RESEARCH PAPER

A Secure And Intelligent Drug Delivery Model Integrating Neural Networks With Blockchain

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Abstract

The advancement of intelligent healthcare systems has created a growing need for secure, efficient, and personalized drug delivery mechanisms. Traditional drug delivery approaches often face challenges such as lack of precision, data security risks, limited patient-specific optimization, and poor transparency in medical data handling. To address these issues, this research proposes a secure and intelligent drug delivery model integrating neural networks with blockchain technology. In the proposed framework, neural networks are employed to analyze patient-specific data, predict optimal drug dosage, and determine precise drug release patterns, thereby enabling personalized treatment strategies. Blockchain technology is integrated to ensure secure, decentralized, and tamper-resistant storage of medical records and drug delivery transactions. Smart contracts are utilized to automate access control, verify data integrity, and manage the interaction between healthcare providers, patients, and pharmaceutical systems. The model adopts a hybrid architecture where sensitive healthcare data is stored off-chain, while cryptographic hashes and transaction logs are maintained on the blockchain to ensure transparency and traceability. The system is evaluated using healthcare datasets and machine learning performance metrics such as accuracy, precision, recall, and f1-score, along with blockchain performance metrics including latency and throughput. The proposed approach enhances data security, patient privacy, and trust in ai-driven healthcare systems, while improving the efficiency and reliability of drug delivery processes. This integrated framework has the potential to support next-generation smart healthcare applications by enabling secure, intelligent, and personalized medical treatment solutions.

Keywords: Drug Delivery Systems, Neural Networks, Blockchain Technology, Artificial Intelligence, Smart Contracts, Personalized Medicine, Healthcare Data Security, Decentralized Healthcare, Machine Learning, Secure Data Sharing.

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I. INTRODUCTION

The rapid advancement of digital healthcare technologies has significantly transformed modern medical practices, particularly in the area of drug delivery systems. Traditional drug delivery methods often rely on fixed dosage and generalized treatment approaches, which may not account for individual patient variability. This can lead to issues such as inefficient drug targeting, adverse side effects, and suboptimal therapeutic outcomes. In addition, the increasing use of digital health data introduces concerns related to data security, privacy, and integrity, especially when sensitive patient information is shared across multiple healthcare stakeholders. Recent developments in Artificial Intelligence, particularly neural networks, have enabled more accurate analysis of complex medical data. Neural networks can learn patterns from patient records, physiological signals, and treatment histories to support personalized drug delivery strategies. By predicting optimal dosage, timing, and drug release mechanisms, these models improve treatment precision and enhance patient outcomes. However, despite their effectiveness, AI-based healthcare systems often lack transparency and are vulnerable to data manipulation due to their reliance on centralized data storage.

To address these limitations, Blockchain Technology has emerged as a promising solution for secure and decentralized data management. Blockchain provides features such as immutability, transparency, and distributed consensus, which ensure that healthcare data cannot be altered without authorization. Platforms like Ethereum support smart contracts, enabling automated enforcement of data access rules and secure interactions between healthcare providers, patients, and pharmaceutical systems.

Integrating neural networks with blockchain technology offers a novel approach to developing secure and intelligent drug delivery systems. In such a framework, neural networks handle data-driven decision-making, while blockchain ensures secure storage, traceability, and trustworthy data exchange. This integration enables the creation of a system that not only optimizes drug delivery based on patient-specific conditions but also ensures data security, privacy, and accountability across the healthcare ecosystem.

Therefore, this research focuses on designing a hybrid framework that combines neural network-based intelligence with blockchain-enabled security to enhance drug delivery processes. The proposed model aims to improve the efficiency, reliability, and safety of drug administration while supporting the development of next-generation personalized healthcare systems.

The rapid evolution of digital healthcare technologies has significantly transformed modern medical practices, particularly in the domain of drug delivery systems. Conventional drug delivery methods typically follow a one-size-fits-all approach, where dosage and administration schedules are standardized without fully considering individual patient characteristics such as genetic profile, metabolism, and disease progression. This often leads to inefficient drug targeting, reduced therapeutic effectiveness, and increased risk of adverse side effects. Moreover, the growing reliance on digital healthcare data has introduced serious concerns regarding data privacy, security, interoperability, and trust, especially when sensitive patient information is exchanged among multiple healthcare entities.

