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APPLICATION OF BLOCKCHAIN TECHNOLOGIES IN ENSURING THE SECURITY OF LENDING TRANSACTIONS IN THE DIGITAL ECONOMY

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Abstract
Currently, the process of digitization of the financial and banking sectors in our country continues consistently. The banking sector is one of the important links of the digital economy. Therefore, the introduction of modern innovative technologies in the digitization of this field is one of the important tasks. This article presents the opinions of world scientists and models of financial organizations on the application of blockchain technology to the field of bank lending, the blockchain model of the UzBCS platform for the implementation of the lending process, blockchain blocks and cryptographic algorithms used in the implementation of the blockchain lending process. Also, the proposed cryptographic algorithms and blockchain system software implementation results are presented.

Keywords. Blockchain, banking, lending, smart contract, hash function, Merkle tree, Electronic digital signature, transaction, decentralized network, cryptocurrency.

РАХИМБЕРДИЕВ ҚУВОНЧБЕК БАХТИЁРОВИЧ
Тошкент давлат иқтисодиёт университети “Иқтисодиётда математик методлар” кафедраси ўқитувчиси. Ўзбекистон Миллий университети таянч докторанти. Тошкент, Ўзбекистон.

Аннотация
Ҳозирги кунда, мамлакатимизда молявий ва банк соҳаларини рақамлаштириш жараёни изчил давом этмоқда. Банк соҳаси рақамли иқтисодиётнинг муҳим бўғинларидан бири ҳисобланади. Шу боис мазкур соҳани рақамлаштиришда замонавий инновацион технологияларни жорий қилиш муҳим вазифалардан бири ҳисобланади. Мазкур мақолада, блокчейн технологиясини банк кредитлаш соҳасига қўллаш бўйича дунё олимларининг фикрлари ва молявий ташкилотлар молеллари, UzBCS платформаси кредитлаш жараёнини амалга оширишнинг блокчейн молели, блокчейн блоклари ва блокчейн кредитлаш жараёнини амалга оширишда фойдаланиладиган криптографик алгоритмлар келтирилган. Шунингдек, тавсия этилаётган криптографик алгоритмлар ва блокчейн тизими дастурий амалга оширилган ҳолда натижалари келтирилган.

Калит сўзлар: Блокчейн, банк, кредитлаш, смарт контракт, хеш функция, Меркл дарахти, Электрон рақамли имзо, транзакция, марказлаштирилмаган тармоқ, криптовалюта.

Introduction

It is known that the issues of improving information systems, the widespread use of digital technologies, the development of methods and algorithms for protecting information and their improvement are relevant all over the world. In particular, in the Republic of Uzbekistan, the consistent penetration of information technologies into many areas serves the growth of the country's economy [1,2].

The growth of economic entities in a market economy requires the improvement of financial relations between them. Therefore, many reforms are being carried out to develop the banking sector, which is one of the important parts of the country's economy. To this end, the government of Uzbekistan adopted a number of resolutions and resolutions. In particular, much attention is paid to ensuring the implementation of the Decree of the President of the Republic of Uzbekistan No. 5992 dated May 12, 2020 “On the Strategy for Reforming the Banking System of the Republic of Uzbekistan for 2020-2025”. [1].

Therefore, the processes of using modern digital technologies to improve banking services continue consistently. However, the rapid information process in the world leads to a number of information attacks and an increase in threats to information. Currently, banks and financial institutions around the world are experiencing economic losses due to similar threats.

Therefore, the main goal of the research is to develop and apply modern crypto-resistant methods to accelerate the process of digitization of banking and financial sectors and ensure information security in the context of the digital economy. Also, in the implementation of this goal, the following tasks are set before us.

Scientific research includes the following tasks:

1. Analysis of symmetric and asymmetric cryptographic encryption methods and algorithms;

2. Study of information security policies and cryptographic algorithms in the financial sector and propose a basic methodology;

3. Study of modern cryptographic algorithms and information security mechanisms used in the financial sector;

4. Study of world financial and cryptocurrency markets, analysis of effective cryptographic algorithms used in them;

5. Application of these tools and evaluation of their economic efficiency;

It is considered appropriate to use blockchain technology as a modern information security mechanism in solving the above-mentioned problem and performing the specified tasks. The application of blockchain technology to the financial sector is important in ensuring economic and information security.

