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Enabling blockchain-IoT convergence for industrial revolution 4.0 innovation: A critical review

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Abstract: The Fourth Industrial Revolution (4IR) has revolutionised global interactions through the Internet of Things (IoT), connecting over 40 billion devices by 2030, raising significant security, protection, and privacy concerns. Blockchain technology offers a decentralised, secure, and transparent solution for data sharing and storage, leveraging its core characteristics—immutability, data integrity, transparency, and consensus—to enable tamper-proof records, real-time tracking, and secure data sharing in supply chain management and healthcare. Despite high implementation costs, blockchain-IoT convergence promises transformative benefits, including enhanced efficiency, reduced costs, and improved security. This study provides an in-depth analysis of blockchain's applications in IoT, highlighting its potential to enhance data security and privacy, improve supply chain management, facilitate secure healthcare data exchange, and enable real-time tracking and monitoring. Future research directions include scalability solutions, interoperability protocols, regulatory frameworks, blockchain-based supply chain management, and quantum-resistant blockchain networks.
Keywords: *Datafication, Fourth industrial revolution (4IR), Healthcare, Internet of things (IoT), Security.*

1. Introduction

The Internet of Things (IoT) is an evolving and innovative technology that is becoming increasingly important due to its potential impact and role in our everyday lives to build smarter societies in the Fourth Industrial Revolution (4IR). In 1999, Kevin Ashton coined the term "Internet of Things" (IoT) and described the ability of connected sensors to bring new services to the Internet. At that time, 2025 years ago, it was the scope of the Internet of Things (IoT). On the other hand, blockchain (BC) is a decentralized, distributed ledger technology that enables secure, transparent, and tamper-proof data management. Interest in blockchain technology began significantly in 2008 and has been growing continuously. Blockchain technology development has created an impact, especially in terms of tracking, coordinating, executing, and storing information from many devices and providing data transparency, security, and provenance. Secure and traceable transactions can be processed and executed by using blockchain technology without third-party involvement. Furthermore, smart and digital devices have become smarter and smaller in size, which is being implemented in various Internet of Things (IoT), such as smart home appliances, agriculture, infrastructure management, healthcare, defence, intelligence, education, and supply chain management. IoT devices can collect data both confidentially and privately, and there are many security-related threats and weaknesses that aim to realise today's IoT infrastructure. This high generation of data is being regarded as the datafication of societies. In addition, IoT solutions in usage are expensive due to the costs associated with the hardware infrastructure and maintenance. The scalability and widespread usage of the IoT raise serious protection and security issues. Further, existing integration strategies for providing protection, security, and information processing require high-specified servers with centralised network architectures supporting the IoT. In short, the failure of a centralised server increases the risk of the entire network

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infrastructure. For instance, a denial of service (DOS) successful attack on a centralised server can result in a single point of failure. Therefore, a centralised approach can be risky for the development of applications on the IoT-based platform. These challenges require a fundamental rethinking of the structure of the IoT.

Interestingly, blockchain technology is one of the best options as it is a secure, decentralised ledger maintenance system that can support the Internet of Things. Blockchain innovation has become the mainstream standard and is broadly utilised in different businesses, such as agriculture and finance. From a high-level perspective, the blockchain uses a large amount of encryption to provide "untrusty" functionality. There is no centralised authorisation network so that data transaction nodes can achieve faster coordination. Serverless infrastructure is built using the unique capabilities of the BC. This research argues that the integration of internet of things (IoT) with blockchain (BC) results in an interesting combination of blockchain IoT that will eliminate several issues and improve fault tolerance. Furthermore, it can also prevent the bottleneck inherent in the growing IoT that relies on centralised servers. As blockchain is based on a distributed peer-to-peer network offering a decentralised architecture that enables IoT device autonomy, end-to-end communication can run services without running a central server. In addition, in the blockchain network, the participants can verify the integrity of the data being sent and the sender's identity. There is no single entity to control the blockchain content; the internet of things (IoT) information and logs stored in the blockchain (BC) are permanent, ensuring transparency, security, privacy, and traceability. A reliable internet of things (IoT) is a major contribution to blockchain. The blockchain provides logical functions through smart contracts and can treat internet of things (IoT) interactions as transactions [7-11, 18-20].

Figure 1.
A model of the blockchain technology.

