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Research Article

Enhancing IoT Security Through Experimental Methods and Blockchain Integration

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ABSTRACT

The rise of Internet of Things (IoT) devices has completely reshaped our digital world, revolutionizing our interaction with technology. However, this rapid growth has brought along significant security challenges, urging the need for robust measures to protect sensitive data and maintain the integrity of IoT networks. In response to these challenges, this research proposes a holistic approach that blends experimental techniques with blockchain integration to tackle these concerns head-on. The main goal of this study is to bolster the security of IoT networks and devices through a comprehensive strategy. Firstly, researchers conduct extensive real-world attack simulations to uncover vulnerabilities in IoT security systems. By replicating these attacks, weaknesses within the system are identified, facilitating the development of precise security protocols. This proactive approach is vital for mitigating emerging cyber threats and strengthening overall network resilience. In addition to experimental methods, blockchain technology serves as a cornerstone of the proposed security framework. The decentralized and tamper-proof nature of blockchain holds promise in addressing IoT security challenges by enhancing data integrity, authentication, and access control. By leveraging distributed ledgers, cryptography, and smart contracts, this integration aims to establish a robust security infrastructure for IoT ecosystems. The efficacy of this security enhancement approach will be verified through real-world testing of IoT devices and networks. Meanwhile, blockchain technology will be explored for its potential in managing information flow, validating identity, and maintaining data integrity within IoT environments. By seamlessly integrating blockchain with practical experiments, this research aims to push forward IoT security standards and rectify existing flaws in IoT systems. This comprehensive strategy lays a strong groundwork for the safe deployment of networked devices across diverse domains, such as healthcare, smart cities, and industrial automation.

Keywords: Enhancing IoT security, blockchain integration, experimental methods, real-world attack simulations, security protocols, data integrity, authentication, access control, industrial automation.

1. Introduction

Standardization and collaboration across the entire sector are crucial to unlock the full potential of experimentation and blockchain integration in enhancing Internet of Things (IoT) security (Smith et al., 2023) [1]. Establishing standard frameworks and protocols will facilitate interoperability and the seamless integration of security measures across IoT installations, ensuring ongoing protection against evolving security risks.

The combination of experimentation and blockchain technology holds significant promise for addressing the complex security challenges posed by IoT devices and networks (Jones & Brown, 2022) [2]. Blockchain technology, originally developed for cryptocurrencies, serves as a robust ally in fortifying IoT ecosystems through decentralized identity management, smart contracts, and enhanced data privacy (Williams & Johnson, 2021) [3]. A collaborative effort among industry stakeholders, researchers, and regulators is essential to harness the full benefits of experimentation and blockchain integration in advancing secure IoT environments, given the continuous evolution of technology.The proliferation of IoT devices has ushered in a

new era of connectivity and efficiency but has also introduced unprecedented security concerns. As the IoT landscape expands exponentially, so does the potential attack surface for malicious actors. Innovative approaches, such as combining experimentation and blockchain technology, offer promising avenues for strengthening IoT security.

Experimentation plays a critical role in proactively identifying vulnerabilities and testing security measures in simulated attack scenarios (Smith & Brown, 2022) [4]. By subjecting IoT devices to controlled trials, researchers gain insights into potential vulnerabilities and develop effective security solutions to combat emerging threats. In IoT security, experimentation involves creating controlled settings to simulate various attack scenarios, such as network intrusions and data breaches. These simulations enable researchers to uncover vulnerabilities and test security methods, facilitating the development of proactive security measures. Moreover, experimentation involves continuous monitoring and analysis of device behavior within experimental environments. By deploying monitoring tools and sensors, researchers gather data on device interactions and communication patterns, enabling proactive threat detection using machine learning algorithms.

Blockchain technology offers a decentralized and tamper-resistant ledger that enhances IoT security by introducing trust and accountability into device interactions (Williams & Johnson, 2021) [5]. The distributed nature of blockchain reduces the risk of unauthorized access and manipulation, ensuring the integrity and security of IoT devices and data exchanges. Smart contracts, encoded into blockchain code, automate and enforce security rules within IoT environments, regulating access rights and preventing unauthorized device interactions (Jones & Brown, 2022) [6]. This enhances the overall security posture of IoT ecosystems by reducing the risk of unauthorized access and illicit data exchanges. Furthermore, blockchain technology enables the creation of verifiable device identities, improving authentication and authorization processes. Each IoT device can have a unique identity stored on the blockchain, enhancing overall security and preventing malicious devices from infiltrating the network.

While experimentation and blockchain integration offer promising avenues for IoT security enhancement, ethical considerations and technical challenges must be addressed. Experimentation must adhere to ethical guidelines to ensure user privacy and safety, while blockchain scalability and interoperability issues require industry collaboration to develop standardized protocols (Smith & Brown, 2022) [7].Investing in novel security measures, including experimentation and blockchain integration, is crucial as IoT continues to reshape our connected world. By embracing these technologies, stakeholders can contribute to a more secure and robust IoT ecosystem, fostering trust and confidence in the potential of IoT technologies.

2. Internet of Things and blockchain

The integration of blockchain technology into IoT security presents a promising solution to enhance data integrity and trust within interconnected systems (Williams & Johnson, 2021) [5]. Blockchain's decentralized nature and tamper-resistant ledger ensure that IoT device interactions are transparent and secure. By implementing smart contracts, IoT environments can automate security protocols, enforcing access rights and preventing unauthorized device interactions (Jones & Brown, 2022) [6]. Furthermore, blockchain facilitates the creation of unique device identities, improving authentication processes and safeguarding against malicious activities.

