J Inf Process Syst, Vol.16, No.4, pp.935~958, August 2020
https://doi.org/10.3745/JIPS.04.0185

ISSN 1976-913X (Print)
ISSN 2092-805X (Electronic)

JOURNAL OF INFORMATION PROCESSING SYSTEMS JIPS

# A Survey of the Application of Blockchain in Multiple Fields of Financial Services

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**Abstract**

The core value of finance is credit. It can be said that without credit, there can be no finance. The distributed structure of the blockchain and the low-cost trust-building mechanism based on mathematical algorithms provide a new solution and path for solving and optimizing related problems in the financial field. The blockchain technology is applied in the development of the financial industry through consensus mechanisms, smart contracts, and distributed networks. In this research, a comprehensive survey of the blockchain technology is proposed in the development of financial services including equity crowdfunding and credit investigations in inclusive finance, cross-border remittance, Internet financial payment, P2P lending, supply chains finance, and the application of blockchain in the field of anti-money laundering. This paper discusses the role of blockchain in solutions to different issues in the financial field. It also discusses the architectures in different financial service application scenarios from the perspective of the financial trust mechanism and the perspective of the technology and rule change of blockchain participation in financial innovation. Finally, the problems and challenges of blockchain in financial services are discussed, and corresponding solutions are proposed.

**Keywords**

Blockchain, Consensus Mechanism, Financial Service, Fintech, Smart Contract

## 1. Introduction

The backwardness of financial services affects the development of people's livelihood. In the era of science and technology as the first factor, fintech becomes an important source of power to promote the overall intergenerational transition of the financial industry. Countries with lagging economic development needs more on fintech to boost the development of the financial industry. This section describes the current status of the financial industry in Vietnam and proposes important issues and research methods for financial technologies in the financial development of developing countries that need to be resolved. It also briefly introduces the contributions of this survey and research, and proposes a specific survey structure.

### 1.1 Motivation

Recently, the tragedy of a container truck in Essex, England has shocked the world. In-depth investigation revealed that all the dead in the containers came from Vietnam, a country with lagging economic



Manuscript received January 15, 2020; first revision April 9, 2020; second revision May 11, 2020; third revision June 8, 2020; accepted July 10, 2020.

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development. Then, the BBC reported that about 18,000 Vietnamese smuggled into Europe every year in order to earn money to support their families. At this time, the state of Vietnam's economy stood on the cusp. Vietnam has a population of nearly 100 million in a young structure with rapid economic growth, and a high Internet penetration rate. The Internet penetration in Vietnam tripled within 10 years reaching to 47% in 2016 [1].

The inclusiveness of financial services, however, is poor. Only one-third of the people have a bank account and most people are out of traditional financial services and heavily rely on usury. After Vietnam became a French colony, ordinary people had a strong motivation of "advanced consumption". Vietnam Securities Company said that the Vietnamese consumer loan market is expected to reach US$44 billion in 2019, mainly due to the increase of consumer spending, and it heavily relies on urbanization and strict loan rules of domestic banks. Nguyen Quynh Lan from StoxPlus Company stated that Vietnam needs a clear financial intermediary, fintech and peer-to-peer (P2P) lending framework, and customer protection in the digital sector of consumer finance [2]. The results of data analysis by Uyen and Ha [3] indicate that nearly 90% of respondents have been involved in lending or borrowing directly without financial intermediaries such as banks. More than 70% were found who have never loaned from any unacquainted person. Due to its huge potential, Vietnam's consumer finance has so far attracted many foreign investors, and fintech has also contributed to the emergence of a disruptive business model for consumer finance companies. In Vietnam, financial companies with P2P and cash loans, online usury, and licensed consumer loans have been developed rapidly. As of 2019, there are about 50 P2P regular platforms in Vietnam. In 2019, the National Bank of Vietnam and the United States International Data Group (IDG) co-hosted the Vietnam Banking event of "The Status of Inclusive Finance in the Cashless Economy Development Trend". The event focused on the new achievements of the banking industry about digital technologies and their applications and discussed how to enhance the financial services capabilities of the banking industry. The event's ultimate purpose is to provide a platform for promoting the application of digital technologies in the development of inclusive finance in Vietnam.

The development of Vietnam's financial industry is just a microcosm. Fintech will have a significant impact on the financial environment of developing countries. A major challenge to overcome in developing inclusive finance under the traditional financial model is cost barriers. The cost of providing financial services including small loans and small transfer loans to disadvantaged groups by financial institutions is relatively high in general. It requires inclusive financial providers to realize economies of scale, reduce costs and improve efficiency. This helps establish a strong infrastructure system to reduce transaction costs, extend the scope of financial services, and improve transparency of financial services [4]. Those who are poor and low-income generally have less funds, relatively scattered residence, and hardly any written credit records. The review of the credit records of small and micro-enterprises takes time and manpower, which makes traditional financial institutions reluctant to get involved causes of disadvantaged groups.

Therefore, it is important to establish a strong financial infrastructure system including the establishment of a full-flow, secure payment and clearing system for transactions, a comprehensive credit reporting system, technical support services, and network support organizations. However, these are inseparable from the promotion of fintech which a financial innovation brought by technologies creating new business models, applications, processes or products. Therefore, it has a significant impact on the way how financial markets, financial institutions, and financial services are provided. Blockchain technologies are a strong driving force for the fintech progress.

Blockchain technologies have quickly become a global focus in the wave of fintech. Financial services

based on blockchain technologies are more efficient. As such, traditional financial institutions are facing digital transformations and changes. Its huge strategic significance and commercial value have caused high competition in the global financial industry and led to the high attention of governments. For example, governments and authoritative organizations in China, the United Kingdom, the United States, Germany, Japan, and South Korea have issued policies and produced many research reports about the application of blockchain technologies. Swan [5] believes that the economic, political, charitable, and legal systems will benefit from the development of blockchain technology. Blockchain technologies are innovative, requiring reconfiguration of all aspects of society and how it operates.

From the above, it can be expected that the application of blockchain in the financial industry is not only about developing technologies, but also involving institutions as a dual drive. In this context, this paper conducts research on challenges in blockchain financial technologies.

