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The Cost- Saving Role of Blockchain Technology As a Data Integrity Tool: E-health Scenario

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Abstract

The digital economy of health and its global proliferation have led to the use of health information systems in the daily health services delivery to patients. Consequently, there is a development of a web-based electronic healthcare aimed at providing electronic health services in real time. In this way, through the implementation of the concept of electronic health, there is an exchange of health information among all stakeholders of the health organization, all with the aim of monitoring the health status of patients, timely intervention and adequate allocation of medical resources. Processing and sharing a large amount of health data in real time, with the constant need to maintain a high level of interoperability and scalability of network infrastructure, requires the highest possible level of security in accessing data, in order to reduce the misuse of health data. By using blockchain technology, the risk of misusing health information, asymmetry of information and the risk of increasing transaction costs are reduced in a very short time. Blockchain is a robust mathematical algorithm that can provide maximum security of the transaction using cryptographic methods. This type of technology is based on a distributed database that contains encrypted data that can not be changed or disturbed. For this reason, the application of this technology as a data integration tool is increasingly reflected in the electronic business of health organizations - electronic healthcare. Blockchain technology is especially used in information-intensive electronic healthcare records and medical applications, which ultimately results in reduced costs of providing health services, especially when it comes to system maintenance and security costs, interoperability and data redundancy. According to above mentioned cost- saving role of blockchain technology in processing, sharing and analyzing healthcare data, in this paper, there will be more to say about the positive economic impact of blockchain technology on electronic healthcare, especially in the case of Estonia. This European country is a pioneer in creating, implementing and using the e-Health concept as an integral part of health information system through its healthcare system, in order to increase efficiency of healthcare services.

Keywords: Blockchain technology, data integrity, e-Health, health economics

jel CLASSIFICATION codes: I10, C89, O33

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1. Introduction

The synergy of the health sector and information technology generated health information systems and their part that refers to electronic health (e-Health). Information systems in health care support healthcare organizations and other healthcare entities for e-business that are carried out in the health sector under very specific conditions. Accordingly, electronic healthcare is a modern provision of medical services based on modern technologies. By developing and implementing the concept of electronic healthcare and in general the electronic business of health organizations, with the support of health information systems, there is a new direction in the digital market. The electronic healthcare and digital market orbit on which it is located has led to the creation of such health information systems that are oriented towards the needs of the stakeholders, and the highest end users-patients. Therefore, the electronic business of healthcare organizations is compatible with the postulates of consumer healthcare, and is based on the functioning of health information systems that strive to increase the quality of healthcare services, cost optimization and efficient relocation of medical resources. Emerging public health pillars such as the pharmaceutical industry and the production of medical devices have led to the development of a third pillar that actually represents electronic health.

In order to ensure the security and integrity of data and information exchanged in large numbers via electronic health channels, it is necessary to use a blockchain technology that acts preventively on the possible misuse of medical data. Also, the economic side of the blockchain technology is very important, given its role in reducing the cost of additional medical information checks, increasing interoperability, and reducing the occurrence of data redundancy. The paper will first show the basics of blockchain technology in electronic health, both from its technical and economic point of view regarding the speed and processing of data passing through the network. The second part of the work will be related to the impact of this technology on the interoperability of electronic healthcare and the data integrity and validation, transmitted through wireless body area networks.

2. Related Works

The popularity of the blockchain technology as a kind of instrument for increasing security and data privacy, especially in the health sector, has prompted many researchers to work on its improvement. Namely, with the emergence of electronic healthcare and

especially mobile health as its integral part, using medical devices for creating a wireless area body network, there is also a need for protecting the data being transmitted in this way. Thus, Nugraha & Alaydrus (2017) conducted a research on the subject of authentication, confidentiality and availability of mobile medical data within the wireless area body network, where blockchain technology would have key algorithms in verifying data and preventing their abuse by their algorithms. They came to the conclusion that it is the best to apply the SHA-512 algorithm because of modifying medical data. On the other hand blockchain technology is a technology that will trump access to medical data. [1] Blockchain technology should play a role as a data keeper especially when sharing information from portable medical devices or interactive healthcare information systems such as CAALYX. [1]

