International Science and Technology Journal
المجلة الدولية للعلوم والتقنية
Volume 36 العدد
Part 1 المجلد
المجلة الدولية للعلوم والتقنية
International Science and Technology Journal
ISTJ

http://www.doi.org/10.62341/rmms1757

Received	**2025/01/19**	**تم استلام الورقة العلمية في**
Accepted	**2025/02/18**	**تم قبول الورقة العلمية في**
Published	**2025/02/21**	**تم نشر الورقة العلمية في**

Study the impact of integrating blockchain and neural network technologies in predictive models: A survey

Rashed M Marimi

Electrical and Electronic Department, Faculty of Engineering,
University of Zawia - Libya

r.mariami@zu.edu.ly

Abstract

The integration of Blockchain technology with Artificial Neural Networks (ANNs) presents a promising advancement in predictive modeling by enhancing security, transparency, and accuracy. Blockchain ensures data integrity through decentralized and tamper-proof storage, while ANNs leverage deep learning algorithms for improved pattern recognition and decision-making. This paper explores the impact of combining these technologies, particularly in critical sectors such as healthcare, finance, and cybersecurity.Despite their advantages, several challenges hinder their seamless integration. Blockchain introduces computational overhead, scalability limitations, and regulatory concerns, while ANNs require vast datasets, making them vulnerable to adversarial attacks and biased learning. This study highlights solutions such as federated learning, hybrid blockchain architectures, and optimized cryptographic techniques to address these challenges. Future research should focus on enhancing computational efficiency, developing scalable frameworks, and establishing regulatory standards to facilitate broader adoption. By overcoming these barriers, Blockchain-ANN integration can revolutionize predictive analytics, providing secure, efficient, and intelligent decision-making systems across various industries.

Keywords: Blockchain, Artificial Neural Networks (ANNs), Predictive Modeling, Security, Scalability, AI Integration.

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دراسة تأثير دمج تقنيات سلسلة الكتلة والشبكات العصبية في النماذج التنبؤية: دراسة استقصائية

رشيد محمد المريمي
قسم الإلكترونية الكهربائية، كلية الهندسة، جامعة الزاوية – ليبيا
r.mariami@zu.edu.ly

الملخص

إن دمج تقنية سلسلة الكتلية (Blockchain) مع الذكاء الاصطناعي (AI)،وخاصة الشبكات العصبية الاصطناعية ، (ANNs)لديه القدرة على تعزيز الأمان وقابلية التوسع والدقة في النماذج التنبؤية. تستكشف هذه الورقة تأثير الجمع بين هذه التقنيات، خاصة في تطبيقات الرعاية الصحية والتمويل والأمن السيبراني. وتسلط الدراسة الضوء على المزايا والتحديات المرتبطة باعتمادها، بما في ذلك الأمان والأداء وقابلية التوسع والكفاءة الحسابية. ومن خلال مراجعة واسعة النطاق للأدبيات، يحدد هذا البحث الاتجاهات والعقبات الرئيسية، ويقدم نظرة ثاقبة لاستراتيجيات التنفيذ المستقبلية. وتشير النتائج إلى أن Blockchain تعزز سلامة البيانات، في حين تعمل الشبكات العصبية الاصطناعية على تحسين الدقة التنبؤية، مما يجعل دمجها حلاً واعداً لمختلف المجالات.

الكلمات المفتاحية: سلسلة الكتل، ANNs، الشبكات العصبية الاصطناعي، النماذج التنبؤية، الأمان، قابلية التوسع، تكامل الذكاء الاصطناعي.

1. Introduction

Two leading digital technologies within contemporary society consist of Blockchain and Artificial Neural Networks (ANNs) (El Nokiti & et al, 2022). Blockchain operates as a secure digital system which stores data in a decentralized manner with complete transparency while keeping the information unalterable thus making it an optimal solution to protect information within complex digital environments (Dwivedi & et al, 2021). Blocks linked through encryption create a system that records trusted transactions as its core functionality. The technology provides solutions across digital currencies and contractual agreements as well as information security protection systems (Jabarulla& et al, 2021).

Artificial Neural Networks (ANNs) represent computational systems based on human brain design for data processing while also

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acquiring patterns through empirical learning and decision-making capability from trained data (Shrimali& et al, 2022). ANNs find extensive usage in artificial intelligence applications because they help organizations process natural language, identify images and analyze big data. These devices carry out their functions through mathematical algorithms and deep learning methods to become effective predictive model tools (Attaran, 2022).

The predictive models deliver critical value throughout different sectors because numerous industries need to forecast trends through analysis of historical information (Elhoseny& et al, 2021). The financial industry relies on predictive models to track market patterns as well as control risks and find banking-based fraud. Medical professionals take advantage of predictive models for diagnosing diseases and predicting epidemics in addition to using them to enhance patient outcomes through data analysis. E-commerce businesses use prediction methods to examine how customers behave which allows them to improve their marketing initiatives (Wustmans & et al, bridging trends and patents: Combining different data sources for the evaluation of innovation fields in blockchain technology, 2021).

Cybersecurity protective models assist in detecting forthcoming cyber attacks thus resulting in better defensive measures. Smart transportation systems apply predictions for monitoring traffic patterns which helps decrease congestion while enhancing network performance. Predictive models provide the energy sector with tools to measure energy usage while forecasting requirements along with developing superior production systems (Ullah & et al, 2023). Predictive models represent fundamental elements for innovation and efficiency in different fields instead of being simple analytical tools. The Need to Integrate Blockchain with ANNs for Enhanced Security and Accuracy ANNs continue to bring major progress in the field but struggle to address data security issues and reliability together with transparency problem (Wustmans& et al, 2021). Al models particularly ANNs experience three main drawbacks which include adversarial Using Blockchain together with ANNs engineers decentralized programs that enhance predictive model precision through data integrity protection as well as source verification before conducting training procedures. Blockchain technology guarantees authentic banking data integrity while stopping financial data manipulation during market trend assessment in financial institutions. Healthcare improves its

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medical predictions accuracy and prevents unauthorized tampering of patient records through Blockchain technology. Through an integration of Blockchain and ANNs in cybersecurity operations one obtains real-time detection of cyber threats and continual learning capabilities for breach prevention. Figure 1 shows the co-relation between Blockchain and various applications (Prakash & et al, 2022).

