Digital registry of professional competences of the population drawing on distributed registries and smart contracts technologies[1]

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Abstract

At a time when the digital economy is emerging, the preservation and multiplication of intellectual capital, which is currently a key factor in social development, are paramount. The national economy's orientation toward the use of modern achievements of the digital industry will contribute to a faster transition to the global information society. Digitalization of education will make it possible to use the latest scientific achievements for the development of other areas of life in society.

This study presents a model that applies distributed registry technologies based on blockchains and smart contracts for the reliable storage and efficient use of date relating to the population's professional competencies. This model aims to create a unified information environment for interaction between all the actors of the economic system. The authors developed the model for registering professional competencies of the population and their developmental paths based on modern digital technologies. We substantiate the efficiency and security assured by blockchain technology for information storage and transmission. Educational institutions of all levels,

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governmental authorities controlling education, and people taking part in the educational process are the basic actors of the system presented.

The proposed model presents the educational level and professional skills of each registered person as an education index (EI), which keeps track of all educational achievements and professional competencies of the participant over their lifetime. When calculating the EI, the authors also propose to consider ratings of the educational institutions responsible for the participant's professional skills. The implementation of the EI will significantly simplify the process of employing graduates from various educational institutions, as well as the college admissions process. In addition, analytic tools could be used to create ratings of colleges, school departments, and even specific teachers. The registry of professional competencies we developed is directed at the processing and storage of large volumes of data (Big Data). In the future, this will allow us to open access to the registry to employers, pension insurance funds, and other state authorities that require complete and reliable personal data.

Key words: digital economy; professional competencies; blockchain; smart contract; digital registry; digitalization of education; cryptography.

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Introduction

Active implementation of modern information and telecommunication technologies calls for the digital represantation of all areas of people's activities. Nowadays, digitalization plays an important role in the economy of every country, since it affects all areas and industries [1]. Thus, there is a need to develop a qualitatively new business model, to modify the educational format, healthcare, and governmental control. Digitalization also changes the means and intensity of communication links between people [2].

The main directions and stages in the development of a digital society are introduced in the program "Digital economy in the Russian Federation for the period up to 2025" [3]. The main goals for development of the nationwide digital space stated in the program are fast Internet access for everybody, including the residents of rural areas, replacing college diplomas and work record books by development paths, "smart cities," and even an automated system for government decision-making.

Decree 203 of the President of the RF "On the strategy of the development of the information society in the Russian Federation for 2017–2030" dated 9 May 2017 states that development of a digital economy is a strategically important step for the country and that it will determines its global competitiveness [4].

The educational system is undergoing digitalization as well. In this area, the complete digitalization of documents of educational institutions (EDIN) is one of the most important and urgent steps. At the same time, digital technologies are being integrated into the educational process and EDIN management. It is obvious that in the near future all educational documents (high school diplomas, college diplomas, certificates, and so on) will be converted into a digital format. This necessitates the development of a unified digital registry of

personal data with the means of storing confidential information, as well as the development of an identification procedure that would allow the users to access the registry.

Achieving the stated goals makes it necessary to develop a unified digital information environment and to implement innovative technologies for the handling of digital data, such that they would ensure the utmost reliability and security of information storage, the relevance, validity, and accessibility of the information, as well as high speed of the network processing [5].

1. Blockchain technology as a communication basis for a registry of professional competencies

1.1. Blockchain technology

Blockchain technology has marked a breakthrough in the field of reliable storage of information over public networks [6]. A blockchain is a type of a distributed database in which the data are grouped into blocks, and each consecutive block is connected with the previous one by a hash key [7]. This makes it impossible to modify the information inside a block without changing the information stored in the consecutive blocks. A chain of the blocks is stored at each member's node computer, creating a distributed data registry. When a new block is appended, each member's copy of the chain is updated. A consensus on what types of blocks and transactions can belong to a blockchain is achieved if the majority of the blockchain holders agree on the proposed blocks.

The innovation of the blockchain technology lies in the possibility of embedding a business logic inside a transaction. Each block contains a set of entries, and new blocks are always appended to the end of the chain. This technology differs from traditional databases where the business logic is implemented in the database itself or in the software.