The aforementioned group of authors also insists on the use of the proof-of-work model of blockchain technology. Also, the mentioned role of blockchain technology as a data keeper would have the role of controlling the diverse eHealth scenarios used in the interaction of various health organizations. In order for a blockchain technology to achieve certain interoperability, it is also necessary to select the appropriate blockchain platform, which can be done by multi-criteria decision making. Some authors recommend that these be parameters such as transaction speed, innovation capability, overall maintenance costs of the platform, and the availability of the platform for virtual health communities. [2]

3. Blockchain Cost- Saving Algorithms in Healthcare Industry

Blockchain consists of blocks that are strung, or connected in a chain where each of the blocks has a series of records. Blocks are linked by an algorithm that uses a hash function. The link between blocks is very hard to fake or hack, because it is also an algorithm that uses high-level cryptography. As we mentioned earlier, blockchain technology was created primarily as an idea on which Bitcoin digital encryption will be based. Today, many sectors, such as the health sector, recognize the quality of the technology itself and are trying to implement it in their business. On the example of Bitcoin as the first digital currency that uses hash functions and blockchain, we see how a secure transaction has been achieved without a central authority, which was also used by healthcare organizations to share information about the health status of patients and to create electronic medical records with medical data (Figure 1)

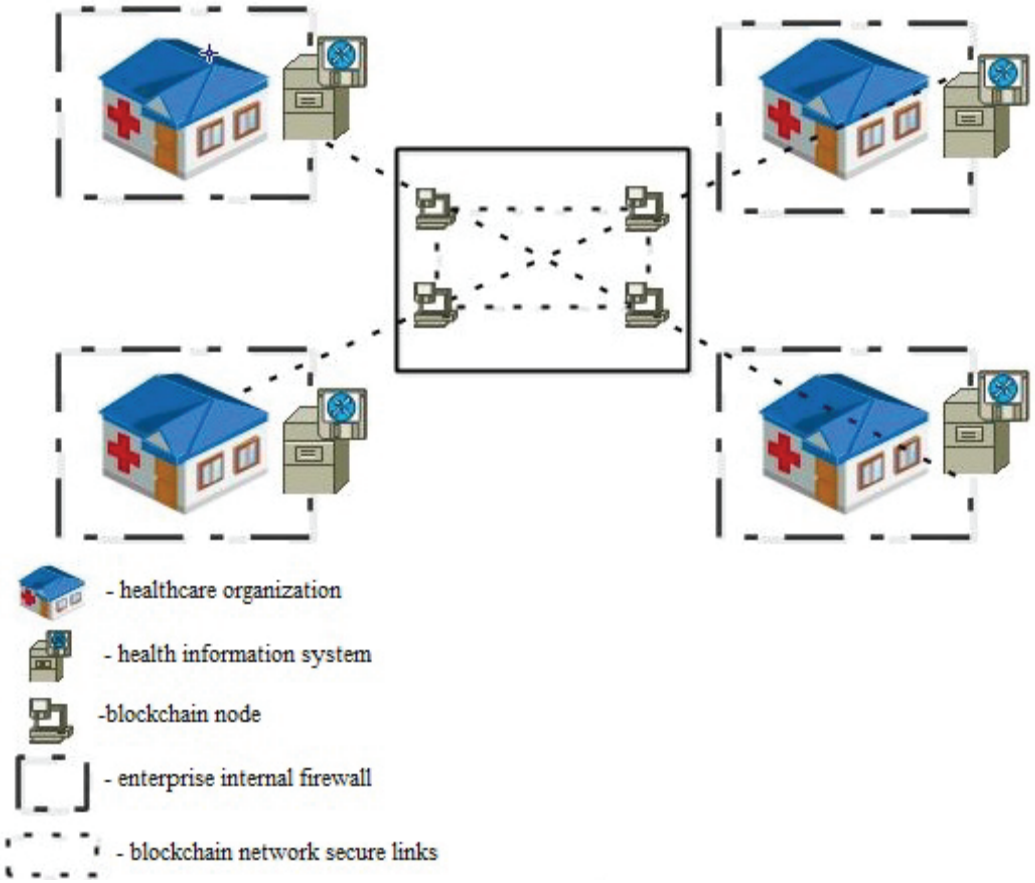

Figure 1: Blockchain technology structure in electronic health (Source: Author' own work).

