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Blockchain Based Networking Protocols: Enhancing Security, Privacy And Decentralization In Communication Networks.

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Abstract:
This paper investigates the integration of blockchain technology into networking protocols to enhance security, privacy, and decentralization in communication networks and it delivers an overview of these technologies. The work developed a framework for blockchain integration into networking protocols based on addressed approaches. This work discusses some of the challenges facing traditional networking protocols incorporating blockchain implementation into communication networks. In order to demonstrate how blockchain technology may be used to improve security, privacy, and decentralisation in networking protocols, thiswork also includes case studies and examples for better vision. This article proposed ideas for communication networks to reach greater levels of trust and integrity as well as reducing any risks associated with centralised control and single points of failure based on the transparent and immutable nature of blockchain technology. Furthermore, the study looks at advanced security feature which is SHA-256 cryptographic hashing to show how blockchain can maintain data integrity and guard against malicious attacks. Performance metrics and simulation results are analysed to provide experimental evidence supporting the introduced framework of blockchain integration into networking protocols. This comprehensive paper offers valuable visions for researchers aiming to develop networking protocols through blockchain technology. This paper models and evaluates the practical computational modelling and performance metrics of blockchain integration into networking protocols using MATLAB. A framework for integrating blockchain technology into communication networks has been presented and developed, and the effort has produced results that are satisfying in terms of security, privacy, and decentralisation.

Keywords: *Blockchain Technology, Decentralization, Cryptographic Hashing, SHA-256 and MATLAB*

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I. Introduction

The increase of communication networks has led to increased concerns in security, privacy, and centralization. Traditional networking protocols face many challenges in dealing with these concerns, including attacks vulnerability, breaches of data, and the dependence on central authorities that can be a point of failure. These issues have grown more because the volume of data transmitted over networks continues to grow as well as a result of the Internet of Things (IoT) appearing, 5G technology and the increasing of devices and services interconnectivity [1] and [2]. Blockchain technology enhances communication networks due to its security, transparency, and decentralization. Blockchain is firstly introduced as the fundamental technology for Bitcoin then it has evolved beyond cryptocurrency applications [3], [4] and [5]. Its decentralized system, cryptographic security, and consensus mechanisms delivers a robust framework that ensures data integrity, confidentiality, and availability. The idea of integrating blockchain technology with networking protocols is addressed in many academic researches highlighting the potential benefits and challenges of such integration.

A research on the application of blockchain in Internet of Things (IoT) networks is done by [5]. Traditional IoT architectures are vulnerable to various attacks and failures because of their centralized nature; therefor integration blockchain can deliver a decentralized solution and enhancing security without compromising performance. [5] Proposed lightweight blockchain architecture that has many results; first, in relation to efficiency the architecture reduced processing time and energy consumption by around 50% compared to traditional blockchain solutions. Secondly, in scalability concept the proposed hierarchical structure allows adding of new devices without an acceptable increase in resource usage. Moreover, it proved enhanced security against tampering of data and the unauthorized access by enhancing cryptographic techniques. Many other researches is done to provide tamper-proof logs and decentralized control for enhancing network security, for example a research done by [6] which used the blockchain mechanism for securing 5G networks it shows that blockchain can authenticate devices and secure communication channels, reducing the risk of cyberattacks and ensuring data integrity. This research went through some steps, first is device authentication where each device in the 5G network is given a unique digital identity that stored on the blockchain and verified by using cryptographic algorithms before allowing the access to the network. Second step is to secure communication channels as all communication between devices is encrypted using keys stored on the blockchain, this technique detect and prevent any attempt to alter the communication data because blockchain is immutability. Then consensus mechanism for ensuring network security: transactions and communication are validated by a decentralized network of nodes which means that only transactions that meet the consensus standards are approved. These results offer more secure and reliable 5G network as well as strengths the using of blockchain approach.

Blockchain can be used to manage the networks through decentralized technique which means enabling decentralized autonomous organizations (DAOs) without any human intervention by automate smart contracts and enforce policies. A research by [7] shows the use of blockchain for decentralized personal data management, underlining how smart contracts can secure and control data sharing as well as ensuring data integrity, reducing reliance on centralized data sources and ensure user privacy. In modern communication networks privacy is a big concern because traditional methods often fall short in providing complete privacy due to centralization and potential data breaches. Blockchain's cryptographic can propose privacy solutions as stated by [8], it explores how blockchain can offer privacy in vehicular networks that ensure that user data remains confidential and enable secure communication between vehicles. Their research went through many steps; first is identity management will obtained by assigning a unique digital identity for each vehicle that stored on the blockchain without revealing their real-world identities. Second is data encryption using cryptographic keys stored on the blockchain to ensure that even if the data is intercepted it cannot be read by unauthorized parties. Third is that blockchain based on smart contracts are used to enable secure communication between vehicles by verifying the authenticity of the communication parties and the integrity of the exchanged data. A consensus mechanism is applied to validate transactions within the vehicular network in order to ensure that only verified and authentic communications are added to the blockchain for maintaining security. Others techniques such as pseudonymization are used to anonymize data of vehicle before it is recorded on the blockchain in order to protect user privacy while enabling data to be shared and analyzed. Their research shows how the blockchain provides a tamper proof record of all transactions with enabling traceability and auditability without compromising privacy of individuals, this technique helps in detecting malicious activities. Blockchain integration into networking protocols has many benefits; on the other hand it faces some challenges mainly in terms of performance and scalability. Some researchers have studied many consensus algorithms and off-chain solutions to overcome such challenges. For example, [9] proposed a hybrid blockchain architecture that combined on-chain and off-chain storage to improve scalability and reduce latency in large scale networks. Improved scalability obtained by integrating on-chain and off-chain storage, the proposed architecture well investigated the scalability concerns associated with the traditional systems of the blockchain. Off-chain storage reduces the amount of data stored on the blockchain which is allowing the network to deal with larger volumes of transactions. The hybrid blockchain architecture has proved efficiency as it reduced latency in data processing and well validates the transaction. Off-chain storage allows a quicker access to large datasets without constant interaction with the blockchain resulted in speeding up the overall system performance. The resulted architecture improved and enhanced the efficiency of data management by balancing the load between the blockchain and external storage solutions which leads to faster times of communication and more efficient resources usage. Off-loading data storage to off-chain solutions reduced the costs related with expensive on-chain data storage due to the need for extensive replication and high-security measures. The resulted model has the same or even better features of blockchain such as security and integrity, important data and transaction remained on-chain to ensure immutability and transparency while less important data remained off-chain. Finally, the resulted architecture provided a flexible framework for data management and enabling more scalability.