2. Literature Review

Blockchain is evolving to become a platform for securing Internet of Things (IoT) ecosystems. Still, challenges remain. The purpose of this literature review is to highlight the applicability of blockchain as a medium to secure IoT ecosystems. A two-dimensional framework anchored on (1) IoT layers and (2) security goals is used to organize the existent IoT security threats and their corresponding countermeasures identified in the reviewed literature. The framework helped in mapping the IoT security threats with the inherent features of blockchain and accentuated their prominence to IoT security [1]. This study also includes a taxonomy that mentions the aspects and areas in the healthcare domain incorporating the traditional system with the integration of IoT and blockchain to provide transparency, security, privacy, and immutability. This study also includes the incorporation of related sensors and platforms of blockchain, the objective focus of selected studies, and future directions by incorporating IoT and blockchain in the healthcare domain. This study will help researchers who want to work with IoT and blockchain technology integration in the healthcare domain [2]. This paper provides the opportunities brought about by the Internet of Things, machine learning, Global Positioning system, and blockchain in various waste management techniques, their application scenarios, real-time tracing and tracking of waste, reliable channelization and compliance with waste treatment, efficient waste resource management, protection of waste management documentation, and fleet management. Based on the conducted review, this paper presents open challenges associated with waste management techniques that act as future research directions. Waste bin placement and its security, internet connectivity with waste management components, transportation of waste, and waste disposal techniques are the main categories of challenges associated with waste management. This paper also provides a comparison of the presented review with other published review papers [3]. The research findings show that the blockchain can guarantee fundamental security requirements such as authentication, privacy-preserving, confidentiality, integrity, and access control. Finally, open issues and challenges related to the combination of blockchain and Internet of Drones (IoD) technologies are discussed [4]. In this chapter, we explore the potential role of blockchain technology in addressing the challenges of IoT security and privacy. We begin by examining the fundamental characteristics of blockchain technology and how it can be applied in IoT systems. We then delve into several use cases showing how blockchain technology can enhance the security and privacy of IoT systems, such as SCM, healthcare, and energy management. Finally, we discuss the challenges and limitations of using blockchain technology in IoT, as well as potential future directions for research and development in this area. Overall, this chapter provides insights into the potential benefits of using blockchain technology in IoT and highlights the importance of considering security and privacy in the design of IoT systems [5]. Blockchain (BC) IoT-based applications ensure security, confidentiality, access control, scalability, privacy processes, and authentication to improve processes and performance. This article studies such similarities and analyses to solve blockchain BC-based IoT-related problems, technical limitations, challenges, and privacy issues blockchain (BC) can bring to the internet of things (IoT). This article also presents the use of the blockchain (BC) method in IoT, blockchain (BC) IoT-based application domains, its research challenges, and future directions [6]. The main objective of this work is to conduct a systematic review of the literature on internet of things (IoT) technology and the application of blockchain technology. For this, exhaustive research was carried out, and when analysing the documentation of aspects such as the area of study on the integration of technologies, most used consensus techniques and the benefits of technology were considered. The results of the study indicated blockchain technology with IoT being implemented in companies and industries, with the most consensus techniques being POW and POS, while the benefits are manifested in terms of improved scalability and security of companies [12]. This study utilized the PRISMA review protocol. Two main databases, Scopus and IEEE, were used. Findings show that 20 research papers on security and privacy in blockchain were published between 2020 and 2023 and involved 13 different journals. There are 13 various application areas that are relevant to the security and privacy aspects of blockchain, where the Internet of Things claims the largest portion of representation. The thematic analysis identified seven main themes related to challenges in blockchain security and privacy. The findings also highlight that security and privacy are among the future works that should be focused on in blockchain technology. In conclusion, the article suggests that the integration of blockchain with IoT can improve security and proposes the development of a framework that enforces privacy on the blockchain [13]. This study shows that security, transparency, and efficiency are the top three motivations for adopting these platforms. The energy, agriculture, health, construction, manufacturing, and supply chain domains are the top domains. The most adopted technologies are cloud computing, fog computing, telecommunications, and edge computing. While there are several benefits to using hybrid blockchains, there are also several challenges reported in this study [14]. The article presents an analytical overview of the issues of integrating blockchain technology into the Internet of Things [17]. The results of the analytical review make it possible to substantiate the purpose and advantages of integrating blockchain technology into the Internet of Things, as well as to summarize the main issues and substantiate a number of tasks for relevant and progressive scientific research in the field of modern information systems. [15].