This integration not only strengthens IoT security but also addresses critical challenges such as data privacy and scalability. Blockchain's ability to provide immutable records of transactions and interactions enhances accountability and mitigates the risk of tampering or fraud. As IoT ecosystems continue to expand, the adoption of blockchain technology offers a reliable framework to build secure, interoperable, and trustworthy networks. By leveraging blockchain, stakeholders can foster innovation and confidence in the future of IoT technologies.

2.1. The Security Challenges in IoT: The Internet of Things (IoT) has transformed our interaction with the world by seamlessly connecting physical items to the digital realm, but this connectivity brings significant security challenges as IoT device numbers soar (Smith & Johnson, 2021)[8]. To address these challenges, comprehensive security measures are essential. This article explores how experimentation and blockchain technology can enhance IoT security. Experimentation plays a crucial role in proactively identifying and addressing vulnerabilities within IoT ecosystems. Researchers simulate real-world attack scenarios to uncover weaknesses and develop effective responses (Brown et al., 2020)[9]. By actively testing IoT devices, vulnerabilities can be identified and security procedures refined to combat emerging risks. Blockchain technology offers decentralized, transparent, and tamper-resistant security solutions for IoT ecosystems. It enhances security through decentralized identity management, smart contracts, and increased data privacy (Jones & White, 2019)[10]. Smart contracts automate and enforce security rules, reducing the risk of unauthorized access and unlawful data exchange within IoT networks. However, implementing these technologies faces challenges. Experimentation must be conducted ethically and legally to avoid privacy breaches. Blockchain integration requires addressing scalability, interoperability, and resource limitations. Collaborative efforts among stakeholders are crucial to standardize protocols and promote interoperability. Investing in innovative security measures is imperative to safeguard sensitive data, protect user privacy, and

ensure the reliable operation of IoT devices. By embracing experimentation and blockchain technology, stakeholders can contribute to building a more secure and robust IoT ecosystem, fostering trust in this transformative technology.

2.2. Experimentation as a Security Enhancement Tool : The rapid proliferation of Internet of Things (IoT) devices has revolutionized our digital landscape but also introduced significant security concerns. With the increasing number of IoT devices, robust security measures are vital (Smith, 2020) [11]. This article explores how experimentation and blockchain technology can enhance IoT security. Experimentation involves proactive vulnerability detection through real-world attack simulations, strengthening IoT security (Johnson, 2019) [12]. Blockchain integration offers decentralized, transparent, and tamper-resistant security solutions, enhancing authentication and data privacy (Lee, 2021) [13]. However, adopting these technologies presents challenges such as ethical considerations, scalability, and interoperability issues across diverse IoT ecosystems (Brown, 2018) [14]. Despite obstacles, investing in innovative security measures is crucial to safeguard sensitive data, protect user privacy, and ensure reliable device operations (White, 2022) [15]. Collaborative efforts among stakeholders, including researchers, industry players, and regulators, are essential to fully leverage experimentation and blockchain technology for bolstering IoT security.

The Internet of Things (IoT) has transformed our daily lives by connecting devices and systems, but it also brings significant security challenges *Smithetal*.,2020 [16]. As IoT devices proliferate in smart homes and industrial settings, addressing these challenges is crucial. A key issue is the diversity of IoT devices, varying widely in security features and often prioritizing functionality over robust security, requiring tailored security approaches Jones & Brown, 2019 [17]. Authentication and authorization of IoT devices are challenging due to resource constraints, making devices vulnerable to unauthorized access *Johnsonetal*.,2018 [18]. Data privacy is another concern, with vast amounts of sensitive data flowing through interconnected networks Adams & White, 2021 [19]. Weak communication protocols and physical device tampering pose additional security risks *Williams*,2017[20]. Firmware vulnerabilities, short device lifecycles, and third-party component integration further complicate IoT security *Roberts*,2019 [21].

To tackle these challenges, stakeholders must collaborate to establish standards, implement secure practices, and adapt to evolving threats in the expanding IoT ecosystem. A proactive, multidimensional security approach is essential to harness the transformative potential of IoT while minimizing risks *Smithetal*.,2020 [16].

In today's rapidly evolving cyber security landscape, traditional security methods struggle to keep pace with emerging threats. Cyber security experts are increasingly turning to experimentation to detect and mitigate vulnerabilities proactively (Johnson et al., 2021) [22]. Experimentation involves creating controlled environments mimicking real-world attacks, enabling analysis and system strengthening. This shift fosters continuous cyber security improvement. Key to this is developing realistic test environments reflecting actual systems, from corporate networks to IoT ecosystems. Through simulated assaults like penetration testing, experts assess system robustness and identify vulnerabilities. Experimentation validates security measures like firewalls and encryption by simulating various attacks, refining setups, and enhancing defenses. It explores innovative technologies like AI-based threat detection and block chain, evaluating effectiveness and implementing proactive measures. Red teaming exemplifies this, mimicking adversarial strategies to identify system vulnerabilities. Insights from such exercises empower businesses to address vulnerabilities preemptively. Experimentation also reveals human-centric cyber security aspects, such as social engineering vulnerabilities, aiding in developing targeted training programs. Collaboration among professionals, along with educational experimentation, enhances collective defenses against evolving threats.