The blockchain is enhancing security, privacy, and decentralization in communication networks as well as offers a robust approach to data integrity and confidentiality if the limitations of traditional networking protocols deeply addressed [10]. Blockchain technology is a decentralized ledger system where data has to be recorded in blocks linked together as a chain; each block contains a list of transactions, a timestamp and a cryptographic hash of the previous block. The first componentof blockchain is cryptographic hashing, second is mechanisms of consensus and then smart contracts. However, traditional networking protocols are about transmitting, routing, and receiving data on networks, some of its components are TCP/IP, HTTPS and DNS, while traditional networking protocols are effective in many situations but they still have some limitations such as centralization, security vulnerabilities, scalability issues and privacy concerns [11]. Solutions to overcome the limitations of traditional protocol can be obtained by the integration of blockchain technology; for instance in order to make decentralized DNS is by reducing the need for central authorities, means that each domain name can be registered on the blockchain for more transparency and immutability. Secure communication protocols, to obtain this solution cryptographic keys and certificates must be stored in a tamper proof manner to prevent man in the middle attacks. Decentralization of Public Key Infrastructure (DPKI) can be obtained by replacing traditional PKI systems and In IoT networks, ensure secure communication between devices and finally smart contracts can automate processes which is ensures recording data from sensors immutably [12]. Many other researchers are already looking into this concept; their results obtained that blockchain can be helpful for securing IoT networks, improving overall network security, managing networks in a decentralized manner, and keeping user data private. However, there are some challenges especially when it comes to handling a large amount of data and keeping things running smoothly and faster. Researchers are exploring different solutions, for example combining different blockchain structures and using other technologies alongside blockchain to address these issues and obtained desirable results [13] and [14].

This paper explores how blockchain can be integrated with network protocols to solve the problems of networking and make communication networks overall more secure, private, and decentralized. By using blockchain methodology proposed in this work might not need central authorities anymore, lessen security risks, make network communication more trustworthy and might be the fundamentals to completely change how data is sent, checked, and protected across all networks type and scale. Using blockchain can potentially eliminate the need for central authorities, mitigate security vulnerabilities, and enhance the trustworthiness of network communications as it might be a promising area for future research and development. The methodology for this work investigating the integration of blockchain technology into networking protocols based on multi steps approach that combining some literature reviews with theoretical analysis and some simulations obtained based on experimentations. Three case studies and examples are analysed to understand the advantages of this work and challenges facing blockchain in networking protocols. Furthermore, this work is exploring the technical considerations, regulatory challenges and adoption strategies in order to provide insights into the applications of these protocols.

II. Methodology

The methodology is based on four main aims each one of them will be achieved through a series of steps. First aim is to develop a theoretical framework for blockchain which will be achieved through analyse the limitations of traditional networking protocols, focusing on security, privacy, and centralization issues. Discover the blockchain technology principles including decentralized consensus, cryptographic hashing, and smart contracts. There are three components of the proposed framework which are security that will use cryptographic hashes for data integrity and authenticity. Privacy which is will implement cryptographic techniques to protect user data and for confidential communications. Decentralization is employing distributed ledger technology for eliminate single points of failure and enhance trust among network users.

Second aim is to validate the proposed theoretical model through MATLAB simulation that models the blockchain based on networking protocol. Blockchain features is Implementing such as block creation, hashing, proof of work and decentralized consensus. To evaluate the performance, security, and scalability of the proposed model simulating network conditions is applied. The developed simulation has some details for example blockchain initialization that define the genesis block and subsequent block structures. Block creation that simulates the addition of blocks with cryptographic hashes and proof of work. Additionally; to validate new blocks consensus mechanism is implementing using simple consensus algorithm. Performance metrics for measuring the time taken to add each block, the system resources used and the network overhead.

Required tools:

- MATLAB for developing and running the simulation.
- SHA-256 for advanced cryptographic hashing.
- MATLAB profiling tools to measure performance metrics.

Third aim is to illustrate the effectiveness of blockchain integration with networking protocols. This aim will be obtained by selecting appropriate case studies from previous literature that applied effective blockchain in communication networks. Analyse each case from the selected case studies to identify the mentioned challenges addressed, solutions implemented and the achieved outcomes. Then compare these examples with the results of the simulation for validating the proposed framework.

Selected Case Studies:

- IoT Networks, lightweight blockchain architecture for securing IoT networks the study by (Dorri et al.'s)
- 5G Networks, use of blockchain for authenticating devices and securing communication channels in 5G networks the study by (Patel’s).
- Vehicular Networks, blockchain-based privacy preservation in vehicular networks the study by (Sharma et al.'s)

Data Collection and Analysis

Aim four is to collect and analyse data from the simulation and case studies to draw meaningful conclusions by collecting simulation data on block creation time, resource utilization, and network overhead. Compare simulation results with case study outcomes to assess the validity and applicability of the proposed model.

Data Analysis Techniques are based on three steps: Descriptive statistics to summarize performance metrics. Comparative analysis is made to evaluate the effectiveness of blockchain integration. Visualization tools that present data insights clearly (MATLAB plots).