Let us list the main advantages of the blockchain technology:

✦ decentralization which minimizes the risks of a global failure in case one of the local systems fails;

✦ increased security due to the use of cryptography during each transaction;

✦ impossibility of tampering with the data in an accepted block, since the hash for each block's identifier is calculated based on the cumulative hash for the data of the whole block and the hash identifier of the previous block;

✦ efficiency, due to automated data exchange eliminating the human factor;

✦ transparency, because all the actions are registered and open for all members of the system to verify.

In our opinion, the last feature is an unsurpassed advantage of the blockchain technology, since it allows the regulator to make sure that the database content was not tampered with.

1.2. Practical aspects of the digitalization of education

At present, blockchain technology in education can help to drastically reduce the costs and time of transactions, and most importantly, ensure the highest levels of security [8]. Implementation of this technology in education was approved in 2017. This is reflected in the European Commission report "Blockchains in education" [9]. The key factors considered by the Commission are the feasibility, goals, advantages, and risks of using this technology at schools and colleges. Priority attention is given to the possibility of using this technology for digital accreditation of personal and academic learning. The Commission presented eight possible scenarios of how blockchains could be used to solve current problems in the field of education, such as the transfer of credits, dig-

ital certification, step-by-step accreditation, and education-related payments. Unfortunately, such technologies have not found their way into educational practice yet.

However, global experience provides us with some advances in this direction, namely:

✦ the patent application by the Japanese technology conglomerate SONY to create a blockchain-based educational platform to store and exchange data on student performance (the document can be found on the official site of the United States Patent and Trademark Office) [10];

✦ an agreement between the Malta Ministry for Education and Employment and the blockchain startup Learning Machine Technologies on the development of an experimental platform which allows its users to securely store and transfer educational documents, as well as to prove their authenticity [11];

✦ more than 100 digital diplomas based on blockchain technology were issued to MIT graduates [12].

All these facts indicate that digitalization of the educational field is inevitable and is a major step in the development of a digital economy.

1.3. Evolution of blockchain technology in the context of a digital economy

Blockchain technology was developed in 2008 [13] and has gone a long way since then from individual cryptocurrency transactions to the development of flexible blockchain platforms for their further implementations in various areas.

In her book *Blockchain: Blueprint for a New Economy*, Melanie Swan, a researcher and the founder of the Institute for Blockchain Studies, outlines three areas where this technology can be applied [14]:

Blockchain 1.0 – cryptocurrency transactions (cryptocurrencies are used in various applications for financial transactions, for instance, for money transfers and digital payments) [15];

Blockchain 2.0 – smart contracts (applications in economics, markets, and finances dealing with various instruments: stocks, bonds, futures, mortgages, title deeds, assets, and contracts) [16];

Blockchain 3.0 – applications to areas other than financial transactions and markets (governmental control, health care, science, and so on) [17].

Since the field of application of the blockchain technology has expanded significantly, the main tendency here is not the development of new cryptocurrencies as means of payment, but rather the development of multifunctional platforms which serve as infrastructures for a variety of business applications [18]. Developers of various complex information systems such as solutions implementing the Smart City concept are employing and advancing the applications of the blockchain technology [19]. The blockchain technology is being actively applied in facial recognition systems [20]. The use of smart contracts allows one to transform a distributed data registry into a system that controls the stored data; the blockchain technology ensures the security of personal data and the business logic of the entire system's operation.

Analysis of the applications of the blockchain technology performed in this paper shows that the blockchain is a stand-alone technology that can find its applications beyond the field of cryptocurrencies. Applications of this technology are especially justified in areas where there is a need to optimize the interactions between the members of socio-economic systems [21]. In this particular case, we consider the development of a national registry of professional competencies and developmental paths of the population based on blockchain technology.

Such a system could lay the foundation of the digital economy of a country. In the future, it could be globally integrated with similar systems.

2. Implementation of distributed registries and smart contracts technology in the registry of the population's professional competencies

2.1. The choice of a blockchain platform

Blockchain technology can be considered as a public digital registry secured against unauthorized access that registers transactions in a public or closed ad hoc network. The registry distributed between all the nodes continuously keeps track of the transactions with assets carried out between the ad hoc chain nodes (information blocks). Therefore, the blockchain serves as a single source of reliable data, and the blockchain members can only see those transactions that are relevant to them.