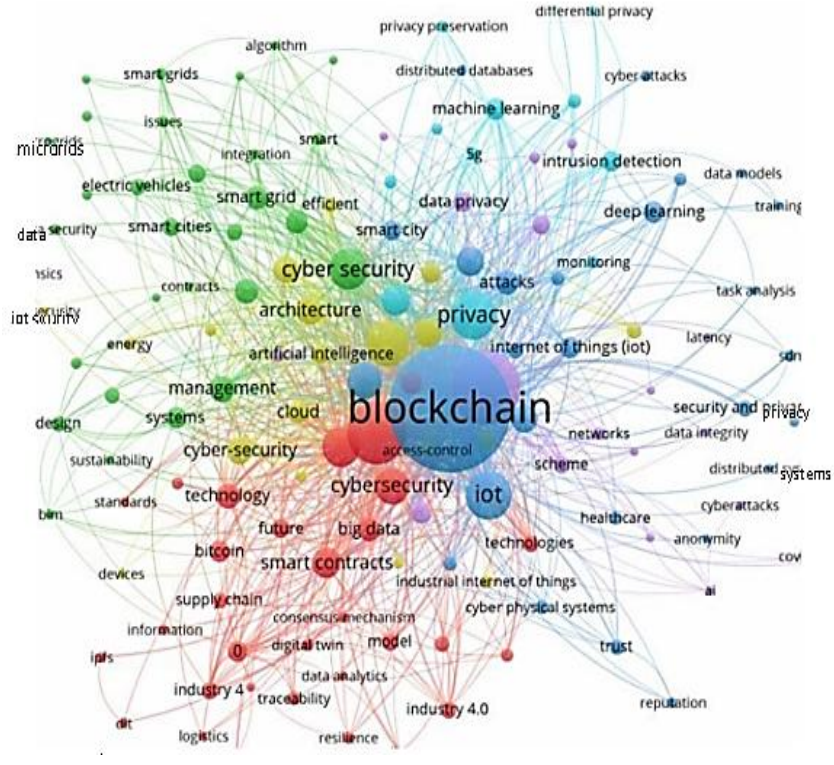

Figure 1: The co-relation between Blockchain and different sections, (Prakash & et al,2022).

The aim of this work is to analyze the security and accuracy improvements gained by integrating Blockchain and ANNs, also to assess the challenges related to performance, scalability, and real-world deployment, moreover, provide insights into future research directions for enhancing Blockchain-AI integration.

2. Literature review

Multiple studies in the literature expand on how emerging technologies including Artificial Intelligence (Al) Blockchain

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together with Internet of Things (IOT) are used in healthcare and global health sectors. Research has evaluated the practical uses and advantages of these technologies among different applications. A detailed evaluation of medical and global health applications involving Al and big data and blockchain technologies was presented by (Chattu, 2021). The authors demonstrated that Al improves healthcare decision systems yet blockchain technology provides protective measures for medical records and enhances healthcare transparency. Big data analytics demonstrates critical importance for handling massive healthcare information to lead to better patient results according to research findings (Chattu, 2021).
Alrubei et al. (2022) worked on creating blockchain platforms, which maintain security for Al-enabled I0T applications functioning at the edge layer. The authors developed a security model, which merges Al with I0T systems and blockchain technology to boost real-time healthcare monitoring data protection. These researchers demonstrated the requirement of safe data exchange protocols to support healthcare applications running at the edge for enhancing both 10T device performance and scalability (Alrubei et al, 2022).
Al-Marridi et al. (2021) investigated how reinforcement learning helps deliver effective security solutions for blockchain-smart health systems. The work described a framework based on reinforcement learning which optimized security and performance features of blockchain health applications. The authors demonstrated how machine learning integration with blockchain networks produces improved healthcare system capabilities during the processing of vast datasets (Al-Marridiet al, 2021). On the other hand, Kuznetsov et al. (2024) performed research, which integrated Al with blockchain for the purpose of security enhancement. The researchers detected weaknesses in present-day systems then introduced innovative protection measures for the integration of Al and blockchain technology. Through their research, they brought insights regarding the merging potential of these technologies which result in reliable healthcare solutions for maintaining data integrity (Kuznetsov & et al, 2024). Kumari et al. (2021) conducted an assessment of Blockchain and I0T convergence applicable to smart cities through 6G communication systems. The researchers conducted their study on smart cities but their findings deliver key value to healthcare when analyzing IoT devices and secure data systems. The authors demonstrated how blockchain technology

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optimizes IoT network performance leading to enhanced electric distribution systems of the future (Kumari & Gupta, 2021). Li et al. (2022) performed a systematic evaluation of blockchain-as-a-service models, which serve as management tools for IoT. Their research identified multiple usable methods of employing blockchain technology in 10T device management to achieve secure and functional data exchange. The authors examined diverse blockchain systems which Healthcare systems require combined with blockchain-powered IoT management to ensure protected medical data transfer and increase patient data confidentiality (Li et al, 2022).

These research papers demonstrate both the rise of Al and blockchain and IoT integration and the current healthcare system enhancements. Implementation of blockchain technology faces ongoing obstacles regarding genuine deployment techniques and testing because researchers have concentrated their efforts on security development and data scalability. This investigation expands upon established research by resolving scalability and performance along with security problems to improve the fusion of these technologies, which it investigates through literature review and previous study evaluation and application-specific integration analysis. The research explores both the current and potential advantages and difficulties, which affect predictive model prediction accuracy while presenting potential solutions.

3. Research Methodology and Evaluation Framework

This research method utilizes a systematic approach to gather existing studies that study the combination of Blockchain and Artificial Neural Networks (ANNs) in predictive modeling. The research strategy implements a step-by-step procedure for data acquisition followed by analysis classifications and research comparison evaluations. The research methodology provides a complete view of Blockchain and ANNs applications throughout all areas of business and reveals the key advantages and weaknesses along with scientific gaps in this field. Figure 2 shows this research methodology.

3.1 Data Collection

Relevant findings for this work came from peer-reviewed journals alongside conference proceedings and well-established databases which encompass IEEE Xplore, ScienceDirect, Springer, and ACM Digital Library. The research team relied on papers

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published during the recent ten years because the study required actual industry progress reports. Search queries included:

- "Blockchain in predictive modeling"
- "Artificial Neural Networks and security"
- "Machine learning with Blockchain"

Relevant papers were selected based on their focus on Blockchain-ANN integration, security enhancements, and predictive model accuracy. Research conducted on this topic was thoroughly examined to discover significant patterns and modern approaches together with essential obstacles arising in the integration of Blockchain with ANNs as shown in figure 2.