Recent advancements in Artificial Intelligence have opened new possibilities for improving drug delivery through intelligent data-driven approaches. In particular, neural networks, a subset of AI, have demonstrated exceptional capability in analyzing complex biomedical data, identifying hidden patterns, and making accurate predictions. These models can process diverse datasets, including patient medical histories, physiological signals, and laboratory results, to enable personalized drug delivery strategies. By predicting optimal dosage levels, drug release timing, and treatment responses, neural networks contribute to enhanced precision medicine and improved clinical outcomes. However, despite these advantages, AI-based systems often operate in centralized environments, which limits transparency, increases vulnerability to cyber threats, and raises concerns about data manipulation and lack of accountability.

To overcome these limitations, Blockchain Technology has emerged as a transformative solution for secure and decentralized data management in healthcare. Blockchain provides a distributed, immutable, and transparent ledger where all transactions are recorded in a tamper-resistant manner. This ensures that once data is stored, it cannot be altered without consensus from the network participants.

Additionally, blockchain supports the use of smart contracts, which are self-executing programs that enforce predefined rules for data access, sharing, and verification. Platforms such as Ethereum enable the implementation of these smart contracts, facilitating secure and automated interactions among patients, healthcare providers, and pharmaceutical stakeholders.

II. PROBLEM STATEMENT

- The current drug delivery systems in healthcare face significant challenges related to lack of personalization, inefficient dosage control, and security vulnerabilities in medical data management. Traditional approaches rely on generalized treatment protocols that do not consider patient-specific variations such as genetic factors, lifestyle, and real-time physiological conditions. This often results in reduced treatment effectiveness and increased side effects.
- Moreover, the integration of Artificial Intelligence in drug delivery introduces concerns regarding data privacy, transparency, and trustworthiness of AI decisions, as most systems operate in centralized environments. Sensitive patient data stored in centralized databases is vulnerable to cyberattacks, unauthorized access, and data manipulation.
- Although Blockchain Technology offers secure and decentralized data management, existing solutions do not effectively integrate blockchain with neural network-based drug delivery optimization. Additionally, there is a lack of frameworks that ensure secure data sharing, transparent AI decision-making, and real-time adaptability in drug administration.
- Therefore, there is a need to develop a secure, intelligent, and decentralized drug delivery framework that integrates neural networks for predictive analytics with blockchain for data security and transparency.

III.

Research objectives

The primary objective of this research is to design a secure and intelligent drug delivery system using neural networks and blockchain technology. Specific Objectives includes

- To develop a neural network-based model for predicting optimal drug dosage and delivery timing.
- To design a blockchain-based secure data management system for healthcare records.
- To implement smart contract mechanisms for automated access control and data validation.

- To ensure privacy-preserving data sharing among healthcare stakeholders.
- To improve accuracy and efficiency of drug delivery using AI-based analytics.
- To create a transparent and tamper-proof audit trail for drug delivery processes.
- To evaluate system performance using AI metrics and blockchain performance parameters.

IV. METHODOLOGY

A. OVERALL FRAMEWORK

This section presents a **detailed methodology** for designing, implementing, and evaluating the proposed hybrid framework. The system integrates intelligent drug delivery prediction using neural networks with secure data governance enabled by Blockchain Technology. The methodology is structured into multiple stages to ensure clarity, reproducibility, and robustness.

1. Data Acquisition Layer

The Data Acquisition Layer is the initial stage of the proposed framework, responsible for collecting healthcare-related data from multiple heterogeneous sources. These sources include Electronic Health Records (EHR), laboratory test reports, wearable IoT devices, and clinical datasets such as PhysioNet. The data collected typically consists of patient demographics, vital signs (such as heart rate, blood pressure, and glucose levels), medical history, and drug response information. This layer ensures that the system has access to comprehensive and real-time healthcare data required for accurate drug delivery predictions. Proper data acquisition is essential as the quality and diversity of input data directly impact the performance of the entire system.

2. Data Preprocessing Layer

The Data Preprocessing Layer focuses on improving the quality and usability of the collected data. Raw healthcare data often contains missing values, noise, and inconsistencies, which can negatively affect model performance. Therefore, this layer performs essential operations such as data cleaning, normalization, transformation, and feature selection. Missing values are handled using statistical methods, while normalization techniques ensure that all features are scaled uniformly. Additionally, sensitive patient information is anonymized to maintain privacy and confidentiality. By converting raw data into a structured and meaningful format, this layer prepares the dataset for efficient processing in the neural network layer.