Blockchain technology in electronic health uses every block in the chain as a final amount of data or a transaction it can store. At the moment when the block is filled, a new one is created that will be linked to the block preceding it and to the one that will only be created in the future. The security of technology rests on this because if attacker wants to change the data in one block, he should do that for all blocks, that is almost impossible. This is extremely important in the case of electronic health records. The data at the time it is written can not be changed anymore, all the orders and actions are written and can not be manipulated by the data. In the header of the block we encounter technical information about it itself and with all the information related to connecting with other blocks that are also part of the blockchain. The hash of the previous block is the final result obtained after the double application of the SHA-256 hash function. [1] Note that the hash of the block itself is not part of the block structure; it is usually calculated only when there is a need for such action, then the result is executed on the side of each node. 4 bytes, which are timestamp predictions, contain information about when the block is added to the chain. The root of the binary hash tree has information in its possession from all the blocks in the block. Weight markers

and nonce are meta-data, their application is only visible when adding a block to a blockchain (Table 1).

Table 1: Structure of the blockchain blocks.

Size	Name			Description
4 bytes	block size			block size in bytes
80 bytes	Block header			meta data
	Size	Name	Description	
	4 bytes	version	protocol version	
	32 bytes	Previous hash	Reference on the previous block	
	4 bytes	root	Hash that has all the information mentioned in one block	
	4 bytes	timestamp	Block creating time	
	4 bytes	weigthstamp	Algorithm weight for the block implementation	
	4 bytes	nonce	Solution number for the algorithm	
1-9 bytes	transaction counter			number of transactions in block
variable	transactions			transactions in block

The hash function argument is the data of an arbitrary length, but the result is fixed. The entire blockchain technology is based on the utilization of the hash property. Hash of a block is very easy to calculate, but it is very difficult, or it is not possible to detect which data is hidden in the background of the calculated hash. It is enough that only one letter is changed to some input information or sentence, hash of that information will look completely different. Therefore, electronic healthcare is suitable for the application of a blockchain technology that will reduce the error rate both in transcribing diagnosis and therapy electronically, and in interpreting the patient's health status. This is especially important when it comes to patient transport, triage and pharmacy options for electronic healthcare, as unlike paper, electronically, using blockchain technology can reduce the error rate in setting diagnosis. Consequently, unnecessary logistical costs and costs of allocating medical resources are reduced. Given that, it is extremely important that the algorithm will be applied in the processing and protection of medical data by blockchain technology. So far, MD 5 has been used according to the HL 7 (Health Level Seven) standard, while SHA-512 is increasingly recommended for the speed of processing the transaction and reducing the level of abuse. The processing speed of the MD5 algorithm is 182.6 seconds (Figure 2), whereby one who wants to misuse data can not only read them but can also modify them with a minimum of 9 characters. According to Sirep et al.

with the SHA-512 algorithm, he can only decode the password but does not modify the data, because with this processing algorithm processing speed is 125.4 seconds.

