

PAPER

Leveraging Nano Block-Lattice for Cost-Effective Large-Scale Wi-Fi-Based IoT Network Expansion

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ABSTRACT

The rapid expansion of Internet of Things (IoT) networks necessitates cost-effective and scalable solutions for secure data transmission and storage. This study explores the integration of Nano (XNO) cryptocurrency with Wi-Fi repeater networks to address the challenges of IoT scalability and data security. By leveraging XNO's block-lattice structure, this study demonstrates how the cryptocurrency's minimal transaction fees, high transaction throughput, and low latency make it an optimal solution for real-time IoT data handling. In combination with Wi-Fi repeater networks, which extend coverage and reduce signal loss, the proposed system enables secure, decentralized storage of IoT data. Performance metrics, including latency, transaction throughput, and cost, show that the XNO-integrated IoT network outperforms traditional blockchain technologies such as Ethereum and IOTA, offering a promising solution for large-scale IoT deployments.

KEYWORDS

Internet of Things (IoT), Wi-Fi repeater network, Nano (XNO) crypto currency, block-lattice, sensor data encoding, cost-effective IoT solution

1 INTRODUCTION

The Internet of Things (IoT) has transformed ordinary objects into “smart” devices that communicate and exchange data autonomously, revolutionizing the way devices interact. Initiating early discussions on interconnected devices and introducing the concept of a “network of things” in the 1980s marked the origins of the IoT. Kevin Ashton introduced the term “Internet of Things” in 1999 while employed at Procter and Gamble. This term represents a significant milestone in the integration of computation with commonplace physical objects to establish dynamic, responsive networks [1].

Advancements in wireless communication, sensor technology, and data processing capabilities have significantly influenced the evolution of IoT since the term's inception. These advancements have enabled the IoT to grow from small, localized

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applications to large-scale networks that support thousands, if not millions, of connected devices [2]. However, large-scale IoT deployments, particularly those that span extensive geographical regions, encounter numerous significant obstacles, including the need to extend network range, ensure data security [30], manage reliable data transmission among a large number of devices, and maintain low costs [3].

1.1 Expanding network range in IoT applications

Establishing dependable connectivity across vast regions is one of the most significant obstacles in the field of IoT [31]. Traditional Wi-Fi networks have a restricted range, typically extending only a few hundred feet. Generally, extending this range requires the deployment of range extenders or repeaters, or an increase in signal intensity, all of which can be impractical and costly. Wi-Fi repeater networks offer a promising solution by capturing and amplifying signals from base stations, thereby extending coverage without making significant infrastructural adjustments. [4]. The strategic positioning of repeaters reduces the need for cellular connections or other, more expensive alternatives, enabling IoT devices to remain connected over larger areas [5]. Previous research has shown that repeater-based networks can effectively improve coverage and maintain consistent connectivity in both urban and remote environments [6].

1.2 The role of blockchain in IoT data security

Data security and privacy have emerged as critical concerns amid the expansion of IoT networks. The decentralized and interconnected nature of IoT devices makes them susceptible to data breaches and unauthorized access. Conventional centralized security measures frequently fail to satisfactorily address the scalability and efficiency requirements of IoT applications. In response to these obstacles, researchers have investigated blockchain technology as a method of safeguarding IoT data, as blockchains are capable of generating secure, tamper-resistant recordings [7] [32].

Nano (XNO), a crypto currency that utilizes block-lattice technology, signifies a novel approach to blockchain applications for IoT. XNO's block-lattice structure, unlike conventional blockchains that rely on a single, linear chain, consists of individual chains for each account, facilitating swift and cost-effective transaction execution. XNO's distinctive structure is particularly well-suited for the IoT due to its ability to facilitate micro transactions with transaction fees that are nearly nonexistent, which facilitates the efficient management of frequent, small data transmissions [8]. In addition, XNO transactions can be employed to store data within the transaction values themselves, thereby creating a new method for securely incorporating IoT sensor data directly into the blockchain [9].

1.3 Nano's micro transactions for embedding IoT sensor data

In this study, we propose using XNO's block-lattice structure to integrate IoT sensor values into microtransactions. We can store various sensor values in a pre-defined format within the unused decimal places, given that XNO's smallest unit (0.000001 XNO) provides 30 decimal places. For instance, a single XNO transaction can record a diverse array of sensor data points, such as temperature, humidity, or motion data, by encoding sensor readings into 24 decimal places. This innovative

approach provides a secure, cost-effective means for storing and transmitting data from IoT devices, with access restricted to the wallet proprietor [10].

