

Possibilities of blockchain technology application for the health care system

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Abstract. The blockchain technology has many applications in modern medicine. This can be data management, accounts and finance, as well as others. It is important for each category of tasks to choose their own solution and bring the maximum effect for the participants of the system, which will interact on new terms. The key beneficiaries of the participants will be health care users, health care providers, and insurance companies. The paper considers projects with a choice of different types of blockchain with the corresponding advantages and disadvantages. It also lists specific problems and risks inherent in blockchain projects in healthcare, as well as some recommendations for their reduction or elimination. The normative legal acts adopted in Russia, which regulate the legal field in the industry, has analyzed, recommendations for improvement has presented. At the moment, there are only a few laws and regulations governing this area, which is insufficient for their full application in practice. Our paper is aimed at choosing the suitable algorithm of consensus and also the architecture of all system working with blockchain technology.

Keywords. Blockchain technology, smart contracts, the medical organizations, health care, databases, the distributed register.

1. Introduction

Now the blockchain technology actively finds the application in various spheres of business, gradually taking root where it is really applicable and effectively helps to solve many problems. One of areas of application where the blockchain can bring essential effect, both economic, and social, health sector is [1]. Great advantage of this technology in this area is that its use does not demand participation of any centralized organization. Blockchain technology in the healthcare market is used to exchange clinical data, work with accounts, manage the supply chain of medicines, as well as to develop them and clinical trials. Blockchain technology is able to completely transform the way we receive and store clinical information, as well as the exchange of data between partners, payers and patients. In addition, the use of the blockchain ensures the safety and security of data, which is of great importance for protecting privacy. The trust to a system and a set of the rules in advance registered in it is far higher, than to any organization as there is a transparency element. The trust issue in the field of health care, and specifically interactions of people among themselves, when it comes to health, is vital now. For example, the employer did not learn about specific features of the worker because the second did not consider necessary about it to notify, but at the same time working conditions are inadmissible for his

state of health. Insurance companies cannot trust medical indications of the insurer, perform the examination, respectively incur additional expenses.

At the same time there is also a number of the difficulties connected with confidentiality, safety and compatibility [2], [3]. First, the modern system has the centralized architecture. Effective integration of medical data and also functional compatibility between various health care systems remain difficult tasks. Secondly, data on the state health of patients, being in open access, lose the confidentiality, it is necessary to define access rights very carefully.

Purpose: a research of an opportunity and efficiency using blockchain technology and smart contracts for the medical organizations, discharge and risk analysis.

Tasks:

- A. To analyze the directions of using a technology in medicine.
- B. To mark out advantages and shortcomings of using a blockchain in comparison with other decisions.
- C. To describe each type of a blockchain and its applicability in the field of health care.
- D. To study the decisions and projects which proved to be in practice. To provide recommendations.
- E. To construct architectural model of the medical organization using blockchain technology.

Research object: Interaction of the persons and institutions participating in a health care system.

Research subject: influence of using a blockchain technology on activity of the medical organization and its partners and also other interested persons.

2. Methods

2.1. *System overview.* To solve the tasks set, the authors conducted a systematic review of the architecture of the medical organization using blockchain technology. We analyzed the existing practices integration of blockchain technologies, Internet of things (IoT) and machine learning in medical organizations. Then we investigated the development of blockchain technology in Russia.

2.2. *Architectural approach.* Based on the analysis the possibilities of introducing blockchain technology in a medical organization, an architectural model of the upper level is proposed, which allows to determine the set of business and IT services, the information exchange, the IT-architecture and technology architecture.

3. Results.

3.1. *Relevant directions blockchain projects*

Modern the blockchain projects in the field of health care can be divided into the following categories:

- 1) Data management;
 - a. EHR projects
 - b. Drafts of the analysis and storage of DNA genomes
 - c. Drafts of the analysis and storage of visual information
- 2) Management of the pharmaceutical sector;
- 3) Management of accounts and finance;
- 4) Analytics.