3. Benefits of Blockchain Technology

3.1. Immutability

Since blockchain technology promotes immutability, recorded data cannot be removed or replaced. As a result, the blockchain stops data manipulation inside the network. Immutability is not a feature of traditional data. To guarantee correct application operation, the traditional database employs CRUD (create, read, update, and delete) at the primary level. The CRUD paradigm makes data erasure and replacement simple. Such information may be vulnerable to hacking by outside parties or rogue administrators.

3.2. Transparency

Any network user can validate data entered into the blockchain because it is decentralized. The public can therefore have faith in the network. A typical database, on the other hand, lacks transparency and is centralized. A limited set of data is made available by the administration, and users are unable to confirm information at any time. However, they are still unable to confirm the information.

3.3. Censorship

Since blockchain technology is not governed by a single entity, it is unaffected by censorship. As a result, the network cannot be stopped by any one entity, even governments. In contrast, traditional databases have centralized authorities that control network operations and have the power to restrict content. Banks, for example, have the authority to suspend users' accounts.

3.4. Traceability

Blockchain makes it simple to trace network changes by creating an irreversible audit trail.

There is no guarantee of a persistent trail because the typical database is neither visible nor unchangeable [16].

4. Drawbacks of Blockchain Technology

4.1. Speed and Performance

Because blockchain technology performs more operations than traditional databases, blockchain is significantly slower. It first verifies signatures, which entails cryptographically signing transactions. Additionally, blockchain uses a consensus process to verify transactions. Proof of work is one of the consensus methods with a poor transaction throughput. Lastly, there is redundancy, in which every node in the network must be essential to confirming and storing every transaction.

4.2. High Implementation Cost

Blockchain is more expensive than a conventional database. Incorporating blockchain into a business's operations also requires careful strategy and implementation.

4.3. Data Modification

Blockchain technology does not allow easy modification of data once recorded, and it requires rewriting the codes in all of the blocks, which is time-consuming and expensive. The downside of this feature is that it is hard to correct a mistake or make any necessary adjustments.

Not every need can be satisfied by a single solution, and blockchain technology is no exception. The industry is abuzz with talk about Web3 and blockchain, and many companies are trying to make the transition from Web 2.0 to Web3, but this is not a simple "lift-and-shift" kind of solution. Businesses should plan their development or Web3 migration appropriately after doing a thorough study and due diligence to see whether blockchain technology meets their demands [16].

5. Conclusion

The integration of blockchain technology and the Internet of Things (IoT) has transformative potential. Our review of existing literature highlights the benefits, drawbacks, and challenges of this convergence, and indeed, the future directions required.

The key Findings:

1) Enhanced security: Blockchain's decentralised architecture and cryptographic algorithms secure IoT data.

2) Improved transparency: Blockchain's immutable ledger enables real-time tracking and monitoring.

3) Efficient data management: Blockchain-based IoT networks optimise data storage and processing.

4) Scalability limitations: Current blockchain infrastructure struggles to support large-scale IoT deployments.

5.1. Future Research Directions

This paper argues on the need to prioritise some innovative activities as the research direction in the future. These are:

1) Scalability Solutions: Investigate novel consensus algorithms, sharing, and off-chain transactions.

2) Interoperability Protocols: Develop standards for seamless communication between blockchain and IoT devices.

3) Regulatory Frameworks: Establish guidelines for data privacy, security, and intellectual property.

4) Blockchain-based Supply Chain Management: Explore applications in inventory tracking, authentication, and logistics.

5) Quantum-Resistant Blockchain Networks: Develop cryptographic techniques resilient to quantum computing threats.

5.2. Recommendations: The Following are Also Recommended

1) Implement hybrid blockchain architectures combining public and private networks.

2) Leverage edge computing for real-time data processing and analysis.

3) Develop IoT-specific blockchain platforms with optimised resource utilisation.

4) Foster collaboration between industry stakeholders, academia, and regulatory bodies.

5) Conduct thorough risk assessments and security audits.

By addressing these research directions and recommendations, we can unlock the full potential of Blockchain-IoT enabled systems, driving innovation and growth across industries.

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References

[1] El-Masri, M., Hussain, E.M.A., "Blockchain as a mean to secure Internet of Things ecosystems – a systematic literature review", Journal of Enterprise Information Management, Vol. 34, No. 5, pp. 1371-1405, 2021, https://doi.org/10.1108/JEIM-12-2020-0533.

[2] Zainab, U. K., at al., "Integration of Internet of Things and blockchain technology in healthcare domain: A systematic literature review", International Journal of Communication Systems, Volume 36, Issue 16, 2023, https://onlinelibrary.wiley.com/doi/epdf/10.1002/dac.5582.