Also, at present, blockchain technology-based lending platforms are widely used in some developed countries, and its size in the global financial market is increasing. In recent years, many foreign organizations have been using blockchain platforms to implement secure and transparent financial processes. For example, the Prosper and Lending Club platform was developed, one of the peer-to-peer lending platforms based on blockchain technology [3]. PPDAI and Zopa lending systems based on blockchain technology were developed in China and European countries [4]. This scientific work assumes the use of blockchain technology for user authentication and the development of a one-time key

generator algorithm on the UzBCS (Uzbekistan Blockchain Credit System) lending platform based on the Peer-to-Peer (P2P) lending system. For this, models of blockchain platforms, number generators, random and pseudo-random number generators for banking or credit organizations were considered.

Literature review

When studying blockchain technology, you should first of all get acquainted with the work of a person (or a group of persons) under the pseudonym Satoshi Nakamoto [2].

In recent years, scientists around the world have been widely studying the creation of remote lending platforms and the provision of interactive services to customers for banks and other organizations operating in the field of lending based on the P2P network and blockchain technology.

In particular, in the scientific works of S. Berger and F. Gleisner, the issue of effective modeling of the P2P lending process using blockchain technology was studied [4]. According to the research findings of S. Berger and F. Gleisner, the credit platform, acting as a non-traditional intermediary for participants in the credit market, assesses the level of risk of non-repayment of loans [3].

S. Friedman and Gz. Jin's scientific research looked at how to solve the information problems that arise in the Prosper lending platform using social networks. They found that the estimated profitability of group loans of lenders is much lower than that of loans from a single lender [5].

In the scientific works of A. Gupta, S. Gupta, the basic concepts, methods and algorithms of blockchain technology, its advantages and disadvantages are analyzed and a methodology for application is developed. Basically, in this scientific work, recommendations and suggestions on the use of blockchain technology in the implementation of Indian banking services have been developed [4]. We can also meet several scientists in their scientific works on the cryptographic and technical structure of blockchain technology. Including,

In particular, in the scientific work of Chang, S.E., Chen, Y., the following is presented on the mathematical, cryptographic and technical structure of blockchain technology. A distributed ledger, the blockchain is a chain structure connected in timestamp order through cryptography. Among them, the peer-to peer network structure conducts the chaining or verification of transaction events through a consensus mechanism. This allows the blockchain to involve transactions between parties, and to be an immutable, secure and trustless model [5].

Sven Magnu, S. Degener in a research paper compares the Rabobank and fintech start-up Ripple in order to filter out implications to the business model of traditional banks integrating blockchain technology to process international payments. Ripple represents a value proposition offering a 'blockchain-as-aservice' solution, RippleNet, to which traditional banks can simply plug in[6].

At the same time, the main instructions were given in the scientific works of Uzbek scientists G.U. Juraev, R. Alaev and other scientific researchers on the practical application of blockchain technology [7,8].

Methodology

At present, many researchers are doing a lot of scientific research and experimentation on the use of blockchain technology and the development of P2P lending platform models and their practical application. Most scientific studies use the following research methods [5,7].

- Method of coming to a mental conclusion
- Empirical method
- Method of theory

In this scientific work, scientific research was carried out using empirical and theoretical methods of scientific research methodology.

Analysis and results

1. Prospects for the use of blockchain technology in the banking sector

Blockchain is a technical breakthrough that can radically change more than one area in the life of mankind. Representing a continuous connection of consecutive blocks, it acts as a guarantor of the protection of the information contained in these cells. More than one state-owned company began to resort to this alternative payment system over time. It now uses blockchain to carry out transactions. The bank maintains the efficiency of operations according to the developed policy. Most of the processes are slow and unsafe. Banking functions are becoming vulnerable. Blockchain technology replaces sequential models with distributive ones, eliminating these shortcomings. But the chains of blocks that fix transactions cannot yet fully replace all financial technologies [8].