A.V. Saskevich and the coauthor [4] marked out these categories and subcategories and also listed names of projects which carry out activity in this direction. One of the popular directions is tracking a supply chain. So, by means of a certain technique [5], for example, it is possible to monitor the

movement of drugs according to the estimates of IBM Institute for Business Value, determination to implement decisions by means of a blockchain is declared by more than 16% companies of the world market medical services [6] already today.

To reach the maximum effect of use a technology, it is necessary to pick up correctly the platform which will be suitable in the best way for the solution of specific objectives in a certain area. One of the platforms existing and already shown the efficiency, is Hyperledger Fabric of the HyperLedger project [7]. The founder is The Linux Foundation – non-profit consortium of development Linux. The main feature – orientation on corporate use. The platform can start the smart contracts implemented in the Go/JAVA/Nodejs language. The most widespread programming languages are applied that reduces costs of training developers. HyperLedger – the project with an open source code created for advance a blockchain technologies in various industries.

Relying on results of article [8], it is possible to notice that Hyperledger Fabric advances a blockchain of Ethereum which is one of the most popular blockchains with implementation of smart contracts, on many indicators: transaction performance time, average delay, average capacity of network. At the same time Ethereum has a bigger indicator on the maximum number of simultaneous transactions. However already on January 3, 2020 there will be a zero phase transition of an ecosystem Ethereum to a stage 2.0 which will support an algorithm of consensus PoS (Proof of Stake) unlike the current PoW (Proof of Work) [9]. According to plans of developers, Ethereum 2.0 will have indicators better than "predecessor".

Without going deep into technical characteristics of HyperLedger Fabric, it is necessary to consider an algorithm (scenario) execution of transaction [10]:

- 1) Transaction initiation.
- 2) Performance of the smart contract.
- 3) Data transmission in the client application.
- 4) The application sends transaction with data for a certain service (Ordering service) which builds the arriving transactions in the correct order. Here Kafka a cluster which maintains the correct sequence of transactions enters.
- 5) The created block goes to all nodes of network. Participants of network according to the policy of network and rules check and verify result. If all conditions are satisfied and the identical result turned out – transaction is considered valid. Otherwise it is recognized as non-valid and incomplete.
- 6) Addition of the block in the distributed register.

Considering successful results of implementation Hyperledger Fabric in medicine, It should be noted the Change Healthcare company. Change Healthcare offers the software, analytics, services and network decisions on the basis of the innovation technologies in the field of health care. The mission of the company is modernization of the American health care system which "suffers from inefficiency, fraud and squandering". The company set the object to show a possibility of using a blockchain for processing hundreds medical transactions per second. For implementation of this purpose Hyperledger Fabric just was also chosen. Implementation took only several months, and since January, 2018 the test network showed ability to process up to 50 million transactions a day with a capacity up to 550 transactions per second. It was enough for processing of all transactions which happened in network [11]. The consulting company McKinsey, having conducted a research, assumes that the health care system in the USA can save up to 450 billion dollars a year due to use of the updated processes and technologies [12].

Xiaobao Zhu and coauthors offered the platform [13] built on a blockchain consortium where the open Ethereum code, and as an algorithm of generation the PoA block (Proof of Authority) was chosen. On the basis of the offered model the imitating research for classification tumors of a mammary gland is conducted. Authors consider that the offered model has huge potential, and the current work "represents only the first step showing its feasibility". Also problems some of which

were already mentioned in this work were allocated: confidentiality of transactions, "Sibyl's attack", scaling of a blockchain, state regulation and others.

3.2. Using a technology in Russia

3.2.1. Regulatory base. Russian legislation. Technological progress constantly goes forward, but the legal framework and legal registration of any actions can be late. So, the concept of a blockchain and cryptocurrencies appeared in 2008, but only after distribution of this technology to certain scales, regulators of various countries began to think of change/addition in acts of the norms connected with this technology.

