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Model of a decentralised system for storing, processing, and managing medical data using iota tangle technology

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Abstract. The exchange of patient medical records between healthcare providers is essential for quality care but faces challenges related to privacy, security, and centralized control. This article presents the development of a decentralized medical data exchange system using Distributed Ledger Technology based on the IOTA Tangle. The system architecture and core components for immutable storage and transmission of medical records are described. The system uses masking and encryption techniques to maintain patient privacy while allowing healthcare providers to access full records with patient consent. The IOTA Tangle enables fee-less transactions and data integrity verification via its Directed Acyclic Graph structure. System validation through simulation experiments demonstrates the ability to securely share medical data at scale with lower resource costs compared to traditional blockchain designs. The system proves the viability of a decentralized, self-sovereign approach for efficient and confidential medical data sharing using Distributed Ledger Technology. The secure data exchange platform can enable new models of care and research while maintaining patient privacy and healthcare ethics.

Keywords: *electronic healthcare system, medical patient data, distributed ledger technology, IOTA Tangle, blockchain technology.*

Introduction. Now there is an increase in the use of distributed ledger technology (DLT) in various industries, including healthcare [1]. The use of DLT in healthcare can transform data storage and sharing, making processes safer and more efficient. Because the main characteristics of this technology are transparency, traceability, reliability, and decentralization, the introduction of DLT in various healthcare systems will avoid problems related to security, privacy, and compatibility [1]. Blockchain is already used in

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various healthcare systems. In [2], the main areas of blockchain application were presented, among which the main ones can be distinguished: telemedicine, diagnostics, data management and exchange, and supply chain monitoring. However, most of these projects are represented by prototypes or small projects with a small user base. In addition, the blockchain itself has not reached optimal maturity. The technology still has shortcomings that have yet to be addressed. The main ones are scalability, bandwidth, power consumption, and transaction fees. Against the background of all this, IOTA Tangle is a suitable replacement for the blockchain, as it allows you to eliminate all these shortcomings.

A decentralised medical system using IOTA Tangle to protect patients' medical records and medical IoT devices is presented in [3]. As part of this work, four prototype applications were developed to demonstrate the proposed solution: a web recording application, a patient application, a doctor application, and an application for a remote IoT medical device (internet of things). The results show that the proposed framework can improve healthcare services by providing immutable, secure, scalable, reliable, self-managed, and traceable patient health records, giving patients complete control over their own medical records. In [4], the CoviReader architecture based on IOTA Tangle is presented, developed for the medical information management system to combat the outbreak of the COVID-19 pandemic. This system allows you to protect the privacy of citizens and their health data from unauthorised access. The proposed CoviReader architecture provides accessibility and, at the same time, restricts data manipulation. In [5], it is proposed to use DLT to solve problems related to the security and confidentiality of medical data in developing health systems. In particular, it is proposed to use MAM (Masked Authenticated Messaging) for secure data exchange in the healthcare system. The authors proposed an IOTA Tangle-based model for secure and confidential storage and exchange of information.

To solve problems related to the security of medical data and patient privacy, the authors in [6] propose a new system based on blockchain technology. This system allows you to maintain the confidentiality of medical data by providing patients with mechanisms to control their personal information, which allows them to independently grant access rights to their medical data.

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As can be seen from the literature review, in an era of data insecurity, health organisations are increasingly considering the possibilities of global implementation of distributed ledger technology. Blockchain is already being used in all areas of healthcare, from protecting patient data to managing the pharmaceutical supply chain. Distributed ledger technology does not stand still, and, in addition to the blockchain, new types of DLT began to appear. However, the use of the IOTA Tangle, prime example of DLT, is not currently widespread. IOTA Tangle has a number of advantages over blockchain, which can raise the quality of medical care to a new level, therefore, it is important to develop systems using IOTA Tangle in the healthcare sector to ensure secure data exchange.

Main part. The aim of the study is to develop a medical system based on IOTA Tangle for the secure exchange of medical data between patients and healthcare professionals, institutions, and organisations in the healthcare system.

To achieve this goal, the following tasks should be solved:

- review the traditional healthcare model and present a model based on IOTA Tangle, determine the basis of the essence of the new model, and describe their interaction;
- develop a model of a decentralised system for storing, processing, and managing medical data using IOTA Tangle technology and describe the main models for implementing the system.

