Blockchain in the Logistics of Health Technologies

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Abstract. The article focuses on the practical significance of blockchain technology and its contributions to public health. The focus is on innovations in the sphere of logistics such as smart contracts and "Internet of things" that illustrate their contribution to achieving quality and transparent logistics of health technology management.
The methodology of the article includes monitoring technological innovation in logistics. It is based on literary search, tracking development trends, and the importance of blockchain technology in various health care areas.
Innovation in logistics finds its place and role in activities aimed at protecting public health. Blockchain contributes to increasing trust between health logistics and service providers, ensuring a secure production process and flexibility in the distribution chain.

Keywords: Blockchain, Logistics, Health Technologies.

1 Introduction

Blockchain is a fast-growing technology that has the potential to transform the modern industry. As more and more entrepreneurs become aware of the possibility of technology, it raises the question of what blockchain is, how it works, and where it is applied. It is often associated with financial services and logistics but is also relevant for all other industries. The numerous aspects of blockchain technology in the healthcare sector are at the heart of this paper. The role of technology in the implementation of processes in different healthcare fields and the logistics of medical devices has been considered. Whatever the advantages, the approaches, goals, and capabilities of the technology are still largely unknown. One of the paper aims is to bring light to the practical significance of the blockchain and its contributions to public health.

This paper's methodology is based on literary search, tracking development trends, and the importance of the blockchain. Quality tools have been used for data collection, including monitoring and analyzing public health activities, and in particular logistical processes in the health sphere.

Activities and methodologies were studied for various health activities – medical logistics, health records, drug substance tracking, drug falsification, goods transport and storage, clinical trials logistics, medical devices, health care management, human resources, and so on. For each of the processes, blockchain's importance is analyzed to illustrate the optimal benefits of technology for logistics processes.

The subject of analysis in this article is the implementation and benefits of blockchain technology in health logistics. The study looks at ways to optimize healthcare logistics processes at different stages – from drug delivery and distribution to clinical trials. Successful interpretation and integration of innovative logistics approach in the sphere would make it easier for the public to access adequate health care and improve the quality of the healthcare services offered. Critical concepts in the search for survey data are blockchain, logistics, health technologies, medical devices.

2 Blockchain in practice

Blockchain technology stores and shares information across networks between users locating around the world. It was initially designed to manage the Bitcoin crypto-currency. The goal is to protect and secure the ownership of digital currencies in transactions [1] through technology, ensuring a secure, transparent, and reliable operating system.

Blockchain innovation is a data recorder working with information from financial transactions, transfers of goods, medical records. However, what distinguishes blockchain from ordinary databases? An accounting book, for example, is a document in which the actual transactions are recorded. Traditional paper books include consecutive pages in which each line records a transaction. When the page is complete, the process is repeated the next. The data for the operation is available and correctly reflected but very easy to manipulate. The information can easily be changed, lost, or misused.

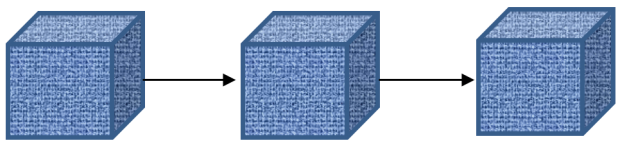

Fig. 1. Blockchain can be visualized with a chain of interconnected blocks.

Each block is a peer-to-peer page. Each operation's data is recorded in a separate block, and the record is made using a time-tagged approach. When a block is filled with data, a new one is created. Unlike traditional books, when the block is complete, the system creates a hash value [2]. A unidirectional mathematical

function serves to "fragment" a multitude of data. In other words, a variable-sized text can be recreated as a strictly defined, corresponding text, called hash, hash value, or digest [3]. Thus, the recorded information exists in the form of a unique code that is a random number generated by an algorithm based on the block's contents [4]. This hash value is recorded as the first record in the next created block [5].

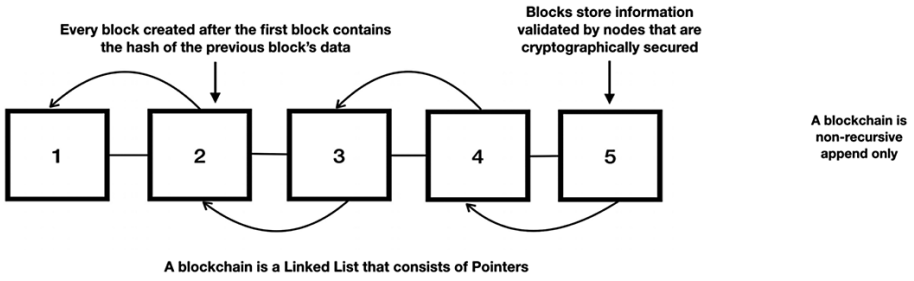

Fig. 2. Blockchain design [6].