As for specifically Russia, in 2017 the Russian President Vladimir Putin urged to develop digital economy. On March 12, 2019 the State Duma at a plenary session adopted in the third, final reading amendments to the Civil Code of the Russian Federation about "the digital rights". This law comes into force since October 1, 2019.

Besides the adopted federal law, there is a bill "About Digital Financial Assets". The draft federal law "About Digital Financial Assets" is drafted according to an order of the President of the Russian Federation V.V. Putin of 21.10.2017 No. Pr-2132 following the results of a meeting on using digital technologies in the financial sphere on October 10, 2017. According to the document of the conclusion of legal department which is placed in the system ensuring legislative activity was it is specified that the project needs completion. This decision was made after holding the second reading in the State Duma of the Russian Federation 19.03.2019.

What is significant for the considered ways of implementation of blockchain technology in medicine, It should be noted that the Federal Law about "the digital rights" enters bases of a concept of smart contracts. "The written form of the transaction is considered the transaction with the help of the electronic or other technical means allowing to reproduce on the material carrier in an invariable look contents of the transaction observed also in case of commission by the person, at the same time the requirement about availability of the signature is considered executed if any method allowing to define authentically the person which expressed will" [14] is used. Thus, smart contracts can be one of possible ways of transaction. This law creates basic conditions for introduction to the legislation of the acts regulating issue and a turn of the digital rights and also simplifies the conclusion of transactions in an electronic form. However this condition is not sufficient, it is necessary to improve the legislation in this area. In particular, it is necessary to introduce amendments and to improve the bill "About Digital Financial Assets". CEO Tokenomica and the head of Sputnik DLT believes that "the law in general is worked out rather qualitatively, however it practically does not regulate a blockchain, tokens and smart contracts in any way. In essence the entered digital rights are as close as possible on the status to undocumented securities that calls into question their need per se" [15].

To all other, It should be noted that in 2018 Russian Federation Government decree No. 447 of 12.04.2018 "About an order of interaction the state and non-state information systems in the field of health care" and also Russian Federation Government decree No. 555 of 05.05.2018 "About a uniform state information system in the field of health care was accepted". These resolutions have not a direct bearing on a blockchain, however you should not deny their importance in an overall picture.

2.2.2. Using a blockchain technologies in Russia in practice. One of blockchain routes of administration in health care as it was already told, is monitoring and data storage. In Russia one of the first projects is the joint project of "Vnesheconombank" and the Novgorod region on monitoring of providing with medicines. According to the chairman of bank, Sergey Gorkov, the created system allows the patient to control presence of drug in a warehouse, given about the producer and issue date, and at the time of receiving drug to be convinced that it is its drug, to confirm receiving and integrity of the package [16].

The Russia's first information system clinical trials using blockchain technology is created in the National medical research oncology center N.N. Petrov with assistance of the Ministry of Health in the Russian Federation and the technological platform "Future Medicine". The system created on the basis of the center will allow all participants in the process of clinical trials of anticancer drugs to interact in real time, such as: Ministry of Health of the Russian Federation, to researchers, medical organizations, research customers, patients and insurance companies [16]. According to Konstantin Zakharov, the deputy manager of "Eco-bezopasnost" (eco-safety) research center, this project is paid back. "Data from base can be monetized, and access to a system can be paid" [17]. As advantages of a blockchain to carrying out CT (clinical trials), in oncology SMRC of N.N. Petrov allocate the next moments:

- Integrity (loss of data and their fragments is excluded)
- Ethics (new opportunities for ethical examination)
- Safety (unlimited period of storage)
- Saving of time (electronic document flow)
- Confidentiality (impersonality of data)
- Automation (use of smart contracts)
- Availability (simple access to the authorized users)
- Depreciation (reduction of the main costs)
- Control simplification (control and risk management)
- Increase in responsibility (personal responsibility for data entry)
- Improvement of quality of researches (reliability and completeness of data)
- Decrease in number of mistakes (minimization of a human factor)