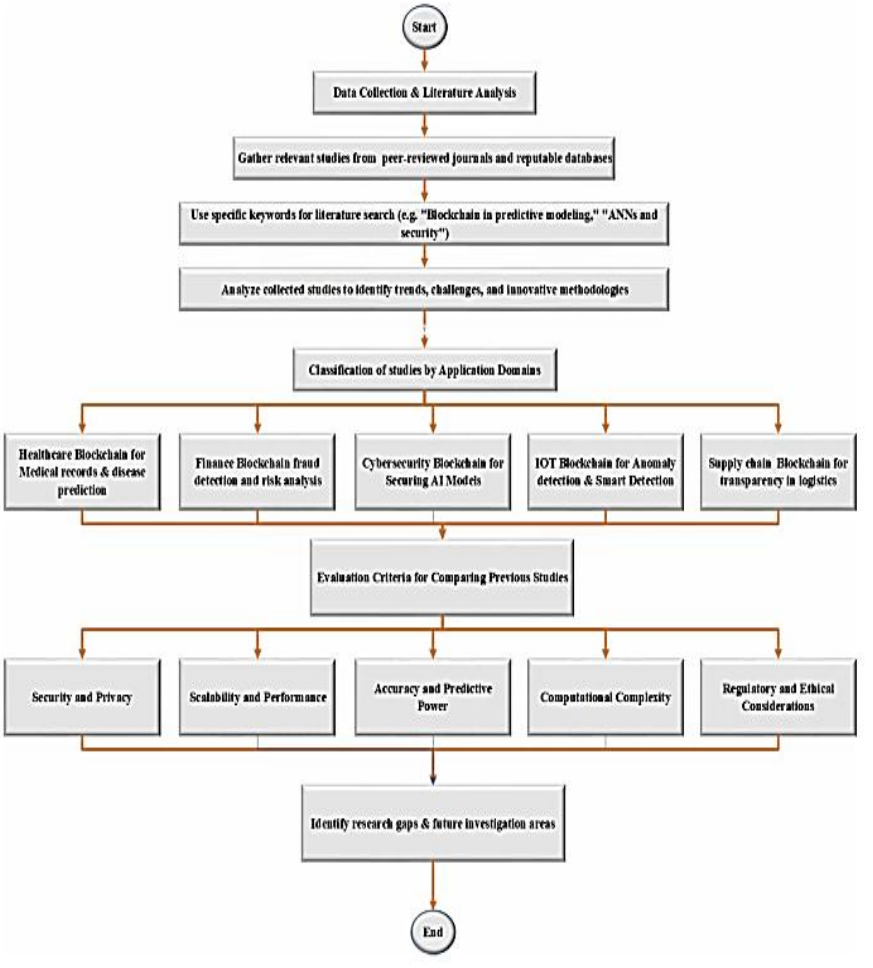

Figure 2: Research methodology

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3.2 Classification of Studies

Based on Figure 1, the reviewed studies were categorized based on application domains:

Healthcare – Blockchain secures patient records, while ANNs improve disease prediction.

1. **Finance** – Blockchain prevents fraud, and ANNs optimize risk assessment models.
2. **Cybersecurity** – Blockchain protects AI models, while ANNs enhance cyber threat detection.
3. **IoT & Smart Cities** – Blockchain improves IoT security, and ANNs optimize network performance.

- Healthcare research establishes Blockchain storage of medical files with ANNs working to improve disease diagnoses and treatment individualization.
- The study of finance through Blockchain technology examines methods of fraud detection supported by Blockchain systems as well as secure financial transaction mechanisms and Al-based risk evaluations for investment decisions.
- A number of academic publications analyze Blockchain's function to safeguard Al models from adversarial strikes while protecting important datasets used in security systems powered by ANN.
- Research has focused on Bluetooth-ANN integration within Internet of Things because of its significance for networked power grids, connected motor vehicles and instant anomaly monitoring systems.
- The integration of Blockchain within supply chains provides transparent control according to research documents and ANNs enhance the prediction of market needs and logistics operations optimization.
- The classification scheme helps researchers understand specific ways Blockchain and ANNs work together in different sectors to better recognize domain-related difficulties and possible advantages.

3.3 Evaluation Framework

The studies were evaluated using the following criteria:

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- **Security & Privacy** – Blockchain's role in enhancing AI model security.
- **Computational Efficiency** – The impact of Blockchain on ANN model performance.
- **Scalability** – The feasibility of large-scale Blockchain-ANN integration.
- **Regulatory Compliance** – Legal and ethical challenges of implementation.

The security measures provided by Blockchain systems determine both the protection of ANN model security as well as the integrity of stored data.

The computational efficiency and scalability of Blockchain integrated Al models in real world applications. Blocks Chain technology advances both preparedness accuracy and reliability levels of ANN-based predictive models. Integration of Blockchain requires examination of security benefits versus the added computational problems that result from the implementation. Examination how various works handle both regulatory compliance and ethical matters in Al-Blockchain implementation procedures.

The study employs these evaluation standards to analyze former study outputs by demonstrating their impact and showing what knowledge remains unaddressed. The established research methodology creates an effective base for additional investigations about Blockchain and ANNs integration in predictive analysis.

4. Blockchain and ANNs: A Separate Examination

It is necessary to review the individual research on Blockchain and Artificial Neural Networks (ANNs), therefore it would be possible to explore their potential amalgamation. The examination of individual applications and strengths as well as challenges of these technologies builds a strong base for supporting combined analysis. This part gives an extensive breakdown of studies, which investigate Blockchain technology along with Artificial Neural Networks individually.

Mohit Kumar, 2022 evaluated Blockchain and Artificial Neural Networks (ANNs) when used independently in wearable healthcare systems. The authors provided solutions to 10T security problems in healthcare devices through blockchain data storage security measures along with health status prediction authentication protocols as presented in Figure 3. Security processes in the

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research relied on the RP2-RSA algorithm with reversed public-private key implementation while feature selection operations used the CF-SSOA algorithm. The prediction of health status used an advanced weight initialization adapted Signorelli activation function-based artificial neural network (ASR-ANN). The system operated through two categories, which identified patient medical status as normal or abnormal before securing abnormal results within the blockchain framework for technical assessment. Research findings showed that the proposed model reached 95.893% accuracy and the RP2-RSA algorithm exhibited superior 96.123% security than base approaches as presented in Table 1, 2 (Kumar & et al, 2022).