This process "connects" the blocks between them, from where the term "blockchain" originates. If someone ever tries to change a record in a previous block, the hash value will no longer match the entry in the next block, and the change is considered invalid. In part, this is the mechanism by which blockchain creates unchangeable records. In blockchains, the information is copied and stored at multiple nodes (or computers) on a shared network. This leads to creating a system in which data is stored in many places and subject to control and transparency for all network participants, guaranteeing the integrity of personal data. The system is decentralized. It imposes the rules that the participants have access to, controlling the storage and verification of transaction data (transactions). This avoids the problem of accumulating stocks of outdated data with no practical value in the databases. In social blockchains (accessible to a broad user table), anyone can create a node (enter information) or view available data. However, in private block circuits, only users with access permissions can share and view documented data. This can help solve the issues of confidentiality.

2.1 Role of smart contracts

Smart contracts are an essential and powerful tool provided by Blockchain technology [7]. It can automatically receive information from various sources (including internet sensors) and apply a program set of rules (if-then) with little or no human intervention. Smart contracts work so that "if" certain conditions (programmed in the smart code) exist, only "then" generates certain activities.

Smart contracts can be used to automate different processes in a very flexible and customizable way. They increase efficiency and reduce costs by removing intermediaries and automating tasks that are typically executed manually. Smart contracts can be used in health care, automation of logistics networks of medicinal products and medical devices, and facilitating tracking distribution chains in real terms.

2.2 Internet of Things (IoT)

The network of sensors – Internet of Things (IoT) can collect data, communicate over the Internet or other systems, or take other action based on a predefined set of conditions. For example, an IoT sensor can be placed on a container of pharmaceuticals or medical devices and thus generate real-time location data of the respective container. In a more sophisticated embodiment, sensor data may be provided as smart contracts inputs. When the data shows and confirms that a packet is delivered from side A to side B, smart contracts can be programmed to transfer data directly to party B and trigger payment to party A without intermediaries. This process supports the logistics of medical devices and medicines by reducing the cost of intermediaries, shortening delivery times, shortening the documentary procedure for picking up and accepting goods.

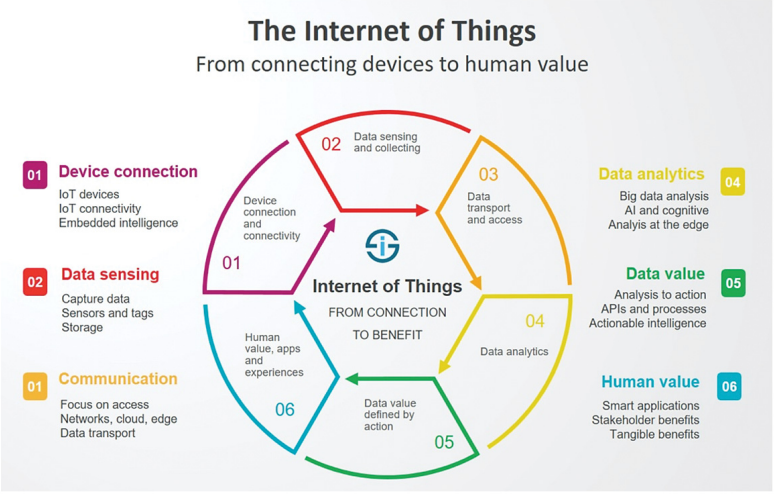

Fig. 3. The Internet of Things (IoT) – essential IoT business guide (8).

