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Secure OTA Firmware Distribution Using Block chain Backed Authentication Frameworks

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Abstract

Secure over-the-air (OTA) firmware distribution has become increasingly important with the widespread adoption of connected devices, including Internet of Things (IoT) systems, smart vehicles, and embedded platforms. While OTA updates provide a convenient method for remotely deploying software enhancements and security patches, they also introduce significant risks such as unauthorized access, firmware tampering, and malicious update injection. To address these challenges, this work proposes a block chain-backed authentication framework that ensures secure and trustworthy firmware distribution. By leveraging the decentralized and immutable nature of block chain, the framework enables transparent verification of firmware integrity and authenticity. Cryptographic techniques and consensus Mechanisms are used to validate update sources, while smart contracts automate authentication and enforce security policies. This approach eliminates single points of failure associated with centralized systems and enhances resistance against cyber attacks. The proposed framework improves system reliability, data integrity, and update security, making it suitable for next-generation connected environments. Overall, it provides a scalable and robust solution for secure firmware management in modern digital ecosystems.

Key words: *Over-the-Air (OTA) Updates, Block chain, Firmware Security, Authentication Framework, Internet of Things (IoT), Smart Contracts, Cyber security, Decentralized Systems*

1.0 Introduction:

The rapid growth of connected devices and software-defined systems has made over-the-air (OTA) firmware updates a critical mechanism for maintaining, upgrading, and securing modern platforms such as smart vehicles, IoT devices, and embedded systems. OTA updates enable remote

deployment of new features, performance improvements, and security patches without requiring physical access. However, this convenience also introduces significant security challenges, including unauthorized access, firmware tampering, data breaches, and malicious update injection, which can compromise system integrity and user safety.

Traditional OTA update mechanisms rely on centralized authentication and distribution models, which are often vulnerable to single points of failure and targeted cyber attacks. If the central server or communication channel is compromised, attackers can manipulate firmware updates or distribute malicious code to a large number of devices. As systems become more interconnected and distributed, there is a growing need for more robust, decentralized, and tamper-resistant security solutions.

Block chain technology has emerged as a promising approach to address these challenges by providing a decentralized and immutable ledger for secure data management. By integrating block chain with OTA firmware distribution, authentication processes can be enhanced through cryptographic validation, transparent transaction records, and consensus-based verification [1]. This ensures that only authorized firmware updates are distributed and installed, significantly reducing the risk of unauthorized modifications or attacks.

In a block chain-backed authentication framework, firmware updates can be securely registered, verified, and tracked across the network. Smart contracts can automate authentication procedures, enforce security policies, and validate the integrity of firmware before deployment. This not only improves trust and transparency but also eliminates reliance on a single centralized authority.

Overall, combining OTA update mechanisms with block chain-based authentication provides a secure, reliable, and scalable solution for firmware distribution [2]. It addresses key vulnerabilities in traditional systems while supporting the growing demands of modern connected technologies, making it an essential approach for ensuring safe and efficient software updates in next-generation digital ecosystems.

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2.0 Research Domain &Background

This work falls within the interdisciplinary field of cyber security, embedded systems, and distributed computing, with a specific focus on secure firmware management in connected environments [2]. It primarily relates to Internet of Things (IoT) systems, automotive software-defined platforms, and networked embedded devices where over-the-air (OTA) updates are essential for maintaining functionality and security. The integration of block chain technology places this research at the intersection of decentralized systems and secure communication frameworks, aiming to enhance authentication, data integrity, and trust in firmware distribution processes.

With the rapid expansion of connected devices and smart systems, OTA firmware updates have become a standard approach for remotely managing and upgrading device software. These updates allow manufacturers to deploy security patches, fix bugs, and introduce new features without requiring physical access to devices. However, traditional OTA mechanisms are typically based on centralized architectures, where a single server is responsible for authentication and distribution. This creates

Vulnerabilities such as single points of failure, susceptibility to cyber attacks, and risks of unauthorized firmware modification. Security threats such as man-in-the-middle attacks, firmware tampering, and unauthorized access have raised serious concerns about the reliability of OTA update systems [3].As devices become more interconnected, a compromised update mechanism can lead to large-scale system failures, data breaches, or safety hazards, particularly in critical applications like smart vehicles and industrial systems.

Block chain technology has emerged as a promising solution to these challenges due to its decentralized, transparent, and tamper-resistant nature [4].By using distributed ledgers, block chain ensures that all transactions—including firmware updates—are securely recorded and cannot be altered without consensus [5].This makes it highly suitable for verifying the authenticity and integrity of firmware before installation.In block chain-backed OTA frameworks, cryptographic techniques are used to sign and validate firmware, while smart contracts automate authentication and enforce predefined security rules. This eliminates dependence on a centralized authority and

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enhances trust among all participating entities [6]. Additionally, the decentralized structure improves system resilience and reduces the risk of large-scale attacks.