It becomes clear that not each marked-out advantage does not pose in itself certain risks and threats. So, confidentiality can be under the threat if the third party takes control of a key from the electronic card of the patient, will have respectively full information on it, to use in the purposes. Availability does not assume absolute access for each person to this system as in case of paid use not all will be able to pay for it. Respectively, amendments to social policy of the state, development of regulations for the persons which do not have an opportunity to pay use of this system are necessary. Increase in responsibility is directly connected with reduction of number of mistakes, however and the price of a mistake can be much bigger. If made to the patient the incorrect diagnosis and entered in the register, to move away him from there (when using a public blockchain) it will not be provided possible that will make certain difficulties for the user.

3.3. Architecture of the medical organization implementing blockchain technologies

3.3.1. System objects. The architecture of the medical organization implementing blockchain technologies has some features. In particular, it is necessary to study objects of a system [18]:

A) Supplier of medical services (medical organization, doctors, etc.). After purpose of medical examination by the doctor, results can be loaded into network a blockchain for data exchange with other suppliers of medical services with the user permission of these services. Also current supplier can request from the user access to its previous data on the state of health which was loaded into network earlier. Thus, the medical record and a case history of the user is formed.

B) User of medical services. The user is the only and full owner of personal medical data and is responsible for granting or refusal of access to data, cancellation of access for other parties (suppliers of medical services, insurance companies and other). In case of need receiving medical care, the user provides a key (access) to the necessary persons. Besides, daily actions according to a certain medical treatment for completeness of information which the user will provide to the supplier for receiving treatment can be written down.

C) Insurance company. To reduce risks and to reduce own expenses, insurance companies can request access to data of users on the state of health during all the time or a certain interval. Users who

have bigger risk to get sick according to history, perhaps, will have to pay an insurance premium at the raised rate. Moreover, the fraud risk from the user as it is impossible to forge these data disappears. Anyway the user has the right not to provide access to the data because of possible questions with confidentiality of information which is contained in it, but in that case it will lose a possibility of receiving an insurance on a reduced rate and also will be perhaps directed to additional medical examination at own expense. That is in most cases it will be unprofitable to it. Besides, claims of insurance company can be also written down in a blockchain.

D) Blockchain. For access to user personal data to the supplier of medical services or insurance company it is necessary to send a request. This request has to be processed according to rules of the decentralized network, get permission from the owner. Indicators of health are brought by the devices, wearable on the person, collecting data (if those are available) and also the supplier of medical services and the insurance company which got access. All entered data and also access inquiries, activity of access register in a blockchain that further, in case of disputable situations, it was clear who entered these data.

E) Readers. If desired and opportunities, the user can provide access to record to special devices which measure various indicators of health and automatically include them in the account.

E) Cloud-based database. The base is users storage about their state of health, inquiries suppliers of medical services and insurance companies and also record of sequence of access to data, control policy of this access.

In figure 1 it is possible to see the scheme of interaction between all system objects. The central link is the user who has full authority of access to the network account in the cloud-based database.