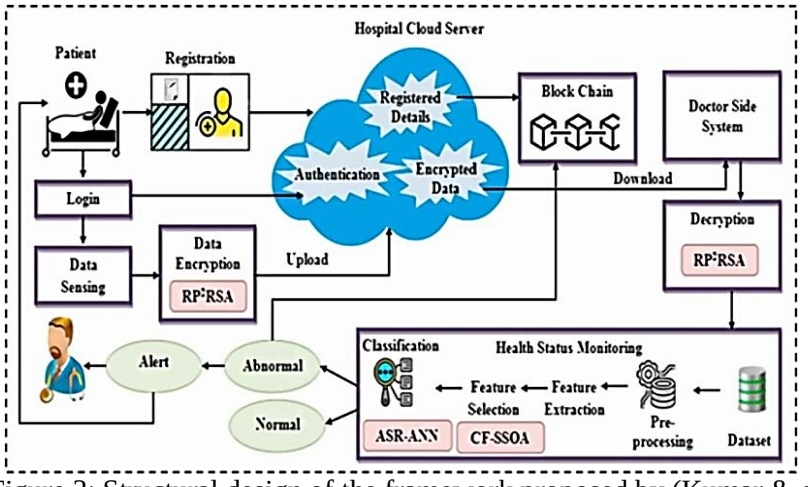

Figure 3: Structural design of the framework proposed by (Kumar & et al, 2022).

Table 1: Encryption, Decryption, Generation times, and Security Level (SL) (%) according to (Kumar & et al, 2022)

Metric	RP2-RSA (Proposed)	ECC	RSA	EIGama1	Best Performa-nce
Encryption Time (ET) (ms)	14,986 17,042	18,200	19,124	20,315	RP2-RSA
Decryption Time (DT) (ms)	14,121 16,874	24,761 32,442	22,135	25,403	RP2-RSA
Key Generation Time (ms)	2,124	3,154	2,662	3,548	RP2-RSA
Security Level (SL) (%)	96.123	91.5	90.234	89.874	RP2-RSA

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Table 2: Comparison between ASR-ANN, ANN, CNN, RNN, and DBNN according to (Kumar & et al, 2022)

Model	Accuracy (%)	Precision	Recall	F-Score	Execution Time (ms)	Memory Usage (KB)
ASR-ANN	95.893	95.654	96.098	96.012	48,432	165,432
ANN	95.152	94.762	95.387	94.742	52,961	1,989,791
CNN	93.383	93.621		93.985	57,378	213,490
RNN	91.725	92.406	92.214	92.359	62,815	246,701
DBNN	89.892	91.01	89.478	90.989	69,721	278,932

(Shynuet al, 2021) demonstrates that health data storage and analysis through Blockchain elements on fog nodes achieves better security than cloud systems (See Figure 4). A cluster analysis performed through rules generated appropriate patient record groups and the FS-ANFIS method displayed maximum accuracy for diabetes and cardiovascular disease prediction. The predictive results from the proposed model delivered higher than 81% measurement accuracy that surpassed alternative neural network approaches. This research showed Blockchain could effectively protect disease prediction models, which operate in fog computing environments (Shynu et al, 2021).

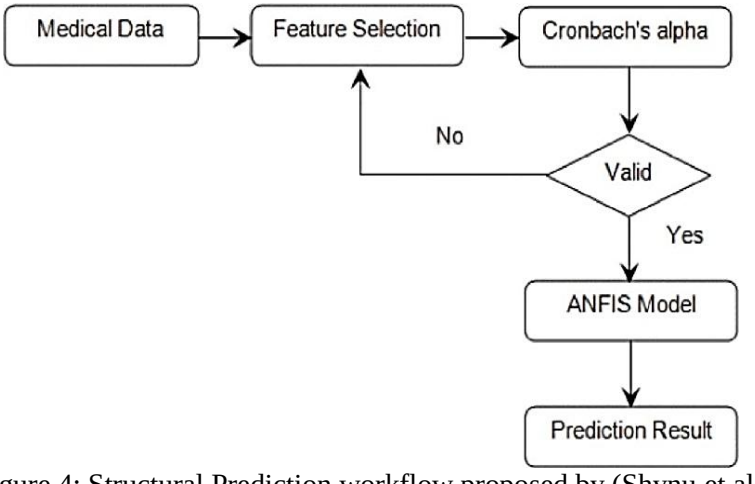

Figure 4: Structural Prediction workflow proposed by (Shynu et al, 2021).

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On the other hand, the fusion of machine learning technology together with blockchain as described in (Bello & et al, 2024) introduced an innovative system, which shines light on financial fraud while doing real-time prevention. Real-time security obtained through blockchain systems allowed ML algorithms to detect patterns across big datasets and expose abnormal activities while maintaining complete data protection and unalterable record organization. Main functions of smart contracts included automated fraud prevention that enabled automatic blocking of suspicious transactions while also sending multiple warning signals. Both components operated together to eliminate detection system breakdowns while improving accuracy levels and allowing immediate fraud prevention. Unfortunately, the integration of blockchain and ML created stronger financial security, which successfully drove the development of automated compliance systems (Bello et al, 2024).

Wylde, 2022 explained that blockchain technology adoption faces major obstacles when supporting cybersecurity measures and data protection elements. Security data management benefits from the implementation of legal frameworks, which include both ISO 27001 and GDPR. The research explained why blockchain systems require linking with smart contracts to improve digital transaction security and transparency as illustrated in Figure 5. The proposed framework uses big data with machine learning and visualization tools to build strong cybersecurity elements and maintain ethical and legal compliance standards. Continuous research investment stands necessary to develop worldwide collaboration potential within healthcare fields together with financial and market approaches (Wylde et al, 2022).

