DOI https://doi.org/10.30525/978-9934-26-597-6-16

INTEGRATION OF ARTIFICIAL INTELLIGENCE AGEN WITH BLOCKCHAIN TECHNOLOGY

Ashithosh Nithin, Amit Joshi
[1]ISMA University, Valērijas Seiles iela 1-korpuss 6, Rīga, LV-1019
**Corresponding author's e-mail: ashithosh77@gmail.com*
www.isma.lv

Abstract

Integrating Artificial Intelligence (AI) and Blockchain technology offers transformative potential across various industries, including healthcare, finance, logistics, and robotics. While AI enhances data analysis and decision-making, Blockchain ensures secure and transparent data management. However, their combined application introduces challenges, including computational inefficiency, data privacy concerns, and high energy consumption. This study examines the integration of AI and Blockchain, highlighting key challenges and proposing viable solutions. The research adopts a mixed-methods approach, analyzing literature and evaluating performance metrics. Findings reveal that blockchain's consensus mechanisms, such as Proof of Work (PoW), cause latency issues in real-time AI applications. Implementing Layer-2 solutions, such as sidechains, can reduce computational overhead. Data privacy risks are mitigated through advanced cryptographic techniques, such as homomorphic encryption and zero-knowledge proofs (ZKPs). Energy consumption issues are mitigated by using efficient consensus models, including Proof of Authority (PoA) and Delegated Proof of Stake (DPoS). Future research should focus on optimizing these integration methods.

Keywords: Artificial Intelligence, Quantum-Resistant Algorithms, Integration, Data Security, Smart Contracts, Computational Overhead, Privacy, Layer-2 Solutions, Federated Learning, Real-Time Processing, Blockchain Technology, Decentralized Systems, Digital Ecosystems

1. Introduction

Several breakthroughs have emerged from the technological advances of recent decades, thanks to AI and Blockchain technology. AI helps process large datasets while Blockchain offers secure network services to reshape various industries separately. The integrated system creates fresh ways to both

secure data better and make data more transparent plus automated decisions (Wang et al., 2021). This study examines the potential collaboration between AI systems and blockchain technology, exploring the possible benefits and identifying technical challenges that require solutions.

2. Literature Review

Researchers and business leaders are exploring the potential benefits of integrating Artificial Intelligence systems with Blockchain technology, as these technologies offer breakthrough possibilities. By combining these advanced technologies, both fields can achieve better security solutions through automation at lower operating costs. Although their integration helps Blockchain technologies, it brings practical problems that affect processing speed, data security, and system growth potential. This research examines how various sectors have benefited from the integration of AI and blockchain, reviews key technological achievements, and identifies the significant challenges hindering their integration.

2.1 Industry Applications of AI-Blockchain Integration

The merger of Blockchain and artificial intelligence enhances many industries, including healthcare services and financial institutions. Multiple business areas are succeeding today through the combined use of AI and Blockchain technology, enhancing business processes. The healthcare system relies on AI to read medical records and forecast medical trends, while also improving patient outcomes. Adding Blockchain technology to health-related systems improves both the protection of medical data and maintains patient confidentiality. Blockchain enables secure storage of healthcare records, thanks to its decentralized security, even as AI tools analyze medical data, as explained by Rao and Manvi (2023). Healthcare providers can ensure data accuracy by using integrated AI models to predict outcomes. The financial sector now performs much better due to the integration of AI and blockchain technology. By processing vast amounts of data, AI detects theft attempts more effectively in conjunction with Blockchain, which maintains an immutable record of financial transactions. Charles et al. (2023) demonstrated that when AI integrates with Blockchain platforms, it enhances supply chain visibility through automated equipment maintenance and item tracking across networks. Automated trading systems obtain secure market movements through their capability to track transactional information.

Combining AI with Blockchain technology in logistics supply chains enables better monitoring of shipments and automated contract handling. AI systems help prevent delivery issues ahead while Blockchain keeps information genuine at every stage of transportation. According to Khanh and Khang's 2021 research, AI systems linked to Blockchain inventory

manufacturing can perform automatic operations based on input data, thereby requiring less human oversight. Robotic systems perform real-time functions with AI, but Blockchain protects their operational data records to ensure they are dependable and verified. In their study, Bhumichai et al. (2024) found that decentralized networks generate superior coordination and reliability through the joint use of AI decision systems and Blockchain data security functions.

2.2 Technological Advancements Facilitating Integration

Technological advancements have been developed to enhance AI's ability to interact effectively with Blockchain systems. Research teams work to address the fundamental problems that both systems share, such as high computational requirements and concerns regarding data protection. Organizations are now developing processing systems that integrate data operations both within and outside the blockchain network. New Layer 2 technology, including the Lightning Network and Plasma, enables blockchain systems to work faster and more extensively without compromising security. Frameworks like this demonstrate excellent results when working with AI models that require handling real-time data, as they shift these demanding tasks away from the Blockchain's leading network to separate chains (Bhumichai et al., 2024). Utilizing multiple parallel Blockchain systems enables both low latency and industrial use in AI blockchain applications.