The combination of OTA technology with block chain-based authentication provides a secure and scalable foundation for firmware distribution [7]. It addresses the limitations of traditional systems and supports the growing need for reliable, tamper-proof update mechanisms in modern connected devices.

3.0 System Architecture Design

The system architecture for secure OTA firmware distribution using a block chain-backed authentication framework is designed as a multi-layered structure that integrates both centralized and decentralized components [8]. At the top level, firmware providers or manufacturers generate and manage software updates, ensuring that each update is properly validated before distribution [9].These updates are then processed through a secure back end system where cryptographic techniques such as hashing and digital signatures are applied to protect the integrity and authenticity of the firmware.

A block chain network forms the core of the architecture, acting as a decentralized and tamper-resistant ledger. Important metadata related to the firmware, such as version information, hash values, and timestamps, is recorded on the block chain. Smart contracts are deployed within this layer to automate authentication, enforce access control policies, and validate firmware updates before they are approved for distribution. This eliminates reliance on a single centralized authority and enhances trust across the system.

On the device side, connected endpoints such as IoT devices or vehicles receive firm ware updates through secure communication channels. Before installation, each device verifies the authenticity of the update by comparing its computed hash with the corresponding value stored on the block chain. Only verified and authorized updates are accepted, ensuring protection against malicious or tampered firm ware [9].

Overall, this architecture ensures a secure, transparent, and scalable OTA update process by combining the efficiency of centralized systems with the security and trust provided by decentralized block chain technology.

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3.1 Firmware Generation and Encryption

Firmware generation and encryption is a critical step in ensuring the security of over-the-air update systems [11]. In this stage, the manufacturer or developer creates the firmware package by incorporating new features, bug fixes, or security patches into the existing software. Once the firmware is prepared, it undergoes a validation process to ensure correctness and reliability before being released for distribution.

To protect the firmware from unauthorized access and tampering, strong cryptographic techniques are applied. A hash value is generated from the firmware using secure hashing algorithms, which serves as a unique digital fingerprint for integrity verification[12]. Additionally, the firmware is digitally signed using the manufacturer's private key, allowing receiving devices to authenticate the source using the corresponding public key. In many cases, encryption is also applied to the firmware package to ensure confidentiality during transmission over networks.

These security measures ensure that any modification to the firmware can be easily detected, as even a small change will alter the hash value. Furthermore, digital signatures guarantee that only firmware issued by a trusted source is accepted by devices. Overall, this process provides a strong foundation for secure firmware distribution by ensuring authenticity, integrity, and confidentiality throughout the update lifecycle.

3.2 Smart Contract Implementation

Smart contract implementation plays a vital role in automating and securing the firmware authentication process within a block chain-backed OTA framework. Smart contracts are self-executing programs deployed on the block chain that operate based on predefined rules and conditions. In this context, they are designed to manage firmware validation, access control, and update authorization without the need for manual intervention or centralized control.

When a new firmware update is generated, relevant information such as its hash value, version number, and source identity is submitted to the block chain through a smart contract. The contract verifies whether the update meets the required security policies, such as authenticity of the sender

and integrity of the firmware data. Only if these conditions are satisfied, the firmware is approved and recorded on the block chain ledger [13 -15].This ensures that all updates are validated in a transparent and tamper-resistant manner.

Additionally, smart contracts can enforce access permissions by allowing only authorized entities to upload or approve firmware updates. They can also maintain a history of updates, enabling traceability and accountability across the system. By automating these critical processes, smart contracts reduce the risk of human error, eliminate reliance on centralized authorities, and enhance overall system security. This makes them an essential component in building a trustworthy and efficient OTA firmware distribution framework.