## 1.2 Research Methodology

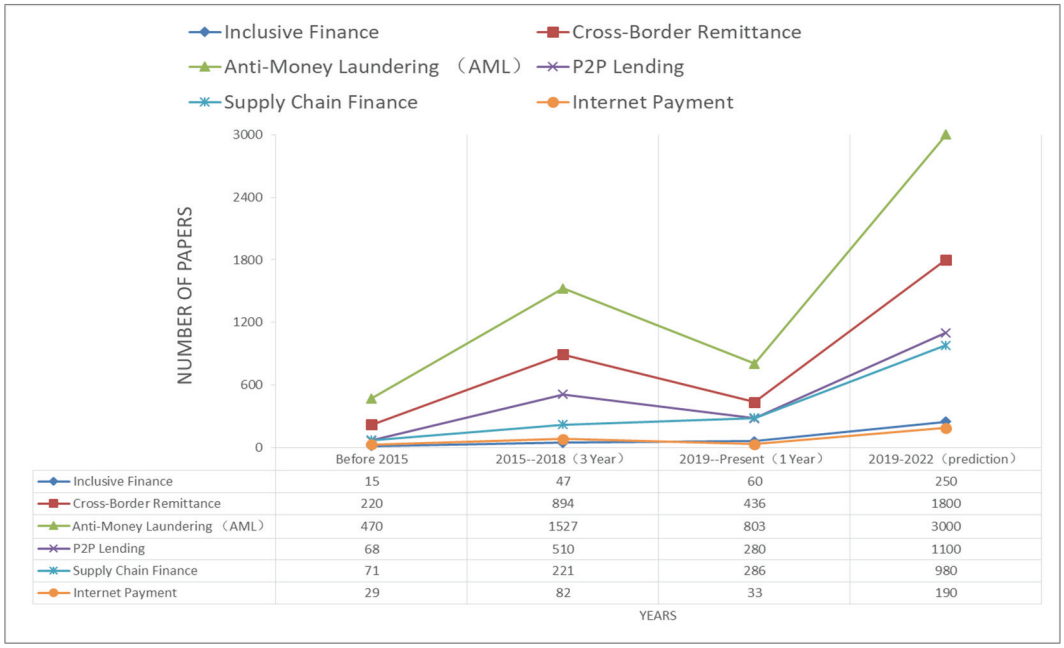
Blockchain is a specific set of rules. The distributed ledger in a blockchain network is a particular set of open and transparent rules which are difficult to change. Why does it require changing the traditional rules in the financial market? That is because some rules in existing financial systems might have flaws. Certain financial activities under the existing financial rules may give too much power to the financial intermediaries. It may also weaken the influence of individuals such as enterprises and residents, which would cause many potential problems. For example, the protection of the rights and interests of financial consumers might become a global problem; the financial innovation might become a means of profit for only limited sectors; the cost of capital allocation might become high making financing difficult and expensive; information asymmetry may cause the lack of various financial services. New rules under blockchain technologies may help alleviate the above contradictions and enable many people to become participants and maintainers of the rules. Therefore, blockchain plays a significant role at the rule level.

In this work, we to research and present different application areas of blockchain in the financial industry and key technologies and current practices that are required to develop blockchain financial services. This paper reviews the state of art work on the implementation of blockchain technologies and architectural models that can be used to build blockchain-based financial services applications. Finally, it discusses the current problems and challenges in the application of blockchain in the financial sector and possible solutions to address them.

## 1.3 Research Contribution

This survey covers various aspects of applying fintech to blockchain. To the best of our knowledge, this paper is the first survey work covering blockchain technologies in the field of fintech based on blockchain. In addition, it will discuss unresolved issues and challenges and propose recommendations in the application of blockchain technologies in financial services. Fig. 1 shows the academic research on the application of blockchain technologies to financial services.

In Fig. 1, anti-money laundering is the most active area of research. Per our study, the research contents in anti-money laundering are relatively rich with major topics on prevention, monitoring and crackdown, involving identity identification, data traceability, data supervision, and data sharing. It is also observed that significant research in blockchain-based fintech focuses on decentralization, smart contracts, big data, consensus mechanisms, distributed ledgers, financial supervision, and artificial intelligence.




| | Before 2015 | 2015--2018（3 Year） | 2019--Present（1 Year） | 2019-2022（prediction） |
|---|---|---|---|---|
| Inclusive Finance | 15 | 47 | 60 | 250 |
| Cross-Border Remittance | 220 | 894 | 436 | 1800 |
| Anti-Money Laundering （AML） | 470 | 1527 | 803 | 3000 |
| P2P Lending | 68 | 510 | 280 | 1100 |
| Supply Chain Finance | 71 | 221 | 286 | 980 |
| Internet Payment | 29 | 82 | 33 | 190 |

**Fig. 1.** Research papers on the application of blockchain to financial services.

### 1.4 Structure of the Survey

The paper is structured as follows. Section 2 gives a review of blockchain technologies in the context of financial services. Section 3 surveys on the application of blockchain technologies in various fields of financial services. Based on the survey, Section 4 discusses challenges and suggestions to address them. Section 5 concludes the paper.

## 2. Blockchain Technologies in Finance

In 2008, Nakamoto [6] launched a P2P electronic cash system which uses a point-to-point distributed timestamp server to generate electronic transaction certificates that are arranged and recorded according to time, thus solving the double payment problem. Yuan and Wang [7] think that blockchain can be viewed narrowly and broadly. In a narrow view, blockchain is a combination of data blocks in a chronological order into a specific data structure. On the other hand, it is a new decentralized infrastructure and distributed computing paradigm in a general view. Yli-Huumo et al. [8] think that blockchain is based on cryptography and can fully record the whole process of value transfer through a distributed multi-node “consensus” mechanism. Bitcoin is just one of many solutions using blockchain technologies. The security and privacy of blockchain is an active area of research for new types of disturbances and attacks. While blockchain is a new technology, there already exist profound studies in the security domain and the distributed domain.

Blockchain is a data structure chain that connects multiple data blocks in sequence according to time nodes. It includes various technologies such as network technology, computer technology, and information technology. Blockchain uses modern mathematics and cryptography to analyze the information

formed by a distributed ledger to guarantee authenticity and originality. From the hierarchy of the block-chain architecture, blockchain as a distributed ledger technology is composed of computer technologies of distributed storage, point-to-point transmission, consensus mechanisms, asymmetric encryption algorithms, and time stamps.

Initially applied to the development and operation of digital currency systems, blockchain serves as a distributed database having characteristics of decentralization, consensus trust, immutability, and traceability. Blockchain contains general theories and laws of sociology, economics, and computer science. In terms of computer technology, it includes a series of complex technologies such as distributed storage, Byzantine fault tolerant (BFT) [9], cryptography [10], P2P networks [11], smart contracts [12], and consensus algorithms. Because of interdisciplinary integration and support, blockchain has enabled the development of self-governing, trusted, and traceable systems in the digital world.