2.3 Key benefits of blockchain technology

Revolutionary technology has the potential to become a driving force for the development of modern societies. In a World Economic Forum report released

in September 2015, 58% of respondents expect that by 2025, 10% of the global gross domestic product will be held through the World Economic Forum technology [9]. Therefore, it is not surprising that blockchain attracts investors who are betting nearly half a billion dollars in 2015 [10], with the trend growing. Some of the advantages of blockchain technology are listed below:

- Unmodifiable data – hash content records, the link between blocks, and hash-tracking to a subsequent block, makes data unchangeable;
- Layout – by storing and controlling copies of data in multiple nodes (blocks), single points of failure of the information are avoided, ensuring its security;
- Decentralization – validation of transactions (operational activities) through a trustworthy sharing mechanism between participants, prevents the need for control of one (central) body;
- Transparency – Blockchain data is visible to all participating parties, which can provide greater transparency of supply chains from point A to point B;
- Security – the use of digital signatures through critical public infrastructure (PKI) [11] provides the most advanced level of security;
- Automation – the use of intelligent codes to automatically apply business rules allows a higher level of automation [7, 12];
- Efficiency – eliminating unnecessary intermediaries, eliminating manual processes, and reducing fraud can reduce operating costs and increase economic efficiency;
- Auditable – store verified transaction data (logistics) on the serial, timestamp, facilitate auditing and regulatory reporting.

3 Role of Blockchain in Healthcare

Blockchain technology has numerous possibilities for application in the logistics of health services and services, which impacts public health. It contributes to quality production, transport, storage, distribution, and health technologies (pharmaceuticals, medical devices, consumables). Decentralization and encryption of block-based information can have many uses in health care. These include rationalizing insurance activities, managing health processes (immunizations, prevention and prevention campaigns), logistics of medical devices and medicinal products, and provision of detailed confidentiality settings for personal medical data.

Blockchain can contribute to the safe production, transport, storage, distribution, and application of health technologies (pharmaceuticals, medical devices, consumables) and improving patient privacy. The patient's participation in his treatment and communication with various health professionals is increasingly

encouraged [13]. A process that Blockchain would be helpful. The key lies in implementing and applying the technology through partnerships with healthcare professionals willing to be part of the software applications operating with a blockchain.

Blockchain technology is well suited for tracking merchandise and managing logistics chains to supply production materials, consumables, drug substances, and medical devices. The pharmaceutical industry is actively exploring its potential, seeking ways to deliver quality, safe, and effective medicines on the market. Many of these studies already have evidence that has generated interest in healthcare. The key lies in implementing and applying the technology through partnerships with healthcare professionals, medical institutions, and manufacturers wishing to be part of the users of software applications operating with Blockchain.

The main logistics units with a direct impact on public health are listed below:

3.1 Logistics of medical examinations and laboratory tests

The process of protecting public health begins with the proper organization of medical and laboratory examinations and tests. This is related to the coordination of work schedules, the availability of operating rooms and examination rooms, laboratories. The observation and coordination of the whole process of diagnosis and treatment in the outpatient and hospital care facilities is a prerequisite for a quality process for public health protection. The presence of trusted and accessible specialists in the diagnostic and treatment process at all levels is a guarantor of professional attitude on the part of doctors to public health.

3.2 Management and control of medical records

The review, diagnosis, and treatment procedures generate a massive amount of medical data that needs to be correctly recorded, stored, and used to protect patients' rights. The collected medical information (records of diagnostic examinations, scanners, research, laboratory tests, and medical records) is valuable for determining the population's health profile. Information flow logistics is a complex task due to real chances of error, misuse, or correction. These risks are kept to a minimum through blockchain, ensuring secure storage and protection of patients' data.

Another medical data source is the numerous records of various mobile healthcare applications, gaining increasing popularity in recent decades. Modern technology development makes it possible to record in several real-time indicators such as blood pressure, pulse, changes in sleep, motor activity, and many others. This data stream can be used to solve current medical issues. Blockchain

offers a variety of storage, processing, and application capabilities [14]. An example of this is the Healthbank application, a Swiss healthcare startup, which offers its users a platform for sharing personal data and health information that uses technology to store and manage health information in a secure environment [15]. Such personal data, reflecting blood sugar, blood pressure, heart rate, diet regimens, sleep, motor activity, can be taken from healthcare applications and medical examinations. In a blockchain, they can be stored and used to develop programs for the prevention, prevention, and treatment of patients and ultimately improve public health.

3.3 Checking and tracking of drug substances and substances

Verification and traceability of drug substances and substances in the pharmaceutical industry are common when medicinal products are returned to producers in case of irregularities. When the wholesalers order a larger quantity is another situation. Then unsold unnecessary amounts may need to be returned to the pharmaceutical manufacturers.