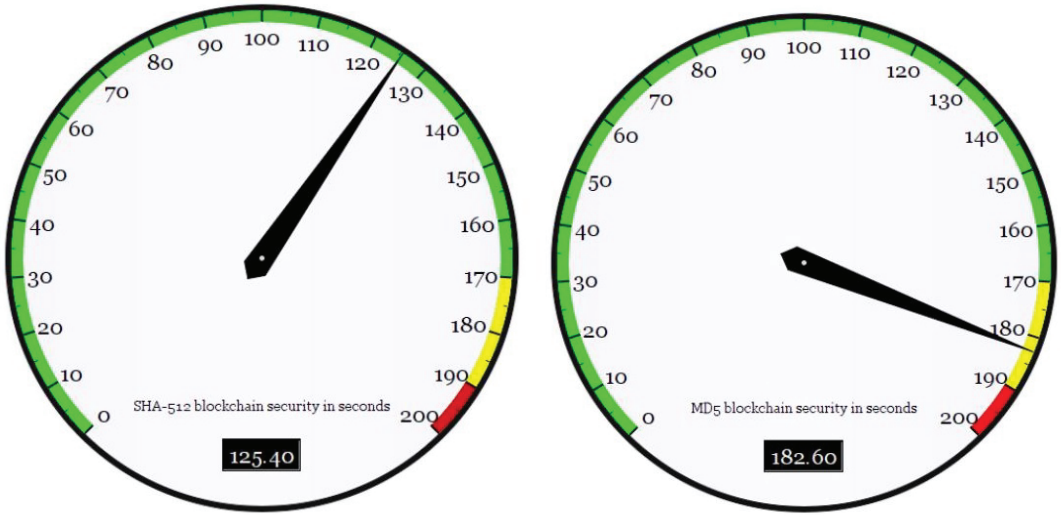

Figure 2: Transaction speed via blockchain algorithms MD5 and SHA-512 for e-Health (Source: Authors calculation according to Nugraha & Alaydrus (2017)).

The medical information that will enter the function should first be expanded in such a way that its length is split with 512. The length of the data (d) will be extended by adding the bit "1" to the end of the data. Then, we add to the path the bit of the opposite value "0", where k denotes the least nonnegative equation solution d + 1 + k = 448 mod 512. After these operations, a 64-bit block is added, which is at the same time the previously mentioned length of the data, but in the binary record. When the data extension is completed, then the data will be divided into blocks P (1), P (2), P (3), P (4),..., P (n) each of which has a size of 512 bits. In this way, blockchain technology in electronic health functions, which ultimately plays a role in increasing the interoperability and scalability of network infrared. The recursive formula that depicts the SHA function is [3]

$$H(i) = H(i-1) + KOMP(i)(H(i-1)) \quad (1)$$

where the COM-decomposition function, H (i) - some hash lengths of 256 bits, H (n) -tested result, + - operator, H (0) - recursive value at the very beginning.

4. E-Health Interoperability Cost- Saving Improvement Using Blockchain

One of the greatest challenges of health information systems in modern medical practice is the integration and storage of data from several separated and information-based health repositories. Large amounts of health electronic records as well as split medical

documents and recordings are in the data created by clinical diagnostic equipment using the health information system. These important data should be processed in an adequate manner in order to serve important medical decisions and to be used in a heterogeneous clinical administration system.In this way, the process of providing electronic healthcare services, as well as the optimization of the patients' treatment in the health institution, is improving. Traditional operational databases of health organizations do not meet the needs of storage and analysis of data important for the process of making health decisions.

Namely, these traditional databases do not have a detailed history of patient health records and often can not provide relevant information for the needs of clinical reports.The processing of health data with the prior application of blockchain technology is therefore, in modern conditions, based on integrated subject-oriented and time-realistic data collection in order to contribute to timely medical decision-making by preserving and analyzing data while preserving the integrity of data. These data are stored correctly and are always available at any time interval and are always updated regularly, in detail and even when they are not critical for further treatment of patients. The benefits of electronic health based on modern principles of functioning of health information systems using blockchain technology are: [5]

- Standardization of data through a health organization
- A faster response time to queries by healthcare staff, in order to conduct analysis and reporting on the patient's health status
- Facilitating the sharing of health data
- Increasing the quality and consistency of health data
- Removal of unnecessary administrative and procedural operations when using health data
- Integration of electronic health data from multiple sources into a single repository, Improving quality by reducing data redundancy
- Restructuring of collected electronic health data in order to improve their performance, in order to respond in the most precise way to the request of the health information system
- Using queries to support the health decision-making system