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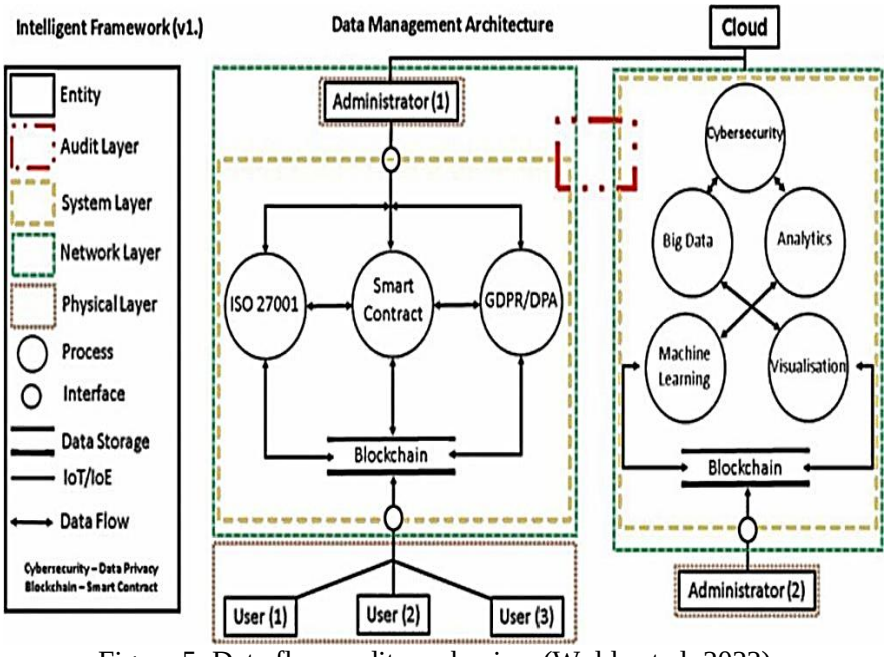

Figure 5: Data flow audit mechanism (Wylde et al, 2022)

Mahmood, 2022 highlighted numerous deficiencies in present-day cybersecurity research regarding blockchain technology (BCT) in both empirical investigations and industrial applications. The review discovered that malleability attacks, 51% attacks and wallet security attacks represent the main adoption hurdles in BCT yet fails to present established defensive approaches. Most available research falls within conceptual categories instead of using empirical methods with insufficient information about solving these security problems. The research shows a limited emphasis on industry-specific study while Al integration plays a minimal role (Mahmood et al, 2022).

Khan (2022) developed a blockchain framework, which uses Hyperledger sawtooth to increase both security and reliability. The designed framework delivered multiple security benefits through safe execution along with unchangeable ledger records and optimized communication protocols. The design of pseudo-chain codes together with consensus protocols brought performance improvements and trust optimizations to the system. Table 3 demonstrates how different Hyperledger frameworks differ in terms of encryption functions and their storage solutions and implementation expenses. Hyperledger Fabric includes multiple encryption capabilities while it stores data through IPFS/File coin

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infrastructure at no expense for simulation operations. Guest payments exist for Hyperledger Besu, Indy and Composer since these frameworks use hash-encryption combined with third-party storage solutions. The findings show Fabric stands out because it adapts well to different needs and saves costs whereas the other solutions need external storage services that add expenses. The study results have helped tackle industrial I0T problems and enhance the effectiveness of blockchain implementations (Khan et al, 2022). Real-world applications become possible by conducting combined comparison-based research between Blockchain and Artificial Intelligence (Al) technologies after moving past independent studies of each field. Ensuring data security rewards blockchain technology with its ability to present systems that viewers can understand while artificial intelligence introduces analytical forecast capabilities followed by automated system management and intelligent choice mechanisms. Research on individual technologies does not uncover the two-fold benefits that occur when systems connect and act together.

Table 3: A comparison between Hyper ledger frameworks based on encryption, storage, and cost. Hyper ledger Fabric according to (Khan & et al, 2022)

Other States of the Art Hyperledger	Transaction Encryption (TE)	Storage (S)	Cost (Co)
Fabric	Supports another encryption algorithm as well	IPFS/Fi1ecoin	Not required before simulating
Besu	Hash-encryption	Third-party mechanism used	Guest charge required
Indy	Hash-encryption	Third-party mechanism used	Guest charge required
Composer	Hash-encryption	Third-party mechanism used	Guest charge required

5. A comparison between different approaches to integrating Blockchain and ANNs

The study of Blockchain integration with Al through comparison provides better insights into how Al models receive Blockchain security protection and how blockchain operations receive Al optimizations and how the combined approach solves efficiency and regulatory issues and scalability problems. The combination of Blockchain with Al offers better data protection during sharing in

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healthcare and finance applications and enhances the identification of frauds and predictive analysis accuracy in cybersecurity sectors. (Tagde& et al, 2021) described the merger of Blockchain with Al technology in healthcare to strengthen medical risk administration and analytical operations. The findings showed that Blockchain delivers safe medical record transfer through its transparent system alongside Al deployment of decision-making algorithms. Healthcare systems achieved better efficiency and reduced medical expenses through combined implementation of these technologies while extending medical service access to wider audiences. Blockchain implemented cryptographic storage which enabled Artificial Intelligence technologies to advance medical healthcare (Tagde& et al, 2021). The rapid evolution of modern healthcare technology becomes evident in Table 4 although the implementation requires improvement of security measures and scalability implementation to achieve best adoption results.

Table 4: Overview of Modern Technologies in Healthcare: Trends, Strengths, Challenges, and Future Directions.

Section	Details
Trends in Healthcare Technology	Blockchain & Al Dominance: Offer security, scalability, and automation.
	10T & Wearable Tech: Improve real-time monitoring and energy management.
	Cloud & Fog Computing: Provide scalability and efficiency, but require more validation.
	UAV & Robotics: Enhance automation and efficiency in healthcare operations.
Strengths of Each Technology	Blockchain: High security, authentication
	Al: Reduces operational costs, improves decision making
	IOT: Enhances service quality and robustness.
	Cloud Computing: Ensures low latency and high feasibility
	Wearable Tech: Enables real-time execution.
Common Challenges & Limitations	Scalability & Performance: High transaction fees and com tuitional overhead, especial with blockchain.
	Security & Privacy: Al models face risks like data modification, spoofing,and cyberattacks.
	Implementation Gaps: Lack of real-world deployment and validation.

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Future Directions	Integration of Blockchain & Al to balance security, trust, and automation.
	Optimizing 10T & Cloud Solutions to improve scalability and efficiency
	Enhancing real-time capabilities in wearable and UAV technologies.
Conclusion	Modern healthcare technology is evolving rapidly, but challenges in security, scalability, and real-world imp-lamentation must be addressed for optimal adoption.

Both studies shown in Table 4 investigate unique aspects of blockchain security and predictive fraudulent behavior detection with ML as per (Bello & et al, 2024) and (Ashfaq & et al, 2022). Individual classification models displayed preference for the majority class because data records were heavily imbalanced based on findings from Ashfaq in 2022 (Figure 6). Al integration with blockchain created an enhanced solution for fraud detection that produced better results than relying solely on blockchain security measures according to Figure 7. A first study maintains digital transaction security using smart contracts for prevention of manipulation and the second study uses Al analytics to conduct real-time fraud detection. The main obstacle which persists is improving defense against innovative cyber threats that attack both blockchain systems and machine learning frameworks.