Data shows that the portion of returned medicines is small compared to sales (about 2-3% of sales), with the annual volume ranging from $ 7 to $ 10 billion. Economic indicators show that in 2016, the US pharmaceutical producer's sales were $ 323 billion [16]. The estimated 2018 revenue for the top 10 global pharmaceutical companies (representing half the sales of the top 50 companies) is $ 355 billion [17]. Accordingly, instead of destroying the returned medicines, pharmaceutical companies prefer to resell them. To do so, they are legally obliged to check the authenticity of the returned medicinal products. Here is the blockchain's place to provide the necessary information by pre-collected unique codes or serial numbers from each primary or secondary packaging.

In the United States, the Drug Supply Chain Security Act (DSCSA) states that all US manufacturers must enter serial numbers or packet-level codes by November 2018. In the coming years, these serial numbers will be used to check the authenticity of returned medicines. In Europe, the Falsified Medicines Directive (FMD) requires all medication similarly marked by February 2019.

While the EU has chosen a centralized approach (allowing manufacturers to upload serial numbers into a single EU regulator database and distributors to contact it to verify medicines' authenticity), such a centralized database regulator does not exist in the US. Without such a system, one option is for any distributor to integrate data with any pharmaceutical manufacturer that is logistically unacceptable. A much better and recommended approach is for pharmaceutical manufacturers to record their packages' serial numbers through a blockchain that serves as a decentralized database. After that, wholesalers and retailers can check the authenticity of packages delivered through technology.

3.4 Prevent counterfeiting of medicines and medical devices

The ability to trace the origin of materials and products through blockchain is particularly suited to distributing goods. Pharmaceutical companies that produce, deliver, and sell products experience severe difficulties in tracking their products, creating conditions for introducing counterfeit medicines into the system. Counterfeiting is not limited to the production of medications but also covers a significant share of medical devices manufacture. According to the World Health Organization (WHO), 8% of medical devices in circulation are forged copies (18). Counterfeit medicines and medical devices pose a serious risk to consumers while causing severe losses to legitimate producers [19]. The introduction of serial numbers of the packages recorded in the blockchain can guarantee the originality of the products and the traded goods' traceability. By switching the drug through the supply chains, transactions can be recorded on a blockchain, thus providing an unchanging register of the goods' origin. This will enable all stakeholders to track medicinal products and products throughout the lifetime of deliveries. This would make it more challenging to import counterfeit medicines into the distribution chain.

Several pharmaceutical companies are experimenting with blockchain and IoT to identify counterfeit medicines and track the temperature of delivery and storage of their products, with real-time visibility for all actors in the supply chain. The Innovative Medicines Initiative (IMI) is a consortium of small pharmaceutical companies, universities, clinical laboratories, hospitals, patients' representatives. Within the EU aimed at investigating cases of use and action to detect counterfeit medicines in supply chains, using patient data and clinical trials.

3.5 Coordination and provision of certain transport conditions

Logistics companies must adhere to strict rules on the transport and storage of medicinal products and medical devices. These may include maintaining a specific temperature range, humidity, air quality within certain limits, degree of illumination. Environmental conditions during transport may have a direct impact on the quality and efficacy of the medication.

Thermally labile products such as vaccines, insulin preparations, and others must be correctly packaged and thermally stabilized throughout the logistics chain. A slight deviation in these conditions may render them unfit for use. Today, the entire supply chain can be monitored through intelligent IoT devices, whereby environmental factors are recorded over the lifetime of delivery. However, as all actors in the chain (manufacturers, logistics companies, pharmacies, and hospitals) maintain their accountability and control of distribution processes, problems within individual segments along the chain are difficult to track.

Blockchain technology provides a better way of coordinating between individual actors and managing processes at individual distribution levels. Due to its transparency, security, and accessibility to information, technology provides a mechanism allowing each logistical trader to ensure that strict delivery rules (including conditions for subsequent handling and storage) are respected. The technology ensures traceability of the supplier's transport route and shows everyone in the chain the localization of the goods carried at any given moment. This reduces the chances of fraud, theft, and counterfeiting of distributed goods, which is a severe problem in the pharmaceutical sector [19].

Smart contracts can also be programmed, which are automatically executed when the necessary conditions are not met by notifying the chain's parties. For example, suppose that if there is a temperature difference during transport, the user can easily see when the temperature fluctuation occurred and how fatal it was for the product. Smart contracts can be automatically called within a blockchain, which will reduce the amounts due to logistics companies based on non-compliance with the storage conditions.