Hence, the authors propose to use a universal blockchain platform to create a registry of professional competences of the population. The system is based on open source solutions, namely Ethereum, which is the second most popular blockchain project after Bitcoin [22]. In our opinion, this project is the most convenient one because it allows the developer to solve a wider range of problems, ultimately ensuring the conditions needed to complete transactions using the smart contracts technology.

Moreover, Ethereum has the following advantages:

✦ the ability to maintain an optimal security level due to large-scale deployment and irreversible processes;

✦ the transparency of a public blockchain is ensured, in particular, by the use of open source franchising contracts;

✦ the possibility of various improvements, especially via scalability.

Therefore, the blockchain platform Ethereum gives us an opportunity not only to create a secure and transparent public registry which stores all professional achievements for every person over their lifetime (professional assets), but to register them using the smart contracts technology.

When a person is granted a certificate, school diploma, college diploma, or any other educational document, it can be entered into the registry by the educational institution that issued the document. Governmental authorities that oversee education can serve as the validators of such transactions.

2.2. Calculation of an individual education index using the smart contracts technology

Smart contracts technology can be used to quickly recalculate the Education Indices (*EI*) for individuals with entries in the registry of professional competencies. When a particular event related to a change in the educational level or professional competency occurs, a smart contract is activated. In the same way, the smart contracts can be used to recalculate the ratings of educational institutions, centers, departments, and teachers. Technically, a smart contract is a source code stored in a blockchain that is embedded into a special block (a software container). The block also contains all the messages concerning this smart contract. They serve as input and output data for the algorithm, and they initiate certain operations outside the blockchain when necessary.

Figure 1 presents the algorithm of a transaction based on the blockchain platform Ethereum. Here a smart contract is activated to recalculate *EI* when either the educational level or professional competencies of the members of the system have changed.

