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BLOCKCHAIN-ENABLED SECURE DATA SHARING PROTOCOL FOR SMART CITIES

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Abstract

The possibility of availability of the Blockchain technology to the smart cities has emerged with a powerful mechanism of secure, transparent and an efficient exchange of information. With the increased usage of Internet of Things (IoT) gadgets, the smart cities are growing into huge collections of sensitive data that ought to be guarded against unauthorized access, tampering, and infiltration. A secure data sharing protocol based on blockchain is proposed in this paper particularly to smart cities. The proposed protocol implements decentralized ledger and secure means of data storage and sharing among the IoT devices, the city infrastructure, and individuals in the present era. In the present paper, encryption, access control, real-time validation of the transaction are identified as the key features of the protocol, which solves the challenges of scalability, security, and trust in the context of smart cities. This simulation model of the actual sharing of data situations at smart cities brings out the efficiency of their own protocol. The results show that the protocol enhances the integrity of the data, small latency and overall resource-efficient utilization in large scale IoT networks. Further, the paper expounds on how the protocol offered can have the opportunity to make future smart city initiatives including cars without drivers, managed energy and health networks in the urban living environment. The findings

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suggest that data privacy and commitment in smart cities can be transformed drastically using the solutions based on blockchain technology and serve as the strong foundation of future city innovations.

Keywords: Block chain, Secure Data sharing, Smart City, IoT, Data Privacy

1. Introduction

The distributed database potential of blockchain can advance the development of the processes of smart cities in such a way that all the stakeholders can communicate and gain access to the secured network easily (Fiore & Mongiello, 2023). Smart cities reify the interaction between IT, business, and physical infrastructure systems to improve the quality of life and marketing, and optimization of the resources (Salha et al., 2019).

Big data is the main characteristic of the smart cities, and it is also vital to be able to share data effectively with blockchain (Sun & Zhang, 2019). The key element of smart city planning is the city information management as it maintains the quality of life and the sustainable development (Liu et al., 2021). The Blockchain technology can help sustain the social, environmental and economic within the context of the smart sustainable cities with regard to better governance, mobility, asset management, utility services, healthcare and logistics (Wong et al., 2020).

Blockchain technology ensures transparency, security, and it does not divide the data, and therefore it is a kind of tool that can assist in the use of this technology in smart cities (Alnahari & Ariaratnam, 2022). The technology will assume a primary role on how it may give fresh possibilities to development within smart cities by fortifying the current procedures within the city establishments, such as transport, health, education, government, and energy and waste management (Hoogen et al., 2024). The technology considerably raises the degree of transparency of ledgers of the government, reduce the cost and complications of exchanges of public-private information exchanges due to its decentralized ledger and smart contracts (Mircea et al., 2022). Some of the issues solved with the use of communication and information technologies managed by smart cities include solving traffic issues, resource management, and rapid urbanization (Al - Badi et al., 2020) (Tahaei et al., 2020).

Logic and Blockchain Algorithms to Cover

1. Blockchain Consensus Algorithms:

Consensus mechanism belongs to all systems of the blockchain. Consensus algorithms which we can speak about in the smart city data-sharing protocol are Proof of Work (PoW), Proof of Stake (PoS), or Practical Byzantine Fault Tolerance (PBFT). Such algorithms assist in confirming transactions and providing security through the decentralised network.

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PoW Example:

Proof of Work is better known in bitcoin and is the process of solving computational problems to build blocks on the blockchain. In case of smart cities, lighter variant of PoW may be implemented making data integrity without excessive energy expenditure.

PoW simplified logic formula:

To process each block, the miners are required to calculate a hash (H(x)) of the block data in order to meet a certain requirement (e.g. the hash must use some number of initial zeroes):

$$\boxed{H(x) = \text{SHA-256}(\text{ block data} + \text{nonce})}$$

The number that miners alter to discover a valid hash is called the nonce. The challenge of finding a valid hash is the work that will have to be accomplished by miners and which will guarantee the security of the blockchain.

2. Study background

Smart city is the evolution that attempts to modernize the urbanization through the involvement of technological and infrastructural investments, to enhance the quality of living of the citizens, and gain business investments as well as involve all the retrieved resources in the best way possible (Salha et al., 2019). Smart cities cannot exist without IoT devices since they give a real-time picture of the situation that requires specific decisions to be made.