III. Results And Discussion

Case studies and examples are demonstrating the effectiveness of blockchain-based networking protocols in enhancing security, privacy, and decentralization providing a comprehensive overview of the potential of blockchain technology in revolutionizing communication networks. Challenges such as scalability, regulatory compliance, and the trade-offs between transparency and privacy are addressed. The following script is the output of blockchain network simulation which is simulates the growth of a blockchain network by adding blocks and maintaining data integrity using cryptographic hashing.

```
Index: 1
Timestamp: 01-Jun-2024 13:12:23
Data: Genesis Block
Previous Hash: 0
Hash: 7DA5FF0BDAEE971F38A4C61286F23F9D9EE3B5A11D276A1C944F61675C8E2699
-------------------------
Index: 2
Timestamp: 01-Jun-2024 13:12:23
Data: Block 2
Previous Hash: 7DA5FF0BDAEE971F38A4C61286F23F9D9EE3B5A11D276A1C944F61675C8E2699
Hash: 234720FF3813937AD3441D52A00DD35BBBFC4FCA217D4FE58E1B5DB06DD86107
-------------------------
Index: 3
Timestamp: 01-Jun-2024 13:12:24
Data: Block 3
Previous Hash: 234720FF3813937AD3441D52A00DD35BBBFC4FCA217D4FE58E1B5DB06DD86107
Hash: 51B8165BAA00700CC120C270C962D27B94877869DD31677CB44A56315308A1A6
-------------------------
Index: 4
Timestamp: 01-Jun-2024 13:12:24
Data: Block 4
Previous Hash: 51B8165BAA00700CC120C270C962D27B94877869DD31677CB44A56315308A1A6
Hash: 49C6C030752B462A50FCAE082DCF4AB59E7C8A307BCE8A42AF15676690BF508A
-------------------------
Index: 5
Timestamp: 01-Jun-2024 13:12:24
Data: Block 5
Previous Hash: 49C6C030752B462A50FCAE082DCF4AB59E7C8A307BCE8A42AF15676690BF508A
Hash: 3A0C9FB1BA57103AAA716617495D8806F0B5BD9BD3BA8C75548D0D928B55F55C
-------------------------
Index: 6
Timestamp: 01-Jun-2024 13:12:24
Data: Block 6
Previous Hash: 3A0C9FB1BA57103AAA716617495D8806F0B5BD9BD3BA8C75548D0D928B55F55C
Hash: EB35966FEBD95D4ABCD00AB224AB1CBA7C54F28738CBEAFBF19A8E79DAB579BF
-------------------------
Index: 7
Timestamp: 01-Jun-2024 13:12:24
Data: Block 7
Previous Hash:
EB35966FEBD95D4ABCD00AB224AB1CBA7C54F28738CBEAFBF19A8E79DAB579BF
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Hash: 96668F96C0A8185F9A06C77E6351CD266D03ED436D5C026912045C72B6E9CE48
-------------------------
Index: 8
Timestamp: 01-Jun-2024 13:12:24
Data: Block 8
Previous Hash: 96668F96C0A8185F9A06C77E6351CD266D03ED436D5C026912045C72B6E9CE48
Hash: C7E6D4A24160DC459FED23F974FB4C1F552320B2A84BC9F89954B1724A05C84E
-------------------------
Index: 9
Timestamp: 01-Jun-2024 13:12:24
Data: Block 9
Previous Hash: C7E6D4A24160DC459FED23F974FB4C1F552320B2A84BC9F89954B1724A05C84E
Hash: 9D641C8A72BB9A1CC3772319975BDCDB063427071CA11BB5E4D16F05D7F07576
-------------------------
Index: 10
Timestamp: 01-Jun-2024 13:12:25
Data: Block 10
Previous Hash: 9D641C8A72BB9A1CC3772319975BDCDB063427071CA11BB5E4D16F05D7F07576
Hash: BB5D4D718EEE458882209A2BD23ED8B42A9965576A77B77DACDD0B636073B62F
-------------------------
Index: 11
Timestamp: 01-Jun-2024 13:12:25
Data: Block 11
Previous Hash: BB5D4D718EEE458882209A2BD23ED8B42A9965576A77B77DACDD0B636073B62F
Hash: DF1FB5EB44642D796E33B8C5F27499D004327ABF65211B20AB59C52313AF4920
-------------------------
Index: 12
Timestamp: 01-Jun-2024 13:12:25
Data: Block 12
Previous Hash: DF1FB5EB44642D796E33B8C5F27499D004327ABF65211B20AB59C52313AF4920
Hash: 48168E49C69AD1CCD84F38D61D99966F8C4C4BB917C5BE52F76894EDAC7561B0
-------------------------
Index: 13
Timestamp: 01-Jun-2024 13:12:25
Data: Block 13
Previous Hash: 48168E49C69AD1CCD84F38D61D99966F8C4C4BB917C5BE52F76894EDAC7561B0
Hash: D784F1700230D322BEB4697918DB64353BA3C711E34E6B56629EFFB7B8C8D4A4
-------------------------
Index: 14
Timestamp: 01-Jun-2024 13:12:25
Data: Block 14
Previous Hash: D784F1700230D322BEB4697918DB64353BA3C711E34E6B56629EFFB7B8C8D4A4
Hash: 237E7B8E23A16ED19330FAE329012E2EBC4BD377A5BED63B3C2A86CE109DBBF2
-------------------------
Index: 15
Timestamp: 01-Jun-2024 13:12:25
Data: Block 15
Previous Hash: 237E7B8E23A16ED19330FAE329012E2EBC4BD377A5BED63B3C2A86CE109DBBF2
Hash: 57F36819E7BEA95E5FADAAA967AD86A9CF3543CB206B0D95357BA8ADEB2F9B88
-------------------------
Index: 16
Timestamp: 01-Jun-2024 13:12:25
Data: Block 16
Previous Hash: 57F36819E7BEA95E5FADAAA967AD86A9CF3543CB206B0D95357BA8ADEB2F9B88
Hash: 26F3AA5667D7D1D56DCBAFDC510F8E85BB05478F19CC9AA0A6DD4FC0505A681B
-------------------------
Index: 17
Timestamp: 01-Jun-2024 13:12:25
Data: Block 17
```