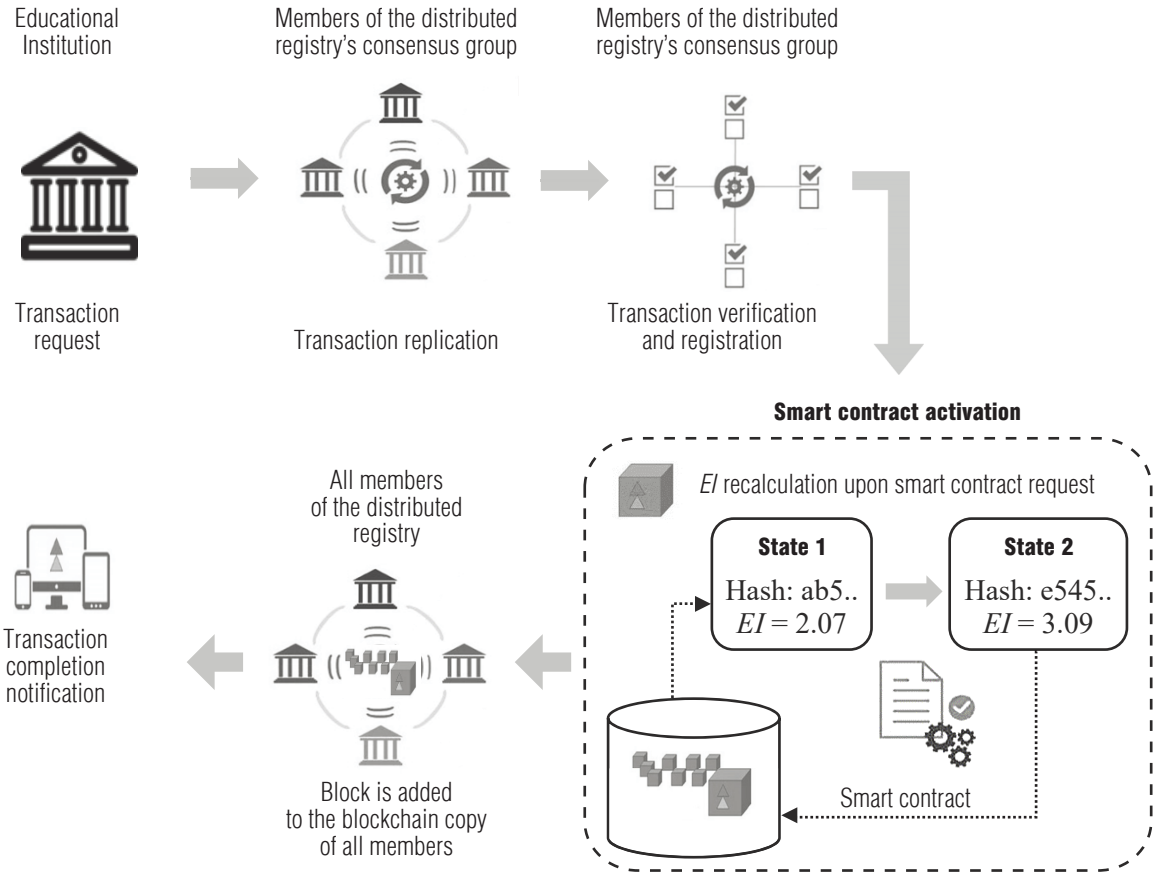

Fig. 1. Workflow of a transaction for the registry of competencies of the population based on the blockchain platform Ethereum.

Such a transaction can be initiated by any educational institution whose information is recorded in the registry of professional competencies that is authorized to issue educational certificates. Then the transaction is sent for verification to the members of the distributed registry that are authorized to register the transaction. Such members could be the governmental authorities in charge of education. Upon receiving the data on a suggested transaction, all the aforementioned members must confirm that the data are correct by reaching a consensus.

If the transaction is registered successfully, meaning that an educational certificate was issued, the smart contract is activated and that particular member's *EI* is recalculated. Then the value of the recalculated *EI* is appended to the transaction, and the transaction is combined with other transactions, creating a new block of the digital registry. This block has a unique place in the blockchain and cannot be changed. Now the updated chain is replicated and distributed to all the members of the digital registry, thus completing the transaction.

2.3. Development of a model for a rating points-based registry of professional competencies of the population

We developed a model for a rating points-based registry of professional competencies. We calculate the overall educational index (*EI*) for

each person representing their achieved level of education by a decimal. The digits before the decimal point reflect the basic level of education (*BLE*) mandated by the government. The digits after the decimal point show the educational level rating (*ELR*), which reflects the person's professional competencies. These coefficients take into account both the level of an educational certificate and the status of the educational institution that issued the certificate.

The authors propose the following algorithm for the calculation of the aforementioned coefficients. The *BLE* coefficient corresponds to the completed level of education that can be described by a certain set of requirements. According to Federal Law No. 273-FL "On education in the Russian Federation" dated 29 December 2012, there are the following levels of education in Russia [23]:

1. Secondary vocational education;

2. Higher education – bachelor's degree;

3. Higher education – specialist degree, master's degree;

4. Higher education – beyond master's degree.

Hence, BLE can take values from 1 to 4, which reflect the completed level of education.

The *ELR* coefficient reflects the total accumulated professional competencies of a person. We propose to assign points for each educational certificate issued to a person. The number of points is calculated as the level of the educational document (*LED*) multiplied by the rating of the educational institution (*REI*) that issued the document. Then ELR can be calculated as follows:

$$ELR = \sum_{i=1}^{n} LED_i \cdot REI_i \qquad (1)$$

where *n* is the total number of issued and registered educational documents in the system.

Therefore, the final educational index *EI* may be presented in the following form:

$$EI: BLE.ELR \qquad (2)$$

For example, an *EI* of 2.13 means that a person has a higher education, namely a bachelor's degree, and their total educational rating is 13.

The proposed method of the calculation of the total *EI* is implemented by a smart contract, which is activated each time a transaction is registered successfully, meaning that an educational document is issued.

For the implementation of a smart contract based on the Ethereum platform, Solidity programming language was created. This language has syntax close to JavaScript's and is Turing-complete. Using Solidity syntax, the state of a contract can be presented by two variables *BLE* and *ELR* of uint8 type. These variables are processed and stored in the block's state separately because Solidity does not fully support fixed-point numbers yet. For the future, key words fixed / unfixed are reserved for signed and unsigned fixed-point numbers of different lengths.

For convenience, the *EI* index can be presented at any time in the format *BLE.ELR* by converting *BLE* and *ELR* into the string format.

2.4. Interactions between the members of the registry of professional competences

Thanks to the blockchain technology, each registered member of the system can easily check their achievements and *EI*, creating a complete chronological chain. The authorized access problem is solved by using open-key cryptography. Each user gets two keys – a secret one and an open one. The open key can be easily used to determine the digital identity of the user, because the secret key cannot be

obtained from the open one. Therefore, we will build a digital registry of intellectual archives that store all the data recorded in them in a permanent and reliable fashion.