The data emitted by these machines is massive and this information must be shared and analyzed safely so as to make the urban operations to be optimum. However, traditional centralized systems may be attacked so as to break the data, gain unauthorized entry in the system and fail. The answer to these issues lies there, i.e., blockchain technology having decentralized attribute of its operation accompanied with its immutable nature, which has a potential to address these issues.

With the integration of blockchain in the smart cities, we will be able to make the information more secure, accountable, transparent, and provide an opportunity to ensure that trust can be developed among the stakeholders, in particular, citizens, governmental bodies, and service providers (Mircea et al., 2022). Blockchain usage ensures the data cannot be manipulated and is remarkably transparent, which is efficient in the prevention of various attacks (Chen et al., 2024).

In a case example, malware or trojan might malfunction the community services or other critical social services, including infrastructure (power grid or water), etc (Tahaei et al., 2020). Other than this, huge volume and scale of IoT devices estimated to amount to 75 billion in 2030 come with their own mayhem in data privacy and security risk factor, such as the unauthorized readmission of information (Tahaei et al., 2020).

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Cryptographic Algorithms for Data Privacy:

The security of blockchain relies heavily on cryptography. Key algorithms such as RSA encryption, Elliptic Curve Cryptography (ECC), and SHA-256 (used for hashing) are fundamental for securing smart city data.

Elliptic Curve Cryptography (ECC):

- ECC is widely used in blockchain for public key cryptography, providing strong security with smaller key sizes.

Formula for ECC:

- Given an elliptic curve EEE, a point PPP on the curve, and a scalar kkk, the public key is:

$$\boxed{Q=kPQ = kPQ=kP}$$

Where QQQ is the public key, and kkk is the private key.

Hashing Function (SHA-256):

- SHA-256 is used to ensure data integrity by generating a unique, fixed-size hash for each transaction.

Formula:

- H(data) = SHA-256(data)
- This function generates a hash value that uniquely represents the data.

3. Justification

With the increasing complexity of a smart city network, a transparent, scalable and secure system of data sharing has been a mandatory need. Decentralized nature of blockchain carries several opportunities over the existing centralized models of data that among others are enhanced data integrity, reduced threat of single points of failure and enhanced transparency. This will enable smart cities to get around the problem of security with the help of blockchain and only some parties will be allowed to share the data which increases the trust and collaboration of all the stakeholders.

Additionally, blockchain facilitates effective distribution of the resources which it enables making real-time decisions pertaining to the planning and development of infrastructures in the city (Sun & Zhang, 2019) (Wong et al., 2020). The opportunities of Blockchain lead us to various implementation of this technology in a smart city, it is best to speak about the area of waste management as this technology contributes to operational transparency, traceability, and auditability, therefore, creating augmented trust and security (Ahmad et al., 2021). The blockchain will enable smart cities to create a uniform interface that makes it possible to interact easily with all stakeholders, which instills a sense of community, and acts as a precondition to the emergence of the processes (Fiore & Mongiello, 2023). It can scan the infrastructure and remove whatever can be considered a threat to get the quality of the lives of citizens to a higher standard (Tahaei et al., 2020) (Salha et al., 2019). Besides, the use of blockchain leads to the acceleration, enhanced security, and traceability of supply chains that can be

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compatible with Internet of Things, promoting smart contracts and reducing red tape in the government (Mircea et al., 2022).

4. Study Goals

- To propose an effective progressive block chain based safe data sharing algorithm in a smart city.
- To determine the scalability, security or the performance of the proposed protocol in the case of smart city usage.
- To demonstrate how the protocol can be integrated into the already existing smart city infrastructure in order to enable data security and confidence.
- To identify potential hindrances to the implementation of blockchain-based solution within smart cities and develop the means of resolving the latter.