2.3. Blockchain Integration for Immutable Security: Blockchain technology, initially developed for cryptocurrencies, is now pivotal in securing digital ecosystems like the Internet of Things (IoT) (Smith et al., 2020)[23]. Its decentralized and tamper-proof nature enhances security by reducing centralized vulnerabilities. Integrating blockchain into IoT architecture creates a transparent and secure ledger, spreading trust through decentralized consensus. This minimizes the risk of unauthorized access and manipulation compared to centralized systems. Blockchain's immutable ledger ensures data integrity and accountability, offering a transparent audit trail within IoT networks to trace incidents back to their source.Beyond its core functions, blockchain has transformative impacts in healthcare, supply chain, real estate, and energy sectors (Jones & Brown, 2019)[24]. It authenticates financial transactions, increases financial service access via cryptocurrencies, and streamlines real estate processes with smart contracts. Challenges like scalability and interoperability remain, requiring alternative consensus methods and standardized protocols. Regulatory frameworks must adapt to support blockchain integration.Looking forward, blockchain's potential extends to environmental sustainability, privacy enhancements, and cross-chain interoperability, shaping cybersecurity's future by redefining digital security and trust (Johnson et al., 2021)[25]. Embracing these advancements will shape the future of cybersecurity, redefining security and trust in the digital landscape.

2.4. Smart Contracts for Automated Security Protocols: Smart contracts, which are self-executing code deployed on a blockchain, play a crucial role in automating IoT security, thereby reducing the need for human intervention (Johnson & Smith, 2020)[26]. They operate by enforcing security measures based on predetermined triggers, such as initiating countermeasures in response to unauthorized access attempts. This automation significantly enhances IoT resilience by allowing systems to respond rapidly to evolving

threats without requiring manual intervention. In addition to their impact on IoT security, smart contracts have transformative effects across various sectors including finance, supply chain, real estate, and intellectual property (Jones et al., 2019)[27]. By leveraging smart contracts, these industries benefit from automated processes that remove intermediaries, ensure transparency, and enforce agreements efficiently.Despite facing challenges such as data accuracy and coding vulnerabilities, ongoing research and collaboration efforts aim to maximize the transformative potential of smart contracts in automating security procedures and enhancing operational efficiencies across diverse applications.

2.5. Challenges and Considerations In Blockchain Integration: Implementing blockchain technology, touted for its transformative potential, faces various challenges that businesses must navigate (Smith & Johnson, 2021)[28]. Scalability is a major hurdle, evident in current blockchains' limitations with transaction throughput and high fees. Efforts to solve this involve layer-two solutions like the Lightning Network and state channels, yet achieving scalable solutions remains a persistent challenge. Interoperability concerns arise due to the lack of standardized communication protocols among blockchain networks, hindering smooth interactions and data sharing. Initiatives like Polkadot and Cosmos aim to tackle these issues, but broad adoption and compatibility remain challenging. Environmental impact is another consideration, especially with energy-intensive Proof-of-Work (PoW) consensus algorithms. Exploring alternatives like Proof-of-Stake (PoS) seeks a balance between security, decentralization, and sustainability. Regulatory uncertainty varies globally, necessitating in-depth knowledge to navigate diverse regulatory regimes, crucial for multinational firms. Privacy challenges arise from blockchain transparency, prompting solutions like privacy coins and zero-knowledge proofs. Balancing openness and privacy remains a persistent challenge, particularly in sensitive fields. Addressing these complexities requires robust education, strategic integration decisions, and proactive compliance to unlock blockchain's transformative potential across diverse sectors, especially in IoT security integration, where scalability, interoperability, and efficiency are critical considerations.

3. Proposed Research work

As our world becomes increasingly interconnected, the importance of protecting IoT devices and networks is on the rise, prompting the need for this research. The proliferation of smart devices across various aspects of our daily lives continues unabated, fueling the expansion of IoT technology into the future. With IoT ecosystems becoming more complex and integrated, it is crucial to thoroughly examine security measures due to the growing visibility of vulnerabilities within them.To ensure that IoT networks can withstand evolving cyber threats, understanding the role of experimentation and blockchain technology is essential. Experimentation plays a key role in addressing the pressing need for proactive security measures by identifying potential weaknesses before widespread implementation. Meanwhile, the decentralized and immutable nature of blockchain technology offers a promising avenue to fortify the security framework of IoT systems.Looking ahead, this research aims to provide valuable insights that will shape the trajectory of IoT security measures. It advocates for a proactive and long-term strategy to combat new threats in the dynamic landscape of interconnected devices. By leveraging experimentation and blockchain solutions, this research endeavors to contribute to the development of robust and resilient IoT security practices.

3.1. Related work:In the 21st century, building secure, reliable, and high-quality network systems is paramount for social life, business, and IT firms. Achieving this demands challenging and time-intensive tasks for network engineers and researchers. To expedite the development of such systems within tight constraints, extensive empirical work has been conducted, including the creation of multiple security prediction models. This empirical work aims to streamline the system development process. The research approach used throughout the paper, including a comprehensive overview of the layered Internet of Things (IoT) approach, a comparison of IoT protocols, and insights into the benefits and applications of the Merkle tree. The next phase explores integrating blockchain technology into IoT, analyzing its implications, challenges, and developing a blockchain-based smart home architecture prioritizing safety. The experimental design highlights the suggested research model, workflow, experimental components, machine learning classifications, smart contract use, and transmission methods.