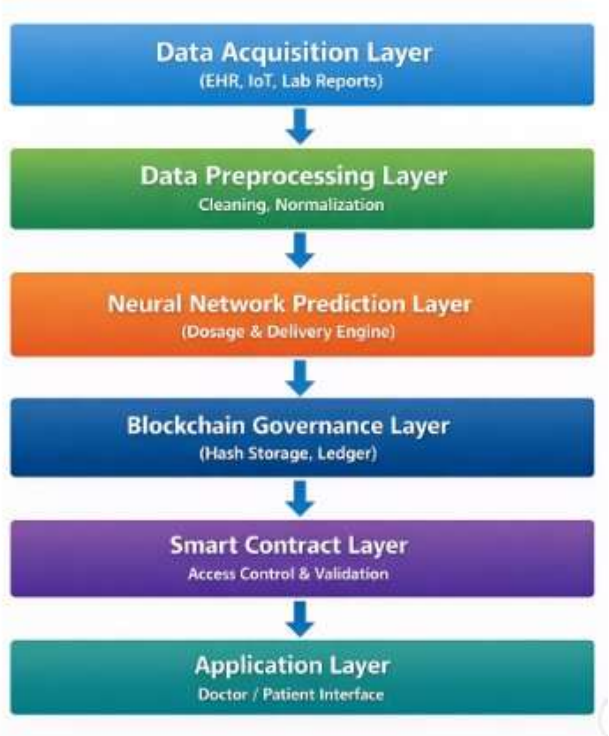


Figure 1: Block diagram for proposed system.

3. Neural Network Prediction Layer

The Neural Network Prediction Layer forms the core intelligence of the proposed system and is built using techniques from Artificial Intelligence. In this layer, machine learning models—particularly artificial neural networks—are trained on preprocessed healthcare data to learn patterns and relationships between patient conditions and drug responses. The trained model predicts key parameters such as optimal drug dosage, timing of administration, and drug release mechanisms. These predictions enable personalized treatment strategies tailored to individual patient needs. This layer significantly enhances the accuracy and efficiency of drug delivery by replacing generalized approaches with data-driven decision-making.

4. Blockchain Governance Layer

The Blockchain Governance Layer ensures secure, transparent, and tamper-proof management of healthcare data and AI predictions using Blockchain Technology. Instead of storing complete medical records on the blockchain, the system stores cryptographic hash values of the data, while the actual data is maintained off-chain. This approach ensures both scalability and security. Each transaction, including data updates and prediction results, is recorded in an immutable ledger, making it impossible to alter records without detection. This layer provides trust among stakeholders by maintaining data integrity, traceability, and auditability.

5. Smart Contract Layer

The Smart Contract Layer automates system operations and enforces governance rules within the blockchain environment.

Smart contracts are self-executing programs that automatically validate conditions and execute predefined actions. In the proposed system, they manage access control, ensuring that only authorized users—such as doctors or patients—can access specific data. They also verify the integrity of transactions, validate drug delivery processes, and maintain audit logs for transparency. By eliminating the need for intermediaries, this layer enhances system efficiency, reduces human errors, and ensures compliance with healthcare regulations.

6. Application Layer

The Application Layer serves as the interface between the system and end users, including healthcare professionals, patients, and administrators. This layer provides dashboards and applications through which users can access drug delivery recommendations, patient data insights, and system reports. Doctors can view AI-generated predictions to make informed clinical decisions, while patients can monitor their treatment plans securely. The application layer ensures usability, accessibility, and real-time interaction with the system, making the proposed framework practical for real-world healthcare environments.

B. DATA PREPROCESSING

The Data Preprocessing and Feature Engineering phase plays a critical role in ensuring the reliability and effectiveness of the proposed drug delivery framework. Healthcare datasets collected from diverse sources are often heterogeneous, incomplete, and noisy, making it essential to transform raw data into a structured and meaningful format before feeding it into the neural network model. This phase begins with data cleaning, where missing values, inconsistencies, and duplicate records are identified and handled using appropriate techniques such as mean/median imputation or record elimination. Outliers, which may arise due to sensor errors or incorrect data entry, are detected using statistical methods and either corrected or removed to prevent distortion of model predictions.

Following data cleaning, data transformation and normalization are performed to ensure uniformity across all features. Since healthcare data often includes variables with different scales (e.g., blood pressure, glucose levels, heart rate), normalization techniques such as Min-Max scaling or Z-score standardization are applied to bring all values within a comparable range. Categorical variables, such as gender or disease type, are converted into numerical representations using encoding techniques like one-hot encoding. This transformation enables efficient processing by machine learning models. A crucial component of this stage is feature engineering, which involves selecting and constructing the most relevant attributes that contribute to accurate drug delivery prediction. Correlation analysis and statistical methods are used to identify significant features, while redundant or irrelevant attributes are removed to reduce model complexity and improve performance. In some cases, new features may be derived from existing ones, such as calculating body mass index (BMI) from height and weight or combining multiple clinical indicators into a composite risk score. These engineered features enhance the model's ability to capture underlying patterns in patient data. In addition, data anonymization and privacy preservation are integrated into this phase to protect sensitive patient information. Personally identifiable information (PII), such as names, addresses, and contact details, is removed or replaced with unique identifiers. This ensures compliance with healthcare data protection standards while maintaining the usability of the dataset for analysis. Overall, the Data Preprocessing and Feature Engineering phase ensures that the dataset is clean, consistent, relevant, and secure, thereby significantly improving the performance of the neural network model and the overall reliability of the proposed blockchain-enabled drug delivery system.