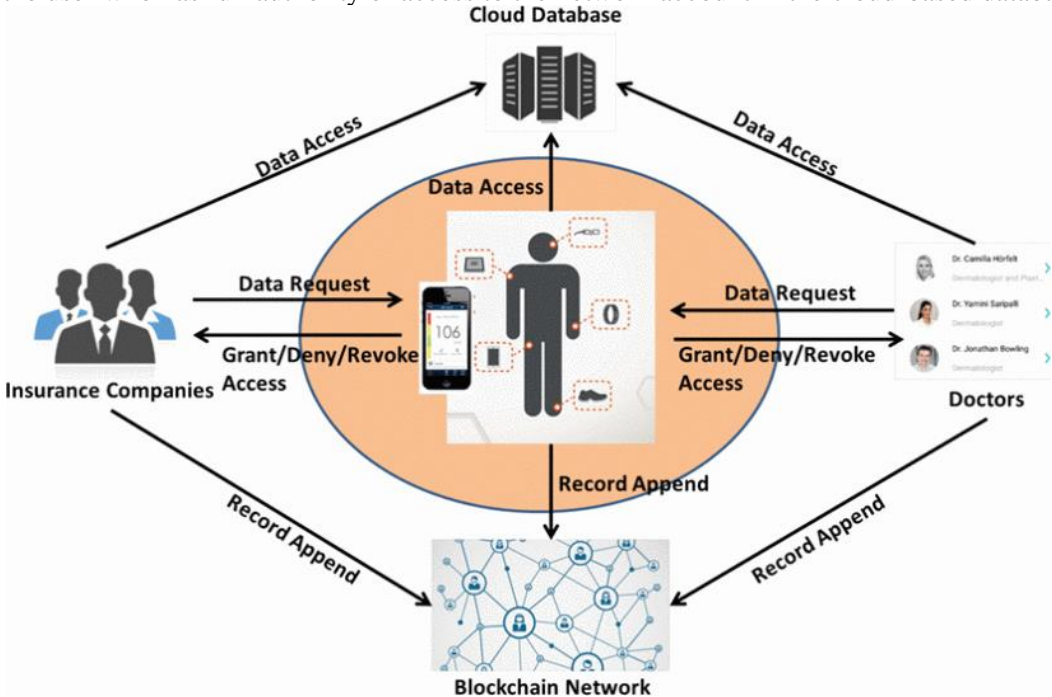


Figure 1. Exchange of personal data on health with using a blockchain [1]

3.3.2. *Association blockchain technologies, Internet of prophetic (IoT) and machine learning.* The IoT module deals with extraction process and data read-out from wearable devices which are a system object. This device is a good way of monitoring data if the patient is not in a hospital. It is possible to bring into qualities an example of indicators: heart rate, discharge of calories, monitoring stages of a dream, etc. Devices can be both external, and implanted.

There are several types of blockchains which have the advantages and shortcomings in terms of functionality: inclusive and exclusive [19].

The first type is the peer decentralized network where participants (nodes) of network can carry out certain transactions without need to rely on the third party. All transactions are stored in blocks and have public access. Each transaction is checked and subsequently is added to a blockchain according to the established rules of network. If the system of the proof is PoW (Proof of Work), then transactions are checked by so-called miners which provide the computing power. The block is added to a chain after reaching consensus, and miners receive a remuneration from a system. Thus the reward compensates miners, costs of electricity, providing rent of the capacities and also stimulates other users to join network. Ethereum can be an example of such platform. As for the field of health care, MedRec can be an example of using a public blockchain. According to a research [20], MedRec uses the Ethereum platform for creation of the decentralized exchange system of medical records on the basis of smart contracts. Health workers can add entries about patients at any time. At the same time, they decide to what information they want to provide access to other suppliers. Also there are two reward models.

