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## AI-Powered Blockchain for Decentralized IoT Applications: Enhancing Security and Efficiency in Edge Computing

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### ABSTRACT

The Internet of Things (IoT) disrupted all the industries that allowed controlling the processes of all businesses in the real-time regime using automatization and optimization. Security issues, centralized control as well as inefficient processing of data on the other hand may face the IoT networks. On edge computing, this is aggravated by the fact that the data being processed is done near the source to minimize latency and bandwidths utilized by the IoT devices. This can be solved because the decentralized blockchain technology is able to offer security and transparency to the process of using the IoT. Besides it, the Artificial Intelligence (AI) had an opportunity to enhance the quality of decision-making and create opportunities to predict and identify anomalies. The paper will address the combination of AI and Blockchain as one of the ways of making the decentralized IoT system much safer and faster in an edge computing environment. The strategy therefore helps in ensuring that the IoT applications will be secure and more productive whereby; BlockChain will be used to handle the data securely and; AI will be used to process and make real-time decisions on how the data will be used. The paper suggests the theoretical framework considering the presence of such technologies in the decentralised IoT platforms and the possible implications to the security, scalability as well as the effectiveness. The possible future applications and trends as well as the real world applications are provided, especially of the smart cities, healthcare and industrial IoT.

**Keywords:** AI, Blockchain, IoT, Edge computing, Security, decentralization.

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### 1. Introduction

These convergence make it possible to analyze data in real-time and data such as being managed securely, and they give rise to growing demands of IoT data processing (Saha et al., 2023). Illegal liaisons of AI and Blockchain provide unbeatable and de-centralized platform that promises privacy and the entire association of data in the IoT networks (Tauseef et al., 2023). The synergy promotes processing of the data in real-time, which protects the privacy of the network edge that can improve the demand response, equipment

maintenance and energy optimization in a non-central location (Paula et al., 2025). This solution would be quite beneficial in terms of the prevention of the attacks and the confidence in the use of the UAV systems as the immutability of the data and the transparency of the processes are achieved (Chen et al., 2024). The challenges of implementation of the blockchain in the UAV networks are power consumption and remote accessibility (Chen et al., 2024). Moreover, new approaches have been considered, that entails

blockchain and novel technologies, including software defined network, machine learning and fog/edge computing, to achieve the higher level of security and reliability of the IoT networks (Hassija et al., 2021). It is due to the said integrations that it is possible to utilize such an application as safe data storage, and the gathering of these data at the cost of lower computational overhead (Chen et al., 2024). Along with AI, blockchain technology will combine, too, as it implies organizing the circulation of the growing amounts of information and the protection of the networked IoT devices (Tahaei et al., 2020) (Tauseef et al., 2023).

## 2. Study background

These are challenges that are crucial to overcome in the process towards achieving the pledge of realizing the full potential of using decentralized IoT systems that would offer more autonomy, security and efficiency. New opportunities and issues (Tahaei et al., 2020) (Singh et al., 2021) are presented by the possibility to access other technologies that can be combined with IoT, such as edge computing, blockchain, or AI (Tahaei et al., 2020). This demands that the aspect of quality of service consideration, standardization, and data source management ought to be adequately placed into consideration (Tahaei et al., 2020). They are especially applicable to edge settings, where resources can be supplied in short amounts, and the requirement to act in the real-time is extremely high (Singh et al., 2021) (Oktian et al., 2020). Such technologies accelerate the process of digitalization, which creates a chance to see new applications in a plethora of areas (Firouzi et al., 2022).

In this, at this pitch, we will have the briefings of the following most notable technologies in which the research is carried out: IoT in Edge computing: In order to discuss the application of IoT and how the edge computing can bring the data closer to the processing (i.e. it can enable one to bring the processing near the device where the data has been generated). IoT Security with Blockchain: A narrative on the potential applications of the Blockchain technology in providing an impregnable, decentralized and impassable control to transactions within the IoT networks and hence ensuring transparency and the integrity of data (Chen et al., 2024).

## 3. Justification

The combination of the potential of IoT, edge computing, Blockchain and AI requires conducting research to combine these technologies, which will lead to the appearance of new possibilities in the

processing of the increasing volume of data and its security (Saha et al., 2023) (Tauseef et al., 2023). Due to the inclusion of the artificial intelligence and Blockchain in edge computing, it results in improving the real-time processing of large data on the outskirts of a network, the possibility of obtaining instant insights/actions even when it is no longer necessary to transmit huge volumes of data to a central location (Gill et al., 2024). In addition to the positive change in data privacy and latency that the synergy brings to it, the synergy would help to redesign the resource allocation to run on a distributed system (Paula et al., 2025) (Tauseef et al., 2023).