Fig. 2 shows the general blockchain architecture in financial services. The architecture consists of 6 layers: data layer, network layer, consensus layer, incentive layer, contract layer, and application layer. The data layer manages data blocks in a chain structure, and the network layer handles communication between nodes. The consensus layer manages agreement using a consensus mechanism, and the incentive layer provides an issuing mechanism and distribution mechanism. The contraction layer supports contracts and the top layer lends itself for applications.

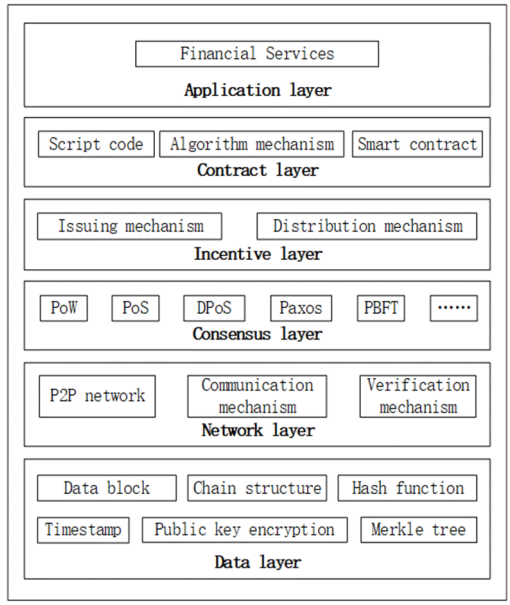



**Fig. 2.** Blockchain architecture in financial services.

## 2.1 Technical Principles of Blockchain Trust Mechanism

The financial industry is an industry of trust. The most important purpose of introducing blockchain technologies is to establish a better trust. The realization of such a trust mechanism is greatly supported by the core principles of blockchain technologies. This section gives an overview on asymmetric encryption algorithms, P2P networks, timestamp server, workload proof mechanism, and four types of blockchain data layer technology principles.

### 2.1.1 Asymmetric encryption algorithm

In 1976, Diffie and Hellman [13] conceived an encryption algorithm setting a pair of keys X and Y where X is used to encrypt information and Y is used to decrypt information. X and Y are linked by a specific mathematical algorithm where Y can unlock X, while X cannot unlock Y. If a pair of keys meets the above conditions, one of the keys is to be public serving as a public key. The other key is secretly held in the hands of one party as a private key. This type of encryption algorithm is called asymmetric encryption.

The specific operation process of the algorithm in a blockchain network is described for the communication between A and B as follows: (1) a generates a pair of keys through a specific mathematical method and the public key is broadcasted, while the private key is kept secret; (2) if B wants to send encrypted information to A, B needs to obtain the public key, encrypts the information with the public key, and returns the public key to A; (3) upon receipt, A uses its own private key to decrypt the returned public key to obtain the encrypted information. In this process, since A's private key is completely confidential (even if it is stolen by a third party during the public key transfer), the encrypted information remains safe.

### 2.1.2 P2P network

A P2P network transmits information through distributed user nodes. There is no longer need for a central server. Nodes serve not only as clients to obtain information from the blockchain network, but also as servers to provide external data. All nodes in the P2P network are connected to each other and any one of them can publish data information which is propagated to every other node in the network [14].

### 2.1.3 Timestamp server

In order to solve the problem of repeated payment of digital currency, Nakamoto [6] designed a mechanism to guarantee time series, namely a timestamp server. It adds a timestamp string that is generated by a random hash function applied to each block. The server requires the payer to broadcast the random hash value on the entire network. Using the hash value, one can know all the transactions that have occurred and the existence of a certain transaction. In this way, all participants on the payment network can confirm the existence of a certain data string at a certain moment.

When the next owner uses the digital currency, the person also needs to generate a timestamp. At the same time, the timestamp puts another timestamp in front of it as a random hash value. In this way, each block connects to the next block, forming a chain which is an open and transparent time series. De Weerdt et al. [15] proposed the business process of financial services to include a process-oriented information system and illustrates the necessity of a timestamp server in financial services through a case.

### 2.1.4 Proof-of-work mechanism

To ensure the immutability of the information on a blockchain, Nakamoto [6] introduced a proof-of-work mechanism to add a random number to the blockchain to start the random hash value of the given block from zeros. As the number increases, the time required to find the solution takes exponentially, but only one random hash operation is needed to verify the result. When a node wants to generate a block, it repeatedly tries to find this random number until found, which requires a high amount of CPU workload.

Before completing the work, the information in the block cannot be changed. A blockchain does not run from a single server, but on a network of computers that hold all data and data changes in the blockchain.

These computers, which are called miners, are essential to the blockchain that uses a proof-of-work mechanism [16] to achieve consensus. Proof-of-work mathematically ensures the validity of a consensus as long as no single entity holds enough computing power to add an illegitimate block to the blockchain. Each miner competes with other miners to earn the reward of being able to add a block to the blockchain. This is accomplished by the miner doing a computationally intensive work. Bitcoin requires the miner to find a string that returns a string by concatenating the string with the hash value of the previous block header and then re-hashing it. Anyone trying to spoof the blockchain (e.g., changing data in old transactions) must recalculate the proof-of-work for all the subsequent blocks. Convincing the system to use a bogus chain would require continuously adding blocks to the chain faster than a legitimate chain that would evolve. Ethereum is developing an alternative consensus scheme that uses a proof-of-stake that does not require the computational resources of a proof-of-work, largely in response to processing intensity and energy use as noted in [17].

The consensus of a blockchain is achieved through a proof-of-work mechanism. The advantages of this mechanism are obvious. Each node can participate in the competition on an equal footing and build a positive cycle economic system through incentives, so that it accumulates a huge computing power to protect system security.

## 2.2 Technical Characteristics of Blockchain Technologies Applied to Fintech

The transformation of financial service application scenarios with the help of blockchain can reduce costs and financial risks, while improving efficiency. The following describes the characteristics that are related to financial services.

### 2.2.1 Decentralized

Blockchain is essentially a decentralized and centralized database. It does not have a centralized management organization such as a financial institution in the traditional financial model, and there is no host for storing transaction information in the Internet financial model. These functions are equally imposed rights and obligations on each node in the blockchain network.