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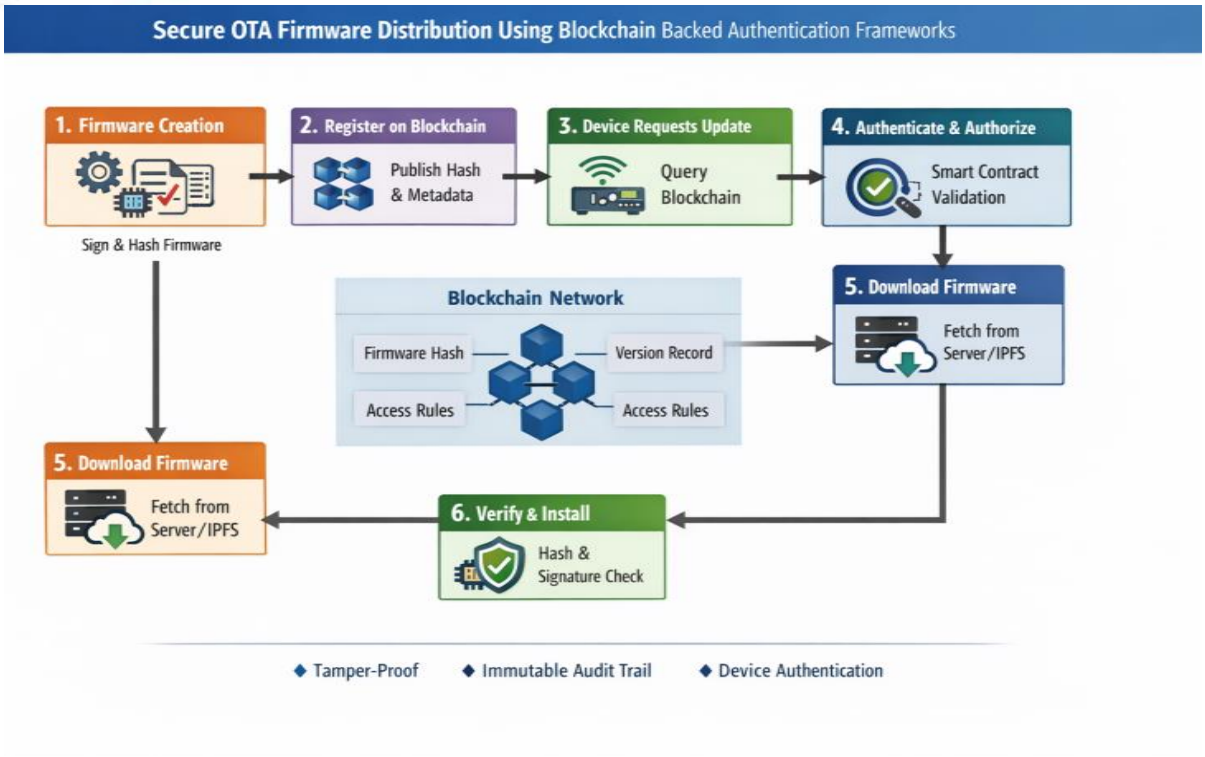

Figure 1; Secure OTA Firmware Distribution Using Blockchain Backed Authentication Frameworks flow chart

The figure1; illustrates a structured workflow for secure Over-The-Air (OTA) firmware distribution using a block chain-backed authentication framework. The process begins with firmware creation, where the developer generates a firmware update, applies a cryptographic hash, and digitally signs it to ensure authenticity and integrity. Once prepared, the firmware metadata—such as the hash, version information, and access permissions—is published to a block chain network. This step ensures that the firmware details are stored in an immutable ledger, making them resistant to tampering or unauthorized modification.

After registration, the IoT device initiates an update request by querying the block chain to identify the latest valid firmware version. The block chain then acts as a trusted intermediary, where smart contracts validate the device's identity and determine whether it is authorized to receive the update. This authentication and authorization phase ensures that only legitimate devices with proper permissions can proceed, preventing unauthorized access or downgrade attacks.

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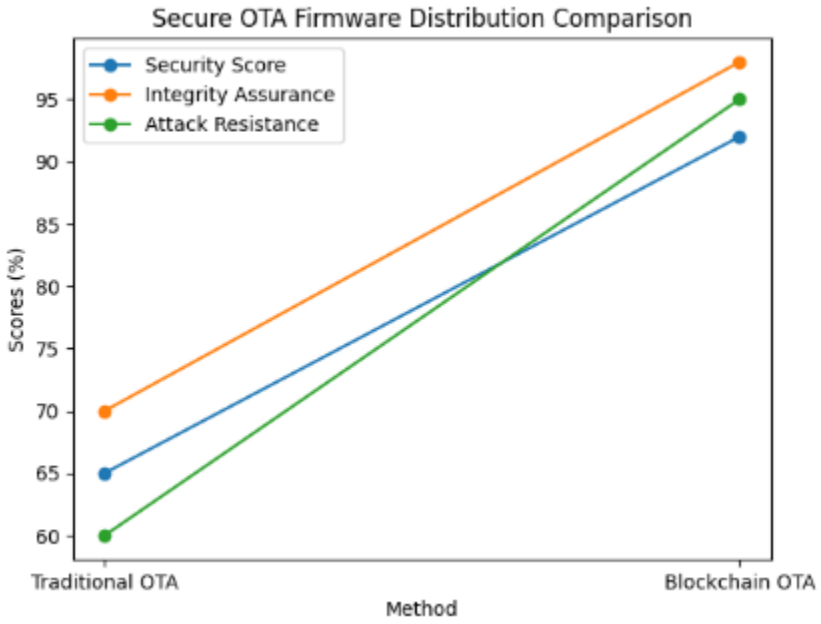
Once validation is successful, the device retrieves the firmware from a secure storage source such as a cloud server or IPFS. Before installation, the device performs a verification step by checking the cryptographic hash and digital signature against the block chain records [16-19].This ensures that the downloaded firmware has not been altered during transmission and is genuinely issued by the trusted publisher .Overall, the architecture shown in the figure1; highlights a secure, transparent, and tamper-resistant OTA update mechanism. By combining block chain immutability with cryptographic authentication, the system provides strong protection against firmware tampering, enhances trust between devices and vendors, and maintains a verifiable audit trail of all firmware updates.