Due to the combination of technologies, the digital transformation of the world and the emergence of the new possibilities in different spheres, such as healthcare sphere, financial sphere, industry 4.0 take place (Firouzi et al., 2022). Blockchain and AI have an extremely similar effect of increasing the security and transparency of financial operations because they apply the AI features to the processing of large amounts of data and the Blockchain systems in order to capitalize on the secure ledger (Martinez et al., 2024). The opportunities and the challenges introduced by the hybrid of the AI and Blockchain technologies should be considered equally as well to allow maximizing the proceeds and minimising the hazards (Kuznetsov et al., 2024). The improvement of security, which occurs during the implementation of the blade blockchain with the help of the IoT tools, is the mitigation of the attacks, and the immutability of the data (Chen et al., 2024).

## 4. Research study objectives

To determine the possibilities of integration of AI and Blockchain that would ensure safety and the decentralized coordination of the Internet of Things.

To determine the extent to which Blockchain can improve the level of security, transparency and scalability in types of IoT systems during the procedure of edge computing.

To explore how AI has to be implemented in order to augment the decision-making, data analyses and the performance of Blockchain in the IoT ecosystems.

To offer a suggestion, that the system of decentralized IoT is a possibility of AI and Blockchain combination.

To evaluate this practice of the integrated approach, difficulties in this approach, and vision of this approach in future.

## 5. Literature Review

The forming of the merger has enabled the possibilities of the appearance of more efficient, harmless, and intelligent IoT ecosystems (Saha et al., 2023). These technologies will be able to raise the degree of security, openness, and performance of information and transform businesses and operations (Hassan et al., 2024) (Chen et al., 2024). They are the technologies of a new online dimension and a synthesis that precondition the emergence of new applications in the broad scope of areas, such as the spheres of health, finance, and the industry 4.0 (Firouzi et al., 2022). In the current research work, the following areas will be analyzed with regards to the study:

The overview of how Blockchain has been used in enhancing the security of IoT data transmissions, the integrity of IoT data and decentrality of the IoT networks. The examples of the usage of AI in IoT, that is, predictive maintenance, anomaly detection, checking optimization of the process, or intelligent

decision making. A claim on the edge computing of the IoT networks and how it minimized the latency and the obstacles that the edge computing placed on the processing of the data and the security. The present paper is a review of the existing body of knowledge on the use of AI and Blockchain that needs to be integrated in IoT, specifically, as its edge computing components, and the frameworks, complications, and opportunities (Tauseef et al., 2023).

**6. Material and Methodology**

**Materials**

**1. The IoT devices and Edge Environments**

Edges will provide an edge computing environment in real-time using the data collected by IoT devices that can be smart sensors, wearable health tracking equipments, and environmental trackers among others.

Step Number	Step Description	Tools/Technologies Utilized	Purpose/Outcome
1	<b>System Design:</b> Create a framework combining Blockchain and AI for decentralized IoT in edge computing.	- Blockchain (Ethereum, Hyperledger)	Address security and efficiency gaps in decentralized IoT systems.
2	<b>Model Development:</b> Develop AI models to process IoT data in real time, enabling decision-making.	- AI Algorithms (Machine Learning, Anomaly Detection)	Process real-time data, augment decisions, and optimize data use.
3	<b>Test and Evaluation:</b> Test the system using real or simulated IoT data in an edge computing environment.	- IoT Devices, Edge Nodes, Blockchain Platform, AI Algorithms	Assess system speed, scalability, and energy consumption.
4	<b>Data Collection and Analysis:</b> Collect data from IoT devices (sensors, wearable devices) and analyze it.	- IoT Devices (smart sensors, trackers)	Collect and securely process data, utilizing edge computing and Blockchain.
5	<b>Deployment:</b> Implement the AI-Blockchain solution in a real-world IoT ecosystem (e.g., smart city).	- Smart City IoT Ecosystem, AI-Blockchain Hybrid System	Evaluate performance, scalability, and security in practical applications.

**2. Blockchain Platform**

Transactions of the data will proceed on a decentralized Blockchain platform, e.g. Ethereum or Hyperledger, in a secure and transparent way.

**3. AI Algorithms**

The IoT data processing will be performed during the real time with the help of machine learning models, anomaly detection algorithms, predictive

maintenance models, implementation of decision optimization techniques, and so forth.

**4. Tier two-edge infrastructure**

The edge nodes (simulated or actual) will process IoT data locally and forward it to the cloud or Blockchain in order to store the data securely and analyze it in the cloud or the Blockchain.

**Methodology**

**1. System Design**

A framework of a concept that will merge Blockchain and AI to address the gap in security and efficiency requirements in the practice of decentralized IoT systems implemented into edge computing will be created.

**2. Model Development**

The AI models will be developed to analyse and process real time data fed by the IoT devices and be able to make real time decisions. Blockchain will provide data transactions and make them transparent.

**3. Test and Evaluation**

The intended framework will be tested using real or simulated IoT information in the edge computing environment. Such indices as the speed of data processing, the scalability of the system and the energy consumptive indices will be taken into account.

**7. Results and Discussion of Section**

**Results**

Security of the Blockchain and its Performance:

Results shall show the role that Blockchain plays in enhancing security to the exchange of Internet of Things, and therefore will only ensure transparency, as no unauthorized user will access or tamper with data.