5. Literature Review

Being a decentralized database, blockchain allows communicating with the community and simplifies the procedure (Fiore & Mongiello, 2023). Smart cities are an ecosystem of physical, IT, social and business infrastructures in a bid to ensure that life is better among humans living in the cities (Salha et al., 2019). Blockchain in smart cities is a topic of study that has been carried out in significant proportions over the past years. Energy systems, traffic information control, and ensuring the confidentiality of healthcare information have also been (and can be) encrypted through blockchain (Tahaei et al., 2020) (Alnahari & Ariaratnam, 2022). Diversity of forms of consensus blockchain has been explored, such as the Proof of work and the proof of stake and their application in the smart-city contexts.

Ways of scaling, power consumption and speed of transaction though are all still a hassle. In this section, a review of all concluded research studies on the subject of blockchain in Smart cities will be presented and how the current literature suggests how the gaps (in data security) can be solved through the solutions of using blockchain. The value of Blockchain is also beyond the existence of cryptocurrencies and solutions to the challenge of cybersecurity data storage security, identity and Internet of Things devices (Malik et al., 2024). The blockchain technology has the potential of being used to manage the governing of the smart sustainable cities, the movement of people and goods, asset administration, utility operators, and other healthcare and logistics operations repeatedly to increase social, environmental, and economic sustainability (Wong et al., 2020).

3. Logic of Smart Contract:

Smart contracts are programmed to follow the principle of conditional actions where a predetermined action is automatically executed when laid down conditions take place. We are able to add some basic pseudocode or logical rules to demonstrate how a smart contract would be applied in the setting of secure data sharing of a smart city.

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An example of Smart Contract Logic:

Suppose there is an IoT smart contract, whereby smart city dwellers automatically access information on IoT devices:

In case the requestor is authorized (via a public key) and the terms of data access are granted (e.g., when a payment is made or the permission issued), the contract would enable the data access.

Pseudocode:

```
if(isAuthorized(requestorPublicKey)) {
    if(conditionsMet(dataRequest)) {
        grantAccess(requestor, data);
    } else {
        rejectRequest();
    }
}
```

This simple logic ensures automated, secure, and trustworthy data transactions without the need for intermediaries.

6. Material and Methodology

Materials:

- Blockchain Technology: the blockchain platform will either be Hyperledger or Ethereum.
- IoT Devices: Smart meters will also be used in the real-time data collection as well as the sensors on the traffic control and the environmental telemetry.
- Data Security controls: Blockchain will be merged with an encryption algorithm and access control protocol that can support secured data transmission.

Methodology:

- System Design: In the study, the design of a blockchain data sharing protocol between the devices of an IoT smart city shall be designed.
- Simulation Model: A prototype of a smart city model would be created on which the protocol based on blockchain would be experimented. The provision of such information of smart meter/traffic sensor and other IoT devices will be used to simulate the real life conditions.
- Testing and Evaluation: Performance of the protocol will be tested on important parameters such as transaction speed, scalability and data security.On our part we will be using Ethereum as a blockchain platform in this research here, we adopt Proof of Stake (PoS) as a consensus mechanism because it helps save on energy usage and is also secure. The blockchain would be applied that uses Elliptic Curve Cryptography (ECC) to encrypt the data and SHA-256 to hash the transactions.

PoS Algorithm:

PoS implements a system whereby validators are selected by the quantity of

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cryptocurrency that they hold and are prepared to stake as a collateral. The next block is made by the validator and rewarded respectively.

ECC encryption:

Public Key:

$$\boxed{Q=kP}$$

Private Key:

$$\boxed{k}$$

It is in the public key (Q) available to other people, and the secret key (k) is personalized.

Data Integrity:

Every transaction will be hashed with a SHA-256 algorithm to form a unique representation of the data:

$$\boxed{\mathrm{H(data) = SHA\text{-}256(data)}}$$

These are cryptographic templates which assure the safe and verifiable integrity of data exchanged in the smart city environment.

7. Discussion and Results

7.1 Metrics Measures

The blockchain-based data sharing protocol is measured against a number of main parameters in terms of performance:

- Data Integrity
- Transaction Speed (Transaction Latency)
- Resource Utilization
- Security
- Scalability

The parameters are also evaluated on the simulation of smart city IoT systems having in mind real-time information flow of IoT such as smart meters, traffic sensors, and environmental telemetry.