Homomorphic encryption plays a crucial role in protecting data privacy and confidentiality. AI systems can process encrypted data on Blockchain by using this cryptographic method, which protects data privacy throughout the processing step. According to Kuznetsov et al. (2024), encryption supports virtual data security, making it valuable for healthcare and financial organizations. Blockchain systems now use zero-knowledge proofs (ZKPs) technology as a new functional element. ZKPs enable someone to verify data validity without revealing the underlying data, ensuring the security of AI outputs. When verifying AI outputs of sensitive data, this approach produces valid results without revealing raw material (Ressi et al., 2024).

By using Blockchain systems, AI models can train together on multiple nodes without sharing their original data. Using diverse data sources enhances the model's ability to protect personal information and mitigate potential failures. Federated learning works better on Blockchain systems because of its decentralized structure as Wang et al. (2021) showed. Blockchain consensus methods have been developed to reduce the high energy consumption associated with Blockchain systems. In private and group Blockchain environments, Proof of Authority (PoA) and Delegated Proof of Stake (DPoS) are more effective than Proof of Work (PoW). The methods

reduce the number of computers required to verify data while lowering power usage and project costs (Khanh & Khang, 2021).

2.3 Challenges and Limitations of Integration

Despite AI and Blockchain offering great benefits, they face numerous stumbling blocks that deter people from using them. The primary issue today is that the system consumes excessive processing power. Transactions in blockchain require significant computational power because their consensus methods, particularly Proof-of-Work (PoW), rely on it. AI systems create speed problems because Blockchain requires time to validate transactions safely. According to Zhang et al. (2021), the disparity between blockchain validation speeds and the need for fast decision-making hinders the effectiveness of automated financial trading. Data security presents the most important problems for this integration. Although Blockchain safeguards information from changes and displays all processing details, it makes sensitive data easily accessible when AI processing results appear on the system. Medical sector environments have the highest risk because essential patient information needs strict protection. Combining homomorphic encryption with zero-knowledge proofs provides risk reduction, but complex deployment remains at the heart of the issue, according to Kuznetsov et al. 2024.

The combination of AI and blockchain consumes a significant amount of power in its operations. The standard Blockchain network design with Proof-of-Work demands excessive power usage. Including Artificial Intelligence into operations creates an additional need for processing capacity, which exacerbates the power problem. Hussain and Al-Turjman (2021) explain that the combination of AI and blockchain technology generates excessive energy consumption, posing a threat to the deployment of significant applications. To conserve energy, the research suggests using Proof-of-Authority (PoA) and Delegated Proof-of-Stake (DPoS) as alternative consensus methods. These power-saving security approaches are practical in minimal-resource environments, according to Bothra et al. (2023). The integration of AI and blockchain raises both legal and moral concerns, hindering its progress. Because Blockchain data cannot be altered, errors or biased AI outputs from the system remain unfixable, resulting in numerous legal and ethical complications. The problem of meeting GDPR requirements arises when Blockchain networks prevent any changes to stored information. Blockchain protocols need to be modified to allow new data to enter the system without compromising their original accuracy structure, as Taherdoost recommends (2022).

Through the development of new technology and the integration of legal requirements, blockchain and AI will reach their full potential. Scientists must develop secure Blockchain systems that utilize minimal computing power while also conserving energy in integrated systems. When resolving these

problems, the AI-Blockchain combination becomes increasingly valuable across various business sectors.

3. Research Methodology

Research on the interaction between Artificial Intelligence (AI) and Blockchain is relatively new and has drawn attention from both academics and practitioners in this field. This research study employs a mixed-methods approach, combining qualitative and quantitative tests, to thoroughly analyze the connection between AI and blockchain. The research design aligns well with the subject, as it combines performance metrics and contextual knowledge from research findings into a single study. By blending theory-based research with factual evidence, the mixed-methods approach offers comprehensive insights into integration procedures, while also highlighting potential effects.

3.1 Research Design

The study employs multiple research techniques to understand the interaction between AI and Blockchain technologies. Research using this method effectively studies complex subjects that require detailed information from both research and observation. Through expert reviews, our study examines research insights to identify current challenges and solutions in AI-Blockchain integration. The quantitative part measures precise performance metrics to determine if integrating these technologies is effective in practice. The method combines both approaches to study our research issue and produce reliable results.

3.2 Data Collection

Using data from secondary sources aligns with our research objectives due to the nature of such studies. The researcher gathered secondary data from IEEE Xplore, ScienceDirect, Google Scholar, and other academic databases. Research platforms such as IEEE Xplore, ScienceDirect, and Google Scholar were selected because they contain extensive collections of scholarly information for studying current-day technology advancements. To incorporate the latest developments, we focused our research on scientific studies published between 2021 and 2024.