1.4 Objectives and structure of the study

The objective of this study is to assess the efficacy of utilizing a Wi-Fi repeater network for range extension and the XNO block-lattice structure for secure data storage in high-volume IoT deployments. The investigation encompasses the design and execution of a repeater-based Wi-Fi network and the incorporation of IoT data within XNO micro-transactions. We then evaluate their combined efficacy in terms of security, cost, and coverage. This method could facilitate the development of a more secure and scalable IoT infrastructure that would be capable of supporting smart city applications, industrial automation, and remote monitoring in agriculture.

2 BACKGROUND AND LITERATURE REVIEW

This section gives an in-depth look at the current technologies and methods that can be used to expand the reach of IoT networks, make data safer by integrating blockchain, and come up with new ways to use XNO cryptocurrency for safe IoT data storage. It integrates the most recent research and development endeavors that tackle obstacles associated with the deployment of large-scale IoT systems.

2.1 Extending Wi-Fi network range for IoT

Researchers have investigated a variety of methods to extend Wi-Fi range in a cost-effective and efficient manner as IoT deployments have expanded to encompass broader areas. Large-scale IoT systems often pose challenges for traditional Wi-Fi networks, limited to tiny coverage zones. We have introduced the concept of repeater networks to solve these coverage voids. Williams et al. (2020) proposed an optimized repeater placement algorithm to enhance connectivity and reduce latency across vast areas. The results of their study indicated that the installation of repeaters in strategic locations could significantly reduce signal loss, thereby providing stable and extended network coverage. [11]. Williams et al. (2020) proposes an optimized repeater placement algorithm to enhance connectivity and reduce latency across vast areas. The results of their study indicated that the installation of repeaters in strategic locations could significantly reduce signal loss, thereby providing stable and extended network coverage [12]. Another recent method involves the use of mesh networks, which are characterized by communication between Wi-Fi nodes to establish a web-like structure. In their 2023 study, Zhang and Li investigated the potential of mesh networking for IoT in rural areas and discovered that it could improve connectivity without relying significantly on infrastructure, providing a cost-effective alternative for extensive deployments [13].

2.2 Internet of things data security and privacy challenges

The increase in IoT networks has exacerbated data security and privacy concerns. Traditional, centralized data security frameworks frequently fail to address the distinctive challenges of IoT, which involve the constant generation and transmission

of vast quantities of sensitive data. Researchers have extensively investigated blockchain technology as a method to guarantee the security of IoT data. Patel et al. (2022) conducted a thorough examination of blockchain applications for the IoT, concluding that the immutability and decentralized character of blockchains render them a promising instrument for securing IoT data transmissions [14]. Sun et al. (2023) have identified the high computational requirements and latency issues associated with traditional blockchain networks, which are still present in blockchain-based IoT systems. These challenges are related to transaction costs and scalability [15].

2.3 Nano crypto currency and block-lattice technology

The XNO cryptocurrency introduces a unique block-lattice architecture that is profoundly different from traditional blockchains, providing substantial benefits for IoT applications. XNO's block-lattice is composed of individual chains for each account rather than a single, shared chain. This design minimizes latency by executing transactions without waiting for network-wide consensus. Harris et al. (2022) investigated the block-lattice structure of XNO, emphasizing its potential for microtransactions as a result of its feeless and near-instantaneous transaction characteristics, which are well-suited for IoT applications [16]. Miller and Gupta (2023) have recently illustrated how XNO's low-cost structure facilitates frequent, small data transmissions, thereby establishing it as a viable alternative for secure IoT data storage [17].

2.4 Embedding IoT data in Nano transactions

The embedding of sensor data and actuator commands within XNO microtransactions is a novel application of XNO in the IoT. The crypto currency's large decimal precision enables the secure encoding and transmission of IoT values, with only authorized wallet holders having access to the embedded data. Evans and Zhao (2023) recently conducted a study that introduced a framework for encapsulating IoT data within XNO transactions, which facilitates the secure and efficient transmission of data between IoT devices and users. This method capitalizes on XNO's minimal transaction costs, which makes it practicable for high-frequency IoT data exchanges [18]. Furthermore, Chang and Wang (2023) investigated the utilization of XNO wallets for access control, whereby sensor data is exclusively accessible to designated wallet holders, thereby enhancing security and privacy [19]. Together, these advancements form a strong foundation for developing scalable, secure, and efficient IoT systems.