3.6 Providing informed consent in clinical trials

The patient's informed consent includes notification of each step in the clinical trial, including any possible risks associated with the study. The reconciliation protocols and their revisions should be transparent to patients and traceable to stakeholders. In practice, however, the informed consent process is challenging to implement rigorously and satisfactorily. There are some issues related to collecting information, including difficulties in obtaining informed consent, incorrect forms, invalid consent documents, non-admission of revised protocols. Documentary frauds are also frequently reported (e.g., generating documents for retroactive agreement).

Establishing protocols from blockchain clinical trials, transparency, and traceability of patient awareness and consent are ensured. It provides a mechanism for compiling, storing, and tracking information in a secure and publicly transparent way that allows this information to be shared in real-time. Besides, smart contracts may be linked to revisions so that any change in the clinical trial protocol requires the patient's consent to be renewed.

3.7 Logistics network in hospitals

Medical establishments are one of the essential structures working to protect public health. Tracking hospital deficiencies and resource planning is a crucial element in hospital logistics. For this reason, more than 30% of total hospital costs are invested in logistics activities, and half of these costs can be eliminated through proper logistics management [20]. Improvements in the supply chain

in hospitals can provide secure operating theaters and the necessary medication and supplies, better resource management, correct supplier relationships, more pleased patients, and more efficient workflow for hospital staff.

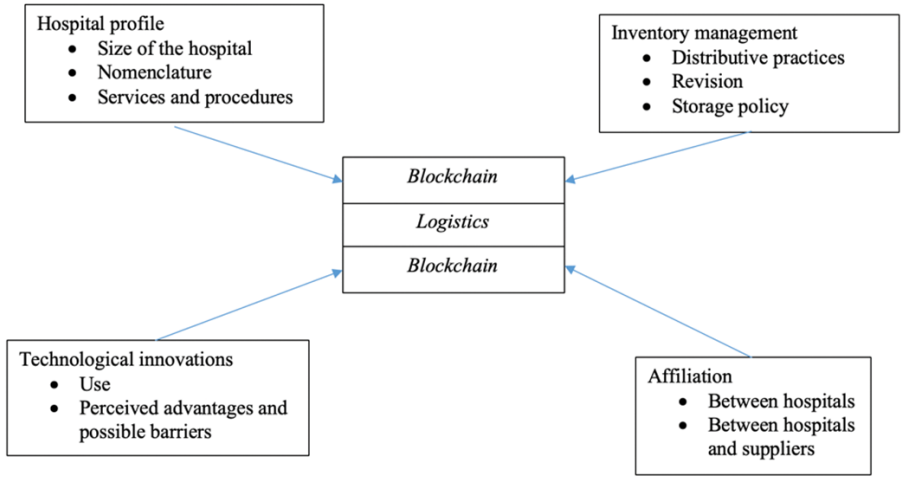

Fig. 4. The theoretical framework of blockchain application in hospital logistics.

Logistics activities in hospitals include purchasing, inventory, and managing medical goods, information systems, nutrition, transport, home care. In the list, the hospital and medical departments interact with the distribution chains. This requires more human resources and space for manipulation, which in turn increases implementation costs.

Schedule planning focuses on adherence to terms and quantities of orders. Thus, the acquisition of essential goods and services is limited by the available resources, avoiding overloading. Process coordination through blockchain can significantly reduce costs by increasing hospital services' effectiveness and benefits to public health.

3.8 Human resources management in Healthcare

Blockchain could be useful in the process of managing human resources at various levels in the healthcare field. Starting at the level of education in schools and universities, we go through healthcare facilities and industries and get to the national level.

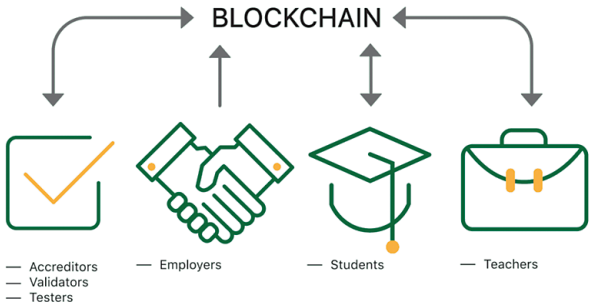

Fig. 5. Health units, potential Blockchain participants [21].