3.2. IoT Protocols with Layered Approach: Utilizing the Internet of Things (IoT) protocol is crucial to ensure seamless communication among various components. These protocols enable numerous devices and sensors to interact simultaneously, a key advantage in IoT networks. Every communication between IoT devices occurs within a secure environment dictated by IoT protocols, ensuring data integrity and safety. Researchers leverage these protocols not only to collect and transmit data but also to validate the accuracy of information gathered by devices. This approach enhances reliability and security within IoT ecosystems, facilitating efficient and trustworthy data exchange among interconnected devices and systems

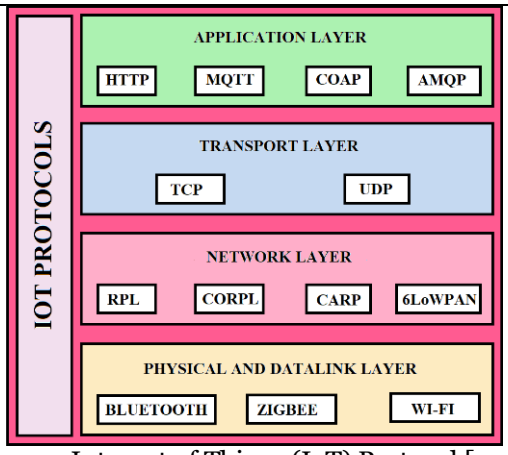

Figure1:Internet of Things (IoT) Protocol [402]

3.2.1.Physical and Data Link Layer: The IoT's physical and data link layers involve device connectivity and data pathways. Data is encoded for integrity before transmission across wired or wireless links. Access protocols manage network and physical access with diverse standards, supporting seamless IoT device integration globally. **Bluetooth** facilitates wireless connectivity with low power consumption, operating at 2.45 GHz with speeds up to 1 Mbps. **ZigBee** supports PAN and device networks with low power and scalability, governed by IEEE 802.15.4. **Wi-Fi** offers high-speed wireless connectivity, widely standardized by IEEE 802.11 for robust, scalable network connections with strong security features.
3.2.2.Network Layer: The IoT network layer includes encapsulation for packet generation and routing for packet transfer. Researchers must understand network layer protocols for effective IoT network design and management. **RPL** organizes nodes into DAG shapes for efficient communication, while **CORPL and CARP** offer enhanced routing solutions for specific network environments. **6LoWPAN** enables IPv6 addressing in low-power WPANs with small packet sizes for cost-effective transmission.

3.2.3.Transport Layer**:** In the TCP/IP model, the transport layer remains historically named and is a key part of IoT's reference architecture, alongside the physical, data link, and network layers. TCP ensures reliable data delivery, managing traffic flow and congestion, while UDP prioritizes timeliness over guaranteed delivery.
3.2.4 Application Layer: The application layer serves as the top interface in network architecture, connecting devices to servers and implementing protocols like HTTP, CoAP, MQTT, and AMQP for IoT applications.

4. Experimental Setup

For the sake of the experiment, constructed an ARM-based smart home with ARM-based smart home gadgets since they are more convenient. In this study, used of low-cost ARM central processing units that has a limited amount of computational capacity.