At the same time, we have to note that it is complicated to develop a direct adaptation of an open blockchain for the organization of optimal interactions between all the members and, most importantly, for providing control to the educational authorities. In this case, to create a registry of professional competencies of the population, we suggest developing a more controlled environment for the management of distributed registries. Here we have to keep in mind that the blockchain technology could help to organize two types of registries: open and closed ones [24]. Each of the types determines its own method of data access and has its own architecture. The concept of a permissioned blockchain, where the transactions are processed by a certain group of members with verified identities, is explained in [25]. The creation of new blocks in an exclusive blockchain does not require the implementation of the proof-of-work algorithm [26]. Here well-known consensus algorithms with authenticated members such as Practical Byzantine Fault Tolerance (*PBFT*) can be used [27]. Considering all of this, to develop a registry of professional competencies of the population, the authors have chosen to use the exclusive blockchain technology. We propose the following organization of the blockchain network (*Figure 2*).

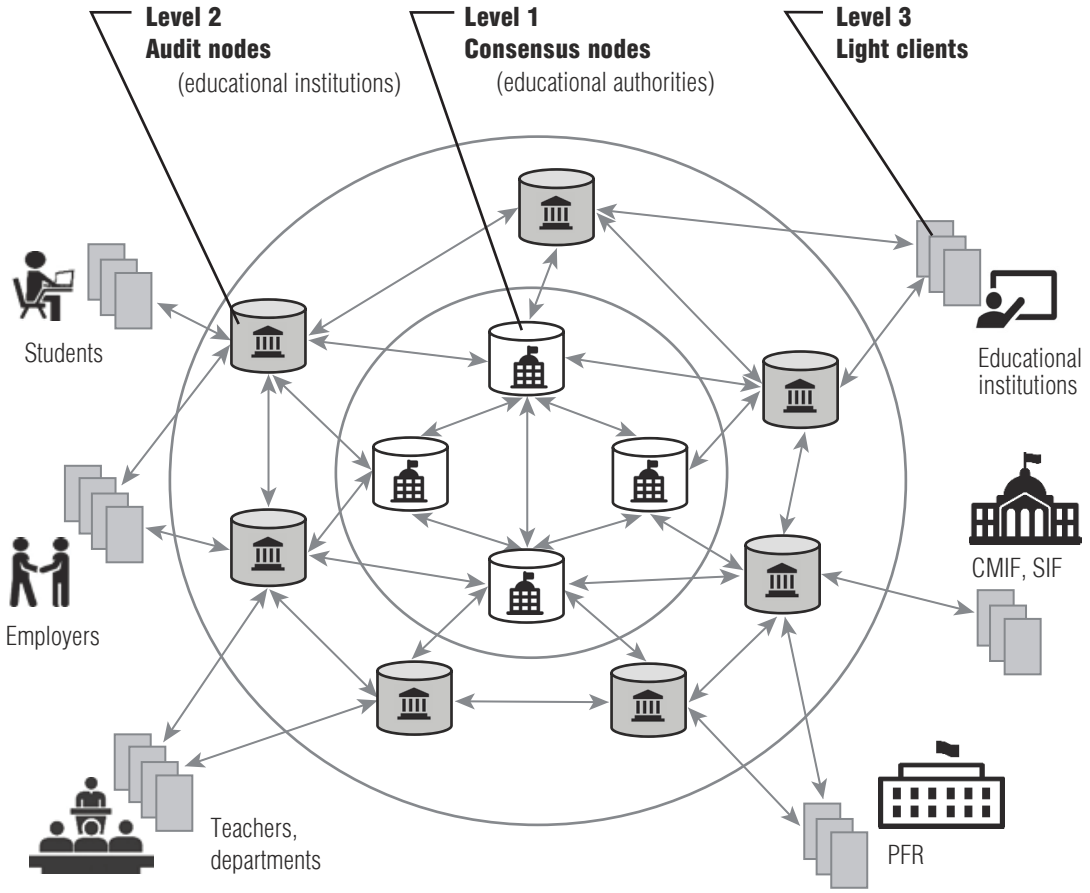

Fig. 2. A diagram of the organizational structure for the field of educational based on a blockchain network

The organizational structure of a blockchain can be broken up into three levels, which are grouping the nodes according to their functions in the registry of professional competencies of the population:

1. Consensus level: nodes that actively participate in the blockchain development, constantly assemble the incoming transactions into blocks, and distribute them throughout the network. These nodes have verification rights and can register new transactions in the system. Governmental authorities that supervise the education field may take a role in such nodes.

