannot be seen physically, their production process is carried out by hardware and software systems that people provide to the network. Bitcoin mining is the backbone of the Bitcoin Network. Miners provide network security and verify Bitcoin transactions. Without Bitcoin miners, the network will be attacked and inoperable. Special

computers do Bitcoin mining. The role of miners is to secure the network and process every Bitcoin transaction. Miners achieve this by solving a computational problem that allows them to chain together blocks of transactions, and this is the famous Bitcoin Blockchain. Miners, in addition to their advantages, have disadvantages for the environment, described below.

Energy

Blockchain technology-based virtual currency network, such as Bitcoin, is deliberately designed to increase their security and prevent fraud and use. The Pow algorithm, as the base of the Bitcoin network, is very complex and forces miners to solve complex mathematical problems. These issues are so complex that they cannot be resolved directly, and the answer is determined by attempt and error techniques.

Naturally, only one computer with powerful hardware and high processing power can handle such an algorithm. Such a system has high power consumption. In other words, the complex structure of the Bitcoin network requires very high processing power. These computers have a lot of power consumption because of their high processing power.

Carbon Dioxide

Carbon dioxide production is increasing with the increase in IoV, and the lack of accurate routing technology has led vehicles to travel more to reach their destination. Also, the heat miners produce can intensify carbon dioxide production.

Noise

Noise (noise pollution) as an unwanted sound is spread in an undesirable time and place and has unpleasant psychological and physiological effects on human. The increase in traffic and traffic between different areas has caused the environmental noise to increase and endanger human life and the environment. Also, miners produce a lot of noise for the environment, which in turn is annoying for human and the surrounding environment.

4.5.Environmental Solutions

To solve the challenges of Noise and Carbon Dioxide, it is better for the automotive industry to move towards solar and electric cars, which makes the noise produced by solar and electric cars much less than fossil fuel cars. Which makes the noise in environment will be significantly reduced. On the other hand, by replacing solar energy in cars, the consumption of fossil fuels will be significantly reduced, thus reducing carbon dioxide.

For the amount of heat miners produce in the blockchain network, you can start building a greenhouse next to the miners' fields so that the heat produced from this part is directly used in the greenhouse system to reduce fuel consumption and provide the required heat.

6. Discussion

According to the studies, the blockchain network with the combination of IoV can be helpful in the development of green smart cities, considering that the blockchain network increases security in IoV; at the same time, it increases energy consumption and generates a lot of data. To overcome the energy problem and improve safety, studies show that it is necessary to produce low-complex encryption algorithms to design a lightweight blockchain network with the help of lightweight encryption algorithms that can provide security simultaneously. With low energy consumption, it is possible to move towards Solar energies, increasing energy efficiency and efficiency. All these things cause less pollution to be produced, thus causing humans to bring a green smart city with the help of blockchain technology.

7. Conclusion

Today, human have come to terms with the pollution of big cities; society must move towards green cities and provide the conditions for a healthy life. In the design of green cities, it is necessary to take advantage of new technology, but these technologies have unique environmental challenges. This paper examines the blockchain network and IoV programs in green smart cities. First, the concepts of blockchain and applications are discussed, then the existing challenges are analyzed, and finally, solutions appropriate to the challenges are presented. Paying attention to the challenges presented in the paper about the energy crisis in blockchain networks and the IoV can be effective in the future; the solutions presented are suitable solutions to achieve green cities with blockchain technology. In the future, we intend to solve the existing problems raised with proposed solutions in the real world.

Conflict of interest

The authors declare that they have no conflict of interest.

Additional Information and Declarations

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