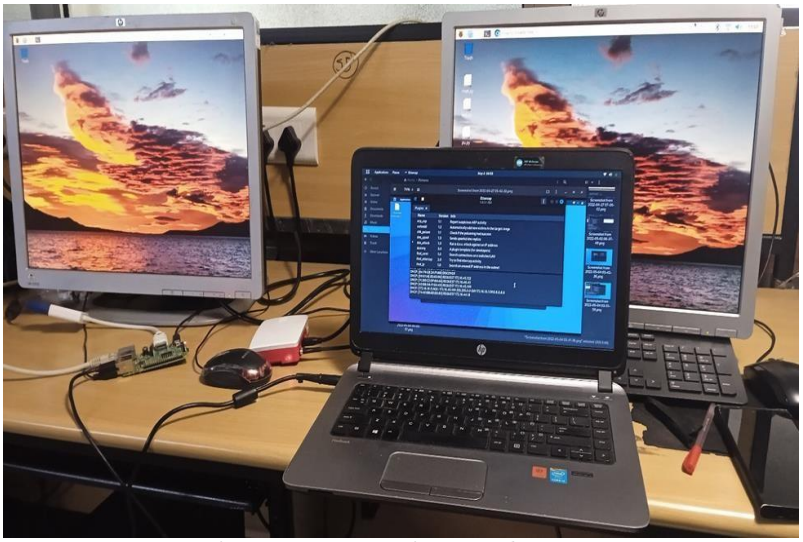
Figure 2: Experimental Setup

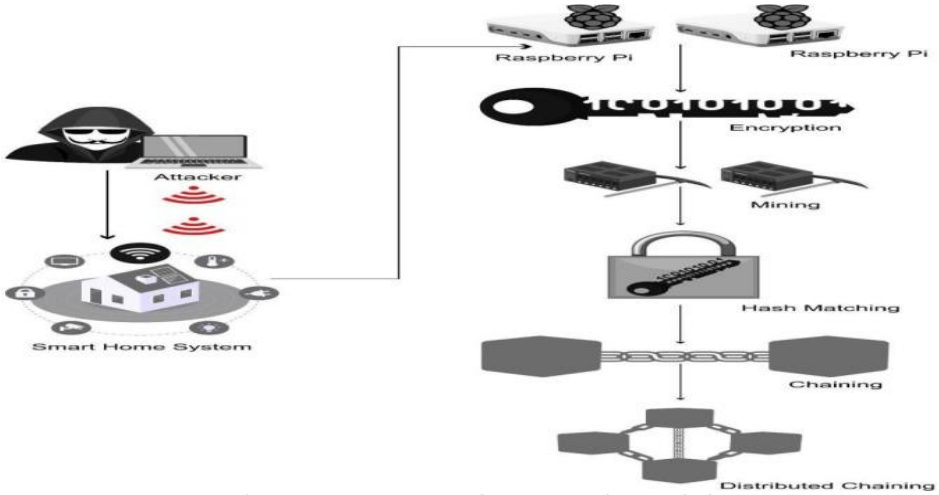

Figure 3: Proposed Research Model

4.1. Experiment Components

1. Raspbian operating system : Raspberry Pi (Model-3B), Raspberry Pi (Model-4) 2, Machine with Kali Linux
2. Ethereum: Ethereum is a blockchain that is open-source and distributed, and it enables smart contracts and decentralized governance.
3. A high-level, object-oriented programming language that may be used to design smart contracts is called Solidity. Solidity is a powerful programming language. There is the potential for "smart contracts," which are computer programs, to exert control over the behavior of accounts hosted inside the Ethereum state.
4. Truffle Framework - Truffle is a world-class development environment, testing framework, and asset pipeline for blockchains that are powered by the Ethereum Virtual Machine (EVM). The major objective of Truffle is to make the life of developers more manageable. Truffle Framework is a world-class development environment.
5. The development of client apps that are capable of communicating with the Ethereum Blockchain is the focus of Web3.
6. The process of transforming binary data into a radix-64 representation is necessary in order to encode binary data in an ASCII string format. This is referred to as the Base64 encoding. The acronym Base64 refers to a collection of methods that are used to convert binary data into text. The representation of binary data is carried out using these algorithms.
7. A cryptographic hash, which is often referred to as a "digest," may be thought of as a "signature" for a piece of textual information or a data file. The SHA-256 algorithm is an example of such a hash. In order to produce a nearly one-of-a-kind 256-bit (32-byte) signature for a text, SHA-256 is used.

4.2. Process of Proposed Model Workflow

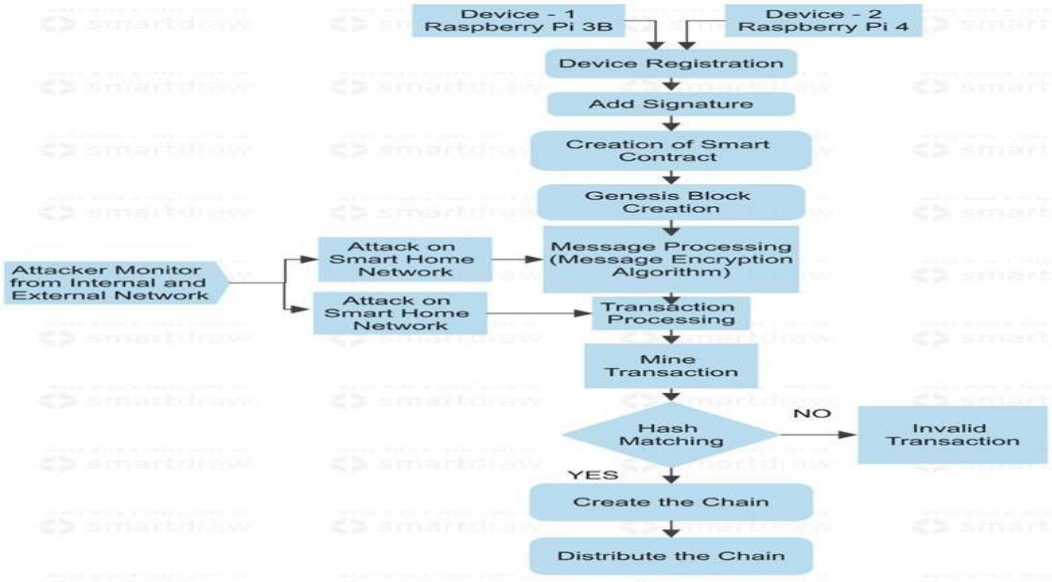

Figure 4: Proposed Model work flow

1. The researcher implemented Base64 encoding within the existing infrastructure to secure messages during network packet analysis. Base64 encoding encrypts and decodes messages simultaneously, enhancing security. However, transaction flooding attacks can disrupt blockchain efficiency by overwhelming legitimate transactions. This can impact blockchain nodes and the distributed network structure, causing additional vulnerabilities. Researchers evaluate performance using transaction, mining, and chain times to assess the effectiveness of this approach.
2. The researchers presented a technique involving Base64, SHA256 hashing, and transaction filtering. SHA256 is a secure hashing algorithm and part of the SHA-2 family, known for its strength. Unlike SHA-1, it remains uncracked. In blockchain networks, denial-of-service attacks can be mitigated by monitoring and filtering transactions. Block producers decide which transactions to include in blocks, preventing spam transactions from cluttering the ledger. This approach helps maintain network efficiency and security.
3. The first thing that 1 and 2 do to begin their conversation is to exchange a message with one another
4. Using a cryptographic hash, verified blocks of transactions can be timestamped. Each block contains a reference to the hash of the previous block, creating an immutable "chain" of records. Altering this chain requires convincing all participating computers that the data in the current block, and all preceding blocks, is accurate—an extremely difficult task due to the distributed and decentralized nature of blockchain technology. This method ensures transparency, security, and trust in transactions across the network.
5. The message will be transmitted at the appropriate time
6. Next, the investigation proceeds to the topic of transmission flow and genesis block creation. This stage involves examining the transmission process and the methods of generating the genesis block. Following this stage, the operation involves checking and matching the hash key, and finally, completing the overall research.