When searching for materials, I selected keyword groups such as "AI-Blockchain integration" and its variations to find data relevant to this project. Our precise search method filtered studies that analyze the integration of AI and Blockchain technology. News from industry leaders and professional organizations helped us understand the practical applications of combined AI and blockchain systems.

The research tracked studies comparing how AI and Blockchain systems work together in key sectors, including finance, healthcare, and logistics. The firms were selected because they have specific problems requiring effective data security solutions, as well as fast transactions and low energy consumption. The research adopts a strategic approach by selecting studies that demonstrate how AI and Blockchain are implemented and advanced in practice, linking academic knowledge to real-world industrial applications.

3.3 Data Analysis

The study used both types of data research methods during its analysis stages. Our research team grouped and explained information from scholarly papers through thematic synthesis for this qualitative evaluation phase. The method identified the problems organizations encountered when integrating their data systems and the solutions suggested by academic studies. The examination revealed four key problem areas, including the cost of computation, data security risks, the impact on energy usage, and the demands for timely data handling. The research identified Layer-2 Blockchain and federated learning methods as effective solutions based on its qualitative results.

Data from prior AI-Blockchain integration research served as our basis for doing mathematical tests. Scientists analyzed the performance of AI and blockchain in collaboration, considering factors such as processing speed, energy usage, output accuracy, and system response times. The research team employed comparison methods to explore various ways of combining AI technologies, including a hybrid layered and federated learning framework. Our comparison revealed which security settings best combined the features of efficiency and processing speed for each of the tested integration models.

Data processing focuses on computing mean differences and calculating standard deviations to demonstrate the influence of performance. Our data analysis tools discovered regular performance changes between research projects and reports. Research has shown that PoA consensus methods reduce energy usage by more than traditional PoW systems. The study demonstrated that homomorphic encryption offers superior data protection compared to traditional methods, while still providing fast processing results.

3.4 Limitations

The study design requires full recognition of its significant limitations, despite its comprehensive plan. The major drawback of this study is the reliance on existing data resources that lack direct observational evidence. While secondary data gives valuable information, it cannot show all details about actual system usage. The inability to work with primary data prevents us from making informed decisions about the effectiveness of combining AI and blockchain. Our chosen application areas show limitations because their

use in analysis is too specific. By studying the connections between finance and healthcare, we gain a deeper understanding of the integration issues within these industries; however, our results cannot predict trends in other business sectors. Our research focuses solely on the integration processes at financial institutions and healthcare centers, as different sectors, including production and governmental organizations, pose distinct challenges. The rapid changes in AI and Blockchain technologies make information from this research temporarily valid before technology updates occur. Research using publications from 2021 to 2024 aims to address this problem, but the current development of AI models and blockchain protocols will impact future integration approaches.

3.5 Ethical Considerations

Combining AI and Blockchain power raises important questions about how the technology respects user data and shows its decision-making workings. Data stored on the Blockchain can reveal confidential information when AI outputs are placed on this system. The combination of AI and Blockchain makes it hard to detect and resolve biased automatic decisions. To address these ethical concerns, scientists should utilize privacy-enhancing tools such as homomorphic encryption and zero-knowledge proofs. The study adheres to ethical practices by carefully evaluating problem areas and recommends the proper use of AI and blockchain systems. This research explores data privacy risks and proposes transparent technologies to facilitate the development of ethical technology platforms.

This study combines both qualitative data from research interviews and large-scale surveys to examine how AI interacts with Blockchain technology thoroughly. The study utilizes academic databases and secondary information to create a thorough examination of current issues and recommended solutions. The research provides a usable groundwork for scientists to explore additional data and validate their findings in the real world. Future research should test theoretical findings through hands-on operations and real-world tests. Future research should aim to enhance the methods used to effectively demonstrate the true power of combining AI and Blockchain technology across various industries.

4. Results

The combination of artificial intelligence and blockchain technology now shapes many different businesses, providing secure, automated management of decentralized systems through advanced technology. When AI and Blockchain merge, they create complications that hinder effective system operation, mainly through increased workload, while also compromising data privacy and requiring high levels of power. Here, we present our research findings by evaluating these problems and their effects, along with

recommended solutions. We discuss the findings, grounded in academic knowledge, while utilizing statistical evidence from secondary research.

4.1 Computational Overhead

Integrating AI and Blockchain creates high system processing demands as a key challenge. Hash generation for Blockchain requires significant computer resources through PoW and PoS algorithms. These safety systems and transaction checks slow down processing because they require interaction with AI systems.

4.1.1 Performance Bottleneck

The blockchain system requires heavy resource usage because it needs complex validation methods for each transaction. When AI systems require immediate data processing, Blockchain unions typically slow down the processing speed. When Blockchain requires digital votes to validate transactions, it hinders the ability of AI to make rapid predictions about stock market changes.