Using blockchain, banks optimize their functionality and reduce risks. The technology is adaptable for a wide range of services:

a) interbank payments;
b) investment;
c) user authentication;
d) information support;
e) operations with securities;
f) lending.

Money transfers are carried out in the presence of a recipient, sender and financial institution (as an intermediary, guarantor and performer). Sometimes intermediate links are included in this chain. The procedure becomes slow and costly. The problem can be solved by technology based on the blockchain. It eliminates intermediaries and allows you to conduct banking transactions at high speed. The identification procedure is hampered by the heterogeneity of data posted by financial institutions or branches. The use of blockchain in a bank will allow saving information about customers in the required form for all participants in a public registry. No bank will be able to change the database because only banks will possess the key. To manage loans, the bank tokenizes securities. Using a blockchain platform, the institution issues loans to thousands of clients and then consolidates them into a single collateral.

In this case, even states with a developed financial sector are not ready to use alternative cloud technology: Switzerland, Luxembourg and Canada. To solve the problem, the Swedish Investment Bank opened a blockchain research center. The news came after a report on banking technology mismatch at a conference in Singapore. In this regard, several banks around the world provide services to customers based on blockchain technology. For example, Sberbank is located in the Russian Federation. The first payments

using cloud technology between financial institutions were made in October 2016. An open source Ethereum-based platform was used [4,11].

Sberbank, with the participation of the Federal Antimonopoly Service, was the first to present a cloud-based document management project. The main task of the solution is to avoid mediation in this area. The technology will reduce the cost of data storage, as it uses its own resources. Sberbank has set up a laboratory where it is planned to research and develop products based on the blockchain. The credit company also used the HyperLedger Fabric platform to make payments.

In addition, the scientific department is faced with such tasks as:

- Creation of product prototypes;
- Implementation of pilot projects;
- Bringing business ideas to life;
- Implementation of business solutions for Sberbank.

The laboratory is not abstracted from other scientific structures, but, on the contrary, seeks cooperation for the exchange of experience. The introduction of blockchain to the masses is one of the goals of the interaction of the Sberbank laboratory with financial market participants - associations and alliances, start-ups and communities. The security of operations with transactions does not depend on their volume, they are equally protected from attacks and hacks. The server is based on the programs: Ethereum, Dash cryptocurrency, Lightning Network, UzBCS (Uzbekistan Blockchain Credit System).

2. Modeling the bank lending process based on blockchain technology

Blockchain technology is one of the main factors of innovative development in the banking and financial sectors. Blockchain is an immutable public distributed ledger of data that allows transactions of a single central intermediary (a decentralized network or a peer-to-peer network consisting of individual user nodes). If we consider in more detail, a built-up sequential chain of cubes containing encrypted or open information. Each block stores, in addition to information, its own hash sum and the hash sum of the previous block in the chain [8,10].

The most popular implementation of Blockchain technology is the Bitcoin cryptocurrency, proposed in 2008 and implemented in 2009. The system was created as a solution to the modern financial system, in which a small number of large banks control the issuance of invoices and transaction processing. To quote Satoshi Nakomoto, the creator of and Bitcoin, in this regard: “Banks must be trusted to hold our money and transfer it electronically, but they issue it in waves of credit bubbles with a barely noticeable share in the reserve” (orig. “Banks must be trusted to hold our money and transfer it electronically, but they lend it out in waves of credit bubbles with barely a fraction in reserve") [2,16].

Thus, blockchain technology is based on the concepts of a decentralized network architecture and uses a distributed ledger of data, controlled by the established rules of the selected consensus algorithm. Based on this, the blockchain has a number of the following properties:

- Decentralization. In a decentralized network, there is no need for a third controlling party due to the equality of each of the participants and the functioning of the consensus algorithm, i.e. decentralization leads to full coherence of the operations carried out (see further in the subsection “Consensus”);

– Immutability. The blockchain is supposed to be an immutable ledger of data due to its architecture. Each action of a participant (for example, a transaction) is recorded in the registry forever and cannot be changed;

– Anonymity. Each participant is assigned an address, which is used in the identity verification process. It is worth paying attention to the fact that the blockchain cannot guarantee perfect privacy due to certain internal limitations;

– Checkability. The consensus algorithm (hereinafter in the "Consensus" subsection) also allows an independent audit of the entire blockchain at a certain frequency and / or depending on certain conditions;

The model of the lending process in banking organizations based on blockchain technology is presented as follows.