De Filippi [18] discusses the core innovation of the blockchain as an ability to validate transactions in a decentralized manner without the need for a trusted authority. Until recently, digital currencies were operated through a central operator or trusted intermediary. Blockchain technologies eliminate the need for a central clearinghouse by allowing for transactions to be verified and computer logic to be executed in a decentralized manner.

### 2.2.2 Openness

A blockchain system is open where its commonality of transaction information is made public. Although the private information of the transaction party is encrypted and protected by the public key and private key, the information can be shared as long as the system has the decryption authority and tools, which enables information transparency [19]. Under the trust mechanism established by block-chain, the higher the information transparency and the information security, the lower the data risk in the financial field.

### 2.2.3 Information cannot be tampered with

The blockchain consensus mechanism makes information non-tamperable and helps determine the validity of transactions [20]. As long as the data information of a block is verified by the entire network and added to the blockchain, this data information will be permanently stored in the blockchain. The blockchain is generated and connected by each block in strict accordance with the actual order, which enables the traceability of the blockchain and makes the information in the blockchain more secure and reliable. Since each transaction on the blockchain is validated and recorded with a timestamp, users can easily verify and trace the previous records through accessing any node in the distributed network. In the Bitcoin blockchain, each transaction can be traced to the previous transactions iteratively, which improves the traceability and transparency of the data stored in the blockchain [21].

### 2.2.4 High security of transactions

The blockchain algorithm is a distributed accounting method based on consistent specifications and protocols. This machine-based absolute algorithm and trust in computing power replace artificial credit checks and reduce human intervention, which consequently increases the safety factor of transactions. Instead of requesting confirmation for every transaction to a centralized authority, the distributed consensus of blockchain rejects any attempt at tampering with the consensus state as an invalid transaction [18].

### 2.2.5 Intelligent trading contracts

Blockchain technologies allow smart contracts to move from theory to practice. Once a piece of program code is put into a blockchain, the code not only acts as a program, but more importantly becomes an autonomous economic activity participant. It can be driven by events and may own and maintain its own state, control assets on their own, and even respond to information received [22]. Blockchain technologies allow smart contract programs to be embedded in the network as an important node. By letting it receive data and information from the entire network and respond accordingly, the entire network mechanism can run smoothly. The enforcement of such contracts allows defaults to be prevented.

## 2.3 Smart Contract Application Deployment under Trust Mechanism

Trust is complicated and difficult to define precisely. It has numerous meanings in many different forms. Yet trust is the underlying fabric of human interactions and of central importance to interpersonal and organizational relationships. Blockchain affects trust. People sometimes refer to blockchain as a technology that overcomes the need for trust in human interactions [17]. The trust mechanism mentioned in blockchain technologies in the financial context is inseparable from smart contracts. The most important application scenario in the future development of blockchain technologies is the deployment of smart contracts.

Szabo [23], a cryptologist and digital currency researcher, came up with the concept of “smart contracts”. He summarizes the definition of smart contracts as “A smart contract is a set of commitments defined in digital form, including agreements on which contract participants can implement these commitments” [23]. In the 1990s, Saab’s theory of how smart contracts are supposed to work could not be realized, mainly because there was no digital financial system capable of supporting programmable transactions at that time. With the breakthrough of blockchain technologies, smart contracts have been

given the opportunity to be reborn, and the "Programmable currency" which people have imagined now has a chance to be put into practice.

Smart contracts based on blockchain technologies can not only exert their advantages in terms of cost efficiency, but also avoid the interference of malicious behaviors on normally executed contracts. Smart contracts are written into the blockchain in a digital form, and the entire process of storage, reading, and execution is guaranteed by the characteristics of blockchain technologies to be transparent, traceable, and unchangeable. At the same time, a state-based machine system is constructed by the consensus algorithm of the blockchain, so that smart contracts can run efficiently.

Smart contracts are basically computer programs that automatically execute the terms of contract. When the pre-configured conditions of a smart contract between participating entities are met, the participants in the contract agreement automatically pay according to the contract in a transparent manner [24]. In 2015, Visa and DocuSign demonstrated smart contracts to rent a car without filling out a form [25]. In 2017, Egelund-Muller et al. [26] proposed a feasible solution for financial contract management on the Ethereum blockchain.

In 2018, Bosco et al. [27] presented the DLS OCS platform in research of blockchain technologies to promote financial services. The DLS OCS platform supports investors and non-conventional financial operators to monitor and manage their renewable energy investments in a secure way. The automated managing mechanisms supported by the DLS OCS platform reduces the risk of investors. All the platform features have been implemented, exploiting Ethereum smart contracts to ensure trustworthiness and transparency.

# 3. Survey on Application of Blockchain Technologies in Various Fields of Financial Services

Blockchain transforms the financial field at three major levels: business, technology, and management. Blockchain is used in various applications in different areas of financial services. Fig. 3 shows the divided financial services into six basic items.

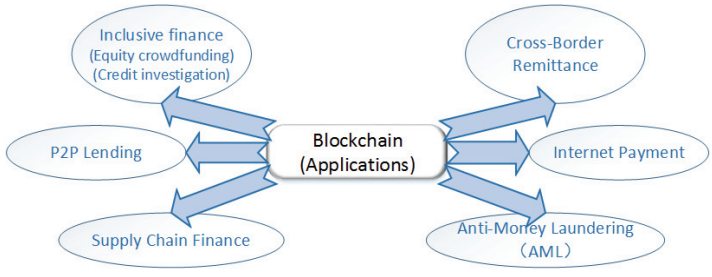



**Fig. 3.** Blockchain and representative financial services.

## 3.1 Blockchain and Inclusive Financial Services

Blockchain technologies have the characteristics of equality, security, and democracy. The application of blockchain is carried out as concise as possible in network operations. It breaks through the precision-

based expression of traditional finance. Blockchain uses a distributed accounting and consensus mechanism to process information, which reduces credit risk, enables the vast participation of people, and makes financial services more universal and popular. Therefore, blockchain finance has inherent consistency in concept and form with inclusive finance [28]. The consistency implies that the application of blockchain technologies is capable of solving the problems in the inclusive financial model. The multi-centric nature of blockchain technologies treats each user as a node in the blockchain, enabling direct P2P transactions between borrowers and lenders and eliminating the need for banks to act as intermediary credit guarantees. It reduces credit risks due to information asymmetry and improves the efficiency of pre-loan approval and post-loan management. It also helps achieve fine management of fund circulation based on electronic transactions, reduce transaction costs, and improve transaction efficiency.