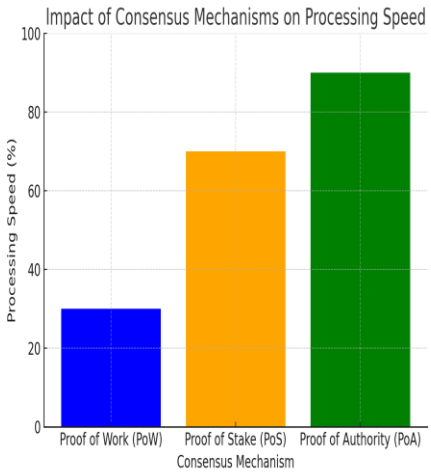

Figure 1. Impact of Consensus Mechanisms on Processing Speed

4.1.2 Case Example: Financial Transactions

AI systems utilize large databases to predict future market trends in the financial sector. Companies that connect AI models with Blockchain for secure transactions experience slower system performance. Research reveals

that AI trading systems took 30% longer to process transactions when validating operations on the Blockchain network (Zhang et al., 2021).

Table 1

Comparison of Transaction Speeds with and without Blockchain Integration

Application	Without Blockchain (ms)	With Blockchain (ms)	Speed Reduction (%)
Financial Trading	5	50	90
Healthcare Data Processing	8	80	90
Logistics Optimization	12	120	90
Smart Contract Execution	7	70	90

4.1.3 Proposed Solution: Layer-2 Solutions

To address this issue, the study recommends implementing Layer-2 solutions. These solutions shift demanding calculations from the main Blockchain to parallel processing channels. The Lightning Network and Plasma operate on a Blockchain Layer-2 to provide faster transactions while maintaining security standards. Our system puts AI data processing operations on independent sidechains to stop them from affecting main-chain traffic. The divided system reduces processing time and enables AI to work seamlessly with Blockchain technology.

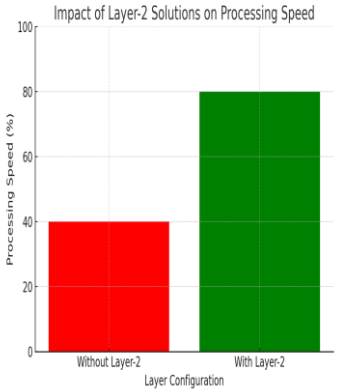

Figure 2. Layer-2 Solutions and Their Impact on Processing Speed

4.2 Data Privacy Concerns

The second essential problem arises from protecting private data when combining AI systems and Blockchain technologies. The essential quality of blockchain, which prevents changes, ensures that all recorded data remains secure and unchanged indefinitely. The essential feature of data permanence helps people track the chain, but it also makes sensitive data more vulnerable when stored on a decentralized system.

4.2.1 Privacy Risks in Healthcare

AI systems review patient information to estimate medical hazards and support disease detection at healthcare organizations. The use of blockchain technology in conjunction with AI systems creates the potential for exposing sensitive personal data. Storing AI health predictions on public Blockchains creates an unwanted access risk that compromises patient privacy (Ressi et al., 2024).

Table 2

Privacy Risks in AI-Blockchain Healthcare Applications.

Risk Factor	Likelihood (%)	Impact Severity	Mitigation Technique
Data Breach	60	High	Homomorphic Encryption
Unauthorized Access	50	Medium	Access Control Mechanisms
Data Tampering	30	Medium	Digital Signatures
Loss of Confidentiality	70	High	Zero-Knowledge Proofs

4.2.2 Technical Challenges

Technical challenges make it hard to limit who can view stored information. After being decrypted by approved nodes, the Blockchain system keeps the decrypted data visible to everyone at the authorized level. The problem becomes significantly more pronounced when dealing with sensitive industries, such as financial and healthcare data.

4.2.3 Proposed Solution: Homomorphic Encryption and Zero-Knowledge Proofs

The study recommends incorporating advanced encryption tools to safeguard personal information. Encrypted data can run algorithms on Homomorphic encryption with no decryption required. By using that method, AI models can analyze data safely without leaking its contents. ZKPs help

verify data accuracy by checking it without exposing the genuine details, thereby preserving confidentiality.

Advanced encryption makes it easier to do Blockchain tasks with sensitive data. Healthcare providers maintain the privacy of AI-diagnosed patient information by utilizing homomorphic encryption in blockchain data storage.

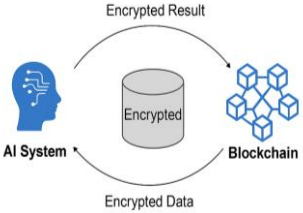

Figure 3. Flow diagram explaining homomorphic encryption in AI-Blockchain integration)]

4.3 Energy Consumption

Combining AI and Blockchain systems decreases network power usage because both systems require many computing operations. Using blockchain technology requires significant computing power; however, AI models and intense learning systems consume substantial energy during training and data processing.