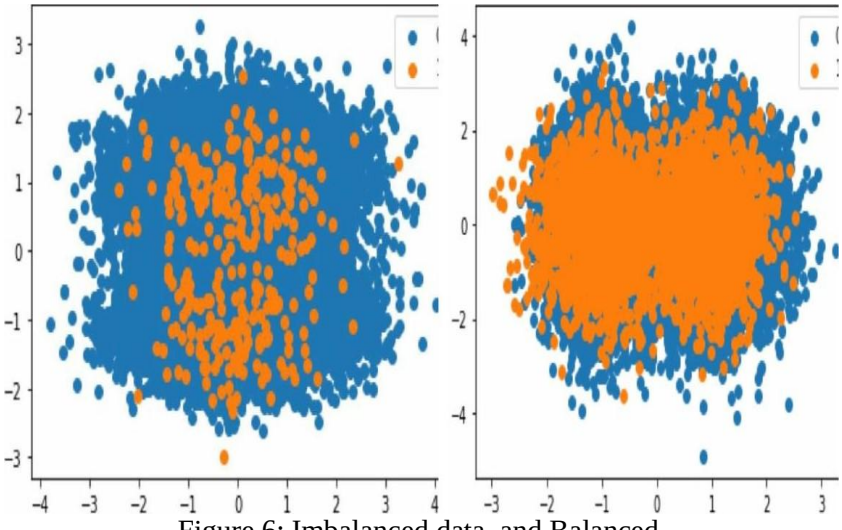

Figure 6: Imbalanced data, and Balanced

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```
INFO:symExec:   ============ Results ===========
INFO:symExec:     EVM Code Coverage:                  99.5%
INFO:symExec:     Integer Underflow:                  False
INFO:symExec:     Integer Overflow:                   False
INFO:symExec:     Parity Multisig Bug 2:              False
INFO:symExec:     Callstack Depth Attack Vulnerability:  False
INFO:symExec:     Transaction-Ordering Dependence (TOD): False
INFO:symExec:     Timestamp Dependency:               False
INFO:symExec:     Re-Entrancy Vulnerability:          False
INFO:symExec:   ====== Analysis Completed ======
```

Figure 7: Security analysis of the proposed smart contract.

Table 5: A comparison between blockchain security and the predictive power of ML in fraud prevention according to (Bello & et al, 2024) and (Ashfaq & et al, 2022), respectively.

Criteria	Security Analysis of Smart Contracts (Bello & et al, 2024)	Integration of ML and Blockchain for Fraud Detection (Ashfaq & et al, 2022)
Main Focus	Security features of blockchain based smart contracts.	Integration of ML and blockchain for fraud detection.
Security Aspects	Covers decentralization, integrity, availability, trust, and confidentiality.	Focuses on security, transparency, and immutability.
Fraud Detection	Uses blockchain's security mechanisms to prevent attacks like replay and MITM.	Uses ML to detect and prevent fraud by analyzing patterns.
Technology Used	Blockchain-based smart contracts with Ethereum and permissioned blockchain.	ML techniques such as supervised and unsupervised learning combined with blockchain.
Attack Resistance	Resistant to DOS, Sybil, and double-spending attacks.	Detects and prevents fraudulent financial transactions.
Limitations	Vulnerable to adversarial attacks, requiring future improvements.	Enhances fraud detection but does not mention adversarial resistance.
Conclusion	Blockchain provides robust security for smart contracts and digital transactions.	The synergy of ML and blockchain enhances fraud detection and financial security.

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The research conducted by (Shinde., et al, 2021) explored the collaborative features between Blockchain and Artificial Intelligence as depicted in Figure 8. The combination of these systems faces barriers in three main areas: scalability, interoperability, privacy and both security and energy consumption according to the study findings. The analysis focused on governance legal and ethical concerns using the information found in Table 6.
Research results demonstrated that Blockchain security enables protection of Al systems and facilitates open innovation procedures (Shinde & et al, 2021).

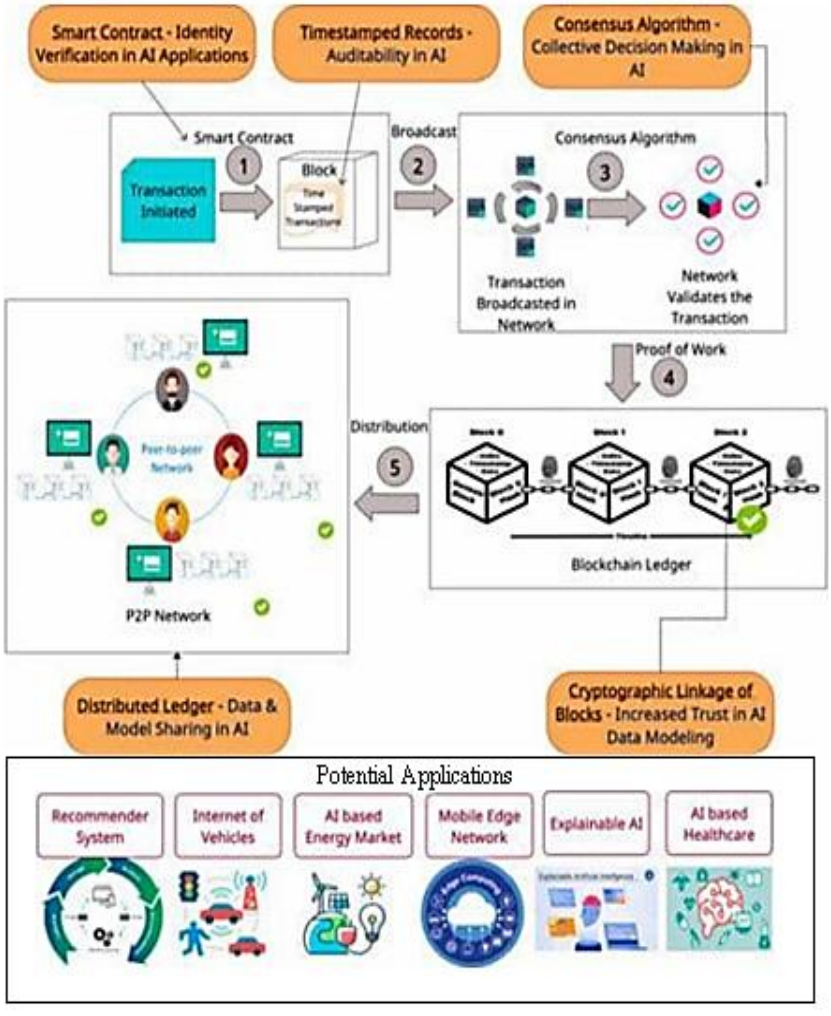

Figure 8: Security analysis of the proposed smart contract according to (Shinde & et al,2021).

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Table 6: Relation between Blockchain, Artificial Intelligence (Al), and their Integration according to (Shinde & et al, 2021)

Aspect	Blockchain	Artificial Intelligence AI	Integration Benefits	Challenges
Functionality	Decentralized ledger for secure transactions	Data-driven decision-making and automation	Secure and transparent Al decision-making	Scalability, security, and interoperability issues
Data Handling	Stores and validates immutable records	Processes and analyzes large-scale data	Ensures data integrity and prevents manipulation	High computational and storage requirements
Security	Uses cryptographic techniques and consensus models	Vulnerable to data poisoning and adversarial attacks	Enhances Al security by making decisions traceable	Increased energy consumption due to complex encryption
Trust & Transparency	Provides an auditable and tamper-proof led er	Often seen as a "black-box" with limited transparency	Makes Al decision-making more explainable	Smart contract vulnerabilities and lack of regulations
Applications	Cryptocurrencie s, supply chain, healthcare	Image recognition , NLP, autonomou s systems	Fraud detection, secure Al models, decentralized Al	Legal and ethical concerns in AI driven smart contracts
Research Trends	Gaining traction since 2019	Al has been growing exponentially	Growing interest in combining Al and blockchain	Need for lightweight blockchain models for Al

6. Discussion

The integration of Blockchain and Artificial Neural Networks (ANNs) offers a transformative approach to predictive modeling, offering enhanced security, data integrity, and predictive accuracy. However, several challenges must be addressed before widespread adoption. Security and privacy enhancements are crucial for the success of Blockchain technology, as it provides a secure and transparent data management system by leveraging decentralized ledgers and cryptographic mechanisms. Smart contracts can automate security protocols, ensuring data authenticity before it is used for training ANNs. However, Blockchain introduces new attack surfaces, such as vulnerabilities in consensus algorithms and private key management. ANNs rely heavily on large datasets for training, making them vulnerable to adversarial attacks and data