All medical data in the traditional healthcare model is stored with the central authority (a medical institution). If the central organ is compromised intentionally (manipulation) or unintentionally (hacking), it can cause significant damage to the medical system. The IOTA Tangle-based model eliminates central authority by distributing copies of records to all network participants. The IOTA Tangle-based model is much more secure than the traditional model, and it does not require an intermediary.

The proposed model is characterised by three main entities: client, iota node, and IOTA tangle.

The interaction of these entities is shown in Figure 1.

The transaction lifecycle begins when a patient or doctor creates a request for consultation with a doctor or patient. To send a transaction to the IOTA network, it goes through the following steps:

- 1) The sender fills out the appropriate form, which can

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be a form with symptoms, prescriptions, and diagnoses. Separate transactions are created based on this data

2) In the next step, these individual transactions are grouped into an atomic unit of the IOTA network called a bundle. Transactions in a package are indexed individually and contain information about how many other transactions are in the package. Once completed, incoming transactions in the package must be signed to confirm ownership. To sign transactions, the system creates public and private keys. Keys are generated based on a unique access key called a seed. Seed is created in the appropriate field in the profile settings.

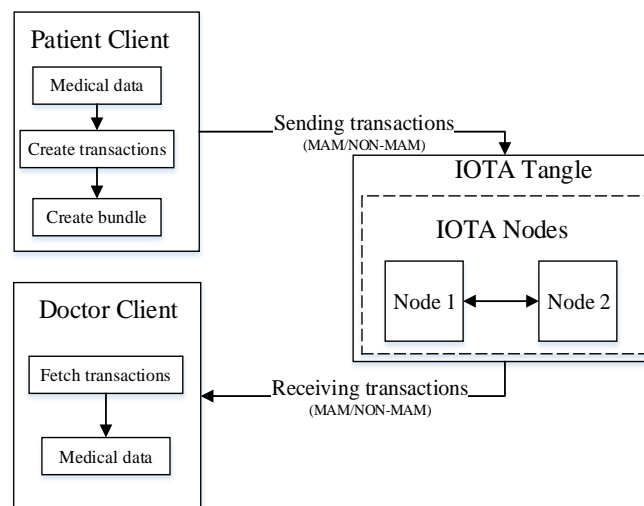


Figure 1
Interaction of Entities

3) To send transactions to the network, you must confirm the previous two transactions. To do this, a request is made to the IOTA network node to select two unconfirmed transactions. The weighted random walk algorithm is used to select two unconfirmed transactions.

4) To join Tangle, each transaction in the package requires a nonce. Nonce is the result of PoW (Proof of Work). The POW confirmation calculation must be performed separately for each transaction, so the more transactions in the package, the longer it will take. The complexity of the calculation also depends on the MWM (minimum weight magnitude) set by the network. The POW calculation takes place locally on the user's device and may take some time.

5) The last step is to fix the packet for the network.

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Nodes will broadcast transactions on the network and store them in their local database.

Data sent by the doctor from his system follows this series of actions. The main difference is that the doctor, after reviewing the patient's symptoms, fills out the diagnosis form. The doctor can also fill out other forms in which he can write out a prescription or prescribe medical exercises. Once transactions have been added to Tangle, they will be marked as unconfirmed. In the future, new transactions that will be added to Tangle will refer to sender transactions. The larger the reference to these transactions, the greater the total weight of these transactions. The higher the total weight of transactions, the higher the chance of their confirmation.

In points 3 and 4 of the transaction lifecycle, it was written that when sending transactions to the network, you need to find two transactions for confirmation and calculate the POW. The IOTA Tangle consists of confirmed and unconfirmed transactions and tips. Each transaction can be represented as the vertex of a graph. Each time a new transaction is created, the node selects two other transactions using the WRW algorithm. The algorithm goes through the tangle and selects the vertices that have the highest total weight. Once a node is sure that the selected transactions are not conflicting, it solves a cryptographic puzzle called nonce search. After that, the transaction is added to the tangle and becomes a new vertex [1].

Conclusions. This work demonstrates the feasibility of using distributed ledger technology, specifically the IOTA Tangle, to create a decentralized platform for the secure and private exchange of medical records between healthcare providers.

The presented system architecture allows patients to retain ownership of their medical history and seamlessly share it with authorized parties to ensure coordinated care. Encryption and access control ensure permanent data privacy. IOTA Tangle's asynchronous transaction model and lightweight consensus are suitable for decentralized medical applications.

Issues related to patient consent management, key management, and ease of adoption remain, which are addressed as challenges for future research. But overall, the developed system provides a critical platform for patient-centered medical data sharing that prioritizes security, privacy, and accessibility.

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