[3] Singh, S., Chhabra, R. & Arora, J., "A Systematic Review of Waste Management Solutions Using Machine Learning, Internet of Things and Blockchain Technologies: State-of-Art, Methodologies, and Challenges", Arch Computat Methods Eng 31, Pp. 1255–1276, 2024, https://doi.org/10.1007/s11831-023-10008-z.

[4] Harbi, Y., Medani, K., Gherbi, C. et al., "A Systematic Literature Review of Blockchain Technology for Internet of Drones Security", Arab J Sci Eng **48**, Pp. 1053–1074, 2023, https://doi.org/10.1007/s13369-022-07380-6.

[5] Pramod R. G., Satish R. J., Jaime L., Karishma A., "The Role of Blockchain Technology in the Internet of Things", Internet of Things, ISBN: 9781003282945, Pp. 54, 2024.

[6] Junaid, N., Q., et al., "Blockchain applications for the Internet of Things: Systematic review and challenges", Microprocessors and Microsystems, Science Direct, 94, 2022, https://www.elsevier.com/locate/micpro.

[7] Kevin. Ashton, That 'Internet of Things' thing, RFID Journal Vol. 22, No. 7, Pp. 97–114, 2009.

[8] Fadele A. A., Mazliza O., Ibrahim A. T. H., Faiz A., "Internet of Things security: A survey.", Journal of Network and Computer Applications Vol. 88, Pp. 10–28, 2017, https://doi.org/10.1016/j. jnca.2017.04.002.

[9] Borgohain, Tuhin, Uday K., Sugata S., "Survey of security and privacy issues of internet of things." arXiv preprint arXiv:1501.02211, 2015, htt ps://doi.org/10.48550/arXiv.1501.02211.

[10] Pureswaran V, Sanjay P., Sumabala N., Paul B., "Empowering the edge-practical insights on a decentralized internet of things.", IBM Institute for Business, Vol. 17, 2015.

[11] Nick. Szabo, Formalizing and securing relationships on public networks, First Monday Vol. 2, No. 9, 1997, https://doi.org/10.5210/fm.v2i9.548.

[12] Alfredo, D. V., et al., "Blockchain Technology Aimed at Solving Internet of Things Challenges: A Systematic Literature Review", Volume 12, Issue 2, pages 757-768, TEM Journal, DOI: 10.18421/TEM122-20, May 2023.

[13] Noraini M. B., Quah W. B., "Blockchain for Security and Privacy: A Systematic Literature Review", Applied Information Technology And Computer Science, Vol. 5, No. 1, Pp. 1360-1382, 2024.

[14] Alkhateeb, A., Catal, C., Kar, G., Mishra, A., "Hybrid Blockchain Platforms for the Internet of Things (IoT): A Systematic Literature Review", Sensors, Vol. 22, Pp. 1304, 2022, https://doi.org/10.3390/ s22041304.

[15] Roman, S., et al., "Integration of Blockchain Technology into the Internet of Things (Overview)", UDC 004.75, 004.77 https://doi.org/10.20535/2786-8729.4.2024.311745.

[16] https://www.forbes.com/councils/forbestechcouncil/2022/10/20/advantages-and-disadvantages-of-blockchain-technology/.

[17] Isa A. I., Muhammad A. B. "An overview of the Internet of Things (IoT) Architecture", In Global Journal of Research in Engineering & Computer Sciences, Vol. 4, Number 5, pp. 34–39, 2024, https://doi.org/10.5281/zenodo.13750012.

[18] Falilat O. J., Usman G. A., Isa A. I., "An Overview of Blockchain Technology Adoption", Journal of Computer Science and Information Technology, Vol. 7, No. 2, pp. 26-36, 2019.

[19] Isa A. I., "Blockchain in Nigeria", December 2019, https://www.researchgate.net/publication/329211999_Blockchain_in_Nigeria?enrichId=rgreq-fe221f50ef210c395d0c3e79e55271cd-XXX&enrichSource=Y292ZXJQYWdlOzMyOTIxMTk5OTtBUzo5Mzk5MDYwMzM1MjA2NDBAMTYwMTEwMjQ2OTI5MA%3D%3D&el=1_x_2&_esc=publicationCoverPdf.

[20] Isa, A. I., "Nigeria's Ethical Issues in the Use of ICT", 2018, https://www.researchgate.net/publication/325253081