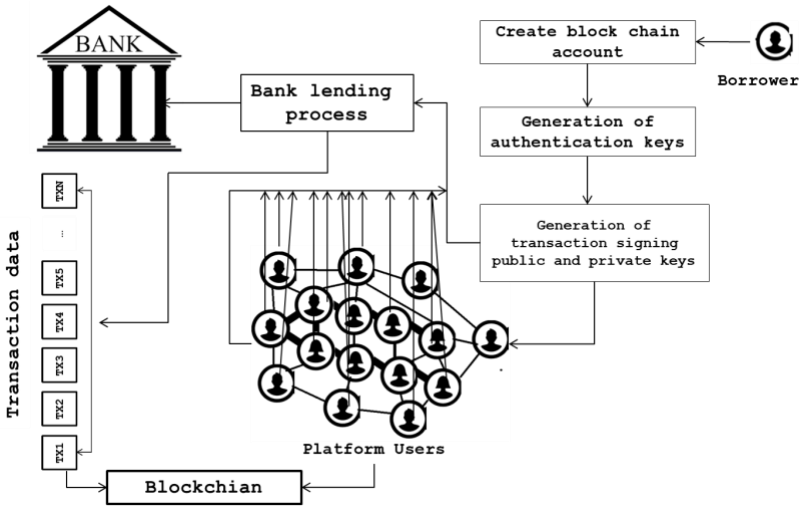

Fig.1.Bank lending process model based on blockchain technology*

**developed by the author*

The blockchain infrastructure with incoming building blocks is shown in Figure 2.

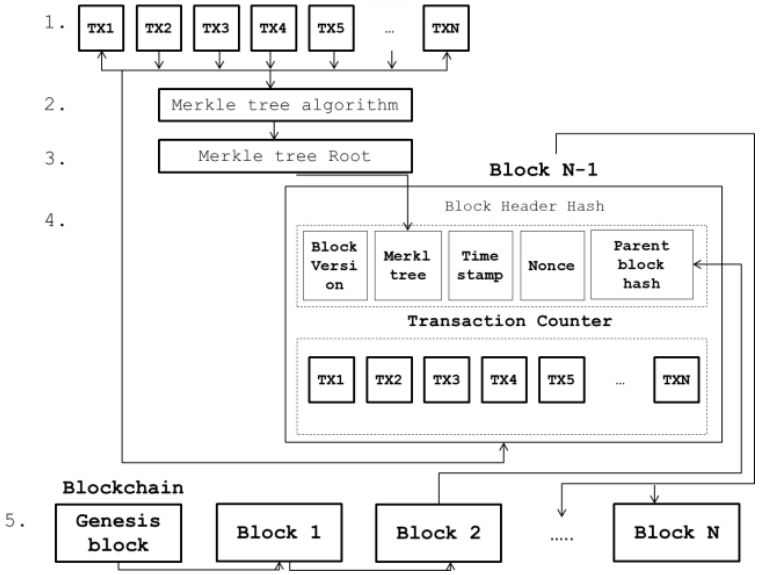

Fig. 2. The structure of the bank lending blockchain model*

**developed by the author*

A block is the main structural element of a blockchain, serving as a container for transactions (see below) or other data types (depending on the implementation). Each block is linked to the previous block through the hash sum of that block's data, obtained using one of the hash functions: SHA1, SHA256, or Quark. The diagram of the internal structure of the block is shown in Figure 3 below with a description of the elements from the BlockHeader in Table 1.