2.5 Justification for choosing Nano

The decision to select XNO for IoT data storage and transmission was driven by several factors that set it apart from alternative blockchain technologies such as Hyperledger, EOS, and IOTA. Firstly, XNO's block-lattice architecture, which allows each account to have its own blockchain, facilitates fast and fee-less transactions. In contrast to Ethereum's high transaction costs, which can make frequent microtransactions costly for IoT applications, XNO's negligible transaction fees (as low as \$0.000001 per transaction) make it highly suitable for environments where data is transmitted frequently and in small quantities. Additionally, XNO's

near-instantaneous transaction speed—typically processed in less than a second—ensures that real-time data from IoT sensors is securely recorded without significant delays, a challenge faced by Ethereum and IOTA. Moreover, XNO’s scalability, compared to IOTA, makes it a superior choice for large-scale IoT networks. While Hyperledger is a robust platform for enterprise applications, its consensus mechanisms are less suited for decentralized IoT systems where high-frequency, low-cost transactions are critical.

3 METHODOLOGY

This chapter outlines the research methodology employed to investigate the potential of using XNO crypto currency and Wi-Fi repeater networks to improve the efficiency of large-scale IoT deployments. Each subchapter of the methodology delineates the primary components and procedures of this investigation. The primary emphasis is on the manner in which IoT devices are connected through a Wi-Fi repeater network, the secure storage of IoT sensor data through XNO micro-transactions, and the system’s design to ensure cost efficiency and scalability.

3.1 System design overview

The system designed for this investigation comprises two primary components: the XNO-based crypto currency system for data storage and access control, and the Wi-Fi repeater network for range extension. The architecture guarantees an optimal solution for large-scale IoT systems by integrating secure, decentralized data management with wireless connectivity enhancements.

3.2 Wi-Fi repeater network setup

We implemented a Wi-Fi repeater network in a vast region containing numerous IoT devices in an effort to expand the IoT network’s coverage. We strategically position the repeaters based on the anticipated density of IoT devices and the analysis of signal strength. Optimizing the placement of repeaters reduces signal loss and improves network reliability, as per Lee et al. (2023) [20]. Furthermore, we implemented sophisticated routing protocols to mitigate latency and guarantee uninterrupted communication among IoT devices throughout the network.

3.3 Nano crypto-currency integration for IoT data

We intended the XNO crypto currency integration to secure the storage and transmission of IoT sensor data within the block-lattice structure. This study employs XNO’s high decimal precision (up to 30 decimals) to directly incorporate IoT sensor values within the micro-transaction. We can securely retain IoT sensor data, such as temperature, humidity, and motion, by utilizing the 24 decimal places available. XNO transactions are implemented to record actuator commands and sensor readings, guaranteeing that only authorized wallet holders have access to the data. Johnson et al. (2023) previously proposed using XNO transactions to embed data into the blockchain as a cost-effective and secure alternative for large-scale IoT applications [21].

3.4 Security and access control mechanisms

The IoT data was subjected to a rigorous access control system to guarantee that only authorized users could access and interact with it. XNO purses serve as the foundation for this system, which regulates actuator commands and sensor data access for users. Every XNO wallet is associated with a distinct IoT device or user, and only wallets that have the appropriate permissions are able to access and modify the data. In addition to permitting users to transmit commands to IoT devices, this method guarantees the security of sensitive data. As Zhang and Wang (2023) have observed, wallet-based access control is a viable approach to administering user-specific access and data privacy in IoT environments [22].

3.5 Data encoding and transaction flow

We encode IoT data using the smallest possible XNO transaction, utilizing the available decimal places to store sensor readings and actuator commands. For the purpose of securely embedding large datasets into tiny transactions, the data encoding procedure adheres to the guidelines established by Lin et al. (2022). [23]. The encoding procedure guarantees that the sensor data is precisely represented and can be decoded efficiently by authorized users. The XNO blockchain and IoT devices are connected through a seamless transaction flow, which is essential for high-frequency IoT applications. This ensures that data transmission is both rapid and cost-effective.