Implementing the concept of blockchain electronic healthcare technology is a complex process consisting of two phases. The first phase refers to the configuration of the database itself in which the data will be processed. The second phase refers to

the extraction of all unnecessary operations in the collection and storage of electronic health data and their determination in accordance with the functioning of the health information system. The database for the storage of data must be regularly updated and modified in accordance with the specifics of functioning of a particular health organization and its information system.Large data capabilities continue to develop rapidly driven by innovations in technologies, platforms and analytical capabilities to manage medical data with the evolution of patient behavior on the web. This applies in particular to the independent use of health portals and the personalization of electronic health cards.

Consequently, four ways to use big data with blockchain technology have been identified that enable the transformation of big data into value and have implications for how health information systems will be created for the needs of a healthcare facility when blockchain technology is concerned [6]:

- Creating transparency - enabling the availability of large data in a timely manner, can help actors create the value of health services. In the health sector, making relevant data more easily available across otherwise separated medical departments, the time to search and process this data can be sharply reduced.
- Experimenting - storing data in digital form and analyzing them, healthcare organizations can discover the needs that arise for a particular medical service and thus improve their performance. Using the analysis of large data through computer simulations of the health condition, clear signals are received about the further course of the disease and treatment of patients.
- Segmentation of the patient population to undertake the action - big data allows organizations to perform a specific segmentation of the population of patients in real time according to the needs for medical services, which enables the precise targeting of health-disadvantaged parts of the patient population.
- Automatic support for decision-making through algorithms- sophisticated analysis of health data can significantly improve decision-making, reducing risk and point out some hidden values that traditional tools would not display.

Blockchain technology in electronic healthcare is generally based on the attributes necessary for the proper management of large data, as in the case of electronic healthcare. These attributes include [7]:

- Scalability - based on low latency, high bandwidth and the resilience of the IT ecosystem to external events. In doing so, scalability ensures a change in the

traffic routes of electronic health services, if there are "bottlenecks" without slow-down, and automatic regulation of network widths through intelligent applications.

- Convergence aims to enable multiprotocol access to data centers for the delivery of specific data and further to the access server from where they are downloaded.
- Network intelligence - the ability to network electronic health channels from different types of network traffic, and then there is no "data vacuum".
- Multiservice architecture - gives high data density in health organizations that can now improve the movement of big data through an organization where each health unit has access to a server that suits its activity and a central server.

In order to justify its role in increasing the interoperability rate in electronic healthcare, blockchain technology should implement a proof-of-work model that guarantees consensus in a network following the principle that nodes will always accept the longest available chain. [1] Blockchain technology enhances interoperability and in a case of data storage, so-called data silo, that can be accessed from various pharmacy e-healthcare channels. However, in order to apply any blockchain technology in eHealth and eliminate the negative effects that the silos have on the interoperability, safety and accuracy of medical data, it is necessary to respond to the following challenges: [7]

- disparity in pharma data
- data analytics is time-consuming and resource-heavy
- data inaccuracies and ambiguity around relevance
- secure data and transfer it safely between devices and health service providers
- income cycle management
- improve medication adherence
- medical history management and sharing
- sell your medical data on a blockchain marketplace.

5. WBAN Cost-Reduction Role Controlled By Blockchain Data Validation

As a result of the aforementioned tendencies in electronic health, which is an integral part of health information systems, there is a specific direction in the evolution of electronic health. This refers primarily to the Wireless Body Area Network (WBAN), which actually represents the wireless network communication of a patient with "smart"

portable mobile devices through wireless sensors inserted in a particular body region affected by a painful process.Generally speaking, WBAN contains interconnected sensors that continuously monitor data and send them to a network coordinator that later distributes data to the health center through conventional network communications. In this way, through applications, WBAN conveys wellness, biomedical, psychological and other data using specific and set monitoring principles. These applications relate to a number of virtual healthcare services and their features that are most often highlighted [8]:

- Monitoring patients for all psychological and neurological parameters and monitoring their relationship with medical personnel.
- Monitoring of brain functions in case of potential epileptic activity, monitoring of blood sugar levels and detection of cancer development.
- Diagnose disease based on parameters measured by "smart" devices using the concept of "medicine from home".
- Administration of medicines through microsensors, in order to minimize the costs of the wrong and irregular way of taking medicines and their prescription in the form of therapy by medical stuff.
- Control patient warning for possible deviations of individual health parameters from normal values.
- Acute and post-acute monitoring of vital signs of patients without physical contact with them.
- Remote monitoring of chronically ill patients.
- Computer simulation and assistance in solving ambulatory health cases in order to reduce costs and release capacities at higher levels of health care.
- Virtual healthcare schemes and pathways for patients who need help in carrying out everyday activities.

One of the unavoidable and fast-growing segments of this electronic health field, and therefore health information systems, are social networks that electronically transmit health information. Social networks and their popularity among patients significantly contributed to the improvement of effectiveness and efficiency in intervention regarding in health services provision. This particularly applies to patients with chronic illnesses, which put social networks at the forefront of the global electronic public health arena.Although the issue of unauthorized access to health information on social networks has created fears in certain patients, so this segment of electronic health has

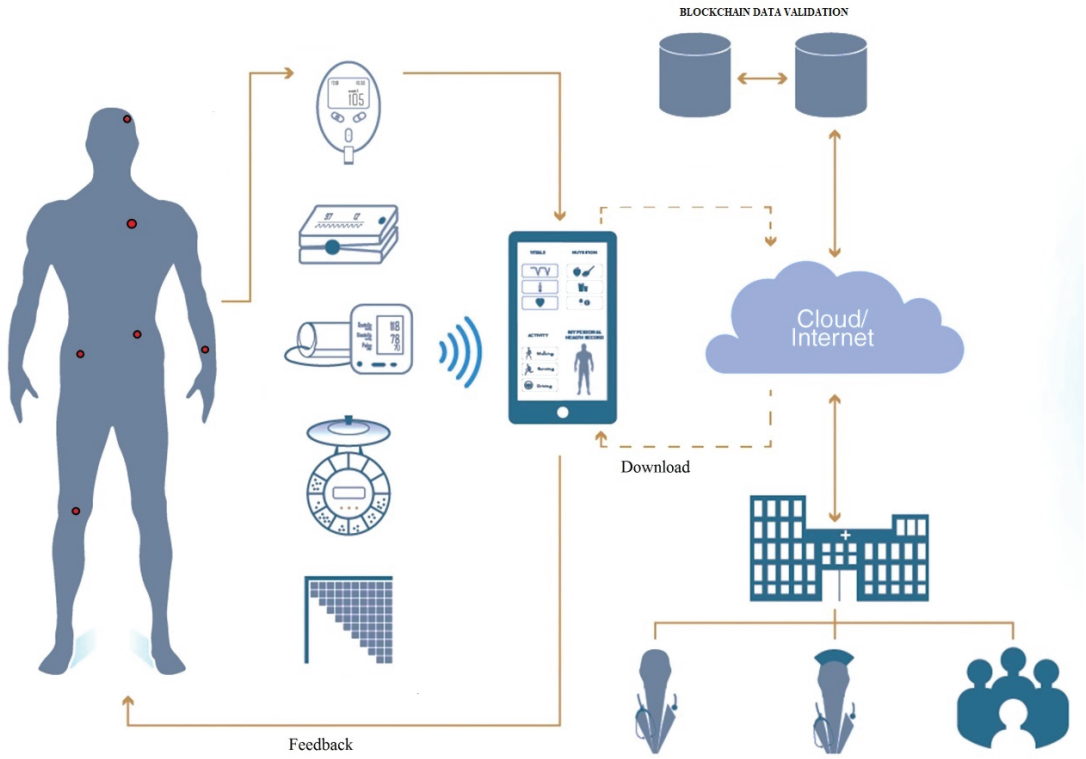

Figure 3: WBAN with blockchain (Source: Authors' calculation).