All the transactions in blockchain finance are completed in the network, so that the marginal cost of expansion becomes low, which gives a scale advantage. The absolute advantage in transaction cost makes blockchain finance attractive to a large number of customers and allows quick expansion of scale. Blockchain technologies can also enable smart contracts to be used in mobile applications to support electronic transactions. These as whole promote the development of inclusive finance.

**(1) Equity crowdfunding:** An important development in inclusive finance is the equity crowdfunding model [29]. The equity crowdfunding platform is to match the needs of the equity financing party with the investors and collect the scattered funds of many investors to meet the requirements of the financing parties. Finally, the two parties reach a relevant investment agreement under the cooperation of the crowdfunding platform, and the platform receives part of the cost. In order to control risks, the equity crowdfunding platform participates in equity crowdfunding transactions using the "platform check + service + lead investment + joint investment" model. Fig. 4 illustrates the equity crowdfunding model under the traditional finance model. Equity crowdfunding creates the opportunities for investment by providing services for attracting capital for start-ups and opportunity to fund for potential investors (e.g., SumUp, iZettle, Jusp, and SetPay) [30]. Fig. 5 depicts the equity crowdfunding model in the form of smart contracts. Blockchain-based crowdfunding platforms are mainly used to support startups to create digital currencies to raise funds and distribute digital equity to investors. These digital currencies serve as an evidence to support the equity that start-ups should receive. Those who initiate a crowdfunding project on a blockchain can act as both a fundraiser and an investor. That is, when the fundraiser initiates a large amount of a crowdfunding project due to insufficient funds, the person can also invest as one of the investors and earn crypto equity with digital currency. When a smart contract is embedded

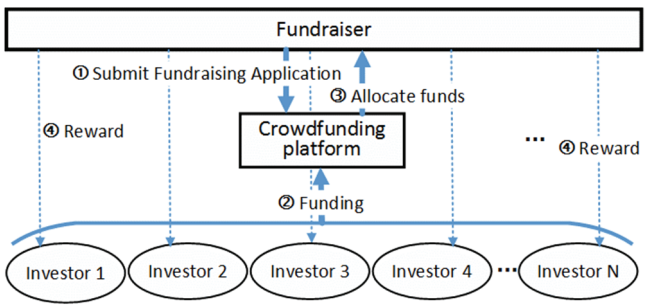



**Fig. 4.** Equity crowdfunding model under traditional model.

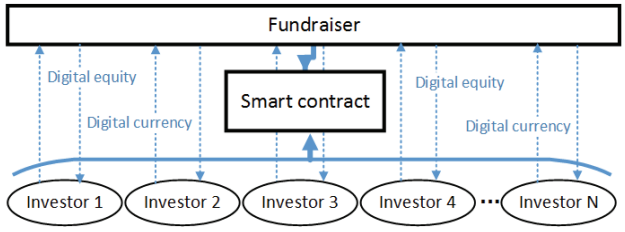



**Fig. 5.** Equity crowdfunding model for smart contracts.

in the crowdfunding model, the smart contract sets the project. If the crowdfunding project does not reach the predetermined goal, the funds can be automatically returned to the account without intervention of a third party.

**(2) Credit investigation:** The advantage of blockchain lies in the fact that a massive amount of information is automatically recorded by program algorithms and stored in each computer on the blockchain network where information is transparent and tampering becomes difficult, while the usage cost is lowered. All the commercial banks store and share their customer's credit status in an encrypted form. When customers apply for a loan, they do not need to go to the central bank to apply for credit information, which is decentralized. The loan institution can obtain the corresponding information from the blockchain and complete all credit investigations.

## 3.2 Cross-Border Remittance

In the formal international remittance market, the most reputable and secure method of cross-border remittances is through bank transfer. A common currency multimodal transportation operator (MTO) is also common [31]. The largest MTO that accounts for 24% of the total remittance market is Western Union, MoneyGram, and Ria Money Transfer. The increase in remittances each year has also attracted companies from other fields of activity to join and act as MTO, such as the Post. An important advantage of MTO is that its customers do not need to be members or have bank accounts, and it has faster payment speed and lower fees than banks, which makes MTO very competitive. Parsons proposed where funds should be prepaid, for example the accounts of MTOs, prepaid cards, electronic wallets, or any other similar services where funds are stored temporarily when the sender faces the risk of failure of the counterparty and the loss of all or some funds [32]. The third is an electronic online remittance system.

A well-known example for a web-based international money transfer platform is PayPal, a web application which directly recalculates the transferred sum into a foreign currency [33]. TransferWise and WorldRemit [34] are the biggest players in the online remittance segment, reducing commissions and fees. The traditional cross-border remittance method is shown in Fig. 6.

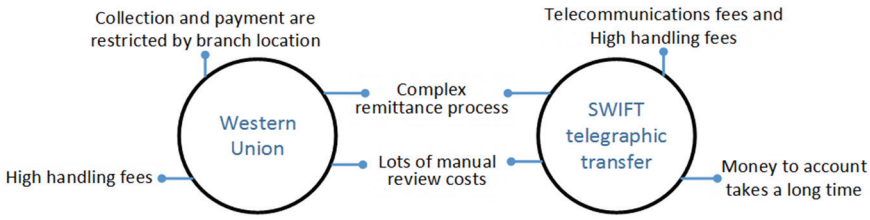



**Fig. 6.** Traditional method of cross-border remittances.

In 2019, Metzger et al. [35] described the Bitcoin remittance model. There are mainly four ways that Bitcoin remittances can be organized. First, Bitcoin users can privately send Bitcoin from their own wallet to a receiving wallet without a remittance service provider at the cost of safety risks. Another way is to use a service provider that manages the customer's transfer process in Bitcoin. A third alternative is that the service provider collects the customer's real currency, uses Bitcoin as a transfer currency, and pays the receiver in another or the same real currency. The fourth method is for the provider to use Bitcoin as a settlement currency and abstain from processing every transaction.

For cross-border remittances, OKLink, which is a new generation global financial network built on blockchain technologies, was researched. It is committed to promote the efficiency of global value transmission, while improving the user experience of global remittances. The application currently covers more than 20 countries and regions, including China, Japan, South Korea, and Southeast Asian countries. The main customers are global small and medium-sized financial participants, including banks, remittance companies, and Internet financial platforms. The monthly transaction volume reaches tens of millions of dollars. The process of OKLink is shown in Fig. 7.