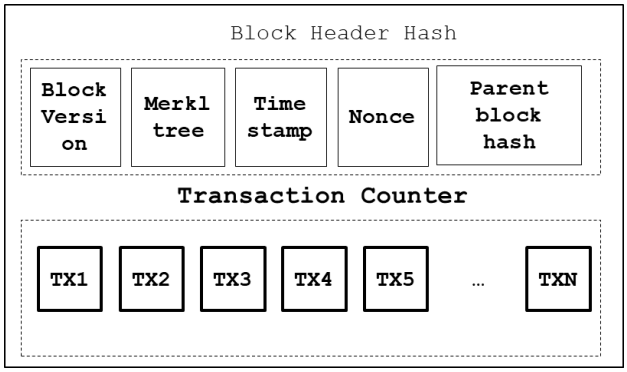

Fig.3. Diagram of the internal structure of the block
**developed by the author*

Table 1. Meaning of block elements in BlockHeader.
**developed by the author*

Name	***Description***
Block Version	Current version of block field structure
Merkle Tree Root Hash	The hash sum of the state of the block through the use of a hash tree of the transactions included in the block
Timestamp	Block creation time (Unix format)
n Bits	Block state length in bits
Nonce	The length of the generated hash sum after running the Proof-Of-Work consensus algorithm (see later in "Consensus")
Previous Block Hash	Hash sum of the state of the previous block in the chain

To ensure the security of bank lending operations based on blockchain technology, the following cryptographic mechanisms are used:

2.1. SHA-256 hash function algorithm

Function of hashing the state of the current block to create a chain of blocks that refer to each other (immutability). The hash function, in this case, is used to create a string of 256 bits (when using SHA256) in order to further validate the contents of the block [12]. The SHA-256 hash algorithm is defined as follows.

SHA-256 (Secure Hash Algorithm, FIPS 182-2) is a cryptographic hash function with a digest length of 256 bits. This is a keyless hash function; i.e. MDC (Manipulation Detection Code). The message is processed in blocks of 512 = 16 × 32 bits, each block requires 64 rounds.

1) The main operations performed in the hash function:

a) Boolean operations AND, XOR, and OR, denoted by $\wedge$, $\oplus$, and $\vee$, respectively;

b) Bitwise complement, denoted by ¯;

c) Integer addition is done modulo 2^{32}.

The SHA-256 hash algorithm uses logical shift operations as follows. Shift operations are performed on 32-bit words. These operations are a given n-bit right shift or n-bit circular left shift of each bit in the 32-bit word registers.

a) $RotR(A,n)$ denotes a right rotation of n bits of the binary word A;

b) $SHR(A,n)$ denotes the right shift of n bits of the binary word A;

c) $A \| B$ stands for the concatenation of binary words A and B;

2.1.1. Functions and constants

The algorithm uses the following functions:

$$CH(E_t,F_t,G_t)=(E_t \wedge F_t)\oplus(E_t \wedge G_t) \quad (1)$$

$$Maj(A_t,B_t,C_t)=(A_t \wedge B_t)\oplus(A_t \wedge C_t)\oplus(B_t \wedge C_t) \quad (2)$$

$$\sum_0(A_t)=S^2(A_t)\oplus S^{13}(A_t)\oplus S^{22}(A_t) \quad (3)$$

$$\sum_1(E_t)=S^6(E_t)\oplus S^{11}(E_t)\oplus S^{25}(E_t) \quad (4)$$

$$\delta_0(H_t)=S^7(H_t)\oplus S^{18}(H_t)\oplus R^3(H_t) \quad (5)$$

$$\delta_1(D_t)=S^{17}(D_t)\oplus S^{19}(D_t)\oplus R^{10}(D_t) \quad (6)$$

and 64 binary words K_i, given by the first 32 bits of the fractional cube roots of the first 64 primes.

2.1.2. Block filling process

To make sure transaction 1 is a multiple of 512 bits long:

a) bit 1 is added first;

b) k bits of 0 are then added, where k is the smallest positive integer such that l + 1 + k ≡ 448 mod 512, where l is the length of the original message in bits,

c) finally, the length $l<2^{64}$ of the original message is represented by exactly 64 bits, and these bits are added at the end of the message.