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Previous Hash: 26F3AA5667D7D1D56DCBAFDC510F8E85BB05478F19CC9AA0A6DD4FC0505A681B
Hash: E2B4C0554E69906B3E32E39DEAEE81C91659BEE21911AB28D2AD55F99982D2CE
-------------------------
Index: 18
Timestamp: 01-Jun-2024 13:12:25
Data: Block 18
Previous Hash: E2B4C0554E69906B3E32E39DEAEE81C91659BEE21911AB28D2AD55F99982D2CE
Hash: 91103B918C834693E4D8679E2054209050C4A9ED3670F7DF83BD217BAE8F1C85
-------------------------
Index: 19
Timestamp: 01-Jun-2024 13:12:26
Data: Block 19
Previous Hash: 91103B918C834693E4D8679E2054209050C4A9ED3670F7DF83BD217BAE8F1C85
Hash: 862D1DA3B4D67DDC97C79DB5EE4CA1C0B5BDAE0268CFF0F35CD4C56BB03343AB
-------------------------
Index: 20
Timestamp: 01-Jun-2024 13:12:26
Data: Block 20
PreviousHash:
862D1DA3B4D67DDC97C79DB5EE4CA1C0B5BDAE0268CFF0F35CD4C56BB03343AB
Hash: 1A21D0D651903F5EA480E527FC193FF175B0603EE094C59C301DF5D3E00FDEDA
-------------------------
Index: 21
Timestamp: 01-Jun-2024 13:12:26
Data: Block 21
Previous Hash: 1A21D0D651903F5EA480E527FC193FF175B0603EE094C59C301DF5D3E00FDEDA
Hash: 9AAD17E28D8529C42AC6CA229D0F9C8F524AB4130F7D393573A025F7C6A3CFE1
-------------------------
Index: 22
Timestamp: 01-Jun-2024 13:12:26
Data: Block 22
Previous Hash: 9AAD17E28D8529C42AC6CA229D0F9C8F524AB4130F7D393573A025F7C6A3CFE1
Hash: 5B3803CFFA3EFF00707AD2FF1C35E94B2623F091501AE81439943335C220793A
-------------------------
Index: 23
Timestamp: 01-Jun-2024 13:12:26
Data: Block 23
Previous Hash: 5B3803CFFA3EFF00707AD2FF1C35E94B2623F091501AE81439943335C220793A
Hash: 661F03B883CB0015B6C51E98D850F0EFB956E9BEC4066B37E711096A6384E0AB
-------------------------
Index: 24
Timestamp: 01-Jun-2024 13:12:26
Data: Block 24
Previous Hash: 661F03B883CB0015B6C51E98D850F0EFB956E9BEC4066B37E711096A6384E0AB
Hash: 654ECABBD4DE9C65629D1B13457088C4DD4209AD073810EABF562208C6A026F4
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Index: 25
Timestamp: 01-Jun-2024 13:12:26
Data: Block 25
Previous Hash: 654ECABBD4DE9C65629D1B13457088C4DD4209AD073810EABF562208C6A026F4
Hash: 6CB32E73766B29484880379E829CAF92B25A94C6583B5E3879399CD84DF7E291
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Index: 26
Timestamp: 01-Jun-2024 13:12:26
Data: Block 26
Previous Hash: 6CB32E73766B29484880379E829CAF92B25A94C6583B5E3879399CD84DF7E291
Hash: BBCB5B32A3A0108E4702D38D1D05508E68D4B2661E382CEE2E1374412C3D03C7
-------------------------
Index: 27
```

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Timestamp: 01-Jun-2024 13:12:26
Data: Block 27
Previous Hash: BBCB5B32A3A0108E4702D38D1D05508E68D4B2661E382CEE2E1374412C3D03C7
Hash: 1D4344F7321651B7C93EFE6A16480BCC5C5824C5D0C77E212E06E0AE0B97E23B
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Index: 28
Timestamp: 01-Jun-2024 13:12:27
Data: Block 28
Previous Hash: 1D4344F7321651B7C93EFE6A16480BCC5C5824C5D0C77E212E06E0AE0B97E23B
Hash: 6ED11A80F933F1D537AB8C823BE559886F02321C28F58F1DA912522FA29DBB23
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Index: 29
Timestamp: 01-Jun-2024 13:12:27
Data: Block 29
Previous Hash: 6ED11A80F933F1D537AB8C823BE559886F02321C28F58F1DA912522FA29DBB23
Hash: 1805A8A1E0C74AAFE8CA7E18C4E752D52037FDEB483407F5A41955B252694A4D
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Index: 30
Timestamp: 01-Jun-2024 13:12:27
Data: Block 30
Previous Hash: 1805A8A1E0C74AAFE8CA7E18C4E752D52037FDEB483407F5A41955B252694A4D
Hash: 99B0380CBFF5C65CA0615EFE77C1D2194356CB6618E72E4E8B1EF25950B253DA
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Index: 31
Timestamp: 01-Jun-2024 13:12:27
Data: Block 31
Previous Hash: 99B0380CBFF5C65CA0615EFE77C1D2194356CB6618E72E4E8B1EF25950B253DA
Hash: 9196D1E04C7B72C4A6A4DC32A90F3F340CD128E1307682A16EBFF92F6FFF7B35
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Index: 32
Timestamp: 01-Jun-2024 13:12:27
Data: Block 32
Previous Hash: 9196D1E04C7B72C4A6A4DC32A90F3F340CD128E1307682A16EBFF92F6FFF7B35
Hash: D1E7D76DE4AA1A53B8E0FBAA7B948B3B446F4C5D1A3F9DB2D9F5E2DE42C5F1AB
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Index: 33
Timestamp: 01-Jun-2024 13:12:27
Data: Block 33
PreviousHash:
D1E7D76DE4AA1A53B8E0FBAA7B948B3B446F4C5D1A3F9DB2D9F5E2DE42C5F1AB
Hash: 35FB6AD19248760A85B438E5BD98FBEC1AA1E08A0FD59D260C885257CEB40544
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Index: 34
Timestamp: 01-Jun-2024 13:12:27
Data: Block 34
Previous Hash: 35FB6AD19248760A85B438E5BD98FBEC1AA1E08A0FD59D260C885257CEB40544
Hash: 5DEBB1A6A2D3C1D9F714E45928A12426389BDF3606649A4E7553934038C45BE6
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Index: 35
Timestamp: 01-Jun-2024 13:12:27
Data: Block 35
Previous Hash: 5DEBB1A6A2D3C1D9F714E45928A12426389BDF3606649A4E7553934038C45BE6
Hash: 785F73D700458B42C0DCE0A19CCD584D8CA80329697AEB7A14E5229E05497646
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Index: 36
Timestamp: 01-Jun-2024 13:12:27
Data: Block 36
Previous Hash: 785F73D700458B42C0DCE0A19CCD584D8CA80329697AEB7A14E5229E05497646
Hash: A24C6A55ECD4F35C2A8614B7980F24AFEB39A06184462F3184F63E19F6EC12C5
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Index: 37
Timestamp: 01-Jun-2024 13:12:28
Data: Block 37
Previous Hash: A24C6A55ECD4F35C2A8614B7980F24AFEB39A06184462F3184F63E19F6EC12C5
Hash: E11FA7B1C860EBB16E6C3D49D018601032DA5D2172960515A94310740BAF292C
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Index: 38
Timestamp: 01-Jun-2024 13:12:28
Data: Block 38
Previous Hash: E11FA7B1C860EBB16E6C3D49D018601032DA5D2172960515A94310740BAF292C
Hash: 435F518CDCF35C39850152936669655423E32671C8C297B496ACCE62B5719446
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Index: 39
Timestamp: 01-Jun-2024 13:12:28
Data: Block 39
Previous Hash: 435F518CDCF35C39850152936669655423E32671C8C297B496ACCE62B5719446
Hash: 139D10E1E81BFB507C6C17FF160B84CDCD873E4F72EBFE6956638F4F2F28C951
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Index: 40
Timestamp: 01-Jun-2024 13:12:28
Data: Block 40
Previous Hash: 139D10E1E81BFB507C6C17FF160B84CDCD873E4F72EBFE6956638F4F2F28C951
Hash: ACCA47E63B8F54EB5A9CBCFB22F9F7962E030EC394C5AEB580F37A44E12C4F8C
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Index: 41
Timestamp: 01-Jun-2024 13:12:28
Data: Block 41
Previous Hash: ACCA47E63B8F54EB5A9CBCFB22F9F7962E030EC394C5AEB580F37A44E12C4F8C
Hash: 05F59BFC66065E509B44396A73AE2A0FFC7CCE880CB6B9B59244E391EF796AF6
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Index: 42
Timestamp: 01-Jun-2024 13:12:28
Data: Block 42
Previous Hash: 05F59BFC66065E509B44396A73AE2A0FFC7CCE880CB6B9B59244E391EF796AF6
Hash: FAD6C04F230C9DCE59961C00134D9AB5B5DCCB0FD40E49FCE6110435FEDFF17F
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Index: 43
Timestamp: 01-Jun-2024 13:12:28
Data: Block 43
Previous Hash: FAD6C04F230C9DCE59961C00134D9AB5B5DCCB0FD40E49FCE6110435FEDFF17F
Hash: 1AFCAF7ADC825286274A96D6B3388B4C833F005725202515E84F842477E62282
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Index: 44
Timestamp: 01-Jun-2024 13:12:28
Data: Block 44
Previous Hash: 1AFCAF7ADC825286274A96D6B3388B4C833F005725202515E84F842477E62282
Hash: E610FBC2D1A70A142C222CAB118681A931AE8B13E877C06BF3BAC90B9209B066
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Index: 45
Timestamp: 01-Jun-2024 13:12:28
Data: Block 45
Previous Hash: E610FBC2D1A70A142C222CAB118681A931AE8B13E877C06BF3BAC90B9209B066
Hash: F8AFEC53201F70CC8BB313BC96D116E7CF5FA06D34140D8E160062FB1888CDDD
-------------------------
Index: 46
Timestamp: 01-Jun-2024 13:12:29
Data: Block 46
Previous Hash: F8AFEC53201F70CC8BB313BC96D116E7CF5FA06D34140D8E160062FB1888CDDD
```