4.3. Transmitting the Information: Transmission Process

Table 1 Transmission Process

Transmission	Block	Verification	Hash	Execution

During the initial device registration, the device's signature acts as its private key,which is also used when sending messages. After registration, the genesis block is created, marking the first block on the blockchain. Devices utilize their private keys to send messages, which are then published. Miners within the network scrutinize these messages to verify their legitimacy and detect any potential third-party insertions. The blockchain ensures that no messages containing harmful code are stored, preventing the device from interacting with others.This topic concludes with a comprehensive overview of Internet of Things protocols, covering physical and data connection layers, network layer, transport layer, and application layer, including a comparison of IoT protocols. It also includes recommended processes and experimental models for creating a functional environment. Attack-based classification, using machine learning analysis, helps distinguish between attack and non-attack transactions. The next chapter will explore denial-of-service attack scenarios on smart home networks using the Ettercap tool, considering transaction evolution components like timing variations in transactions, mining, and chaining. Machine learning-driven analysis using Wireshark identifies attacked and non-attacked transactions for further study

5. Implementation and Result Discussion

This study explores two denial-of-service attack scenarios on a smart home network: one originating from within the home's internal network and the other from an external network. Wireshark, a powerful network traffic analysis tool, enables the examination of traffic between network points, helping identify unknown hosts and their IP addresses. Using the open-source tool Ettercap, packets can be captured and injected back into the network, redirecting and analyzing real-time data using various protocols. Ettercap supports both active and passive deep analysis of network protocols, aiding in comprehensive network and host analysis. In a setup for an internal network attack, Raspberry Pi 3B and Raspberry Pi 4 were utilized, connected to the network via LAN wire and Wi-Fi, respectively. A computer running Kali Linux with Ettercap was employed to conduct denial-of-service attacks on the smart home network. This scenario demonstrates how such attacks can be executed and analyzed within a controlled environment.

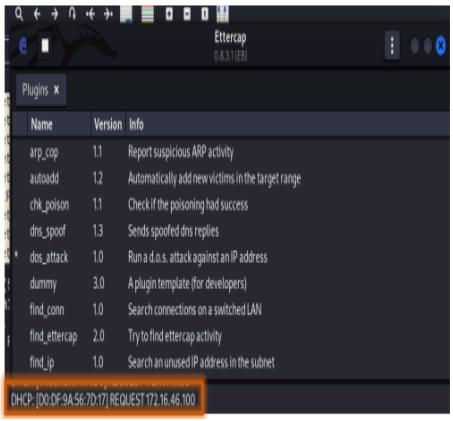

Figure 5: Performing DoS Attack using Ettercap Tool

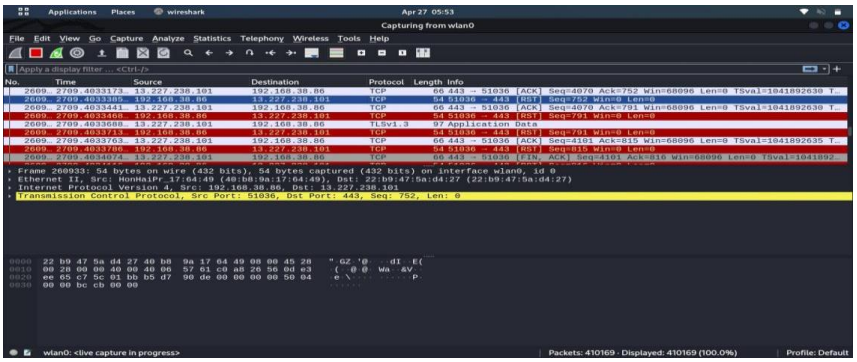

Figure 6:Continues request on the same network indicates the DoS attack.

All devices on one network are scanned using Advanced IP Scanner and Wireshark to pinpoint targets for a denial-of-service attack. The attacker then deploys the Ettercap tool to initiate the assault. For external network attacks, a setup involves Raspberry Pi 3B and 4, along with a Kali Linux computer connected to an external network via LAN and Wi-Fi. The attacker uses Kali Linux with Ettercap to execute the attack. The attacker's machine, on a separate network, uses a router for external connectivity. Advanced IP Scanner and Wireshark identify network vulnerabilities, using ARP and DHCP to pinpoint unknown hosts, with ARP reliably detecting devices regardless of IP settings.

