TETIANA HOVORUSHCHENKO, VITALIY OSYADLYI
Khmelnytskyi National University

METHOD OF ASSESSING THE REPUTATION OF A MEDICAL INSTITUTION (AS A MINER OF BLOCKCHAIN)

The healthcare sector in Ukraine has long been in need of change, and the many opportunities of blockchain technology can help it lead the transformation of this sector and ensure compliance with the requirements of efficiency, safety, novelty and economic benefits.

Blockchain will transform medical enterprises and improve the quality of service, allowing new ecosystems and new business models to develop. Healthcare information stored in the blockchain can change the way clinical information is stored, as well as how information is shared in the organization, with healthcare partners, payers and, most importantly, patients. Blockchain decentralizes medical information by increasing the availability, efficiency, transparency, and credibility of data, but also requires careful planning to maximize the benefits it brings. With the help of the blockchain, users can store important medical data, the authenticity of which can be verified if there is a suspicion of forgery. In addition, cryptographic algorithms can be used to ensure the confidentiality of medical data (for example, an attacker will not be able to read the text if he stole data). Thus, the current challenge is the need to manage medical data based on blockchain technologies.

The reputation of the medical institution (as a blockchain miner) is an important indicator, as the blocks are recorded by verified pre-selected validators and are in fact moderators of the system. It is to determine such validators that the value is not the number of tokens, but reputation, ie the blockchain according to a certain algorithm, taking into account the reputation, chooses a validator who will write the next block. Reputation grows with active life in the blockchain ecosystem and interaction with other participants. The better the reputation - the greater the chance of creating the next block. Therefore, the method of assessing the reputation of a medical institution (as a miner of blockchain), which allows to calculate and assess the reputation of a medical institution, was further developed in the article.

Experiments on blockchain-based medical data management using the developed method of assessing the reputation of a medical institution (as a blockchain miner) - experiments to assess the reputation of a medical institution (for example, two different family medicine clinics) - as a blockchain miner.

Keywords: blockchain technology, blockchain miner, reputation of institution as a miner of blockchain.

ТЕТЯНА ГОВОРУЩЕНКО, ВІТАЛІЙ ОСЯДЛИЙ
Хмельницький національний університет

МЕТОД ОЦІНЮВАННЯ РЕПУТАЦІЇ МЕДИЧНОЇ УСТАНОВИ (ЯК МАЙНЕРА БЛОКЧЕЙНУ)

Сфера охорони здоров'я в Україні давно потребує змін, і безліч можливостей блокчейн-технології (blockchain) можуть допомогти їй очолити трансформацію цієї сфери та забезпечити відповідність вимогам ефективності, безпечності, новизни та економічної вигоди.

Блокчейн перетворить медичні підприємства та підвищить якість обслуговування, дозволяючи розвиватися новим екосистемам та новим бізнес-моделям. Інформація про охорону здоров'я, що зберігається в блокчейні, може змінити спосіб зберігання клінічної інформації, а також те, як відбувається обмін інформацією в організації, з партнерами з охорони здоров'я, платниками і, головне, з пацієнтами. Блокчейн децентралізує медичну інформацію, підвищуючи доступність, ефективність, прозорість даних та довіру до них, але також вимагає ретельного планування, щоб максимально використати переваги, які він приносить. За допомогою блокчейну користувачі можуть зберігати важливі медичні дані, оригінальність яких можна перевірити, якщо є підозра на підробку. Крім того, можуть бути використані криптографічні алгоритми для забезпечення конфіденційності медичних даних (наприклад, зловмисник не зможе прочитати текст, якщо він вкрав дані). Отже, наразі актуальною задачею є потреба у керуванні медичними даними на основі блокчейн-технологій.

Репутація медичної установи (як майнера блокчейну) є важливим показником, оскільки блоки записують перевірені валідатори, що завчасно обираються та по факту є модераторами системи. Саме для визначення таких валідаторів мають цінність не кількість токенів, а репутація, тобто блокчейн за певним алгоритмом, з врахуванням репутації, обирає валідатора, який запише наступний блок. Репутація зростає з активним життям у екосистемі блокчейну та взаємодії з іншими учасниками. Чим краща репутація – тим більший шанс на створення наступного блоку. Тому в статті одержав подальшого розвитку метод оцінювання репутації медичної установи (як майнера блокчейну), який дозволяє розрахувати і оцінити репутацію медичної установи.