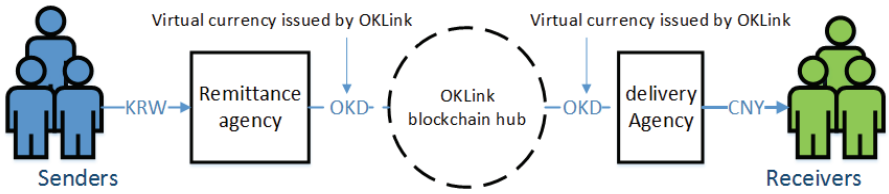



**Fig. 7.** OKLink remittance method under blockchain technology.

For payment and settlement, SWIFT, a communication platform linked to tens of thousands of banks, has been threatened by emerging blockchain technologies. Some blockchain start-ups and cooperative institutions have begun to propose new settlement standards. The alliance has established standards for interactive settlement. As of now, nearly 50 large banks and financial groups around the world have joined R3.

## 3.3 Internet Financial Payment Service

In 2000, Hilt et al. [36] applied for a technology patent for "Electronic bill pay system" and proposed a new method of electronic payment. In 2003, O'Leary et al. [37] proposed a patent titled "Method and system for processing Internet payments using the electronic funds transfer network". These are of great significance in the field of financial payments. In 2009, new forms of payment solutions such as Google Checkout, Alipay and WebMoney appeared. Lin and Liu [38] proposed an incentive-based electronic payment scheme for digital content transactions over the Internet and proposed a privacy and security guarantee system of payment token based on cryptographic technology, providing a secure theoretical basis for the widespread application of modern electronic payment models.

In 2009, O'Flynn [39] proposed the absorption of new technologies in card payment and the application of mobile payment in the Middle East area. Kim and Lee [40] conducted a further analysis of the card payment mechanism and the impact of information technology and development on wealth and population. With the increasing application of electronic payment, the payment framework and payment

protocol have been put on the development agenda of electronic payment to implement applications in different scenarios based on technical common components. In the Internet era, many business models make payments based on the network.

The use of electronic payment in the network is a complex issue, however, because it involves support of multiple payment tools, secure exchange of payment information, and so on. In 2015, Ruiz-Martiez [41] proposed (1) the functions that an online payment framework should provide, (2) the solutions that may be used, and (3) the problems that still need to be resolved for the online payment framework to make electronic payments pervasive. Yang and Lin [42] think that the previous e-payment mechanisms do not support the non-repudiation requirement on the client side. Thus, a malicious client can easily deny transactions, and the merchant might not be paid. In addition, these mechanisms have large computation and high communication cost, which makes them difficult to be applied to the mobile payment for cloud computing. To address that, a new mobile payment mechanism with anonymity for cloud computing was proposed. The mechanism not only reduces the computation cost, but also supports the non-repudiation requirement in the client side.

In 2015, Hedman and Henningsson [43] proposed the use of the Mobile Payments Market Cooperation (MPMC) framework to demonstrate how payment digitization as a technological innovation affects the competition and collaboration of traditional and new stakeholders in the payment ecosystem at three levels of analysis. This is an important breakthrough in modern mobile payment. It is not just being promoted as a means of payment, but also describes a security and defense system under the mobile payment ecosystem, which allows it to promote and supervise marketing. McCorry et al. [44] provide an overview of Bitcoin payment networks with a proposal of facilitating “off-chain transactions” and consulting the blockchain only when an adjudicator is required.

Internet financial payment has risen with the advance of Internet technologies and the development of e-commerce. Internet payment refers to the behavior of customers to purchase specific goods or services through computers and other devices to initiate payment instructions based on the Internet to transfer money. Its main manifestations are online banking, third-party payment, and mobile payment. A major change of the Internet payment model by the application of blockchain is the change of payment process through third parties and decentralization. Fig. 8 shows a comparison of centralized payment process and decentralized payment process.

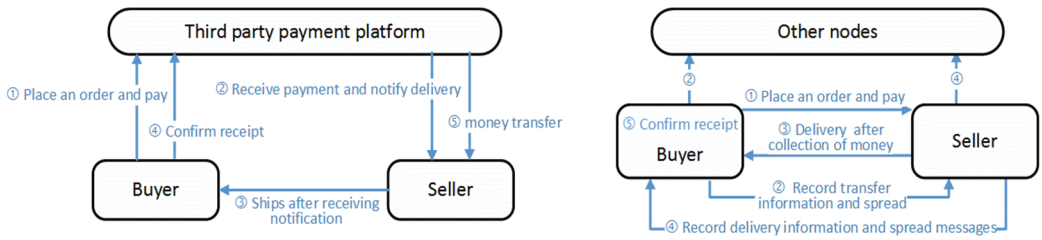



**Fig. 8.** Centralized payment process and decentralized payment process.

## 3.4 P2P Lending Services

The traditional P2P platform uses the Internet to match the borrower’s financing needs (amount, term, interest on cost of funds willing to bear) with the lender of discrete funds and meet the borrower’s requirements by aggregating a large amount of scattered funds from the lender eventually. When the two

parties reach a loan transaction under the cooperation of the platform, and the platform charges a part of the fee. In order to control risks, the platform needs a series of configurations. First of all, it needs to strictly review the borrower's credit ability and repayment ability. Secondly, the platform should be guaranteed by the guaranteeing institution to control risk for the borrower's financing in order to act as a trust. Thirdly, the platform needs to introduce third-party regulatory funds in order to ensure the security of funds.

The P2P platform is not a product provider and thus, not responsible for designing financial products. It is an information intermediary platform for capital demand relationships, which is the connection of supply and demand resources. As shown in Fig. 9, P2P network lending institutions are information intermediaries, not credit intermediaries. P2P lending is represented by European crowdlending companies as an alternative to traditional banking credits (Funding Circle, Zopa [45], Lendico [46], Comunitae, and Bondora [47]).

When using blockchain technologies to serve the P2P network lending business, blockchain only serves as an information platform without participating in transactions. All transactions are direct transactions between points. Fig. 10 shows the transaction process.