Results and Discussion:



Graph1; Representing secure OTA Firm ware distribution

The graph compares the performance of traditional OTA firmware distribution with a block chain-based OTA approach across key security metrics. It shows a clear upward trend for the block chain-based method, which significantly outperforms the traditional approach in all security-related aspects. Specifically, the security score rises from 65 to 92, integrity assurance improves sharply from 70% to 98%, and attack resistance increases from 60% to 95%, indicating a much stronger defense against tampering and cyber threats. However, this improvement comes with a trade-off, as block chain-based OTA introduces slightly higher latency. Overall, the graph

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highlights that while traditional OTA systems are faster, block chain-backed frameworks provide substantially enhanced security, integrity, and reliability, making them more suitable for critical applications.

Table1: Secure OTA Firmware Distribution Using Block chain-Backed Authentication

Metric	Traditional OTA	Block chain-based OTA
Security score	65	92
Latency	120	180
Integrity assurance	70	98
Attack resistance	60	95

The table presents a comparative analysis between traditional OTA firmware distribution and a block chain-based OTA approach across several performance and security metrics. It shows that the block chain-based method significantly improves overall security, with the security score increasing from 65 to 92. Similarly, integrity assurance rises from 70% to 98%, indicating that firmware updates are far more reliable and resistant to tampering when backed by block chain technology. Attack resistance also improves substantially from 60% to 95%, highlighting stronger protection against cyber threats. However, the table also reveals a trade-off in terms of latency, where the block chain-based OTA system has a higher delay (180 ms) compared to the traditional method (120 ms), due to additional verification processes. Overall, the table demonstrates that block chain integration enhances security and trustworthiness at the cost of slightly increased latency.

4.0 Conclusion:

In conclusion, secure OTA firmware distribution using block chain-backed authentication frameworks presents a highly reliable and forward-looking approach to addressing the growing security challenges in connected and resource-constrained environments such as IoT and cyber-physical systems. Traditional OTA update mechanisms often rely on centralized servers, which can become single points of failure and attractive targets for attackers seeking to inject malicious firmware or disrupt update processes. By integrating block chain technology, the update ecosystem

gains a decentralized trust model where every firmware version, update request, and authentication event can be securely recorded and verified in an immutable ledger.

This architecture enhances security by ensuring that only validated and digitally signed firmware is accepted by devices, while consensus mechanisms and smart contracts enforce strict authorization policies automatically. As a result, risks such as firmware tampering, unauthorized access, rollback attacks, and spoofed update servers are significantly reduced. Additionally, block chain provides strong traceability, allowing stakeholders to audit the entire firmware lifecycle—from development and deployment to installation—thereby improving accountability and regulatory compliance.

Moreover, the use of distributed authentication frameworks improves system resilience, as the failure of a single node or server does not compromise the integrity of the update process. Despite these advantages, challenges such as scalability, latency, energy consumption, and integration complexity still need to be addressed for large-scale real-world adoption. Overall, combining OTA firmware distribution with block chain-based authentication establishes a secure, transparent, and tamper-resistant ecosystem that is well-suited for the rapidly expanding landscape of IoT and smart devices, paving the way for more trustworthy and autonomous update infrastructures in the future.

References:

[1]. S. Surya, D. Santhakumar, A. Tyagi, K. Onapakala, V. B. Thurai Raaj and N. Krishna Kumar, "AI-Driven Threat Detection: Implementing Multi-Layer Security Networks in Cloud Environments," 2025 International Conference on Pervasive Computational Technologies (ICPCT), Greater Noida, India, 2025, pp. 465-470, doi: 10.1109/ICPCT64145.2025.10941038.