Проведено експерименти із керування медичними даними на основі блокчейн-технологій з використанням розробленого методу оцінювання репутації медичної установи (як майнера блокчейну) – експерименти з оцінювання репутації медичної установи (наприклад, двох різних амбулаторій сімейної медицини) – як майнера блокчейну.

Ключові слова: блокчейн-технологія, майнер блокчейну, репутація установи як майнера блокчейну.

Introduction

Today, healthcare decision-making processes are time consuming and complex. The productivity of health workers can be increased through the use of information technology. Information technology can reduce medical errors, provide more reliable solutions, and reduce health care costs. Today, medical information technology must meet 4 requirements: efficiency, safety, novelty and economic benefits [1]. The healthcare sector in Ukraine has long been in need of change, and the many opportunities of blockchain technology can help it lead the transformation of this sector and ensure compliance with these 4 requirements [2].

The main difference between blockchain and standard databases is decentralization. That is, first, this process is not monitored by any regulator or organization. And secondly, the information is not focused on servers in one place, but distributed in a huge network of computers around the world [3].

Each new transaction, regardless of its size, is converted into a new hash cluster. It consists of a unique set of symbols and numbers created by a certain algorithm. The new block always refers to the previous one, thus creating a strict sequence [4].

A number of events must occur before the block enters the chain. First, the agreement must be verified. Unlike classic transactions, blockchain transactions are confirmed by a network of computers. Typically, networks consist of thousands and even millions of machines around the world. Second, after the transaction has been verified, the information is sent to the block. It contains the date, time, amount and digital signature of both parties. Finally, the block receives a unique identification encrypted code, as well as the hash of the previous packet added to the chain. After hashing, it can be added to the blockchain [5].

Blockchain will transform medical enterprises and improve the quality of service, allowing the development of the new ecosystems and new business models. Healthcare information stored in the blockchain can change the way of saving the clinical information, as well as how information is shared in the organization, with healthcare partners, payers and, most importantly, patients. Blockchain decentralizes medical information, increasing the availability, efficiency, transparency and credibility of data, but also requires careful planning to maximize the benefits it brings [6]. With the help of the blockchain, users can store important medical data, the authenticity of which can be verified if there is a suspicion of forgery. In addition, cryptographic algorithms can be used to ensure the confidentiality of medical data (for example, an attacker will not be able to read the text if he stole data) [7].

The medical ecosystem has four groups of users:

• users (patients) – patients themselves or authorized third parties (medical centers, for example) who upload medical data to the system;

• validators – check the quality and authenticity of data uploaded by users;

• clients (doctors) – study patient data, compile health reports;

• pharmaceutical and research companies – can access impersonal user data.

Thus, increased attention to distributed blockchain technology has led to an understanding of the potential of blockchain technology using in the health care system. Thus, *the current challenge now* is the need to manage medical data based on blockchain technologies.

Method of assessing the reputation of a medical institution (as a miner of blockchain)

Let's evaluate the reputation of the medical institution as a blockchain miner. To do this, let's enter the following notation:

lb - length of the current blockchain;

sbl - the size of the current blockchain's block;

kbl - number of blocks in the blockchain;

$krtr$ - the number of registry transactions in the blockchain;;

$kmtr$ - the number of medical transactions in the blockchain;

mtr_i - the number of medical transactions in the i -th block, the recipient of which is the medical institution (miner);

rtr_i - the number of registry transactions in the i -th block, the recipient of which is the considered medical institution (miner);

f - logical variable (if this medical institution has proven to be an honest miner, then $f = 1$, else $f = 0$);

(α, λ) - system reputation parameters.