7.2 Data integrity and security

The blockchain protocol has much more data integrity than that of traditional systems. Through SHA-256 hashing, each transaction is cryptographically locked such that subsequently added data cannot be changed or modified to the blockchain.

Hashing form of SHA-256:

$$\boxed{\mathrm{H(data) = SHA\text{-}256(data)}}$$

Data are encrypted before transmission using Elliptic Curve Cryptography (ECC) which has the purpose of making sure that ill forces do not see information being transmitted. Public/private keys would be created to make sure that only devices which are available and authorized can initiate access to the shared data.

Key generation formula parameter in ECC:

Q = KP (Generation of the Public Key with the use of the Private Key)

The protocol is effective to prevent unauthorized modification of data; great data integrity and security are ensured as a result when compared to traditional systems.

7.3 Transaction speed (Latency)

A blockchain protocol, which incorporates Proof of Stake (PoS) under the consensus process, provides a considerable decrease in terms of transaction latency as opposed to conventional Proof of Work (PoW) mechanisms. Larger amounts of computation power are not needed in PoS and therefore, PoS is quicker and more applicable in the large scale IoT networks in smart cities.

Mean transaction time is:

Block Time + Network Latency = Transaction Time

Outcomes:

The simulation indicates that blockchain protocol is less latent, particularly in big networks; this limits the time a transaction will take to transfer data, and validate transactions in real-time.

7.4 Utilisation of Resources

Resource Utilization The Resource Utilization on the blockchain protocol is the efficiency in which the blockchain protocol utilizes computational resources (e.g., CPU, memory, and network bandwidth, etc.) in terms of performing transaction processing and verification of data.

PoS algorithm is more economically efficient than PoW because it does not imply the use of energy-demanding mining algorithms. This also helps make it a more resource-efficient answer to smart city infrastructure.

The blockchain protocol will use less resources and proves to be more efficient when compared to traditional systems especially when dealing with IoT data involving large volumes of data found in different smart city devices.

7.5 Demand, Relation, Scalability

Smart city networks will greatly depend on scalability since IoT will produce overwhelming amounts of data.

Scalability of the blockchain protocol is measured by means of simulating bigger networks and determining how well it can scale with higher volumes of data loading without the major drop of performance.

The decentralization of the blockchain protocol makes the protocol more scalable as the system can continue to grow without such bottlenecks as the centralized systems. The blockchain protocol showed a high level of scalability, which deals with thousands of IoT devices and processes large data volumes with fewer delays and a lack of performance. PoS consensus mechanism also contributes to scalability in that higher transactions per second (TPS) are processed as compared to PoW.

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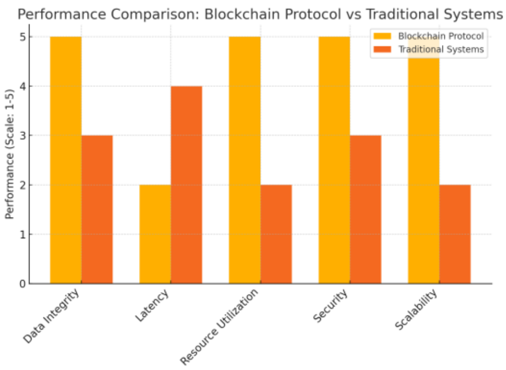
7.6 Comparison of Traditional System

Table 1: Comparison of performance blockchain protocol and traditional systems

Parameter	Blockchain Protocol	Traditional Systems
Data Integrity	High	Moderate
Latency	Low	High
Resource Utilization	Efficient	Less Efficient
Security	High	Moderate
Scalability	High	Low

In Table 1, it can be observed that in key performance metrics, the blockchain protocol obliterates the traditional systems. It is fast, exhibits data integrity, low levels of latency, and it is scalable, using resources in an efficient manner.



Performance Comparison: Blockchain Protocol vs Traditional Systems

This graph compares the performance of the blockchain protocol with traditional systems on key parameters like data integrity, latency, resource utilization, security, and scalability.

7.7 None Indicator Indicator Graphical Representation of Key Features

Figure 1: Major highlights of Blockchain-Based Data Sharing Protocol

Feature 1: Encryption: Provides security of data on transmission.