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poisoning. Integrating Blockchain with ANNs mitigates these risks by ensuring that the training data remains immutable and verifiable, particularly beneficial in sensitive applications like healthcare. However, the additional computational overhead introduced by Blockchain security mechanisms can impact the efficiency of ANN-based predictive models.Scalability and performance challenges are significant challenges in integrating Blockchain and ANNs. Blockchain networks suffer from high latency, limited transaction throughput, and increased storage requirements due to their decentralized nature. ANNs require vast amounts of data for training and real-time inference, leading to performance bottlenecks. Existing solutions, such as layer-2 scaling techniques, off-chain computation, and hybrid blockchain architectures, offer potential remedies, but further optimization is needed to balance security, decentralization, and computational efficiency. Computational complexity and energy consumption are also significant challenges in integrating Blockchain and ANNs. Blockchain operations involve cryptographic hashing, consensus mechanisms, and continuous validation, while ANNs demand extensive computing resources for training, leading to high energy consumption.

Developing lightweight cryptographic models, optimizing ANN architectures, and leveraging quantum computing advancements could offer potential solutions to mitigate these challenges. Regulatory compliance remains a critical barrier to the large-scale deployment of Blockchain-ANN integration. Industries like healthcare and finance are governed by strict data protection regulations, including GDPR, HIPAA, and ISO 27001. Ensuring that Blockchain-ANN systems adhere to global regulatory frameworks while maintaining transparency and accountability requires a well-defined governance structure.

Future research should focus on optimizing computational efficiency, improving scalability, enhancing security measures, establishing regulatory standards, and expanding real-world applications. By addressing these challenges, the synergy between Blockchain and ANNs can unlock new opportunities for secure, intelligent, and scalable predictive modeling, enhancing data-driven decision-making and redefining digital trust and security standards. Studies regarding Blockchain combined with Artificial Neural Networks (ANNs) were analyzed based on five significant factors within Table 7 that encompass Security and Privacy, Scalability and

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Performance, Accuracy and Predictive Power, Computational Complexity, and Regulatory and Ethical Considerations.

Table 7: Comparative Analysis of Blockchain and Artificial Neural Network (ANN), Inte ration Across Ke Dimensions.

Category	Study & Source	Techniques Used	Findings	Challeng es
Security and Privacy	(Kumar & et al, 2022)	RP2-RSA encryption for secure data storage	The security level reached 96.123% which exceeded RSA and ECC ca abilities	High computational resource consumption
	(Shynu & et al, 2021)	Blockchain + Fog Computing for secure healthcare data storage	This approach provided better security than employing cloud-based storage solutions.	Data retrieval delays due to fog nodes
	(Bello & et al, 2024)	ML + Blockchain for fraud detection	Improved transparency and reduced fraud cases	Complexity in system implementation and model training
	(Wylde & et al, 2022)	ISO 27001 & GDPR compliance for blockchain security	Strengthened digital governance and trust	Need for cross-border legal harmonization
	(Mahmoo d & et al, 2022)	Analysis of blockchain attacks (51 % attack, Malleability attack	Identified vulnerabilities in Blockchain security	Lack of empirical studies on mitigation strategies
	(Khan & et al, 2022)	Hyperledger Sawtooth for secure execution	Enhanced reliability through consensus protocols	Increased complexity in system setup
Scalability and Performance	(Kumar & et al, 2022)	ASR-ANN for system performance analysis	The system achieved a 95.89% success rate at the cost of 165,432 KB of memo s ace	Scalability challenges due to high memory usage
	(Shynu & et al, 2021)	Fog Computing to improve performance	Faster response time	Limited scalability for

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			compared to cloud computing	large-scale applications
	(Khan & et al, 2022)	Hyperledger Fabric vs. Besu & Indy comparison	The fabric technology provides flexible functionality at reduced expense.	Scalability issues still exist in large blockchain networks
	(Tagde& et al, 2021)	Al + Blockchain impact on performanc e	Improved efficiency but high energy consumption	Need for optimized processing techniques
	(Shinde & et al, 2021)	Analysis of blockchain encryption energy consumption	Suggested lightweight blockchain models for Al	High computational burden with advanced encryption
Accuracy and Predictive Power	(Kumar & et al, 2022)	ASR-ANN model for health status prediction	Achieved 95.89% accuracy, outperforming ANN, CNN, and RNN	Requires significant computational power
	(Shynu & et al, 2021)	FS-ANFIS for medical data classification	Achieved over 81% accuracy in disease prediction	Lower accuracy compared to advanced ANN models
	(Bello & et al, 2024)	ML + Blockchain for fraud detection	More effective than Blockchai n-only approache s	Susceptible to data bias issues
	(Ashfaq & et al, 2022)	Impact of imbalanced datasets on ML models	Showed that ML models tend to favor majority classes	Addressing data imbalance can improve model fairness
Computation al Complexity	(Kumar & et al, 2022)	ASR-ANN model execution analysis	48,432 ms execution time, faster than CNN and RNN	Still computationally expensive

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	(Khan & et al, 2022)	Comparison of Hyperledger frameworks	Blockchain Fabric consumes less resources than both Besu and Ind versions	Complexity increases with large-scale deployments
	(Shinde & et al, 2021)	Impact of Al on blockchain processing	Research showed that Al-Blockchain integration consumes excessive amounts of energy	Need for more efficient algorithms