Given the introduced notation, the *method of assessing the reputation of a medical institution (as a blockchain miner)* consists of the following steps:

1) enter the value of the length of the current blockchain lb ;

2) enter the value of the block size in the current blockchain sbl ;

3) determine the number of blocks in the current blockchain: $kbl = \dfrac{lb}{sbl}$;

4) count the number of medical transactions in the blockchain $kmtr$;

5) count the number of registry transactions in the blockchain $krtr$;

6) enter the number of medical transactions mtr_i for each block, the recipient of which is the medical institution;

7) enter the number of registry transactions rtr_i for each block, the recipient of which is the medical institution;

8) enter the assessment of the miner in the format of a logical variable f : if the medical institution has proven to be an honest miner, then $f = 1$, else $f = 0$;

9) enter the reputation parameters of the system (α, λ);

10) calculate the average value $mean_{rtr} = \dfrac{\sum_{i=1}^{kbl} rtr_i}{krtr}$;

11) calculate the average value $mean_{mtr} = \dfrac{\sum_{i=1}^{kbl} mtr_i}{kmtr}$;

12) calculate the standard deviation $\sigma_{rtr} = \sqrt{\dfrac{1}{kbl} \cdot (\dfrac{\sum_{i=1}^{kbl} rtr_i}{sbl} - \dfrac{\sum_{i=1}^{kbl} rtr_i}{krtr})^2}$;

13) calculate the standard deviation $\sigma_{mtr} = \sqrt{\dfrac{1}{kbl} \cdot (\dfrac{\sum_{i=1}^{kbl} mtr_i}{sbl} - \dfrac{\sum_{i=1}^{kbl} mtr_i}{kmtr})^2}$;

14) calculate the value $q_1 = \dfrac{mean_{rtr}}{1 + \sigma_{rtr}}$;

15) calculate the value $q_2 = \dfrac{mean_{mtr}}{1 + \sigma_{mtr}}$;

16) determine $x = q_1 \cdot q_2 \cdot lb$;

17) determine $f(x) = \dfrac{1}{2} \cdot (1 + \dfrac{x - \alpha}{\lambda + |x - \alpha|})$;

18) calculate and assess the reputation of the medical institution (as a blockchain miner): $R = \min(1, f \cdot f(x))$;

19) decide on the reputation of the medical institution – the greater the value R, the higher the reputation and trust in the medical institution as a blockchain miner.

Blockchain is still a relatively new technology, so it is not surprising that on the one hand there are enthusiasts who believe that this is a revolution similar to the other Internet, and that it will significantly affect business, industry, society, and on the other hand there are less optimistic views that lack of maturity, lack of legal solutions or problems with scalability are a problem of widespread introduction of technology. To implement blockchain-based solutions, it is important to understand what technology is and what a potential company can offer today – with all its capabilities and limitations.

Using a smart contract in a blockchain can free up funds, transfer information, register and insert data – all in a programmed, autonomic mode. This can affect elements such as digital identification, voting, management, asset tracking, supply chain tracking, and the identity and reputation of the supplier.

The reputation of the medical institution (as a blockchain miner) is an important indicator, as the blocks are recorded by verified pre-selected validators, which are in fact moderators of the system. For determining such validators not the number of tokens, but reputation has the great value, i. e. the blockchain according to a certain algorithm, taking into account the reputation, chooses the validator who will write the next block. Reputation grows with active life in the blockchain ecosystem and interaction with other participants. The better the reputation is the greater the chance of creating the next block. Therefore, the method of assessing the reputation of a medical institution (as a blockchain miner), which allows to calculate and assess the reputation of a medical institution, was further developed in this paper.

Assessing the reputation of a medical institution (as a miner of blockchain)

Let's now evaluate the reputation of a medical institution (for example, two different family outpatient medicine clinics) - as a blockchain miners, using the proposed method of assessing the reputation of a medical institution (as a blockchain miner).