led to the use of blockchain technology as a kind of mechanism for verifying medical information that is shared by this way. This discipline relates to the digital economy of health and its global proliferation through social networks and mobile health-based applications. Social healthcare networks such as PatientsLikeMe, MedHelp, CureTogether and mCare provide several important functions when it comes to electronic health information:

- Clinical access triage function
- The function of giving emotional support to patients Sharing information and tracking health parameters
- Questions and answers from medical staff
- Pharmaceutical studies.

As already mentioned, an integral part of the electronic business of healthcare organizations, blockchain technology, aims to reduce capital costs, repayment costs and IT infrastructure costs while optimizing the resources used to provide health services. The mechanism for the sharing and exchange of health information of electronic health through the use of blockchain technology enhances the quality of the provided health

services through the cloud of electronic healthcare architecture.This architecture is based on the concept of "internet sink" that unites various sources of medical data in a common medical history managed by a terminal or node of cloud access through:

- Personal health record that allows patients to monitor, collect and manage their own health information
- An electronic health record that records health status of a patient being managed through an electronic healthcare provider and the healthcare organization's stakeholders.

By implementing the principles and way of blockchain technology functioning in the health information system infrastructure, there are significant improvements in the end results of the provision of health services. The electronic business of the health organization with the help of mobile healthcare provides better access to patients, especially in medical interventions that now use smartphones for interactive feedback from patients.Also, unlimited mobile access to health status, therapeutic plans, and treatment progress leads to cost optimization in providing health services, as there is no spending of medical resources on unnecessary procedures, and with the validation of data through blockchain technology. Redistribution of these resources creates critical clinical activities on the electronic health database in order to speed up the treatment process.

6. Conclusion

For blockchain technology, we can rightly say that it is still in its beginnings, because its first real implementation is only 10 years back. Digital currencies testify to the beginning of blockchain technology, but the potential is visible and much further. As the manipulation of data inside the chain is hampered by a good technology backdrop, in the future, in healthcare and various other institutions could find this technology as an integral part of everyday life. This is supported by the fact that the current value of only US blockchain technology in the healthcare market is over 48.2 million USD, while in 2019 it is expected to increase this value by as much as 65%. Also, for an example can be taken the sharing or loss of health information in the medical industry which leads to problems and distrust between users and providers of health services, but with the blockchain technology, the exchange of information between the user would be completely safe and deprived of all similar anomalies in the system.

These are, therefore, only trivial examples in which this technology offers revolutionary and currently optimal solutions, but the very future of the blockchain and the time it takes to implement it in various industrial systems will be visible in the coming years.The biggest breakthrough in the application of blockchain technology in electronic healthcare was made by a member of the European Union, Estonia, who has completely switched to electronic health, which is also indicated by certain data. According to research carried out by the Ministry of Health of this country, it is estimated that the use of blockchain technology in electronic healthcare saves up to 2% of GDP annually.

This country strongly accepts, supports and promotes off-chain approach in using blockchain for e-Health purposes. An off-chain approach also known as "data lakes" is a kind of approach whereby health information is encrypted and deposited in data warehouses that live off the blockchain. Germany, France, Spain and Switzerland are among the top contributors to the successful implementation of blockchain technology in health care. Healthcare system of Switzerland expect to raise the saving rate for almost 73% because of using blockchain technology. Also, blockchain technology significantly reduces the cost of the pharmaceutical industry that is also included in the health information system bases. It is estimated that 10% of medicines on the global pharmaceutical market are counterfeit, so blockchain technology would enable the interception, interference and detection of illegal drug channels, which greatly reduces the costs of the health sector. The US healthcare sector achieved a savings of around $ 19.3 million using a blockchain technology that increased the interoperability of this sector, especially in hospitalization, by rewriting the therapy based on data from electronic health records in 2018.

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