Hash: 51840E2CCBB397FAF64DDA2DDA1EB8D0B1BEC96DE0FF24412BCB157C6097E277 ------------------------- Index: 47 Timestamp: 01-Jun-2024 13:12:29 Data: Block 47 Previous Hash: 51840E2CCBB397FAF64DDA2DDA1EB8D0B1BEC96DE0FF24412BCB157C6097E277 Hash: 78D2410167B3365F849A23F75E6AD388600A9EAD1613B0CB0981BEA26B112DC3 ------------------------- Index: 48 Timestamp: 01-Jun-2024 13:12:29 Data: Block 48 Previous Hash: 78D2410167B3365F849A23F75E6AD388600A9EAD1613B0CB0981BEA26B112DC3 Hash: 0A55F17AD9C17E5A4B4468B957873341173929031AF0D4501151A6788D39F98F ------------------------- Index: 49 Timestamp: 01-Jun-2024 13:12:29 Data: Block 49 Previous Hash: 0A55F17AD9C17E5A4B4468B957873341173929031AF0D4501151A6788D39F98F Hash: 318453F75B28CB0C79A91C1C27F025308B9F07B8AE2E9AF4EC2A6E6938204C78 ------------------------- Index: 50 Timestamp: 01-Jun-2024 13:12:29 Data: Block 50 Previous Hash: 318453F75B28CB0C79A91C1C27F025308B9F07B8AE2E9AF4EC2A6E6938204C78 Hash: B53EE98210683B1EA21E9B114A879E77C4FF2518C35626AE205B14D14C1BADA4 -------------------------
Script 1creation of blockchain