2. Audit level – nodes that do not take part in the consensus process but have a full copy of the blockchain. Such nodes automatically verify the work of the consensus group and are responsible for the load distribution in the network, delivering the content for the blockchain data. The institutions of education that directly issue educational documents may take a role in these nodes.

3. Level of light clients – nodes that do not have a complete copy of the blockchain but only contain data relevant to the particular node. Therefore, they are a good option for end users whose competencies are being registered. Such nodes allow users to effectively follow an individual EI as well as other parameters of the registry of competencies. Light clients require less computational resources and storage space, therefore they can operate on mobile platforms.

Therefore, educational institutions, on the one hand, and governmental authorities that oversee the education, on the other hand, should serve as transaction validators in a global registry of professional achievements of the population. However, the data in the registry should be public. These data can be useful, for instance, for colleges when transferring credits, or for employers in their search for specialists to fill particular vacancies.

Conclusion

This paper proposes a procedure for the development of a registry of professional competencies of the population. An algorithm for the calculation of the key components of the educational index EI based on the blockchain platform Ethereum is presented. In addition, a rating points-based model for calculation of these parameters is developed. An outline of the Solidity source of a smart contract that implements the proposed algorithm is presented.

Based on analysis of the types of distributed registries, the use of an exclusive blockchain for the creation of a digital nationwide registry of professional achievements of the population is justified. One of the advantages is the low cost of transactions because their validity is confirmed by trusted and highly efficient nodes as opposed to tens of thousands of user devices in the case of public networks. Moreover, full control by governmental educational authorities over the system is achieved.

The advantages of a secure distributed registry that keeps track of all professional achievements of people over their lifetime are discussed in this paper. Our research has shown that such a registry could lay a foundation for a nationwide system that registers professional competencies and developmental paths. In the future, a distributed registry of professional competencies could verify the qualifications of high school graduates or college students.

When the educational institutions register the diplomas or certificates issued by them in such a system, a potential employer can easily verify whether a person in question has in fact studied at a particular institution, and whether the diploma or certificate presented by that person is valid. Such public data could be also useful for investors looking for promising theses or prospective employees. The system could be useful for online courses as well. A blockchain-based registry of professional competen-

cies of the population would be an important step toward a digital economy.

The main difficulty in the future employment of the proposed system will be to maintain a balance between protecting the interests of the system's members, on the one hand, and meeting the public interests and needs of society, on the other hand. ■