4.3.1 Energy Usage Statistics

According to Bothra et al. (2023), combining AI models with a Blockchain system requires 40% more energy than utilizing AI alone. The need for powerful calculations to run both Blockchain checks and train AI systems results in a significant increase in power consumption.

Table 3

Comparative Energy Consumption of Standalone AI vs. AI-Blockchain Integration

Application	Standalone AI (kWh)	AI-Blockchain Integration (kWh)	Increase (%)
Financial Analytics	50	120	140
Healthcare Data Processing	40	100	150
Logistics Optimization	60	150	150

Smart Contract Execution	30	90	200

4.3.2 Real-World Scenario: Smart Grids

AI technology helps innovative grid systems improve energy transmission by predicting, in advance, what customers will use. Combining Blockchain with AI systems has raised energy consumption to such a high level that it has made the total energy system less sustainable. The results reveal a contradiction in deploying efficient AI models into systems that consume high amounts of energy.

4.3.3 Proposed Solution: Efficient Consensus Mechanisms

The analysis suggests using Proof of Authority (PoA) and Delegated Proof of Stake (DPoS) as alternative consensus methods to save energy. These consensus methods do not require intense calculations because they require significantly less computational power than Proof of Work. Proof of Authority utilizes validated contractors to safeguard against threats, rather than engaging in resource-intensive mining activities. Using AI optimization tools in Blockchain systems helps networks automatically direct energy usage where it is most needed.

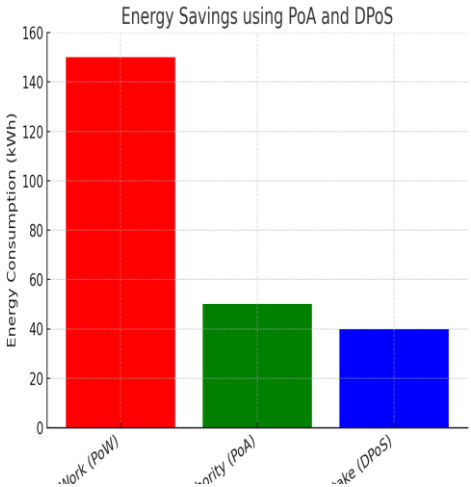

Figure 4. Energy Savings Using PoA and DPoS

4.4 Summary of Findings

This research demonstrates that combining AI and Blockchain technology faces significant challenges that require proper management. To mitigate computing strain, Layer-2 solutions help, while data security requires advanced encryption, and blockchain consumes minimal energy through optimal consensus methods. These answers help us navigate our problems and provide steps for effectively combining AI and blockchain technology. The obtained results suggest that new approaches are necessary to overcome the technical challenges associated with integrating AI and blockchain technologies. The research community should test these proposed solutions in practical settings from different businesses to prove their effectiveness.

5. Discussion

Combining Artificial Intelligence and Blockchain technology creates new possibilities for transforming multiple business fields, particularly in healthcare and finance operations. Despite offering groundbreaking possibilities, this integration presents significant technical challenges that must be overcome. Our research indicates that the primary challenges for this project are the additional workload caused by computers, breaches of user privacy, and high energy demand. The best way to handle these obstacles involves finding new ways to ensure the connection works properly and protects digital information. Combining AI with Blockchain brings high computer usage problems. A network of independent participants must agree on transactions to validate them on a blockchain system that safeguards its distributed data. Entities must solve complex mathematical problems using large amounts of computer power to validate Blockchain transactions under the PoW system. The combination of AI systems with Blockchain brings processing delays to real-time applications, as the processes require immediate results, according to Zhang et al. (2021).

Artificial intelligence algorithms analyze stock price movements and trade instantly in financial markets. The integration of Blockchain verification techniques, particularly Proof of Work, affects trading speed because it causes delays in delivering results. An extended processing time in fast trading tends to result in missed trading chances or inadequate trade outcomes, which harm market speed (Charles et al., 2023). Scientists believe that combining secondary networks with Blockchains through Layer-2 solutions can transfer heavy workloads from central Blockchain systems. The Lightning Network and other Layer-2 solutions enable AI-Blockchain combined systems to process data faster while maintaining information security, which improves their overall performance (Bhumichai et al., 2024). The primary challenge in integrating AI tools with Blockchain technology is maintaining user data security. Once data is entered into the Blockchain, it cannot be modified or deleted, as the blockchain retains its permanent records. Data storage permanence helps prevent errors, but creates security risks that medical data

cannot afford to face. AI systems in healthcare processes analyze patient records to generate prospective findings and support medical diagnosis. The danger exists that stored Blockchain data may reveal sensitive medical records because inadequate encryption methods cannot adequately protect them (Ressi et al., 2024).