2.1.3. Block decomposition

For each block $M \in \{0,1\}$ 512, 64 words of 32 bits each are composed as follows:

a) the first 16 are obtained by splitting M into 32-bit blocks

$$M = W_1 \| W_2 \| W_3 \| ... W_{15} \| W_{16} \| \quad (7)$$

b) the remaining 48 are obtained by the formula:

$$W_t = \sigma_1\left(W_{(t-2)}\right)+W_{(t-7)}+\sigma_0\left(W_{(t-15)}\right)+W_{(t-16)} \quad (8)$$

2.1.4. Calculate the hash value

- First, eight variables are assigned their initial values given by the first 32 bits of the fractional part of the square roots of the first 8 primes;
- Further blocks $M(1),M(2),M(3),...,M(N)$ are processed one by one:

Now the compression functions for registers A,B,C,D,E,F,G,H are applied as follows. In this case, the compression function is calculated using the values of the logical functions given in formula (4) on the interval $0 \le t \le 63$ of the variable t.

$$T_{t+1} = H_t + \sum_1(E_t) + \sum_0(A_t) + CH(E_t, F_t, G_t) + \\ + Maj(A_t, B_t, C_t) + W_t + K_t \qquad (9)$$

$$L_{t+1} = H_t + \sum_1(E_t) + CH(E_t, F_t, G_t) + W_t + K_t + D_t$$

After each iteration of calculations, the values of registers $A_t, B_t, C_t, D_t, E_t, F_t, G_t, H_t$ are updated:That is,

$$H_{t+1} = G_t, G_{t+1} = F_t, F_{t+1} = E_t, E_t = A_{t+1} + D_{t+1}, D_{t+1} = C_t, \\ C_{t+1} = B_t, B_{t+1} = A_t, A_{t+1} = T_{t+1} + L_{t+1} \qquad (10)$$

After the process of updating the register values, the hash value of the $H^{(t)}$-interval t is calculated as follows.

$$H_0^{(t)} = A_{t+1} + H_0^{(t-1)}, H_1^{(t)} = B_{t+1} + H_1^{(t-1)}, H_2^{(t)} = C_{t+1} + H_2^{(t-1)}, H_3^{(t)} = D_{t+1} + H_3^{(t-1)}$$

$$H_4^{(t)} = E_{t+1} + H_4^{(t-1)}, H_5^{(t)} = F_{t+1} + H_5^{(t-1)}, H_6^{(t)} = G_{t+1} + H_6^{(t-1)}, H_7^{(t)} = H_{t+1} + H_7^{(t-1)} \qquad (12)$$

As a result, expression $H^{(N)} = H_0^{(N)} \| H_1^{(N)} \| H_2^{(N)} \| H_3^{(N)} \| H_4^{(N)} \| H_5^{(N)} \| H_6^{(N)} \| H_7^{(N)}$ returns the hash value of the data.

SHA-256 or other hash function algorithms are very important for data security using blockchain technology, placing transactions in blocks, calculating merkle root value, calculating blockchain block header, mining and consensus processes.

2.2. Merkle tree algorithm

Hash tree (English MerkleTree). This algorithm is used to create a hash tree from a given number of inputs (such as transactions). In blockchain, an algorithm is often used to validate the content of a block, as a hash sum of the current block [13]. The Merkle tree for N transactions of the bank lending process will have the following structure.