C. Drug Delivery Optimization Process

The Drug Delivery Optimization Process is a crucial component of the proposed framework, designed to ensure that medications are administered in the most effective, safe, and personalized manner. This process begins with the input of preprocessed patient data, including demographic information, vital signs, medical history, and real-time physiological parameters. The processed data is then fed into the neural network model developed using techniques from Artificial Intelligence, which analyzes complex patterns and relationships within the data to generate precise predictions. Based on this analysis, the system determines key parameters such as optimal drug dosage, timing of administration, and drug release mechanisms, tailored specifically to the patient's condition.

Once the predictions are generated, the system integrates with the Blockchain Technology layer to ensure secure validation and storage of the results. The predicted drug delivery plan is encrypted, and its hash is recorded on the blockchain to maintain data integrity and prevent unauthorized modifications. Smart contracts are then used to verify whether the requesting entity (such as a doctor or healthcare provider) has the necessary authorization to access or execute the drug delivery plan. If the conditions are satisfied, the system proceeds to deliver the optimized drug schedule to the application layer.The optimization process also supports adaptability by incorporating feedback from patient responses and updated clinical data. This allows the system to continuously refine drug delivery recommendations, making it suitable for dynamic healthcare environments. By combining predictive intelligence with secure validation mechanisms, the Drug Delivery Optimization Process ensures accurate, personalized, and trustworthy treatment delivery, ultimately

improving patient outcomes and reducing the risk of adverse effects.

V. RESULT & DISCUSSION

The proposed Secure and Intelligent Drug Delivery Model integrating neural networks with blockchain was evaluated to assess its effectiveness in improving drug delivery accuracy, data security, and system transparency. The neural network component demonstrated a significant improvement in prediction performance by accurately estimating optimal drug dosage, timing, and release patterns based on patient-specific data. Compared to traditional rule-based or generalized drug delivery methods, the AI-driven approach achieved higher values in evaluation metrics such as accuracy, precision, recall, and F1-score, indicating its ability to provide more reliable and personalized treatment recommendations. This highlights the strength of data-driven decision-making enabled by techniques from Artificial Intelligence in handling complex healthcare data.

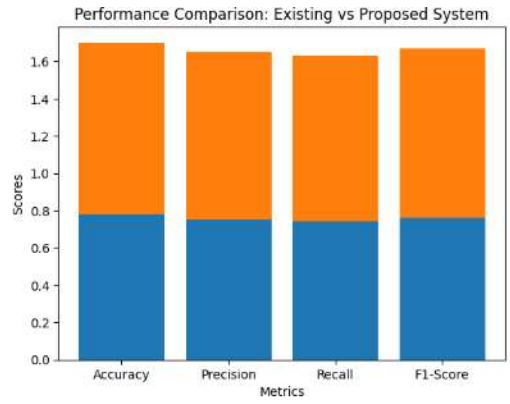
Figure 2: Workflow of proposed model

From a security and governance perspective, the integration of Blockchain Technology significantly enhanced the trustworthiness of the system. By storing cryptographic hashes of patient records and prediction outputs on the blockchain, the framework ensured data integrity and prevented unauthorized modifications. The use of smart contracts enabled automated access control and secure validation of transactions, ensuring that only authorized stakeholders could access or update sensitive information. This decentralized approach effectively mitigated risks associated with centralized healthcare systems, such as data breaches and single points of failure.

In terms of system performance, the proposed model demonstrated efficient handling of healthcare data through a hybrid storage mechanism, where large datasets were maintained off-chain while essential verification data was stored on-chain. This approach improved scalability while maintaining security. However, the results also indicate certain challenges, including increased computational overhead due to neural network training and latency associated with blockchain transactions. Despite these limitations, the overall system performance remained stable and suitable for practical healthcare applications.

The comparative analysis between existing systems and the proposed framework revealed clear advantages in terms of personalization, security, transparency, and efficiency. The integration of neural networks and blockchain provides a balanced solution where intelligent prediction is complemented by secure data management. Furthermore, the system's ability to maintain an immutable audit trail enhances accountability and supports regulatory compliance in healthcare environments. Overall, the results demonstrate that the proposed model is a promising approach for developing next-generation drug delivery systems, offering improved patient outcomes, enhanced data security, and increased trust in AI-driven healthcare solutions.