Regulatory and Ethical Considerations	(Wylde & et al, 2022)	Compliance with ISO 27001 & GDPR	Ensured regulatory adherence and legal security	Legal enforcement varies by region
	(Mahmood & et al, 2022)	Legal and ethical concerns in blockchain adoption	Found gaps in regulatory compliance for Blockchain	Lack of real-world implementation studies
	(Shinde & et al, 2021)	Privacy & governance in Al Blockchain	Stressed the need for a unified legal framework	No clear governance structure yet

7. Conclusion

This study examines the integration of Blockchain and Artificial Neural Networks (ANNs) in predictive modeling, highlighting their complementary strengths. Blockchain enhances security, transparency, and data integrity, while ANNs improve predictive accuracy through advanced learning frameworks. However, their integration faces challenges such as computational complexity, scalability limitations, and regulatory constraints. Addressing these challenges is essential for widespread adoption. Optimizing computational efficiency, developing scalable frameworks, and establishing unified regulatory policies can facilitate smoother implementation. The fusion of Blockchain and ANNs has the potential to revolutionize various fields, including healthcare, finance, and cybersecurity, by ensuring secure and intelligent predictive models. Future research should focus on energy-efficient AI models, lightweight Blockchain architectures, and standardized governance frameworks. By overcoming existing barriers, Blockchain-ANN integration can pave the way for robust, secure,

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and highly accurate predictive systems, significantly advancing the digital landscape.

8. References

Al-Marridi, A., & et al. (2021 Reinforcement learning approaches for efficient and secure blockchain powered smart health systems. Computer Networks, 108279.

Alrubei, S., & et al. (2022). A secure blockchain platform for supporting Al-enabled IOT applications at the edge layer. IEEE Access, 18583-18595.

Ashfaq, T., & et al. (2022). A machine learning and blockchain based efficient fraud detection mechanism. R, 7162.

Attaran, M. (2022). Blockchain technology in healthcare: Challenges and opportunities. International Journal of Healthcare Management, 70-83.

Bello, H., & et al. (2024). Integrating machine learning and blockchain: Conceptual frameworks for real-time fraud detection and prevention. World Journal of Advanced Research and Reviews, 056068.

Chattu, V. (2021). A review of artificial intelligence, big data, and blockchain technology applications in medicine and global health. Big Data and Cognitive Computing, 41.

Dwivedi, S., & et al. (2021). Blockchain-based internet of things and industrial IOT: a comprehensive survey. Security and Communication Networks, 7142048.

El Nokiti, A., & et al. (2022). Is blockchain the answer? A qualitative study on how blockchain technology could be used in the education sector to improve the quality of education services and the overall student experience. Computer. Integer. Manuf. Syst, 543-556.

Elhoseny, M., & et al. (2021). IOT solution for Al-enabled PRIVACY-PRE-Serving with big data transferring: an application for healthcare using blockchain. Energies, 5364.

Jabarulla, M., & et al. (2021). A blockchain and artificial intelligence-based, patient-centric healthcare system for combating the COVID-19 pandemic: Opportunities and applications. MDPI, 1019. Khan, A., & et al. (2022). Internet of Things (IOT) security with blockchain technology: A state-of-the-art review. IEEE Access, 122679-122695.

Kumar, M., & et al. (2022). BBNSF: Blockchain-based novel secure framework using RP2-RSA and ASR-ANN technique for IOT enabled healthcare systems. Sensors, 9448.

http://www.doi.org/10.62341/rmms1757

Kumari, A., & Gupta, R. (2021). Amalgamation of blockchain and IOT for smart cities underlying 6G communication: A comprehensive review. Computer Communications, 102-118.

Kuznetsov, 0., & et al. (2024). On the integration of artificial intelligence and blockchain technology: a perspective about security. IEEE Access, 3881-3897.

Li, D., & et al. (2022). Blockchain as a service models in the Internet of Things management: Systematic review. Transactions on Emerging Telecommunications Technologies, e4139.

Mahmood, S., & et al. (2022). Cybersecurity challenges in blockchain technology: A scoping review. Human Behavior and Emerging Technologies, 7384000.

Prakash, R., & et al. (2022). Blockchain technology for cybersecurity: A text mining literature analysis. International Journal of Information Management Data Insights, 100112.

Shinde, R., & et al. (2021). Blockchain for securing ai applications and open innovations. Journal of Open Innovation: Technology, Market, and Complexity, 189.

Shrimali, B., & et al. (2022). Blockchain state-of-the-art: architecture, use cases, consensus, challenges and opportunities. Journal of King Saud University-Computer and Information Sciences, 6793-6807.

Shynu, P., & et al. (2021). Blockchain-based secure healthcare application for diabetic-cardio disease prediction in fog computing. IEEE Access, 45706-45720.

Tagde, P., & et al. (2021). Blockchain and artificial intelligence technology in e-Health. Environmental Science and Pollution Research, 52810-52831.

Ullah, Z., & et al. (2023). Blockchain applications in sustainable smart cities. Sustainable Cities and Society, 104697.

Wustmans, M., & et al. (2021). Bridging trends and patents: Combining different data sources for the evaluation of innovation fields in blockchain technology, IEEE Transactions on Engineering Management, 825-837.

Wylde, V., & et al. (2022). Cybersecurity, data privacy and blockchain: A review. SN computer science, 127.