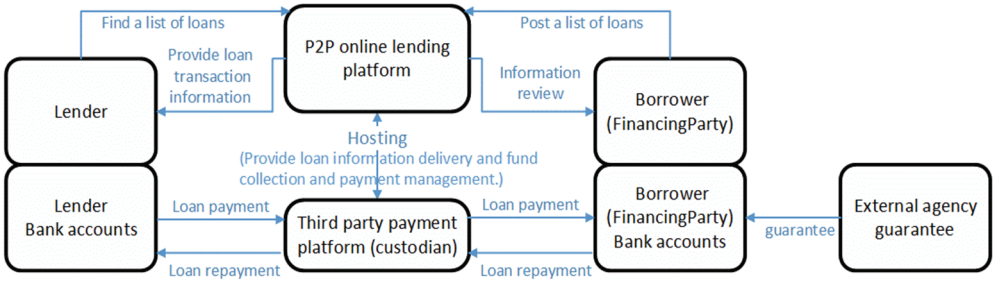



**Fig. 9.** P2P network lending model.

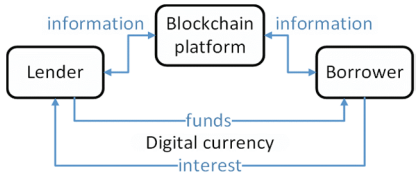



**Fig. 10.** Blockchain technology services P2P network lending model.

It involves financial transaction initiation, pre-transaction verification, contract signing, transaction processing, and risk control after transaction. In financial transaction initiation, borrowers and lenders download the blockchain client and connect the computer to the blockchain network. The borrower requests financing at the blockchain terminal with financing amount, time limit, interest rate, and digital mortgage assets, and other information relevant to money tracking inspection items that they can accept. The lender calls up the borrower's credit history in the blockchain platform and decides borrowing through direct P2P communication. Pre-transaction verification includes fast real-time verification and approval without third party involvement. It is for transparent, secure, and reliable information and anti-fraud. Contract signing is about creating a smart contract where transactions are automatically completed through the smart contract.

Transaction processing uses the Bitcoin client wallet to transfer money and synchronizes information across the system in real time. No account processing is required and all transactions and protocols are transparently and publicly recorded on the ledger. Transaction information recorded on each block is present on all network nodes and visible to the entire network. The transaction records of each node can be queried and are bound to network nodes. The true identity information behind the network nodes is hidden to protect privacy. In risk control after transaction, when applying for a loan on the blockchain platform, the borrower can choose to use the smart assets owned as collateral and set the corresponding program code in the smart contract to automatically lock the smart assets. When the borrower pays off the loan, the system instantly confirms the contract conditions to automatically unlock. In this way, the risk of both borrowers and lenders is reduced.

## 3.5 Supply Chain Finance

The core idea of supply chain finance is to address the difficulty for a single upstream and downstream customer to meet the bank credit access conditions. With the help of the supply chain structure, however, reliance on movable property pledge guarantees (e.g., prepaid accounts, inventory, and receivables based on transactions) is used for financing, self-certification methods for obtaining bank credit support, and self-repaying trade financing with future trade income as the source of repayment.

In a nutshell, supply chain finance is a financing model in which banks link core companies with upstream and downstream companies to provide flexible financial products and services, using funds as a solvent in the supply chain to increase its liquidity. In today's supply chain financial system, the supply chain of a specific commodity includes the procurement of raw materials to make intermediate products and final products. Finally, the sales network sends the products to consumers and links suppliers, manufacturers, dealer, and end users all together. Fig. 11 illustrates the specifics and disadvantages of the traditional supply chain financing.

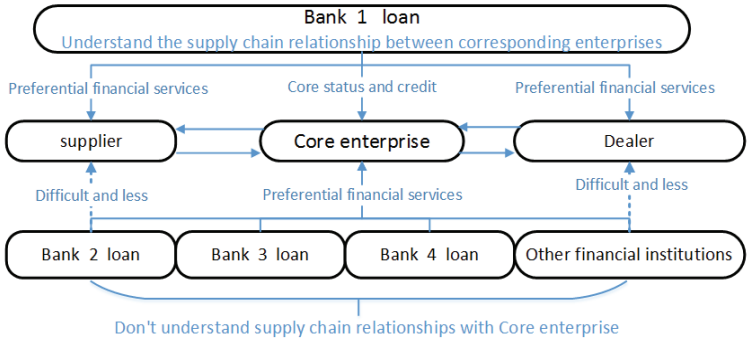



**Fig. 11.** Traditional supply chain finance.

In the entire supply chain financial system, multi-agent participation, asymmetric information, and imperfect credit mechanisms are of typical scenarios. The emergence of blockchain technology has natural applicability to it.

Supply chain finance is the use of technical means to link the upstream and downstream companies (i.e., buyers, sellers, financial institutions) of a commercial entity. Sales, deposits, loans, and guarantees in purchase and other financial activities in the business and financial processes are integrated in a

complete transaction. The core purpose of supply chain finance is to reduce cost and improve business efficiency. The innovation of supply chain finance lies in connecting upstream and downstream enterprises with technical means and placing the receivables and payables of core and affiliated enterprises in transaction records as much as possible. The transaction record is end-to-end, traceable, verifiable, and convenient for auditing and supervision. This is the core problem that can be resolved by the distributed shared ledger using blockchain technologies. Using the shared ledger technology built into blockchain can allow the stakeholders involved in the entire process of supply chain finance to be a node of the shared ledger.

Each node is based on its original ecology and its commercial attributes have their own rights and roles to play in a blockchain network. Everyone is able to read/write transaction data in a supply chain finance link on an authorized or licensed basis. The financial information and value of the supply chain carried by the shared ledger can be freely branched and merged for circulation and transmission. Fig. 12 illustrates the information symmetry with blockchain as the core of supply chain finance.

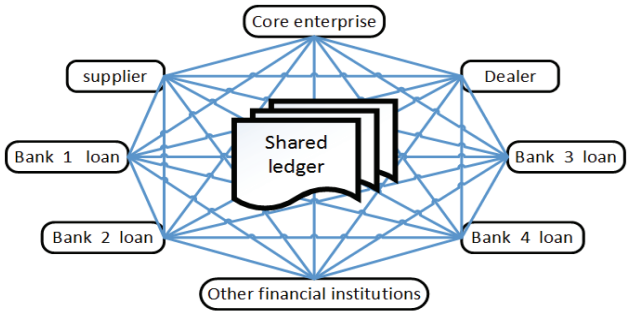



**Fig. 12.** Blockchain as the core of supply chain finance.

## 3.6 Application of Blockchain in Anti-Money Laundering (AML)

In the field of anti-money laundering, the Know Your Customer (KYC) principle is one of the fundamental countermeasures to combat money laundering [48]. The KYC principle requires that for certain types of companies with funds to handle business, the following needs to be done: (1) identify and verify the customer by obtaining the customer's identity certificate, confirm that the customer's identity is consistent with their claimed identity, and ensure the correspondence of the claimed identity to the real identity, (2) assess customer risk by assessing customer behaviors to determine risks and monitor customers who appear to be at greater risk, and (3) monitor abnormal behaviors such as activities that appear to be money laundering or crime. If a customer's identity cannot be fully verified or the customer's behavior does not comply with legal requirements, the KYC principle terminates the business with the customer.