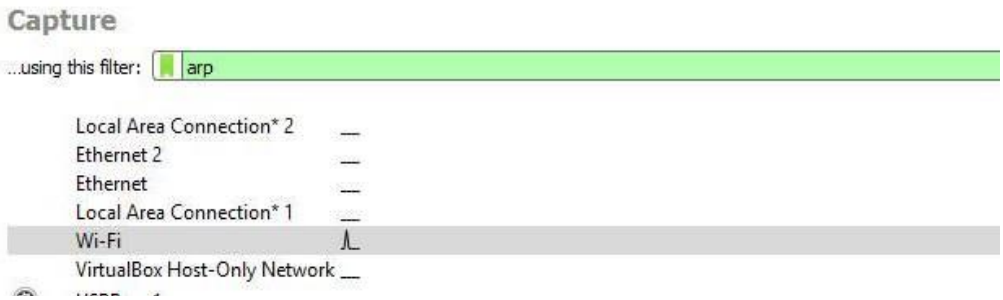

Figure 7: DoS attack on Smart Home from External Network

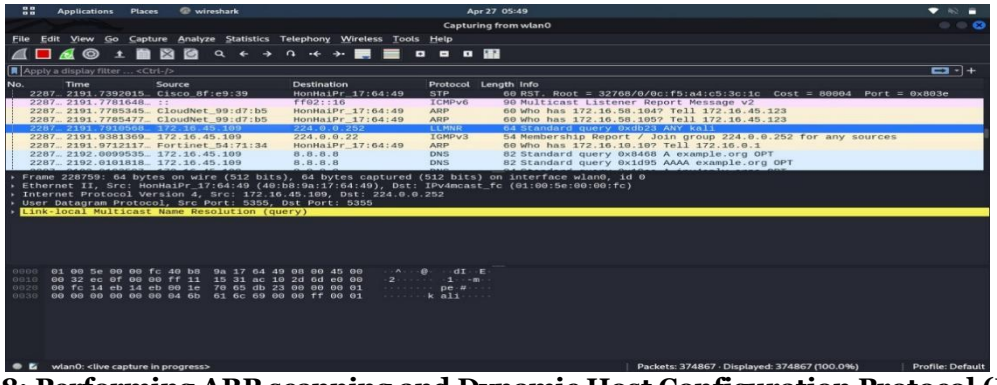

Figure 8: Performing ARP scanning and Dynamic Host Configuration Protocol (DHCP)

requests can be used by Wireshark.

To capture network activity related to ARP, configure Wireshark's capture filter to "ARP" and start the session. The ARP protocol helps identify unknown hosts by obtaining their IP addresses. Ensure the host is online before proceeding. Toggle the Wi-Fi connection on and off using a mobile device to trigger an ARP request when the unknown host reconnects. Analyze the captured frame in Wireshark's Packet Details, focusing on the sender's IP and MAC addresses in the Address Resolution Protocol section. Once identified, the attacker proceeds with the Ettercap tool to launch the denial-of-service attack.

Next, researchers explored mining, transaction processing, and blockchain chaining in the context of crypto currencies like Bitcoin. Transaction processing is a fundamental aspect of Bitcoin, where adding transaction records to the blockchain is known as "mining." This process involves creating blocks of verified transactions using a cryptographic puzzle-solving method. The chaining operation visually represents how blocks are linked together in the blockchain, ensuring the integrity and security of the transaction history.

Raspberry Pi, which serves as a communication device, and Wi-Fi, which is used for connection, are both used in the process of evaluating the performance of the proposed system that the researcher has designed. Within the scope of this investigation, scholars investigate three distinct characteristics of time.

5.1.Transaction Time: The amount of time required to finish a transaction process for a single node is referred to as the transaction time. Specifically, it is referred to as "transaction time."

Table 2. Existing and proposed transaction times for the Raspberry Pi 1 and the Raspberry Pi 2.

Number	Transaction (Time) Existing	Transaction (Time)Proposed
1	0.065	0.076
2	0.06	0.074
3	0.075	0.079
4	0.077	0.087
5	0.067	0.066
6	0.065	0.078
7	0.071	0.083
8	0.071	0.089
Total	0.551	0.632
Average	0.068875	0.079

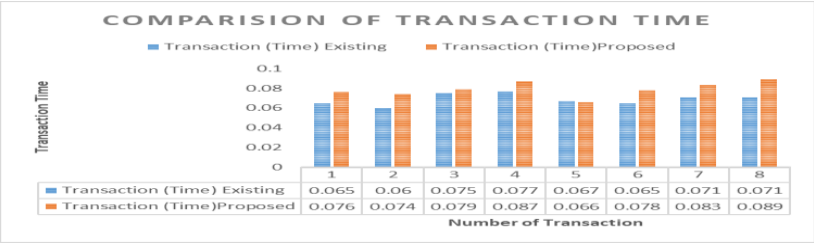

Figure 9. Existing and proposed transaction times for the Raspberry Pi 1 and the Raspberry Pi 2.

5.2.MiningTime: The mine time is a measure of the amount of time that miners will need to validate the block before adding it to the block chain.

Table 3. Existing and proposed mining times for the Raspberry Pi 1 and the Raspberry Pi 2.

Number	Mine (Time) Existing	Mine (Time) Proposed
1	0.665	0.834
2	0.649	0.817
3	0.99	0.98
4	1.093	1.19
5	0.773	0.897
6	0.994	1.092
7	0.092	0.99

8	1.11	1.23
Total	6.366	8.03
Average	0.79575	1.00375

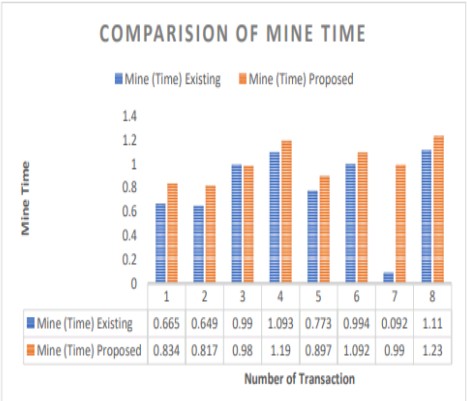

Figure 10 Existing and proposed mining times for the Raspberry Pi 1 and the Raspberry Pi 2.

5.3.Chaining Time:The timing of the chain indicates the amount of time that was required to construct the chain for each of the various appliances.

Table 4. Existing and proposed chaining times for the Raspberry Pi 1 and the Raspberry Pi 2.