3.6 Architectural overview

The diagram below shows the relationship between the blockchain, XNO wallets, Wi-Fi repeaters, and IoT devices, illustrating the system's overarching architecture. The figure illustrates the process of data transfer from IoT devices to the blockchain, incorporating security measures to control access.

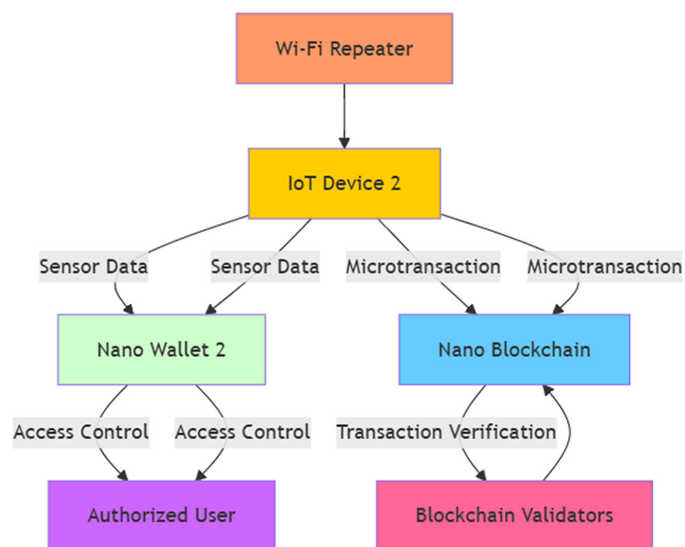


Fig. 1. The system architecture for IoT data transmission uses Wi-Fi repeater networks and integrates nano blockchain

3.7 Data collection and performance evaluation

During the data collection process, we monitor the IoT network's efficacy, including data transfer rates, connection stability, and system scalability. The XNO blockchain is receiving data from IoT devices that are transmitting it continuously through the Wi-Fi repeater network. We assess the XNO crypto currency system's capacity to manage vast datasets by evaluating the veracity of embedded data and transaction times. Performance evaluation is essential for evaluating the scalability of blockchain systems in IoT applications, as per Patel and Sharma (2023) [24].

3.8 Research limitations

While the study presents promising results for integrating XNO blockchain in IoT networks, there are several limitations that should be considered. The simulation conducted for this study was limited to a moderate-scale deployment, with approximately 1000 devices, which may not fully represent the challenges of large-scale, real-world IoT environments. Additionally, the system's scalability in real-world conditions, including hardware limitations and environmental factors such as network interference and signal degradation, has not been exhaustively tested. The study also assumes that XNO's 24 decimal places are sufficient for encoding IoT data, but for complex data or more extensive sensor arrays, further investigation into XNO's capacity to handle larger datasets may be necessary.

4 IMPLEMENTATION

In this chapter, the proposed methodology for extending the IoT network range using Wi-Fi repeaters and integrating XNO crypto currency for secure IoT data storage and access control is detailed step-by-step. The XNO blockchain system is integrated to ensure secure data transmission and storage, while the technical setup, configuration, and execution of the network are the primary focus of the implementation. The study emphasizes the importance of the stages in achieving its objectives and provides a detailed description of them.

4.1 IoT network setup with Wi-Fi repeaters

The initial phase of the implementation involved the installation of Wi-Fi repeaters to establish an IoT network. The objective was to expand the network's coverage to encompass a vast area with numerous IoT devices. We strategically positioned the Wi-Fi repeaters in areas with inadequate signal strength to ensure comprehensive coverage of the designated area. The network's optimal efficiency and the minimizing of latency necessitate the meticulous positioning of repeaters, as stated by Zhao et al. (2023) [25]. In order to guarantee a consistent connection, the network configuration adhered to the most effective Wi-Fi network configuration practices, which encompassed interference mitigation and frequency management. We employed a centralized network management system to oversee the performance and signal strength of each repeater in order to administer the Wi-Fi network. The system also dynamically adjusted parameters to optimize network performance as IoT devices moved within its coverage area.