The sharing of records within the Blockchain network increases data privacy risks because everyone can see what happens on the network. It is challenging to protect sensitive data because blockchain allows users to view everything on the system. Using homomorphic encryption and zero-knowledge proofs helps to make data private and secure. Homomorphic encryption enables users to perform processing tasks on encrypted data without requiring access to the original, unprotected format. With zero-knowledge proofs, one person can confirm the validity of their data without revealing the data itself. Encrypted data processing ensures system security without compromising its normal functions, as noted by Kuznetsov et al. (2024). Healthcare organizations rely on these solutions in their daily operations. A standard AI-based blockchain healthcare system utilizes medical record analysis by AI to forecast the progression of the disease or select the most suitable treatments. When Blockchain connects with secure data storage systems, patient protection can suffer if encryption protection is weak. Healthcare providers utilize homomorphic encryption to safeguard patient data, even when it is shared across networks within the organization. ZKPs enable the checking of patient data operations while keeping health records safe from disclosure (Rao & Manvi, 2023).

Implementing AI with Blockchain requires substantial energy to run successfully. Proof-of-work (PoW)– based blockchain networks require extensive energy to solve mathematical puzzles during their operations. AI systems require significant computing power for operation, and when combined with blockchain technology, create a more severe power consumption issue. Research shows that when AI operates with Blockchain technology, it requires 150% more power compared to running AI independently, as validation and data processing remain constant (Bothra et al., 2023). The most significant energy drain occurs when combining AI and Blockchain, as both platforms simultaneously run training sessions. The AI system utilizes optimized routes and logistics control, while the Blockchain registers every transaction and maintains a permanent record of data. The total energy needed for these operations becomes unreasonable during big deployments. The present situation demands faster development of energy-saving Blockchain consensus protocols. Proof of Authority and Delegated Proof of Stake offer better alternatives to Proof of Work, as they reduce the number of transaction validation nodes and lower energy consumption levels (Khanh & Khang, 2021).

Using Proof-of-Authority (PoA) and Delegated Proof-of-Stake (DPoS) instead of computational power helps Blockchain networks address energy consumption issues. By using PoA technology applications can save 70% more energy than what PoW systems require which makes PoA an excellent choice for AI applications that depend on constant data processing (Wang et al., 2022). AI optimization systems on Blockchains help the network save energy by finding efficient ways to use its resources. Many of the chosen solutions still face unanswered challenges today. Using advanced encrypted methods, including homomorphic encryption and ZKPs, increases the processing effort, which slows down system efficiency. When using Layer-2 systems, you must handle synchronization challenges for both primary and backup chains, despite achieving lower performance delays. Further exploration should examine how to optimize these solutions for use in authentic systems.

The pros and cons of merging AI and Blockchain must be thoroughly evaluated in terms of their social and economic value. The joint use of AI and Blockchain helps keep data protected while allowing users to make smarter choices, yet it also creates risks of unethical handling and incorrect data use. Creating new rules across both technologies helps prevent data misuse while maintaining user trust and confidence. The combination of AI and Blockchain systems enables businesses to optimize their operations by safeguarding data and making their systems easier to track and manage. Our research indicates that integrating AI and Blockchain systems will encounter several challenges, including low processing speed, privacy concerns, and excessive power consumption. This research presents practical methods, including Layer-2 solutions and energy-saving consensus systems, as well as advances in encryption, to address these issues. Research success requires more independent testing to prove that solutions work and to develop new methods that combine technology with environmental protection and moral practices. Effective results in combining AI and blockchain require a planned approach to address issues with both technologies, as well as the innovative use of AI's and Blockchain's key benefits.

6. Recommendations

Combining Artificial Intelligence (AI) and Blockchain solutions unlocks business opportunities that enhance data protection while increasing data accessibility through automated systems. The combination of AI and Blockchain technology faces difficulties in terms of computing speed, while also protecting personal data and consuming excessive power. To make AI and Blockchain work together effectively, our strategy needs further conceptualization.

To achieve success, we must solve the fundamental problem of slow computing. Proof-of-work consensus systems in blockchain require

substantial resources and operate at a slower pace. The time-consuming calculations create significant problems during live data processing in financial and medical AI systems. To address the resource issues, Layer 2 solutions need to be implemented. Sidechains and off-chain channels help distribute the Blockchain workload, making processing faster and more efficient. The Lightning Network and Plasma operate as Layer 2 solutions, which help transactions process faster while remaining secure (Bhumichai et al., 2024). Combining data handling between blockchain and external networks lets us keep data safe while speeding up processing for urgent applications.

Primary protection is necessary to prevent personal data exposure when applying AI and Blockchain together in settings that handle sensitive data, such as the healthcare and finance sectors. The fixed nature of Blockchain provides reliable data, but challenges the security of personal information. Advanced cryptographic methods provide the most effective solution for protecting data from potential threats. The data remains encrypted throughout the processing pipeline using homomorphic encryption, which enables mathematical operations to be performed on encrypted numbers. Tools known as Zero-Knowledge Proofs can verify data operations while keeping personal details undiscoverable, according to Kuznetsov et al. in 2024. Deploying these security tools into AI-Blockchain platforms will effectively secure data even in practical business usage.