For the first experiment, the length value of the current blockchain is $lb = 110$; the value of the block size in the current blockchain is $sbl = 10$; then the number of blocks in the current blockchain is $kbl = \dfrac{lb}{sbl} = \dfrac{110}{10} = 11$; the number of medical transactions in the blockchain is $kmtr = 40$; the number of registry transactions in the blockchain is $krtr = 50$; the number of medical transactions for each block, the recipient of which is the medical institution, are

$mtr_1 = 2, mtr_2 = 1, mtr_3 = 2, mtr_4 = 3, mtr_5 = 4, mtr_6 = 3, mtr_7 = 1, mtr_8 = 5, mtr_9 = 1, mtr_{10} = 5, mtr_{11} = 3$; the number of registry transactions for each block, the recipient of which is the medical institution, are $rtr_1 = 3, rtr_2 = 5, rtr_3 = 2, rtr_4 = 1, rtr_5 = 3, rtr_6 = 4, rtr_7 = 6, rtr_8 = 1, rtr_9 = 7, rtr_{10} = 1, rtr_{11} = 2$; evaluation of the miner in the format of a logical variable is $f = 1$, as this medical institution has proven to be an honest miner; system reputation parameters are $(\alpha = 0.75, \lambda = 0.85)$.

Then the average value $mean_{rtr} = \dfrac{\sum_{i=1}^{kbl} rtr_i}{krtr} = \dfrac{35}{50} = 0.7$; the average value $mean_{mtr} = \dfrac{\sum_{i=1}^{kbl} mtr_i}{kmtr} = \dfrac{30}{40} = 0.75$;

standard deviation $\sigma_{rtr} = \sqrt{\dfrac{1}{kbl} \cdot (\dfrac{\sum_{i=1}^{kbl} rtr_i}{sbl} - \dfrac{\sum_{i=1}^{kbl} rtr_i}{krtr})^2} = \sqrt{\dfrac{1}{11} \cdot (\dfrac{35}{10} - \dfrac{35}{50})^2} = 0.85$; standard deviation

$\sigma_{mtr} = \sqrt{\dfrac{1}{kbl} \cdot (\dfrac{\sum_{i=1}^{kbl} mtr_i}{sbl} - \dfrac{\sum_{i=1}^{kbl} mtr_i}{kmtr})^2} = \sqrt{\dfrac{1}{11} \cdot (\dfrac{30}{10} - \dfrac{30}{40})^2} = 0.68$; the value $q_1 = \dfrac{mean_{rtr}}{1 + \sigma_{rtr}} = \dfrac{0.7}{1 + 0.85} = 0.38$; the value

$q_2 = \dfrac{mean_{mtr}}{1 + \sigma_{mtr}} = \dfrac{0.75}{1 + 0.68} = 0.45$; the value $x = q_1 \cdot q_2 \cdot lb = 0.38 \cdot 0.45 \cdot 110 = 18.81$.

Let's define $f(x) = \dfrac{1}{2} \cdot (1 + \dfrac{x - \alpha}{\lambda + |x - \alpha|}) = \dfrac{1}{2} \cdot (1 + \dfrac{18.81 - 0.75}{0.85 + |18.81 - 0.75|}) = 0.98$. Then the reputation of the medical institution (as a blockchain miner) is $R = \min(1, f \cdot f(x)) = \min(1, 1 \cdot 0.98) = 0.98$. Thus, the reputation and trust in the medical institution (family outpatient clinic №1) as a blockchain miner in this case is high.

For the second experiment, the length value of the current blockchain is $lb = 1020$; the value of the block size in the current blockchain is $sbl = 102$; then the number of blocks in the current blockchain is $kbl = \dfrac{lb}{sbl} = \dfrac{1020}{102} = 10$; the number of medical transactions in the blockchain is $kmtr = 70$; the number of registry transactions in the blockchain is $krtr = 85$; the number of medical transactions for each block, the recipient of which is the medical institution, are $mtr_1 = 3, mtr_2 = 5, mtr_3 = 8, mtr_4 = 3, mtr_5 = 2,$ $mtr_6 = 4, mtr_7 = 6, mtr_8 = 5, mtr_9 = 10, mtr_{10} = 1$; the number of registry transactions for each block, the recipient of which is the medical institution, are $rtr_1 = 10, rtr_2 = 9, rtr_3 = 7, rtr_4 = 5, rtr_5 = 3, rtr_6 = 5, rtr_7 = 6, rtr_8 = 2, rtr_9 = 4, rtr_{10} = 1$; assessment of the miner in the format of a logical variable is $f = 0$, as this medical institution has not yet proven to be an honest miner; system reputation parameters are $(\alpha = 0.75, \lambda = 0.85)$.