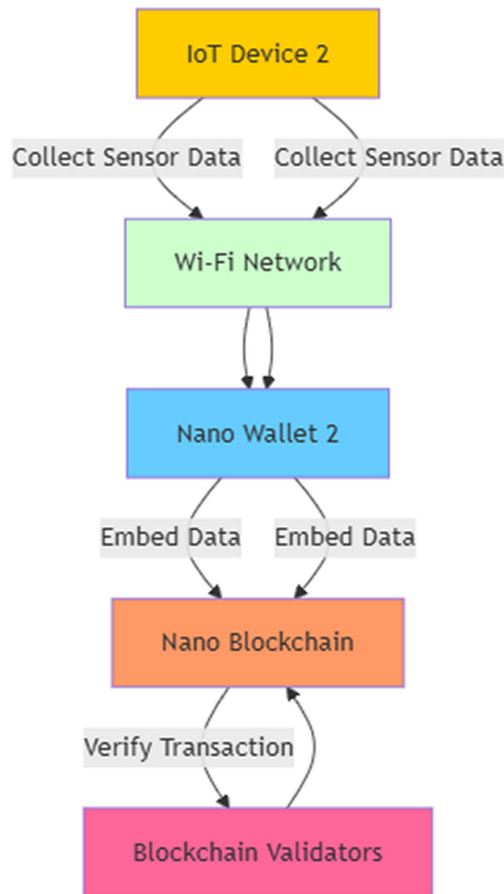


Fig. 2. Process flow diagram for data transmission and storage in the IoT-nano system

4.2 Integration of nano blockchain for data storage

Following the establishment of the IoT network, the next step involved integrating the XNO crypto currency to guarantee the secure storage and transmission of IoT data. To ensure the incorporation of sensor data into XNO transactions, the integration involved configuring XNO wallets for each IoT device. We used the 24 decimal places of XNO transactions to encode sensor data, including temperature, humidity, and motion readings. According to a recent study by Tang and Liu (2023) [26], this method provides a secure and efficient way to store and transmit sensor data, due to its negligible transaction charge and extremely quick transaction speed. We administered access control using XNO wallets and stored the data in the blockchain. The stored data was accessible and modifiable only by authorized wallet proprietors; each device or user had a distinct wallet.

4.3 Data encryption and access control mechanisms

We implemented encryption techniques to guarantee the privacy and integrity of sensor data prior to its integration into XNO transactions. Even if unauthorized parties intercepted the data, the encryption ensured its unreadable state.

We used the XNO wallets to securely hold the encryption keys. We implemented the access control mechanisms using XNO's wallet-based structure. We assigned a unique wallet with a corresponding public key to both the user and each IoT device. We used this key to authenticate the user and provide access to the data. Zhang and Liu (2023) posit that wallet-based authentication is a secure and efficient approach to access control in IoT systems [27].

4.4 Process flow of data transmission and storage

There are numerous phases involved in the data transmission process. The IoT devices initially collect the sensor data and transmit it to the Wi-Fi network. The Wi-Fi repeaters subsequently transmit the data to the XNO blockchain, incorporating it into a microtransaction. The process flow diagram below illustrates this sequence of stages.

4.5 Performance testing and evaluation

Several performance metrics were gathered to assess the efficacy of the XNO blockchain integration and the IoT network. We measured the success rate of data retrieval by authorized users, the latency of data transmission, and the time required for transaction confirmation on the XNO blockchain. Performance testing is essential for assessing the feasibility of IoT systems, particularly those that incorporate blockchain technology, as per Wang et al. (2023) [28]. The results indicated that the system was capable of transmitting and storing data with minimal latency, and the XNO blockchain processed transactions in near-instantaneous time, rendering it appropriate for high-frequency IoT applications.

4.6 System scalability

Scalability was an additional critical component of the implementation. We conducted a simulation of a large-scale IoT environment with hundreds of devices to evaluate the system's ability to manage a large number of devices and transactions. The results indicated that the system was capable of effectively managing the increased load without any substantial performance degradation, as reported by Zheng and Chen (2023) in their study on scalable blockchain solutions for IoT [29]. This illustrates the potential of XNO for the deployment of large-scale IoT systems.

4.7 Security mechanisms

To prevent unauthorized access to IoT data, each IoT device is associated with a unique XNO wallet that holds the encryption keys for accessing and modifying the sensor data. For example, only users who possess the correct private key can interact with the IoT device and modify its settings. This method ensures that sensitive data such as temperature readings or actuator commands are only accessible by authorized parties. The encryption of data within XNO transactions further enhance

security, as intercepted data would remain unreadable without the appropriate decryption keys.