**An AI Optimization**

The AI algorithms will indicate the potential of making the IoT operations more working efficient, the occurrence of failures, and reduce the downtimes through predictive maintenance.

Performance of Edge computing:

Integration of edge computing will show lower latency, efficient use of network bandwidth and optimal use of performance of IoT networks.

Metric	Result/Description	Measurement Method/Tool	Target Outcome
Security	Blockchain ensures secure and transparent data exchange.	Blockchain Transaction Logs	No unauthorized access or tampering of IoT data.
AI Optimization	AI algorithms reduce failures and downtime via predictive maintenance.	Machine Learning Models, Anomaly Detection	Higher operational efficiency, reduced failures, optimized IoT performance.
Edge Computing Performance	Integration reduces latency and optimizes bandwidth use.	Performance Metrics, Latency Measurements	Lower latency, efficient bandwidth use, improved overall IoT system performance.
Scalability	System can handle larger volumes of IoT data without performance degradation.	Load Testing, Scalability Metrics	Ability to scale with increased IoT device numbers and data load.
Energy Consumption	Optimized energy usage during data processing.	Energy Consumption Monitoring Tools	Reduced energy consumption for edge devices and IoT systems.



The graphs illustrating the results for Blockchain data processing speed, predictive maintenance efficiency, latency reduction in edge computing, and energy consumption in IoT networks before and after implementing AI and Blockchain technology.

### Discussion

There will be the discussion of how the combination of Blockchain and AI would not just bring additional utilization and safety to the IoT systems in the edge computing setting, but how an auxiliary gathering of the AI might be utilized to make the above combination more useful. Some of the problems that the research will touch on are the energy demands of Blockchain platforms, the challenge of incorporating artificial intelligence in Blockchain, and the computing limitation of edge devices. The potential solution of deploying this integrated system in the real life that drives application such as smart city, healthcare and industrial IoT will be discussed.

### 8. Study limitation

The issues are particularly sharp in the cases where there is a need to deploy the complex AI models

and process the large volume of data in large amounts of IoT devices (Hou et al., 2021). The fact that the number of IoT devices is increasing may become the problem to the Blockchain network in terms of its scalability (Chen et al., 2024). This can be attributed to the restricted availability of IoT devices and increment in volume of data (Singh et al., 2020) (Gunduz et al., 2020). Other possible burdens on energy needs will be introduced by AI conflicting and Blockchain consensus computational needs (when the volume of AI needs edge computing at large proportions) (Hamdan et al., 2020). The processing of sensitive data in decentralization systems may bring a problem of privacy matters although can be resolved with the security of Blockchain (Paula et al., 2025). Such matters are critical regarding the realization of the opportunities of Blockchain-based edge computing in the IoT (Song et al., 2021) (Murshed et al., 2021). Coupled with the fact that Blockchain can be integrated with other technologies such as Internet of Things and artificial intelligence among others these challenges further prevailed and led to the urgent need of sound security models and privacy protection strategies (Karpiński et al., 2025). A combination of edge computing and AI

has offered a promising channel to meeting the challenges (Saha et al., 2023). The processing of real-time data at the network edge also characterizes edge AI, and yet, at the same time, the following can be outlined as the research problems of edge AI: resource limitation, security question, and scale inefficiency (Gill et al., 2024). In such a way, the aspect of edge-based AI application architecture must be revisited in the framework of specialized edge systems (Liang et al., 2020).

### 9. Future Scope

The ecosystems that can enhance urban environment would be dynamic and predictive through integration of AI, IoT and 5G strategies (Singhvi, 2025). The future researches should suggest the ways of combining these technologies with 6G and optical IoT and generating energy networks that would also be resilient and smart and could support the smart urban formation in a sustainable manner (T et al., 2024). Future work: It

### 10. Conclusion

The paper has talked about combining AI with Blockchain in decentralized IoT applications, which refers to enhancing both the security and efficiency in the scenario of edge computing. The two modern technologies when combined offer potential solutions to challenges like security of the

is possible to focus on researching the more energy-efficient expended Blockchain consensus algorithm such as Proof of Stake or any hybrid algorithm. The complex AI algorithms can analyze the data in real-time and detect the compromises and enhance the security of the IoT network (Tauseef et al., 2023), but the blockchain will also guarantee the intactness of data by eliminating the threat of editing and make the structure decentralized. Deep learning might be used in the federated learning or reinforcement learning in the future to increase the opportunities of AI within the decentralized IoT environment (Firouzi et al., 2022). This can facilitate the data analyses, decision-making at real-time, which is relevant when handling the increasing quantity of IoTs and data flow of a smart city (Tahaei et al., 2020) (Pal et al., 2022). When AI, Blockchain, and 5G are merged, the performance as well as security of IoT networks, especially edge-computing applications can be optimized (Paiva et al., 2021)

data handled by the IoT networks and their privacy, scalability as well as real-time decision-making. Even though issues such as scale, energy consumption still await their solution, the potential of this combined solution are immense, particularly in case of such industries as smart cities and healthcare.

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