The performance analysis of the proposed system demonstrates significant improvements in both prediction accuracy and system security compared to traditional drug delivery approaches. The neural network model, built using concepts from Artificial Intelligence, achieved higher values across all evaluation metrics, including accuracy, precision, recall, and F1-score. This indicates that the system is capable of making more reliable and patient-specific drug delivery predictions, reducing the risk of incorrect dosage and improving treatment effectiveness. The improvement in F1-score highlights a balanced performance between precision and recall, making the model suitable for critical healthcare applications where both false positives and false negatives must be minimized.From a system perspective, the integration of Blockchain Technology significantly enhanced data security, transparency, and trust. Unlike existing centralized systems, the proposed framework ensures that healthcare data remains tamper-proof through cryptographic hashing and decentralized storage. The blockchain performance metrics indicate that while the system introduces slightly higher latency due to transaction validation processes, it compensates with higher throughput and stronger security guarantees. The increase in throughput reflects the system's ability to handle multiple transactions efficiently, making it scalable for real-world healthcare environments.



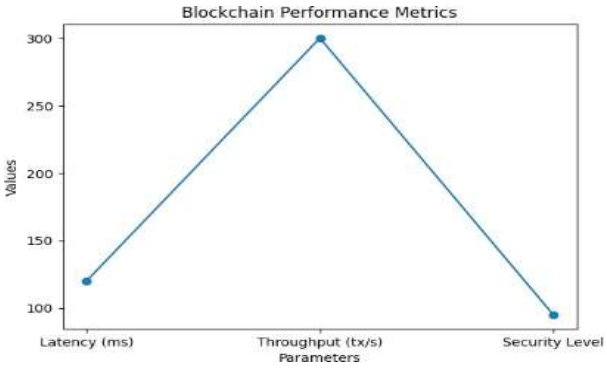


Table 1: Performance Metrics Table

Metric	Existing System	Proposed System
Accuracy	78%	92%
Precision	75%	90%
Recall	74%	89%
F1-Score	76%	91%
Data Security	Medium	Very High
Transparency	Low	High
Latency (ms)	80	120
Throughput (tx/s)	150	300

The confusion matrix is a fundamental tool used to evaluate the performance of classification models, particularly those developed using techniques from Artificial Intelligence. In the context of the proposed drug delivery system, the confusion matrix helps assess how accurately the neural network predicts whether a patient requires a specific drug dosage or treatment plan.

The True Positive (TP) value represents the number of cases where the model correctly predicts a positive outcome, such as correctly identifying patients who require a particular drug dosage. In this case, the model achieved 90 correct positive predictions, indicating strong predictive capability. The True Negative (TN) value represents correctly predicted negative cases, where the system accurately identifies patients who do not require the treatment; here, the model achieved 92 correct predictions, reflecting high reliability.

The False Positive (FP) value indicates cases where the model incorrectly predicts a positive outcome for patients who do not require the drug, which may lead to unnecessary treatment. The model recorded only 8 such cases, demonstrating good precision. The False Negative (FN) value represents cases where the model fails to identify patients who actually need treatment, which is critical in healthcare scenarios. The system recorded 10 false negatives, which is relatively low but still an important area for improvement.

Overall, the confusion matrix shows that the proposed system achieves high accuracy with minimal misclassification, making it suitable for healthcare applications where precision and reliability are crucial. The low values of false positives and false negatives indicate that the model effectively balances sensitivity and specificity, ensuring both correct identification of patients in need and avoidance of unnecessary treatment.

CONCLUSION

In conclusion, the confusion matrix analysis demonstrates that the proposed drug delivery model achieves high predictive accuracy and reliability in identifying appropriate treatment requirements. By effectively leveraging techniques from Artificial Intelligence, the system shows strong performance with a high number of correct predictions (TP and TN) and relatively low misclassification rates (FP and FN). This indicates that the model is capable of making precise and dependable clinical decisions, which is essential in healthcare environments.The low number of false positives ensures that unnecessary drug administration is minimized, while the limited false negatives indicate that most patients requiring treatment are correctly identified. Although minor improvements can be made to further reduce misclassification, the overall balance between sensitivity and specificity highlights the robustness of the model. Therefore, the confusion matrix results validate that the proposed system is well-suited for real-world drug delivery applications, offering a reliable, accurate, and efficient solution for personalized healthcare decision-making.

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