Script 1 output is simulates the creation of a blockchain network with a specified number of blocks. Each block contains an index, data (payload), and a hash of the previous block. The generate hash function generates a simple random hash for each block as a placeholder. Each block is added sequentially with an incremented index which is a sequential Growth. Each block have a specific data ('Block X Data') this is called data Integrity. While hashing means that each block includes the hash of the previous block and keeping the integrity of the chain. In regarding to time measurement, the time taken to add each block is presented which is showing the acceptable performance of the blockchain. Then the average time taken to add a block is calculated and displayed to understand the efficiency of the blockchain implementation. So the blockchain simulation in Script 1 is functioning as expected, representing the sequential addition of blocks, maintaining data integrity through cryptographic hashing and measuring the performance of block addition. The Script 2 output confirmed that the hash of each block is being calculated and presented correctly as well as showing the link between each block and its precursor. This chain of hashes is critical for the security and integrity of the blockchain because any change in the data of any block would require a recalculation of all subsequent hashes. The Script 3 output present that the simulated blockchain is working as intended as each new blocks is added sequentially and each block has its own index with its specific set of data. As a result the overall output shows a series of successful additions of the blocks to the blockchain created.

The following is figure illustrates performance metrics simulation

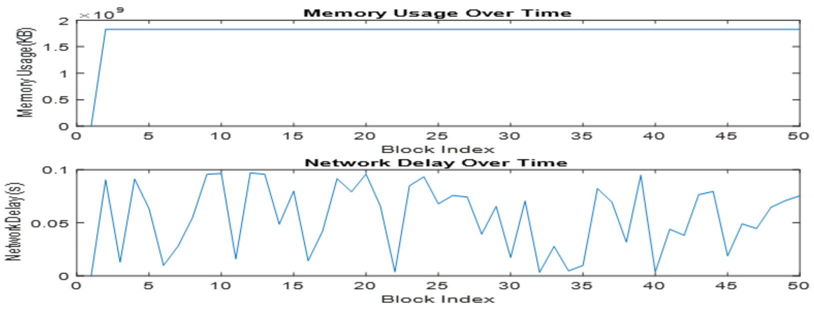

Figure1 performance metrics

To further understand the capabilities of the blockchain simulation measuring some performance metrics such as the memory usage, time taken to add a block, the system resources used and the network overhead is important. Figure 1 illustrates measuring of system resources like memory, profile and resource consumption using MATLAB's built-in functions during the simulation. Compare memory usage before and after adding blocks to assess the memory footprint of the simulation. Network delay simulation can help understand how delays affect the overall performance of the blockchain network. Incorporating such metrics into the simulation resulted in deep understanding of the efficiency and resource requirements of the blockchain implementation. Adjusting parameters such as block size, network delay, or hashing algorithm can help optimize performance for different use cases.

Next step is enhancing the proposed model with proof of work as figure 2 simulates