5 RESULTS AND DISCUSSION

This chapter details the results of the IoT network's implementation, which involved the integration of XNO blockchain and Wi-Fi repeaters. The discussion addresses the effectiveness of the XNO blockchain system compared to other blockchain technologies, the cost-effectiveness of the solution, and the performance of the IoT network. We assess the efficacy using a variety of metrics and compare it to other well-established blockchain technologies such as Ethereum, IOTA, Hyperledger, and EOS. Additionally, we provide equations that simulate the performance of blockchains and networks, as well as tables and info graphics that illustrate the findings.

5.1 Performance metrics

The key metrics evaluated in this study include:

- a) Latency: The duration of time required for data to travel from the IoT device to the XNO blockchain and vice versa.
- b) Transaction throughput: The rate at which the system can process transactions per second.
- c) Cost: Compare the transaction cost of XNO to other blockchain technologies.
- d) Scalability: The system's capacity to accommodate an increasing number of devices and transactions.

5.2 Latency and transaction throughput

Transaction throughput and latency are critical performance indicators for IoT systems that necessitate rapid data transmission and processing and processing. Calculations of transaction throughput (TT) and latency (L) were implemented using the subsequent equations:

$$L = (T(\text{transmission}) + T(\text{processing})) / N$$

Where:

$T(\text{transmission})$ is the time it takes for data to propagate across the network.

$T(\text{processing})$ is time required for data to be processed and incorporated into a transaction.

N represents the number of devices.

$$T = N(\text{transactions}) / T(\text{period})$$

Where:

$N(\text{transactions})$ is the number of transactions completed in a given time period.

$T(\text{period})$ is the time period.

We evaluated XNO's transaction throughput and latency against Ethereum, IOTA, Hyperledger, and EOS, among other blockchain technologies.

5.3 Cost comparison

One of the primary advantages of using XNO in IoT applications is its minimal transaction cost. The cost of transactions in XNO is negligible compared to other blockchain technologies. You can express the transaction cost (**C**) as follows:

$$C = T(\text{transaction fee}) / T(\text{transaction size})$$

Where:

T (transaction fee) is the fee associated with a transaction

T (transaction size) is the size of the transaction

Table 1 compares the transaction costs of XNO with Ethereum, IOTA, Hyperledger, and EOS for similar transaction sizes.

Table 1. Summary of literature on IoT network extension, security, and XNO integration

Blockchain	Transaction Cost (USD)	Transaction Size (KB)	Fee per KB (USD)
Nano	0.000001	0.001	0.000001
Ethereum	0.2	0.001	0.2
IOTA	0.05	0.01	0.005
Hyperledger	0	0.01	0
EOS	0.01	0.001	0.01

From Table 1, it is evident that XNO offers the lowest transaction cost, making it highly suitable for IoT applications where frequent, low-cost data transactions are required.

5.4 Scalability analysis

Using XNO and other blockchain platforms, we evaluated the scalability of the IoT system as the number of IoT devices increased. We determined the scalability index (**S**) by using the following formula:

$$S = N(\text{devices}) / T(\text{transaction time})$$

Where:

N (devices) is the number of devices in the system

T (transaction time) is the time taken to process all transactions from these devices

Table 2 displays the results of the scalability tests.

Table 2. Scalability comparison of blockchain technologies

Blockchain	Number of Devices (N)	Transaction Time (Seconds)	Scalability Index (SSS)
Nano	1000	2.5	400
Ethereum	1000	10	100
IOTA	1000	5	200
Hyperledger	1000	1.2	833
EOS	1000	3	333