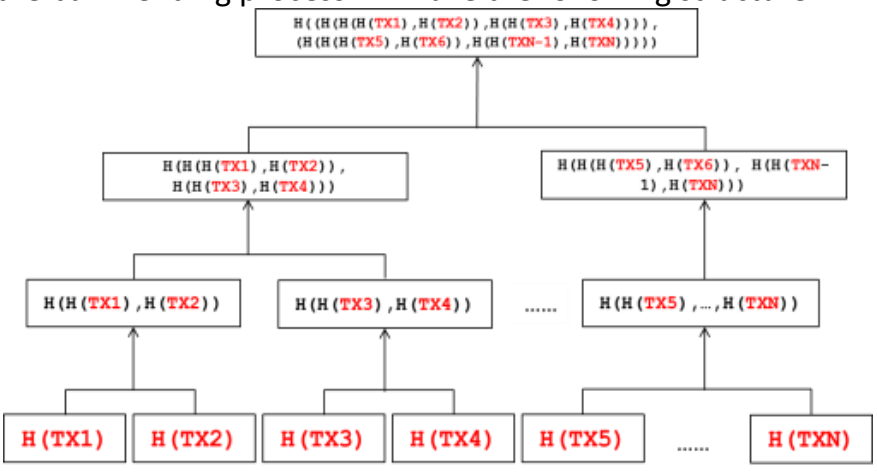

Fig.4. Merkle Tree Mechanism for Persistence of Transactions on the Blockchain

A transaction is a record of the movement of tangible or intangible assets between interacting parties. Also, a transaction can be interpreted as an element in the context of checking an account. Each transaction that claims to be placed in a block.

2.3. Electronic digital signature in blockchain technology

Transactions to send and receive information to verify identity use an electronic signature. In the context of blockchain technologies, an electronic signature is formed on the basis of public and private keys (ECDSA or RSA) and is an encrypted string of arbitrary length [14]. The principle of operation is illustrated in Figure 5 below:

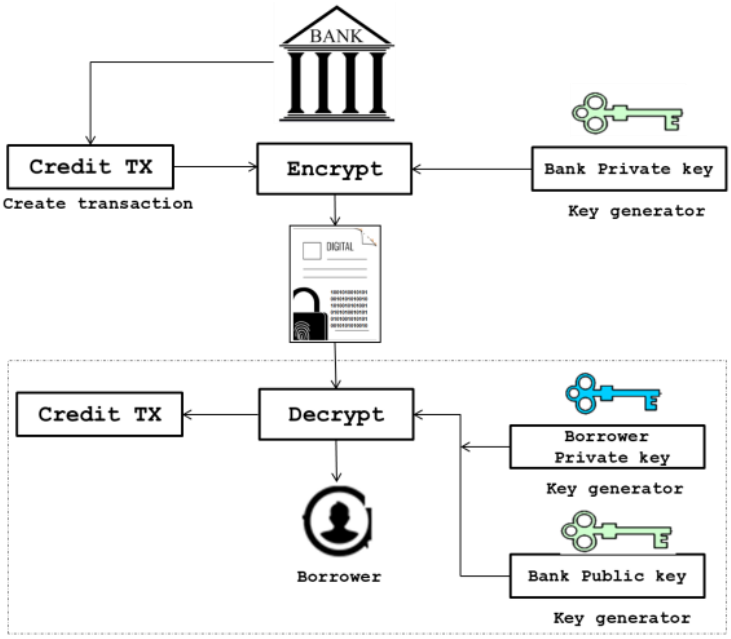

Fig.5. The principle of operation of the electronic signature in the blockchain

The first user (Bank) sends a pre-encrypted transaction to another user (borrower). Before sending, an electronic signature is generated based on the private key of the Bank or other users.

The entire blockchain is built on a decentralized network as a tool for a more efficient distribution of resources (no central verification center). With the use of DHT (distributed hash table), the capabilities of a decentralized network are increased to routing and managing a list of known nodes. Fig. 6 shows a view of a network of this type (somewhat simplified version) [15]:

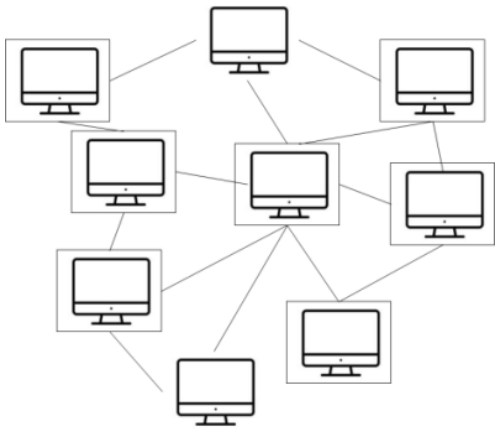

Fig.6. Decentralized network scheme

Each connected device is called a node. The network consists of a set of peer nodes interconnected by some communication protocol, most often it is GRPC or similar protocols based on TCP / IP [16].