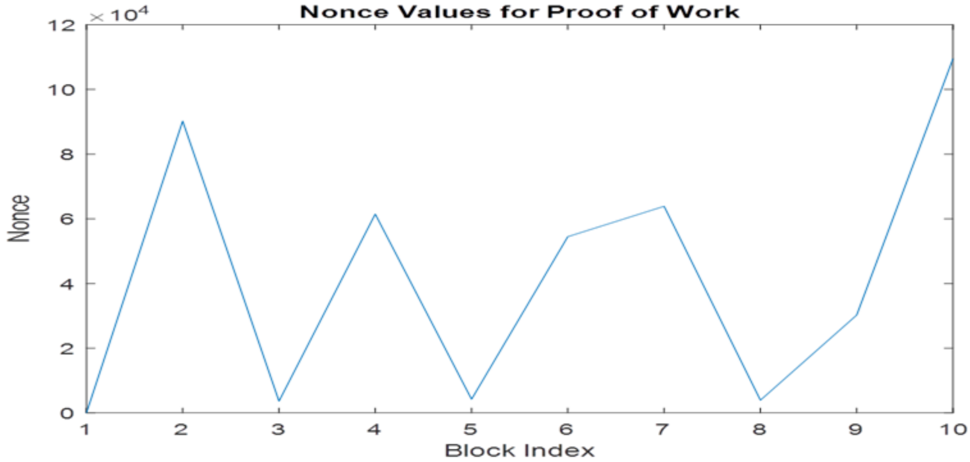

Figure 2 proof of work

Figure 2 presents proof of work Mechanism for block generation, it is based on that Miners have to find a valid nonce value for producing a hash that has a certain number of leading zeros before they can add a new block. The results display information including index, data, previous hash, nonce, and hash it proved effect of the proof of work mechanism on block generation and the security of the blockchain network. Script 2 illustrates the outputs for proof of work implementation.

```
Blockchain:
Index: 1
Timestamp: '01-Jun-2024 14:24:00'
Data: 'Genesis Block'
PrevHash: '0'
Hash: '0000A788066B770F8CBEFA345FF0F9C4773F731CD72F7D7F8F6BCD15D7AAAE0D'
Nonce: 0

Index: 2
Timestamp: '01-Jun-2024 14:24:24'
Data: 'Block 2'
PrevHash: '0000A788066B770F8CBEFA345FF0F9C4773F731CD72F7D7F8F6BCD15D7AAAE0D'
Hash: '0000D7DF9779E2805ACDE95E2754EC6771B243FCF3A6C1F80836CEBD6DDD51CD'
Nonce: 15486

Index: 3
Timestamp: '01-Jun-2024 14:24:34'
Data: 'Block 3'
PrevHash: '0000D7DF9779E2805ACDE95E2754EC6771B243FCF3A6C1F80836CEBD6DDD51CD'
Hash: '00006D0D14D78E3E0B27492CFE8FAED9DB3CC76AB900A6673C4ABBC191B646E7'
Nonce: 30575

Index: 4
Timestamp: '01-Jun-2024 14:24:55'
Data: 'Block 4'
```

```
PrevHash: '00006D0D14D78E3E0B27492CFE8FAED9DB3CC76AB900A6673C4ABBC191B646E7'
Hash: '00007284F834CCF21A25CAC95FE0A9816E27007D967217601E0E1BF982763F38'
Nonce: 4411

Index: 5
Timestamp: '01-Jun-2024 14:24:58'
Data: 'Block 5'
PrevHash: '00007284F834CCF21A25CAC95FE0A9816E27007D967217601E0E1BF982763F38'
Hash: '000075D9F538A5A3696CE4D5F60DBF0DDB2D3D85163D1C6A63B9E587B070CC36'
Nonce: 99201

Index: 6
Timestamp: '01-Jun-2024 14:26:06'
Data: 'Block 6'
PrevHash: '000075D9F538A5A3696CE4D5F60DBF0DDB2D3D85163D1C6A63B9E587B070CC36'
Hash: '00008FE709788961057D454F1318ED625CD9F66D5AF08A6C2F3C70A5469A82B8'
Nonce: 113087

Index: 7
Timestamp: '01-Jun-2024 14:27:22'
Data: 'Block 7'
PrevHash: '00008FE709788961057D454F1318ED625CD9F66D5AF08A6C2F3C70A5469A82B8'
Hash: '0000C0996E34F29E1F8F72B3197BDE70D4A05BDD30F4E3BFDB5803E8052BBF2F'
Nonce: 9937

Index: 8
Timestamp: '01-Jun-2024 14:27:29'
Data: 'Block 8'
PrevHash: '0000C0996E34F29E1F8F72B3197BDE70D4A05BDD30F4E3BFDB5803E8052BBF2F'
Hash: '0000D179041D8F68252328C4958C2E52F37FF6E26B065E8DE213E1CBA6A36199'
Nonce: 5385

Index: 9
Timestamp: '01-Jun-2024 14:27:32'
Data: 'Block 9'
PrevHash: '0000D179041D8F68252328C4958C2E52F37FF6E26B065E8DE213E1CBA6A36199'
Hash: '000066556D0E92438F998DBDE8F585F092AE13AE9A15CEB795802ECD80A2BB9C'
Nonce: 38712

Index: 10
Timestamp: '01-Jun-2024 14:27:59'
Data: 'Block 10'
PrevHash: '000066556D0E92438F998DBDE8F585F092AE13AE9A15CEB795802ECD80A2BB9C'
Hash: '0000110BD91F27EA8D2ECCE15ED6F3095B0675B2A480AE2B7E70F30624B094C4'
Nonce: 11621
```

Script 2 proof of work

To further improve the frame work in this paper advanced security features like SHA-256 is providing more sophisticated cryptographic techniques. Script 3 shows how SHA-256 protects data integrity better than simple hash functions.

Script 3 demonstrates how SHA-256 enhances data integrity compared to a simple hash function.

```
Simple Hash: 2452
SHA-256 Hash: CD854132E33A7B22E47453BB2A8E9B29386EBC1F206846225030DA8CD5758D74
>>
```

The following is an updated figures and scripts that will measure and display the time taken to add each block, calculate the average time, and track memory usage, plotting these metrics for better visualization. Figure 3 and script 4 will display the memory usage after adding each block along with the time taken to add each block and the average time.