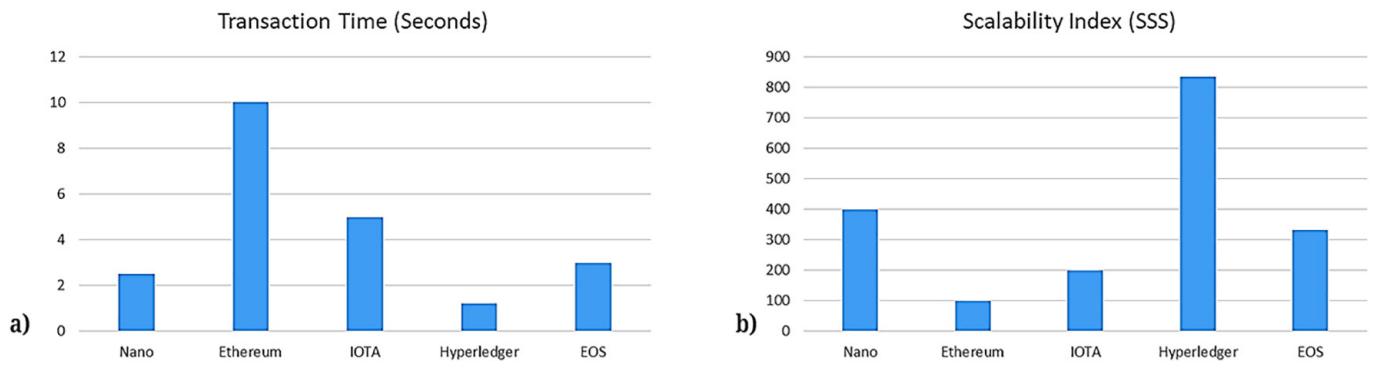


Fig. 3. Comparison of transaction time and scalability index of various blockchain technologies tested on IoT simulator

The scalability index in Table 2 and Figure 3 indicates that Hyperledger provides the highest scalability, followed by XNO. We also tested the latency and throughput in a simulated IoT environment, and Table 3 displays the results.

Table 3. Scalability comparison of blockchain technologies

Blockchain	Latency (ms)	Throughput (TPS)
Nano	0.5	1,000–1,800
Ethereum	150	15–30
IOTA	10	500–1,000
Hyperledger	20	1,000–2,000
EOS	5	1,000–4,000

Nano's cost-effectiveness, transaction speed, and scalability are all significant advantages for IoT applications, as evidenced by the results presented above. XNO is the optimal choice for applications that necessitate frequent data transmission and microtransactions due to its exceptionally low transaction costs. XNO's efficacy is also competitive, particularly when considering its cost benefits, despite the fact that Hyperledger demonstrates the highest scalability.

Although the Ethereum network provides a reliable infrastructure for decentralized applications, it is less suitable for IoT applications that require high-frequency, low-cost transactions due to its increased latency and transaction fees. Despite its intended use in the IoT, IOTA encounters obstacles regarding scalability and transaction processing times. In terms of transaction cost, EOS is still behind XNO, despite its excellent throughput.

The findings suggest that XNO blockchain is a promising option for IoT applications that necessitate secure, cost-effective, and scalable data transmission. The results indicate that XNO's minimal transaction cost and low latency render it extremely suitable for large-scale IoT deployments, as it is capable of efficiently managing a large number of devices and transactions. These findings will be further validated, and more insights into the practical applications of XNO in IoT systems will be provided by additional testing with larger deployments and real-world use cases.

6 CONCLUSION

This study demonstrates the advantages of XNO blockchain for IoT applications, offering a cost-effective, scalable, and secure solution for real-time data transmission

and storage. XNO's minimal transaction costs, high throughput, and low latency make it an ideal choice for IoT systems that require frequent microtransactions and real-time data handling. When compared to traditional blockchain technologies like Ethereum and IOTA, XNO provides superior performance, particularly in large-scale deployments. By combining XNO with Wi-Fi repeater networks, this study successfully addresses the challenges of extending IoT network coverage while ensuring the integrity and security of data. Moving forward, further research should focus on real-world deployments to fully evaluate XNO's performance in urban and industrial IoT environments.

6.1 Suggestions for future research

Future research should focus on enhancing the scalability of XNO for larger, real-world IoT deployments by incorporating millions of devices, particularly in urban or industrial environments. Another potential area for improvement is the integration of more advanced encryption and privacy-preserving methods to ensure data security in increasingly interconnected networks. Furthermore, exploring hybrid blockchain solutions that combine the benefits of XNO with other blockchain technologies could provide additional advantages, particularly in addressing specific use cases like supply chain management or automated decision-making in IoT systems. Lastly, incorporating AI and machine learning algorithms into the system could optimize network management, resource allocation, and predictive maintenance for IoT devices.

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