This would ensure a transparent selection process. Managing information through technology would allow at any moment to trace the level of competence and expertise of experts in the field (22). It will also make visible staff with a staff shortage and stimulate the education system to produce priority specialists from whom the healthcare sector is most in need.

3.9 Logistics of medical devices

Blockchain technology can be very useful in securing the complete logistics chain for medical devices, including "origin" and "tracking" of products in real time.

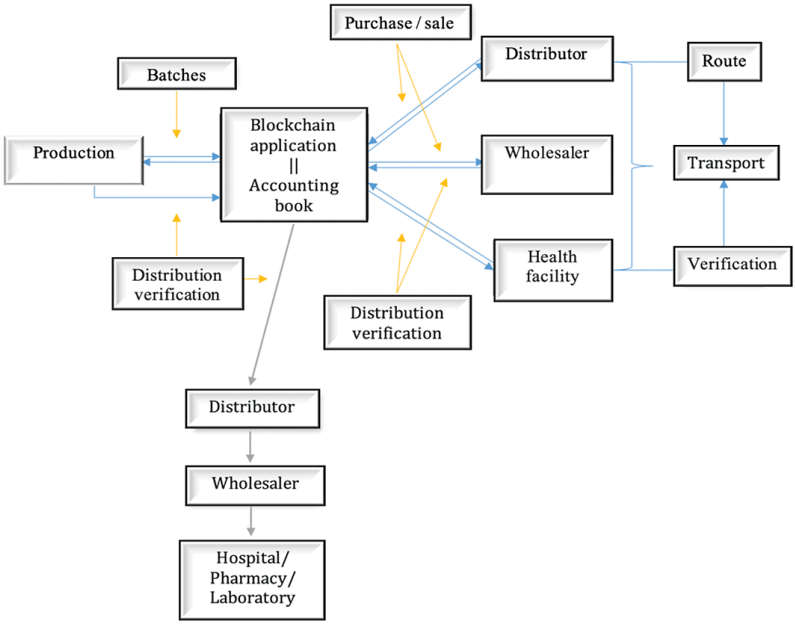

Fig. 6. Logistics chain of medical devices based on the Blockchain.

The record of production data through blockchain proves authenticity, quality, and a guarantee of patent ownership. The technology helps the complex logistics chains associated with the effective tracking of a product's origin, starting with the materials, going through the production process and distribution, and reaching the end-user.

MD production and distribution chain includes various actors – manufacturers, distributors, wholesalers, pharmacies, hospitals. Each participant is interested in knowing the source of the materials/products and can track his/her real-time traffic at any time. This is not easy to achieve with traditional technologies and business models. Despite the ongoing efforts to document the distribution chain, the lack of continuity, the disruption of the individual stages, and the problematic tracking of information, potential frauds, and the counterfeiting of medical devices are possible. Using a blockchain, each transaction in the supply chain can be accurately tracked, from the origin to the ultimate distributor, ensuring the delivery of the desired product. Many stakeholders recognize the role technology can play in solving these problems. Blockchain is an ideal solution to tracking pharmaceuticals and medical devices, as it provides greater confidence through consensus, transparency, and security of the logistics chain.

Over the last two decades, global regulation has introduced unique product identification requirements to provide greater security for delivery. These requirements aim at eliminating falsified and diverted products, which contributes to enhancing the safety of end-users. With the introduction of blockchain, logistics chain partners can exchange data more effectively and securely for specific deliveries. Ultimately, each participant has up-to-date and accurate information about the logistics process. Through a blockchain, established irregularities along the chain will directly alert all affected persons (manufacturers, distributors, distributors, and even patients). They can track and verify the downloaded product by minimizing the time required to dispose of articles while reducing the cost of withdrawing and blocking effects from the market, scrapping losses, and the risks of using poor quality medical devices and medications.

4 Conclusion

These examples describe the numerous capabilities of blockchain technology. The healthcare sector is among the priority users of innovation and serves public health management, the storage of medical data from various sources, including the patient, as well as an active role in counterfeiting of medicines. The considerable potential of this technology is wherever a third party is needed in settlement of a number of market services. With blockchain, direct deals are possible without the availability of intermediaries, which saves time, resources,

and reduces risks. Benefits that make technology indispensable in the world of modern logistics.

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