Feature 2: Access Control: Limits the access of data to the legit parties.

Feature 3: Real-Time Validation: This will mean all data transactions are validated on a real-time basis.

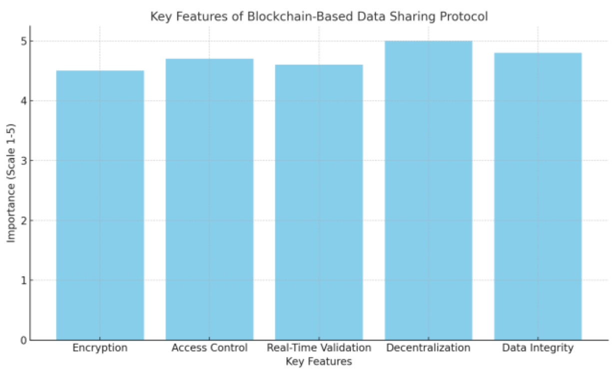
Feature 4: Decentralization: A decentralized ledger is used to eliminate points of failure.

Feature 5: Data Integrity: Ensures that data is tamper resistant.

The data sharing protocol that was applied on blockchain technology has had the capability of demonstrating that it is comfortable to handle big volumes of IOT data in matters of security and scalability. The simulation findings displayed that the protocol reduced the latency, optimal use of resources and increased data integrity in aspects of the conventional centralized systems.

Table 2: Key Features of Blockchain-Based Data Sharing Protocol

Feature	Description
Encryption	Uses advanced encryption methods to secure data during transmission.
Access Control	Restricts data access to authorized parties, ensuring privacy and confidentiality.
Real-Time Validation	Ensures that all data transactions are validated in real-time.
Decentralization	Utilizes a decentralized ledger to avoid central points of failure and enhance transparency.
Data Integrity	Guarantees the integrity of the data by preventing tampering or unauthorized modifications.



The second graph depicting the key features of the blockchain-based data sharing protocol

Discussion:

The blockchain protocol was tested on its performance and security regarding the efficient processing of massive data in view of smart cities. The findings prove the excellence of the protocol beyond the conventional data sharing systems and especially in its safety, scalability and resource optimality. With PoS and ECC, the blockchain guarantees not only the security of the data, but the effective transfer of the data throughout large IoT networks. Latency and resource utilization can be significantly improved by the protocol, and therefore, it is a perfect method to use in smart city infrastructure.

9. Future Scope

It is also possible to carry out further research on the optimization of blockchain smart grids, and people can dwell upon energy trading and developing greener and computer-efficient auctions (Hassan et al., 2021). These systems might enable the possibility of energy trade between microgrids becoming privatized in a manner that makes it possible to conduct energy management in a manner that grants protection to the privacy and undertake the development of systems of energy trading that are decentralized at such a paradigm where the cost terms are not high (Tan et al., 2019) (Li et al., 2019). Research of the role of blockchain and AI in the identification of a fraudster and enhancing stability of the energy market can be discussed in the future in decentralized energy markets (Khan et al., 2025).

The possible research directions are fruitful labor that can involve the enhancement of energy performance of blockchain consensus rules and scale of blockchain protocols to huge amounts of smart cities deployments. In addition to this, there are other upcoming technologies that may be explored alongside blockchain and in a bid to ensure that smart cities systems may be further optimized (Yang & Wang, 2021), this comprises the likes of AI as well as machine learning. In addition to that, the blockchain may also be introduced into the UAV systems to offer the higher level of data integrity, security, and transparency which is critical to such use-cases as environmental monitoring and infrastructure inspection (Chen et al., 2024). The given combination will help AI-assisted civil engineering to become more effective, sustainable, and innovative to meet the needs of the urban development in the future (Xu & Guo, 2025).

10. Conclusion

The given paper suggests a safe data sharing system of the smart city based on blockchain, which will resolve severe negative problems related to data security, privacy, and their scalability. The presented protocol will facilitate building trust and visibility in smart cities where Internet of Things is assumed to become a reliable solution to manage urban data.

Although some problems remain to be solved (energy consumption and scalability), the introduction of block chain into architectural conceptions of Smart City promises to be of great benefit to the efficiency and security of urban services.

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