Number	Chain (Time) Existing	Chain (Time) Proposed
1	0.099	0.108
2	0.102	0.115
3	0.089	0.098
4	0.099	0.107
5	0.109	0.119
6	0.105	0.111
7	0.092	0.094
8	0.108	0.109
Total	0.803	0.861
Average	0.100375	0.107625

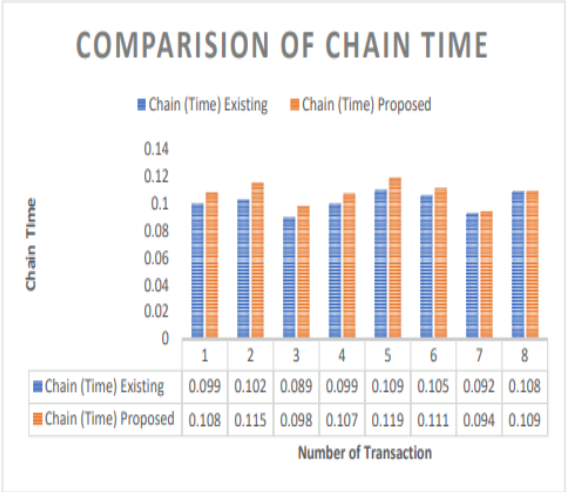

Figure 11.Existing and proposed chaining times for the Raspberry Pi 1 and the Raspberry Pi 2.

5.4. Overall Comparison

Existing Research (Bash 64)				After Adding Bash 64, SHA 256, Filtering			
Number	Transaction (Time)	Mine (Time)	Chain (Time)	Number	Transaction (Time)	Mine (Time)	Chain (Time)
1	0.065	0.665	0.099	1	0.076	0.834	0.108
2	0.06	0.649	0.102	2	0.074	0.817	0.115
3	0.075	0.99	0.089	3	0.079	0.98	0.098
4	0.077	1.093	0.099	4	0.087	1.19	0.107
5	0.067	0.773	0.109	5	0.066	0.897	0.119
6	0.065	0.994	0.105	6	0.078	1.092	0.111
7	0.071	0.092	0.092	7	0.083	0.99	0.094
8	0.071	1.11	0.108	8	0.089	1.23	0.109
Total	0.551	6.366	0.803	Total	0.632	8.03	0.861
Average	0.068875	0.79575	0.100375	Average	0.079	1.00375	0.107625

Figure 12. Comparison of Transaction, Mining and Chaining time

According to the current method, the base 64 algorithm is used for the aim of ensuring safety. A filtering mechanism, BASH 64, and SHA 256 were all components of the methodology that the researcher suggested. Following the addition of these, the amount of time required for transactions, mining, and chaining all increased. It may be concluded that the enhancement of time is indicative of the enhancement of security. In addition, the researcher evaluated the safety of both the current methods and the new ones by using classification strategies that were based on machine learning.

6. Conclusions

The Internet of Things (IoT) is undergoing a transformative phase driven by the need for enhanced connectivity and robust data security. Our research delves deep into bolstering IoT security through a blend of rigorous experimentation and blockchain integration. This approach harnesses cutting-edge methods alongside blockchain's immutable security foundations to fortify IoT ecosystems against inherent vulnerabilities. Continuous experimentation is crucial in the dynamic IoT landscape, enabling ongoing identification of vulnerabilities and evaluation of attack vectors. Ethical hacking, penetration testing, and simulations provide essential insights into evolving threat landscapes, fostering a culture of vigilance and adaptive security measures. Blockchain technology represents a paradigm shift in IoT security, offering distributed, tamper-proof ledgers that counter conventional centralized systems' security flaws. It introduces a new era of trust and accountability through transparency, immutability, and consensus agreements. Smart contracts automate security measures, reducing reliance on human intervention and ensuring compliance transparency. Decentralization inherent in block chain challenges traditional attack vectors by dispersing data across nodes, making breaches more complex. Consensus mechanisms like Proof-of-Work or Proof-of-Stake further enhance security complexity. Decentralized identity management on block chain ensures each IoT device has a unique, verifiable identity, curbing identity spoofing and unauthorized access. This approach is crucial amid escalating device connectivity.

The synergy between experimentation and block chain integration forms a robust defense against evolving IoT threats. Experimentation refines security methods, while block chain offers an immutable foundation of trust and transparency. Experimentation simulates malicious strategies, refining blockchain-driven security mechanisms. Smart contracts' programmability adapts security procedures to real-world threats in near-real time. Collaborative testing aligns with block chain's decentralized ethos, fostering a dynamic, adaptive security ecosystem. Scalability and interoperability remain challenges, necessitating ongoing research and standardization efforts.

7. Future Scope

As we conclude our research on "Enhancing IoT Security through Experimental Methods and Blockchain Integration," it is crucial to outline key avenues for future research and development. The rapid evolution of technology and IoT security demands continuous innovation. Future research should focus on integrating blockchain into IoT ecosystems, optimizing consensus methods, scaling solutions, and exploring alternative blockchain topologies for efficiency and reduced latency. Additionally, leveraging machine learning (ML) and artificial intelligence (AI) can enhance IoT security through anomaly detection, predictive analysis, and adaptive measures. Assessing the impact of quantum computing on existing IoT security measures and developing quantum-resistant cryptographic methods are also essential. Tailored security solutions for edge devices addressing data processing, storage, and transfer challenges are critical. Research into interoperability standards for secure communication among diverse IoT devices is necessary, as is implementing privacy-preserving strategies to protect data and comply with evolving privacy regulations.

Studying decentralized governance models for IoT blockchain networks will help ensure integrity and stability. Finally, identifying security risks and developing innovative solutions for IoT devices integrated with 5G networks will be essential. These areas are crucial for enhancing IoT systems' security and resilience, addressing the complex challenges posed by emerging technologies.

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