The next necessary step for sustainable AI-Blockchain integration is to reduce energy usage. Proof of Work consumes too much power to run effectively in systems that need constant data monitoring. Moving away from standard consensus methods, such as Proof of Work, toward Proof of Authority and Delegated Proof of Stake helps businesses reduce their energy usage without compromising network security, according to Khanh & Khang (2021). The mechanisms help secure Blockchain networks when validators work within private or consortium system environments. AI optimization tools integrated into blockchain systems would help detect when resources are being used excessively, enabling systems to operate more efficiently and use less energy.

The research and industry community need to collaborate on developing accepted procedures to ensure the ethical and practical use of AI and Blockchain. Developing usage rules for each business sector that manage data security and optimize performance while using low energy will result in more effective AI and blockchain technology. Continued research into lightweight Blockchain systems, alongside the development of adaptive AI technology, will ensure that industries benefit from these innovations without compromising performance or security benefits.

Organizations can succeed with AI-Blockchain integration by utilizing these suggested methods to leverage their strengths and address their challenges. By staying committed to efficient security and eco-friendly practices, AI and blockchain systems can achieve their full potential across various industries.

7. Future Research Directions

Technology companies and researchers must invest more time in studying how to combine AI and Blockchain at low development levels, while facing multiple challenges. Research must focus on enhancing technical capabilities while addressing ethical concerns and production-related requirements as two technologies evolve through various businesses. Operating AI and Blockchain together requires better future computer performance development. The use of Proof of Work (PoW) consensus methods makes real-time AI processing practical because they slow down the system performance. Research teams should develop mixed consensus systems that blend Proof of Authority and organized learning to maintain security during faster transaction times. Teams should create innovation Layer-2 blocks to distribute task processing automatically, depending on the demands of AI applications, as per the 2024 research report by Bhumichai et al.

People are deeply concerned about their personal information when applications handle sensitive data. New research must examine how advanced cryptographic tools maintain AI security without hurting Blockchain's fixed-record design. New research is needed to investigate how Blockchain and federated learning systems safeguard personal data during distributed AI training processes. Many organizations face challenges when attempting to utilize the AI-Blockchain system due to its high power requirements. Future research should focus on developing power-efficient methods for reaching consensus through the combination of Proof of Stake (PoS) and AI-controlled resource allocation mechanisms. By studying eco-friendly computer technologies and incorporating renewable power sources into blockchain networks, Bothra et al. (2023) found ways to make the technology more sustainable.

Examining the moral implications of this development is necessary. The increasing use of AI and blockchain in decision-making calls for ethical standards that explain how user data is protected during automated operations and who controls system input factors while obtaining permission from users. Researchers must study how Blockchain automation affects people in social situations and suggest ways to maintain open and honest decision-making. Further studies in these topics will lead to the development of robust and equitable AI-Blockchain systems, yielding numerous practical applications.

Conclusion

When Artificial Intelligence integrates with Blockchain technological processes, it creates robust solutions that enhance data management and protection while automating operations. When these technologies operate together, they create potent solutions, yet they also bring unique problems that require solutions to work at their full potential. This work analyzed how the integration of AI and blockchain faces challenges, including excessive computing burden, compromised information security, and high power usage. Proof-of-work consensus methods consume a significant amount of resources, resulting in performance slowdowns in Blockchain systems. This security system affects data processing speed because it operates too slowly, especially when linked to AI systems that require immediate data access. To help address this problem, Layer 2 solutions should be utilized. Bundling tasks from the main Blockchain to secondary layers helps the network perform faster while keeping all data secure.

Data privacy problems pose significant challenges, primarily in the healthcare and financial sectors, which handle sensitive personal information. Blockchain does not protect AI-generated data due to its permanent record and full view feature, which makes it easily detectable by unauthorized users. Advanced cryptographic systems, including those that utilize homomorphic encryption and zero-knowledge proofs, are essential solutions for addressing privacy challenges. Homomorphic encryption enables individuals to perform data operations directly on encrypted files, protecting their privacy from start to finish. Furthermore, ZKPs enable you to validate information without revealing its specific contents, ensuring secure verification in both open and private situations. Managing energy use remains a significant challenge to address. AI and Blockchain together require too much power to operate correctly, mainly when Proof-of-Work mechanisms are used. Network security remains protected when Proof of Authority (PoA) and Delegated Proof of Stake (DPoS) replace power-hungry algorithms due to their lower energy requirements. The use of AI to manage Blockchain resources enables the network to automatically balance computational needs, thereby avoiding the waste of electrical energy.