Then the average value $mean_{rtr} = \dfrac{\sum_{i=1}^{kbl} rtr_i}{krtr} = \dfrac{52}{85} = 0.61$; the average value $mean_{mtr} = \dfrac{\sum_{i=1}^{kbl} mtr_i}{kmtr} = \dfrac{47}{70} = 0.67$;

standard deviation $\sigma_{rtr} = \sqrt{\dfrac{1}{kbl} \cdot (\dfrac{\sum_{i=1}^{kbl} rtr_i}{sbl} - \dfrac{\sum_{i=1}^{kbl} rtr_i}{krtr})^2} = \sqrt{\dfrac{1}{10} \cdot (\dfrac{52}{102} - \dfrac{52}{85})^2} = 0.03$; standard deviation

$\sigma_{mtr} = \sqrt{\dfrac{1}{kbl} \cdot (\dfrac{\sum_{i=1}^{kbl} mtr_i}{sbl} - \dfrac{\sum_{i=1}^{kbl} mtr_i}{kmtr})^2} = \sqrt{\dfrac{1}{10} \cdot (\dfrac{47}{102} - \dfrac{47}{70})^2} = 0.06$; the value $q_1 = \dfrac{mean_{rtr}}{1 + \sigma_{rtr}} = \dfrac{0.61}{1 + 0.03} = 0.59$; the value

$q_2 = \dfrac{mean_{mtr}}{1 + \sigma_{mtr}} = \dfrac{0.67}{1 + 0.06} = 0.63$; the value $x = q_1 \cdot q_2 \cdot lb = 0.59 \cdot 0.63 \cdot 1020 = 379.13$.

Let's define $f(x) = \dfrac{1}{2} \cdot (1 + \dfrac{x - \alpha}{\lambda + |x - \alpha|}) = \dfrac{1}{2} \cdot (1 + \dfrac{379.13 - 0.75}{0.85 + |379.13 - 0.75|}) = 0.99$. Then the reputation of the medical institution (as a blockchain miner) is $R = \min(1, f \cdot f(x)) = \min(1, 0 \cdot 0.99) = 0$. Thus, the reputation and trust in the medical institution (family outpatient clinic №2) as a blockchain miner in this case is extremely low.

Conclusions

The healthcare sector in Ukraine has long been in need of change, and the many opportunities of blockchain technology can help it lead the transformation of this sector and ensure compliance with the requirements of efficiency, safety, novelty and economic benefits.

Blockchain will transform medical enterprises and improve the quality of service, allowing the development of new ecosystems and new business models. Healthcare information, which are stored in the blockchain, can change the way of storing the clinical information, as well as how information is shared in the organization, with healthcare partners, payers and, most importantly, with patients. Blockchain decentralizes medical information by increasing the availability, efficiency, transparency, and credibility of data, but also requires careful planning to maximize the benefits. With the help of the blockchain, users can store important medical data, the authenticity of which can be verified if there is a suspicion of forgery. In addition, cryptographic algorithms can be used to ensure the confidentiality of medical data (for example, an attacker will not be able to read the text if he stole data). Thus, the current challenge is the need to manage medical data based on blockchain technologies.

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Experiments on blockchain-based medical data management using the developed method of assessing the reputation of a medical institution (as a blockchain miner) were conducted – experiments to assess the reputation of a medical institution (for example, two different family outpatient medicine clinics) as a blockchain miner.

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Tetiana Hovorushchenko **Тетяна Говорущенко**	DrSc (Engineering), Professor, Head of Computer Engineering & Information Systems Department, Khmenlnytskyi National University https://orcid.org/0000-0002-7942-1857 e-mail: govorushchenko@gmail.com	Доктор технічних наук, професор, завідувач кафедри комп'ютерної інженерії та інформаційних систем, Хмельницький національний університет
Vitaliy Osyadlyi **Віталій Осядлий**	PhD Student of Computer Engineering & Information Systems Department, Khmenlnytskyi National University https://orcid.org/0000-0001-7861-4684 e-mail: vitalik9865@gmail.com	Аспірант кафедри комп'ютерної інженерії та інформаційних систем, Хмельницький національний університет