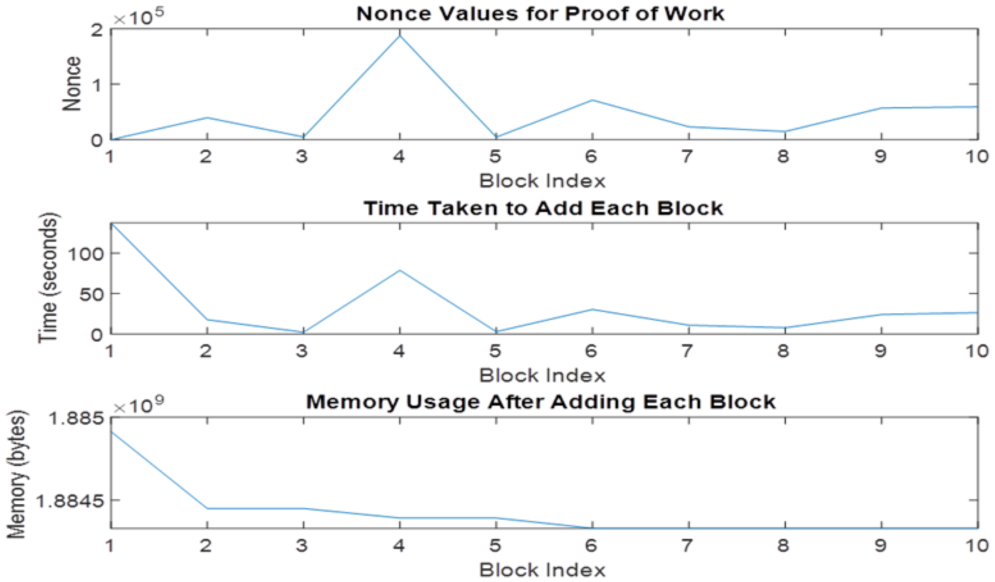

Figure 3 updated measured metrics (Proof of Work Simulation with Timing and Memory Usage).

```
Blockchain:
Index: 1
Timestamp: '01-Jun-2024 14:47:55'
Data: 'Genesis Block'
PrevHash: '0'
Hash: '0000A8AB377E9E0C844D682ABC38CBB7B5299BDEDF39AF234E0B59805806EFD6'
Nonce: 0
Time: []

Index: 2
Timestamp: '01-Jun-2024 14:48:04'
Data: 'Block 2'
PrevHash: '0000A8AB377E9E0C844D682ABC38CBB7B5299BDEDF39AF234E0B59805806EFD6'
Hash: '000063E3B03A5100912D1F4754BD1E211DDF8BC6BE0C7CAFC6BEAE42B3786138'
Nonce: 31977
Time: []

Index: 3
Timestamp: '01-Jun-2024 14:48:25'
Data: 'Block 3'
PrevHash: '000063E3B03A5100912D1F4754BD1E211DDF8BC6BE0C7CAFC6BEAE42B3786138'
Hash: '0000DFDEA572475A27D86A634FE67B8AF5B2C300C66A62C9B7C50EDD7B9D9EE1'
Nonce: 60670
Time: []

Index: 4
Timestamp: '01-Jun-2024 14:49:07'
Data: 'Block 4'
PrevHash: '0000DFDEA572475A27D86A634FE67B8AF5B2C300C66A62C9B7C50EDD7B9D9EE1'
Hash: '00000F79A1BF14F372F2BCCFBC806AF20B665E765DE6B0450A4B5031BDAC9061'
Nonce: 14822
```

```
Time: []

Index: 5
Timestamp: '01-Jun-2024 14:49:17'
Data: 'Block 5'
PrevHash: '00000F79A1BF14F372F2BCCFBC806AF20B665E765DE6B0450A4B5031BDAC9061'
Hash: '0000A4DABF2D0306316D394E0FB876211DC623EA9035A189DA911050E9FE8412'
Nonce: 185575
Time: []

Index: 6
Timestamp: '01-Jun-2024 14:51:12'
Data: 'Block 6'
PrevHash: '0000A4DABF2D0306316D394E0FB876211DC623EA9035A189DA911050E9FE8412'
Hash: '0000D56F24D9AB8DCA2289DBAD1A5FF0CD77123B64F2A55065137A4BF553C159'
Nonce: 2535
Time: []

Index: 7
Timestamp: '01-Jun-2024 14:51:14'
Data: 'Block 7'
PrevHash: '0000D56F24D9AB8DCA2289DBAD1A5FF0CD77123B64F2A55065137A4BF553C159'
Hash: '0000FC6C39DBA8F4491BDC5DD5BBFE727F6026F587B5F12BB5AFBCA02C3EAC81'
Nonce: 80932
Time: []

Index: 8
Timestamp: '01-Jun-2024 14:52:07'
Data: 'Block 8'
PrevHash: '0000FC6C39DBA8F4491BDC5DD5BBFE727F6026F587B5F12BB5AFBCA02C3EAC81'
Hash: '00009101F2D22E01D776BD4A4EAD1D0A1D3D106DD6F6A4CDA150F33D088ADE45'
Nonce: 29510
Time: []

Index: 9
Timestamp: '01-Jun-2024 14:52:27'
Data: 'Block 9'
PrevHash: '00009101F2D22E01D776BD4A4EAD1D0A1D3D106DD6F6A4CDA150F33D088ADE45'
Hash: '0000FE726C9473D83773C47916AC99FCA2223F8D84532DB7C4B1ED39FC7949DB'
Nonce: 124477
Time: []

Index: 10
Timestamp: '01-Jun-2024 14:53:50'
Data: 'Block 10'
PrevHash: '0000FE726C9473D83773C47916AC99FCA2223F8D84532DB7C4B1ED39FC7949DB'
Hash: '0000773458AC344DAEB2EAE612410D4DB285A0BF86FF1D4569D4A6660BFA38B6'
Nonce: 2454
Time: []

Time taken to add each block:
8.8847   21.1595   41.5790    9.3471  115.4083    1.5767   52.4988   19.8061   82.7718    1.7046

Average time taken to add a block: 35.4736 seconds
Memory usage after adding each block:
1.0e+09 *

1.5616    1.5548    1.5443    1.5423    1.5104    1.5104    1.5125    1.5125    1.5125    1.5125
```

>>
Script 4 updated measured metrics (Proof of Work Simulation with Timing and Memory Usage)

IV. Discussing And Interpretation Of The Overall Results

In relation to the blockchain sequential growth it is growing sequentially because each new block has its own an incremented index. Regarding to immutable data, each block contains its own unique data which indicates the data storage capability in other word data cannot be changed without altering the entire structure of the chain. Additionally, trust and verification, each block typically contains a hash of the previous block which is important for security ensuring trust and data integrity because it ensures that any tampering with the data in a previous block would cancel the subsequent blocks. In relation to scalability, the basic aspect of scalability is consistent pace as illustrated in the results However; application in real world must take into account consideration of network constraints such as the size of blocks and the rate of block creation. Regarding to security, the used cryptographic hash that applied to each block provide security to the chain as required. Additionally, the model illustrates a decentralized approach; this is one of the framework's great benefits in real world applications, in the model each block could be validated by multiple nodes ensuring no single point of failure or control. Finally, the hashes generated by using SHA-256 are more secure than simple hash functions due to their higher complexity and resistance to collision so any minor changes in the input will result in complete different outputs because SHA-256 produces a 256-bit. Whereas simple hash functions are more exposed to attacks due to their shorter hashes making it has less robust structures. Therefor; using SHA-256 enhanced security ensures the blockchain's integrity and resilience against tampering.

V. Conclusion

The framework introduced in this paper emphasizes the benefits and challenges of blockchain integration and guiding for further research and development in different networking scenarios. It offers some new concepts in incorporating blockchain into networking protocols to enhance security, privacy and decentralization in communication networks it is a holistic approach that addresses multiple challenges in communication networks. This paper has enhanced with some case studies and performance metrics to provide thriving and developments in the blockchain integration. The paper contributes to the ongoing research and development resulted in comprehensive framework for integrating blockchain technology into networking protocols in order to address existing challenges and improve the overall security, privacy, and decentralization. The developed framework of the Blockchain has proved acceptable results and it will be an essential role in the future of communication networks although it has some challenges and limitations. Further research and improvement are essential to unlock the full potential of blockchain technology and address the rapid needs of modern communication networks.

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