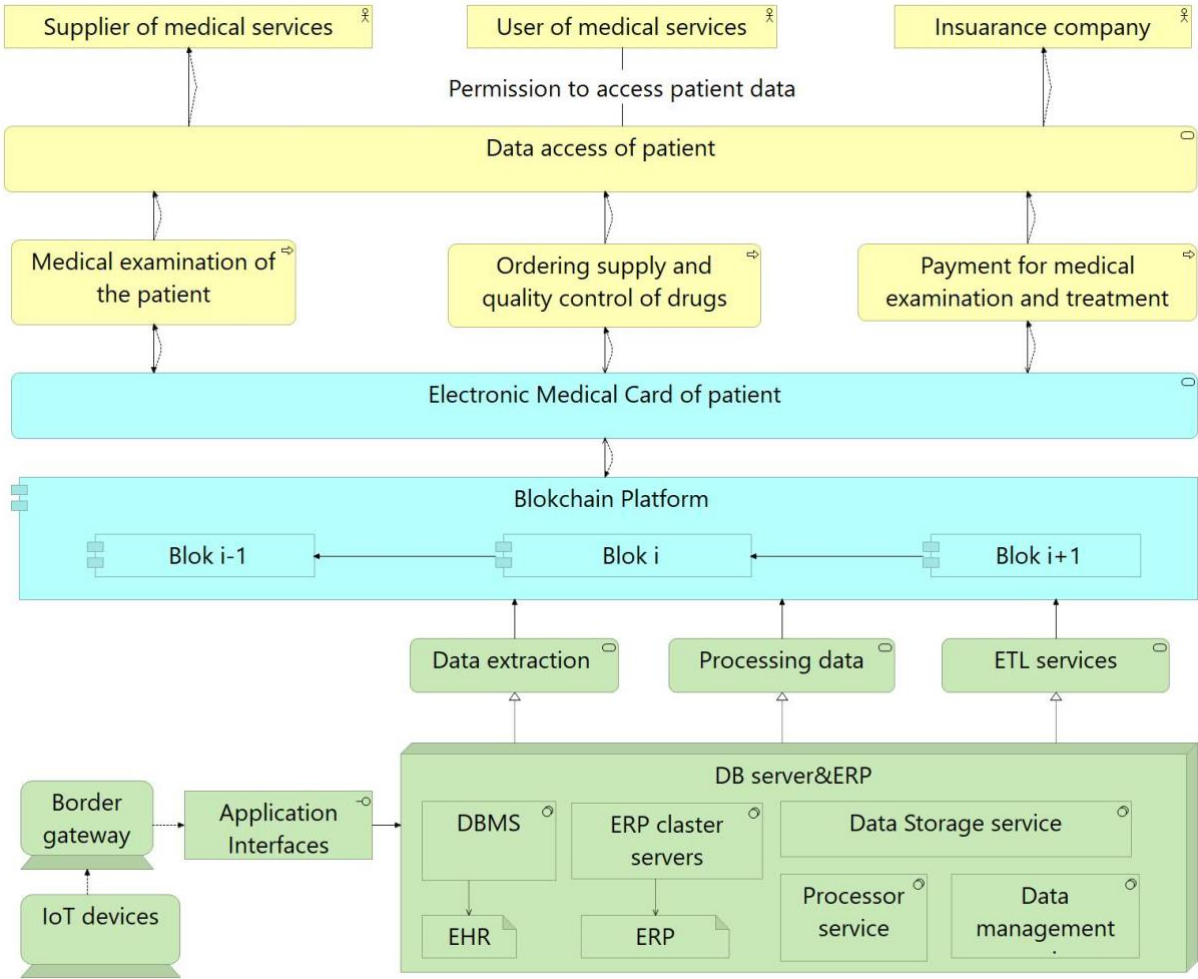


Figure 2. The reference architecture model with using blockchain technologies.

Feature of the second blockchain type is that the rights for record are stored is centralized for one organization, and the rights for reading can be granted to all or to be limited to some extent. Important plus of a private blockchain is high confidentiality just because a possibility of restriction the rights for reading. Other difference from a public blockchain it is possible to call an opportunity to change rules of network and also to cancel transactions. Thus, various failures and errors can be eliminated by

manual intervention. Transactions are checked only by the checked participants that leads to reduction of the necessary computing power (complexity) and, therefore, to cheaper transactions. Thus, the private blockchain because the possibility of the centralized management is very similar to the standard distributed database.

Based on the previous studies results of our research team [21-29], we have formed a reference architecture model with using blockchain technologies (Figure 2). Also it is possible to carry a blockchain consortium to the second type. The right for reading in this case can be open or limited only for participants. The blockchain consortium, unlike a private blockchain, is considered partially decentralized. As for specifically health care, this system allows organization to share the patient's EMR (electronic medical record) through the distributed account book with use of the distributed database. There are several implementations of creation a blockchain consortium for health care, such as MedChain, ModelChai and BlockInsure [19].