References

1. Novikova A.V. (2016) Sostoyanie, problemy i perspektivy razvitiya chelovecheskogo kapitala v nauchnoy sfere Rossiyskoy Federatsii [State, problems and prospects of human capital development in the scientific sphere of the Russian Federation]. *Bulletin of Bryansk State Technical University*, no. 5 (53), pp. 262–266 (in Russian).
2. Novikova A.V., Shlemina I.V., Makhova V.V. (2016) Chelovecheskiy kapital i napravleniya povysheniya effektivnosti ego ispol'zovaniya [Human capital and ways to improve the efficiency of its use]. *Economics and Entrepreneurship*, vol. 10, no. 4–2, pp. 717–720 (in Russian).
3. The Government of the Russian Federation (2017) *Programma "Tsifrovaya ekonomika Rossiyskoy Federatsii"* [Program "Digital economy of the Russian Federation"]. Approved by the Order of the Government of the Russian Federation, 28 July 2017, no. 1632-p (in Russian).
4. The President of the Russian Federation (2017) *Strategiya razvitiya informatsionnogo obschestva v Rossiyskoy Federatsii na 2017–2030 gody* [The strategy of information society development in the Russian Federation for 2017–2030]. Approved by the Decree of the President of the Russian Federation, 9 May 2017, no. 203 (in Russian).
5. Bataev A.V. (2018) Analysis and development the digital economy in the world. Proceedings of the *31st IBIMA Conference (IBIMA 2018), Milan, Italy, 25–26 April 2018*, pp. 61–71.
6. Drescher D. (2017) *Blockchain basics: A non-technical introduction in 25 steps*. Frankfurt am Main: Apress.
7. Harvey C.R. (2014) Cryptofinance. *SSRN*. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2438299 (accessed 12 September 2018).
8. Russell J. (2017) IBM is using the blockchain to speed up and simplify cross-border payments. *Oath Tech Network*. Available at: https://techcrunch.com/2017/10/16/ibm-cross-border-payments-blockchain/ (accessed 12 September 2018).
9. Grech A., Camilleri A.F. (2017) *Blockchain in education. JRC Science for Policy Report*. Luxembourg: Publications Office of the European Union.
10. Heo J.C. (2017) *Electronic apparatus, audio system and audio output method*. U.S. Patent Application No. 15/233,191.
11. O'Leary R.R. (2017) Malta's government is putting academic certificates on a blockchain. *Coindesk*. Available at: https://www.coindesk.com/maltas-government-putting-academic-certificates-blockchain/ (accessed 10 September 2018).
12. Durant E., Trachy A. (2017) Digital diploma debuts at MIT. *Massachusetts Institute of Technology*. Available at: http://news.mit.edu/2017/mit-debuts-secure-digital-diploma-using-bitcoin-blockchain-technology-1017 (accessed 06 September 2018).
13. Nakamoto S. (2008) *Bitcoin: A peer-to-peer electronic cash system*. Available at: https://bitcoin.org/bitcoin.pdf (accessed 10 September 2018).
14. Swan M. (2015) *Blockchain: Blueprint for a new economy*. O'Reilly Media.
15. Grinberg R. (2011) Bitcoin: An innovative alternative digital currency. *Hastings Science & Technology Law Journal*, no. 4, p. 160.
16. Werbach K., Cornell N. (2017) Contracts ex machina. *Duke Law Journal*, no. 67, pp. 313–382.
17. Aune R.T., Krellenstein A., O'Hara M., Slama O. (2017) Footprints on a blockchain: Trading and information leakage in distributed ledgers. *Journal of Trading*, vol. 12, no. 3. pp. 5–13.
18. Davidson S., De Filippi P., Potts J. (2016) Disrupting governance: The new institutional economics of distributed ledger technology. *SSRN*. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2811995 (accessed 12 September 2018).

19. Namiot D.E., Kupriyanovsky V.P., Sinyagov S.A. (2016) Infokommunikatsionnye servisy v umnom gorode [Info-communication services in the Smart City]. *International Journal of Open Information Technologies*, vol. 4, no. 4, pp. 1–9 (in Russian).
20. Mikheenko O.V., Novikov S.P., Novikov P.V. (2018) Biometricheskaya autentifikatsiya lichnosti na osnove blokcheyn-tekhnologii kak nepremennoe uslovie tsifrovoy ekonomiki [Biometric authentication of personality on the basis of blockchain technology as an indispensable condition of digital economy]. *Bulletin of Bryansk State Technical University*, no. 6 (67), pp. 76–83 (in Russian).
21. Olleros F.X., Zhegu M., eds. (2016) *Research handbook on digital transformations*. Edward Elgar Publishing.
22. Tapscott D., Tapscott A. (2016) *Blockchain revolution: How the technology behind bitcoin is changing money, business and the world*. N.Y.: Portfolio Penguin.
23. Federal Law of the Russian Federation (2012) *Ob obrazovanii v Rossiyskoy Federatsii* [On education in the Russian Federation], 29 December 2012, no. 273-FZ (in Russian)
24. The UK Government Chief Scientific Adviser (2016) *Distributed Ledger Technology: beyond block chain*. London: Government Office for Science.
25. Garzik J. (2015) *Public versus private blockchains*. Available at: https://bitfury.com/content/downloads/public-vs-private-pt1-1.pdf (accessed 12 September 2018).
26. Becker J., Breuker D., Heide T., Holler J., Rauer H.P., Bohme R. (2013) Can we afford integrity by proof-of-work? Scenarios inspired by the bitcoin currency. *The economics of information security and privacy*. Berlin, Heidelberg: Springer, pp. 135–156.
27. Lamport L., Shostak R., Pease M. (1982) The Byzantine generals problem. *ACM Transactions on Programming Languages and Systems (TOPLAS)*, vol. 4, no. 3, pp. 382–401.