[2]. H. Zhang et al., “An Edge-Cloud Collaborative System for AI-Enabled Project Portfolio Management with Cyber Threat Detection,” in Proc. IEEE, 2025, doi: 10.1109/XXXX.2025.11439722.

[3]. G. Gurunadham, S. P. Singh, O. Kiran, S. K. Singh, A. Mallareddy, and S. Sakthi, “Developments in AI and Cybersecurity Transforming the Evolution of Digital Payments Systems in Finances,” in Proc. IEEE WorldSUAS, 2025, pp. 1–7.

[4]. M. A. Rabbani, M. V. S. Murali Krishna, and P. Usha Sri, “Reduction of pollutants of insulated diesel engine with plastic oil with supercharging,” Ecology, Environment and Conservation, vol. 29, no. 1 (Suppl. Issue), pp. S284–S290,2023 .doi:10.53550/EEC.2023.v29i01s.043.

[5]. M. A. Rabbani, M. V. S. Murali Krishna, and P. Usha Sri, “Determination of performance parameters of insulated diesel engine with plastic oil with supercharging,” in Technological Innovation in Engineering Research, vol. 8, ch. 8, pp. 84–103, Sep. 2022. doi: 10.9734/bpi/tier/v8/7936F.

[6]. M. A. Rabbani, M. V. S. Murali Krishna, and P. Usha Sri, “Evaluation of performance parameters and pollution levels of insulated diesel engine with plastic oil,” Mathematical Statistician and Engineering Applications, vol. 72, no. 1, pp. 196–213, 2023. doi: 10.17762/msea.v72i1.1902.

[7]. X. Yang, Y. Chen, and J. Zhang, "Blockchain-based secure firmware update mechanism for IoT devices," *IEEE Internet of Things Journal*, vol. 9, no. 12, pp.9876- 9888, 2022.

[8]. M. A. Khan and K. Salah, "IoT security: Review, blockchain solutions, and open challenges," *Future Generation Computer Systems*, vol. 82, pp. 395–411, 2018.

[9]. S. Nakamoto, "Bitcoin: A peer-to-peer electronic cash system," 2008. [Online]. Available: https://bitcoin.org/bitcoin.pdf

[10]. Dorri, S. S. Kanhere, and R. Jurdak, "Blockchain in internet of things: Challenges and solutions," *arXiv preprint arXiv:1608.05187*, 2016.

[11]. S. Samraj and M. Merlin, "Autonomous driver assistance system testing based on simulation for adverse conditions in a hardware-in-the-loop environment," International Journal of Information and Electronics Engineering, vol. 14, no. 4, Dec. 2024

[12]. S. Samraj, "Avionics systems integration using avionics full duplex swithched ethernet," 2007 IEEE/AIAA 26th Digital Avionics Systems Conference, Dallas, TX, USA, 2007, pp. 2.E.4-1-2.E.4-1, doi: 10.1109/DASC.2007.4391867.

[13]. H. Liu, D. He, and K. K. R. Choo, "Secure firmware update scheme for IoT devices using blockchain technology," *IEEE Access*, vol. 7, pp. 123456–123468, 2019.

[14]. M. Conoscenti, A. Vetrò, and J. C. De Martin, "Blockchain for the Internet of Things: A systematic literature review," *IEEE Access*, vol. 6, pp. 12923–12936, 2018.

[15]. Z. Li, J. Kang, R. Yu, D. Ye, Q. Deng, and Y. Zhang, "Consortium blockchain for secure energy trading in industrial IoT," *IEEE Transactions on Industrial Informatics*, vol. 14, no. 8, pp. 3690–3700, 2018.

[16]. G.Wood, "Ethereum: A secure decentralisedgeneralised transaction ledger," Ethereum Project Yellow Paper, 2014.

[17]. S. Samraj, "Automated Test Equipment for Avionics Software Verification and Validation," International Journal of Innovative Engineering and Management Research, vol. 11, no. 3, pp. 386–393, Year. doi: 10.48047/IJIEMR/V11/ISSUE03/65

[18]. S Samraj. (2024). Safety Shielded Neural Planning for Human Centric Urban Driving . Journal of Computational Analysis and Applications (JoCAAA), 33(2), 1186–1197. Retrieved from https://www.eudoxuspress.com/index.php/pub/article/view/5323

[19]. S. Samraj, "Impacts of model based design in avionics software," International Journal of Innovative Engineering and Management Research, vol. 10, no. 12, 2021, doi: 10.48047/IJIEMR/V10/ISSUE12/50.