2.4. Result

According to the results of the scientific work, in the process of bank lending based on Blockchain technology, each loan amount issued by banks represents a transaction and consists of blockchain blocks as follows.

Table 2. Results of the first 2 blocks of the bank lending blockchain system

Block version	**1**	**Block version**	**2**
Block Header	0000000098B58D427A10C860335A21C1A9A7639E96C3D6F1A03D8C8C885B5E3B	*Block Header*	000000000CD339982E556DFFFA9DE94744A4135C53EEEF15B7BCC9BDEB9C2182
Hash of previous Block	000000000019D6689C085AE165831E934FF763AE46A2A6C172B3F1B60A8CE26F	*Hash of previous Block*	0000000098B58D427A10C860335A21C1A9A7639E96C3D6F1A03D8C8C885B5E3B
MerkleRoot	0E3E2357E806B6CDB1F70B54C3A3A17B6714EE1F0E68BEBB44A74B1EFD512098	*MerkleRoot*	E1CF3476234D8446653AD52A8939ED792003EEFDCD0E897319AB9D2CB4C14C8C
Timestamp	1231469665	*Timestamp*	1231567611
Bits Difficulty Parameter	486604799	*Bits Difficulty Parameter*	486604799
Nonce:	2573394689	*Nonce:*	1437882917
Signature (TX1)	E3E2357E806B6CDB1F70B54C3A3A17B6714EE1F0E68BEBB44A74B1EFD512098	*Signature (TX2)*	DF2B060FA2E5E9C8ED5EAF6A45C13753EC8C63282B2688322EBA40CD98EA067A

In Table 3, the transactions performed in the form of a laboratory through the UzBCS platform were placed in blockchain blocks. In this case, transactions were performed between creditor organizations and borrowers in the decentralized network shown in Figure 6. The block size in the blockchain system is 1MB, and the size of one lending transaction is 298 bytes. We can understand that up to 3518 transactions are required to be collected into one blockchain block. In this case, all blocks must accept the transaction. The process of collecting transactions and developing blocks is carried out by the miners of the network. Consensus algorithms are used to verify the authenticity of blocks and transactions. In addition, the UzBCS platform requires resources worth 21.8 billion sums to implement the process of bank lending.

The research resulted in a model based on the net present value intended for the evaluation of the economic efficiency of the blockchain-based decentralized database implementation and use for customer identification by financial institutions. The modeling

showed that under the most favorable values of the model with the minimum cost of development amounting to 21.8 billion sums, minimum operating expenses accounting for 20% of non-recurring expenses and the maximum correction factor of 75% of the potential losses from fraudulent transactions, blockchain can be used in financial institutions with about 1.4 million customers.

Conclusion and offers

In conclusion, the application of blockchain technology to the banking and financial sectors will lead to higher economic efficiency. The reason is that a decentralized network is formed in the blockchain, which ensures the reliability and quick execution of financial transactions. At the same time, the use of blockchain in ensuring the security of financial information allows to achieve high crypto durability. The reason is that the blockchain uses cryptographic algorithms with high cryptoresistance. In this article, UzBCS consortium blockchain based on blockchain technology is proposed for banks and lending organizations in the Republic of Uzbekistan. We propose an investment decision model of lenders in the formation of a P2P lending platform based on blockchain technology. Also, the following suggestions are made for the application and implementation of blockchain technology.

Offers for the application of bank lending systems based on blockchain technology:

Used literature

1. The process of introducing blockchain technology into financial systems is complex and requires technical resources. But blockchain is considered highly crypto-tolerant, thus resistant to crypto-attacks. It is necessary to gradually introduce blockchain technology to all financial organizations in our country.

2. Blockchain is an effective tool for effective regional, regional and international money transfers. In this case, funds are tokenized based on international agreements, or cooperation with international organizations that trade in other cryptocurrencies can be developed through the production of a national cryptocurrency.

3. References

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