4. Discussion

4.1 Possible problems and implementation risk of a blockchain

Besides the general risks which can arise at the enterprise at implementation of this technology it is necessary to consider a specific risks in the branch of health care. The general risks and methods of their decision were described in work K. Hebert and coauthor [30] where they distinguished 8 blocks of risks which the organization can face. Certainly, implementing technology of a blockchain, it is necessary to consider each of these risks.

Allocating problems of using a blockchain in health care, it is necessary to describe the key moments:

1. Providing access to data recording.
2. Providing access to reading information. Privacy.
3. "Sibyl's attack" in peer systems at consensus of PoW.
4. Quantum computers. Breaking threat blockchain network. (far prospect)
5. The legal aspects connected with insufficiency development of the legislation in this sphere.
6. Availability of transition to new technology to each citizen.

Each problem has the methods of the decision. For example, the choice of blockchain private network or accession/creation a blockchain consortium, careful selection of network participants to which access will be provided can be the decision of Paragraphs numbers 1 and 2. At the same time careful development of system architecture with the detailed description and the analysis of all proceeding business processes and also definition of validators is important. The solution with "Sibyl's attack" devoted a set of articles. For example, using hybrid MAP and MAC technology for detection of the attack [4]. Besides, the risk of the attack can be reduced, having increased quantity of nodes by involvement of new users, thereby having forced them to compete in the solution of a difficult mathematical task to add the block (in case consensus Proof of Work and mining existence). For this system use consensus Proof of Work can be the inefficient decision as additional costs of mining will be necessary. Authors offer an algorithm of consensus Proof of Authority where check of transactions and their addition in the block is carried out by a certain number of in advance chosen validators. As for quantum computers, new architectural concepts are necessary for blockchains which will not rely on modern cryptographic algorithms. Without certain advances on Paragraphs 5 and 6, first, there can be some legal issues concerning legal relationship on new conditions. Secondly, free implementation of medical data transfer from traditional carriers on a blockchain and also consumption of other services assumed by technology and described in this article is impossible or complicated. Creation of certain private or public foundations or revision charters of funds, the systems of health insurance can be a solution. It is necessary to arrange social policy under modern realities in case of increase in scales using a technology. And for increase in scales the federal programs stimulating this transition

initially are required. The state, business and the universities as elements of "a triple spiral", have to act together.

5. Conclusion

The blockchain technology opens new opportunities and has broad use in health care. The transparency, safety and other advantages allow to bring to the new level as well as the system of document flow, and to provide revolutionary opportunities for clinical trials. However, it is impossible to forget about possible risks and threats, to select the correct decisions for specific objectives.

In health care it is possible to distinguish data management, management of the pharmaceutical sector, management of accounts and finance and also analytics from the directions of using a blockchain. International experience showed that in these categories it is possible to apply this technology really. At the moment the foreign companies implementing the projects in this area exist and work.

Considering the system of interaction in health care, the following objects are allocated: user of medical services, supplier, insurance company, blockchain, cloud-based database. Also here it is possible to add various readers and also other interested persons (for example the Ministry of Health). Each participant of a system gets from it a job a certain benefit: for example, the insurance company reduces the costs and risks, and the user has available and safe medical history.

In Russia there is also implementation of this technology, but not in so wide scales. The single developments which do not have at present broad use are carried out. As for the legislation, much more the normative legal acts connected among themselves which would define legal relationship of the same participants on new conditions are necessary, created protection guarantees. Though the blockchain technology also has a set of advantages in comparison with a traditional system, it is impossible and to forget about its shortcomings.

6. Acknowledgement

The reported study was funded by RFBR according to the research project № 19-010-00579.

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