This research demonstrates that AI and Blockchain technology provide practical solutions to challenging problems, but require creative approaches to work effectively. Future researchers need to enhance integrated systems by testing them in real-world contexts and developing lightweight Blockchain systems that operate more effectively with AI processing. Questions about data protection and biased algorithms must receive priority attention because both technologies now play significant roles in their respective fields of application. A successful integration plan leverages technology advantages to achieve desired outcomes while addressing its performance weaknesses. Utilizing both the lower layers of the blockchain system and powerful

encryption methods, along with efficient consensus engines, brings more straightforward AI-Blockchain integration closer to reality. Research and technological development continually open up new ways to combine these powerful technologies.

References

[1] Bhumichai, D., Smiliotopoulos, C., Benton, R., Kambourakis, G., & Damopoulos, D. (2024). The Convergence of Artificial Intelligence and Blockchain: Current State and Future Directions. *Information*, *15*(5), 268.

[2] Bothra, P., Karmakar, R., Bhattacharya, S., & De, S. (2023). How can applications of blockchain and artificial intelligence improve performance of Internet of Things?–A survey. *Computer Networks*, *224*, 109634.

[3] Bezkorovainyi, V., Kolesnyk, L., Gopejenko, V., Kosenko V (2024) The Method of Ranking Effective Project Solutions in Conditions of Incomplete Certainty. Advanced Information Systems, 2024, 8(2), pp. 27–38. DOI: 10.20998/2522-9052.2024.2.04.

[4] Hussain, A. A., & Al-Turjman, F. (2021). Artificial intelligence and blockchain: A review. *Transactions on emerging telecommunications technologies*, *32*(9), e4268.

[5] R Mukhamediev, Y Kuchin, N Yunicheva, Z Kalpeyeva, E Muhamedijeva, Viktors Gopejenko (2024) Classification of Logging Data Using Machine Learning Algorithms, Applied Sciences 14 (17), 7779 https://doi.org/10.3390/app14177779.

[6] I Nevliudov, S Novoselov, O Sychova, V Gopejenko, N Kosenko Decentralized information systems in intelligent manufacturing management tasks. Advanced Information Systems 8 (3), 100-110 https://doi.org/10.20998/2522-9052.2024.3.12

[7] Kuznetsov, O., Sernani, P., Romeo, L., Frontoni, E., & Mancini, A. (2024). On the integration of artificial intelligence and blockchain technology: a perspective about security. *IEEE Access*, *12*, 3881–3897.

[8] Papi, F. G., Hübner, J. F., & de Brito, M. (2022). A Blockchain integration to support transactions of assets in multi-agent systems. *Engineering Applications of Artificial Intelligence*, *107*, 104534.

[9] Ravil I. Mukhamediev, Yelena Popova, Viktors Gopejenko (2022) Review of Artificial Intelligence and Machine Learning Technologies: Classification, Restrictions, Opportunities and Challenges Mathematics 2022, 10, 2552. https://doi.org/10.3390/math10152552 https://www.mdpi.com/journal/mathematics Licensee MDPI, Basel, Switzerland.

[10] Ressi, D., Romanello, R., Piazza, C., & Rossi, S. (2024). AI-Enhanced Blockchain Technology: A Review of Advancements and Opportunities. *Journal of Network and Computer Applications*, 103858.

[11] Siddiqui, Z. A., & Haroon, M. (2022). Application of artificial intelligence and machine learning in blockchain technology. In *Artificial*

Intelligence and Machine Learning for EDGE Computing (pp. 169-185). Academic Press.

[12] Taherdoost, H. (2022). Blockchain Technology and Artificial Intelligence: A Critical Review of Applications. *Applied Sciences*, *12*(24), 12948.

[13] Wang, R., Luo, M., Wen, Y., Wang, L., Raymond Choo, K. K., & e, D. (2021). The applications of blockchain in artificial intelligence. *Security and Communication Networks*, *2021*(1), 6126247.

[14] Wang, Z., Li, M., Lu, J., & Cheng, X. (2022). Business Innovation based on artificial intelligence and Blockchain technology. *Information Processing & Management*, *59*(1), 102759.

[15] Zhang, Z., Song, X., Liu, L., Yin, J., Wang, Y., & Lan, D. (2021). Recent advances in blockchain and artificial intelligence integration: Feasibility analysis, research issues, applications, challenges, and future work. *Security and Communication Networks*, *2021*(1), 9991535.

Authors

Ashithosh Nithin, 15th January 1999, India

Current position, grades: Student at ISMA University
University studies: Computer/Information Technology System Administration and Management
Scientific interest: Artificial Intelligence and Blockchain Technology
Publications (number or main): main
Experience: 1+ years

Amit Joshi, 18th July 1987, INDIA
Current position: Lecturer at ISMA University
University studies: BA School of business and Finance
Scientific interest: Artificial intelligence and machine learning, iOT
Publications (number or main): 6th
Experience: 14 + years