KYC requests may cause bank transactions to be delayed, however; typically about 30–50 days to reach a satisfactory level. The current KYC process has also resulted in much duplicate work between banks and other third-party agencies. British banks spend an average of £300 million a year on compliance with KYC. The survey also shows that some banks are compliant with Anti-Money Laundering Act (AML) and Customer Due Diligence (CDD), which costs up to £40 million per year. In 2018, Biryukov et al. [49] proposed privacy-preserving KYC on Ethereum. Parra-Moyano et al. [50] presented an optimized and dynamic KYC system based on blockchain technologies.

When blockchain technologies are applied in the field of anti-money laundering, it would likely change the way regulators work. Huls at Rabobank proposed a use case where KYC can be stored on a blockchain [51]. When a new customer joins a bank, a statement on the blockchain is issued, which includes a summary of KYC. Other banks and recognized organizations can share the statement without having to ask the customer to restart the KYC process. Financial institutions provide electronic identification information (similar to private keys) for entities in transactions, and associate user addresses with electronic identification information. Every transaction needs to be verified by the private key and the public key held by the bank.

Then, the transaction is performed by the user address, which determines the traceability of the data on the blockchain. In this mode, various financial institutions share transaction information on the same blockchain. The supervisory authority may join the blockchain as a node to obtain first-hand data information, which realizes a comprehensive real-time supervision of all transactions and other activities on the blockchain. At the same time, by setting certain rules and logic on the blockchain, the blockchain can automatically verify the compliance of transactions and users. Non-compliant transactions and users may be removed, which improves the compliance level of the entire financial enterprise.

One area that has made a great progress in combating anti-money laundering (AML) is the use of blockchain technologies which can effectively identify suspicious transactions by tracking customer transactions and activities in real time. The Singapore government is exploring the possibility of using blockchain for payments and clearing as well as anti-money laundering and terrorist financing (CFT). Widjaja at Singapore-based OCBC Bank said that it must connect with all the institutions and parties involved in the value chain, which requires a lot of investment from multiple stakeholders and a coordination with them [52]. The Monetary Authority of Singapore (MAS) launched the Ubin project in 2016. This project consists of a consortium of multiple banks to develop decentralized bank payment and settlement software. Since then, it has released the source code to the public.

Having said that, it is suggested to establish an alliance chain based on blockchain technologies between financial agencies and regulatory agencies. This builds a private chain based on blockchain technologies within financial institutions and combines the two models to form a hybrid chain to jointly build a blockchain-based anti-money laundering structure of financial institutions.

# 4. Open Issues, Challenges, and Suggestions

## 4.1 Discussion on Technologies and Rules

From the analysis of blockchain technologies in the context of financial services and the survey of 6 types of applications in the field of financial services, we consider the application of blockchain in the financial background as the combination of technologies and rules in practice. There are two main challenges in adopting blockchain technologies—technical performance and security risks, which are discussed in the following.

### 4.1.1 Technical performance

The performance of the current blockchain system on the market is difficult to meet the needs of actual business. For example, the Red Belly blockchain created by USYD can process a maximum of 440,000

transactions per second. In 2019, during the Double Eleven period of Taobao, Alipay set new records of 544,000 transactions per second. From these, it is observed that when blockchain is applied to e-commerce and financial transactions on a large scale, the performance barrier must be addressed first. In addition, the amount of data generated by such a large-scale exchange in the real world is unimaginable. Even if blockchain technologies are highly integrated with big data, cloud storage, and other performance supporting technologies, it is very difficult to carry all data in a large-scale business. Therefore, the parties involved in transactions must consider what kind of data to put on the block, which also leads to other problems in information selection. Even after scalability, the stability of the blockchain network should be further concerned.

### 4.1.2 Information security and privacy protection

The technical loopholes in blockchain make some financial institutions stay away. If these loopholes exist in the execution code of smart contracts, it can be very difficult to prevent hackers. “Dao”, a blockchain smart contract-based crowdfunding project has been attacked by hackers due to the vulnerability in its smart contract code. It was hijacked with more than 3.6 million ether and about $60 million [53]. Smart contracts in EOSIO [54], a representative delegated proof-of-stake (DPoS) blockchain platform has also been attacked because of vulnerabilities, which resulted in huge economic losses. This testifies that even the smart contracts that are theoretically and absolutely automatic and objective cannot avoid technical risks and subjective moral risks in a real operation process. It is necessary to find a balance between decentralization and centralization.

In addition, a critical issue of blockchain technologies is the data encryption method. The security of the encryption algorithm is directly related to the security of user assets. In the future development, it is necessary to emphasize the risk prevention and control of application platforms based on blockchain technologies as it is immutable and irreversible. Once the code loopholes are hacked, the cost for a solution would be expensive. Finally, people are also concerned about how user privacy and trade secrets are protected. The design of a blockchain stipulates that a user must use the same account for a long time. The problem with this is that any account may be subject to an unlimited number of queries from any node. All of its transaction information and the amount of deposits owed are transparent, which raises a great concern on information security for individuals, enterprises, or financial institutions. The research of zero-knowledge proof algorithm [55] of blockchain continues to address privacy protection.

### 4.1.3 Blockchain and financial rules

Blockchain or distributed ledger technologies are a possibly game-changing innovation [56]. Blockchain and financial rules affect each other. On one hand, blockchain technologies in fintech must be developed based on financial rules. On the other hand, financial rules must be changed for the application of blockchain technologies in fintech. The exploration of blockchain technologies and rules can promote the improvement of the social credit system, especially for those who have a difficulty in entering the traditional financial system to accumulate credit. Intervention in shared financial practice can help them establish a financial credit foundation.

## 4.2 Challenges Posed by Blockchain in Financial Regulation

Blockchain technologies have regulatory advantages. They have the characteristics of data integrity and full traceability through the data chain in sequence. Historical data can be called out at any time for

supervision. Most financial institutions choose to use alliance chains to achieve data interoperability and sharing with private chain solutions. It is difficult for various financial institutions to build alliance chains, because financial institutions are in a commercially competitive relationship, and also financial institutions and regulators are in a game relationship. For various financial institutions and financial supervision organizations to form a blockchain alliance, government support and encouraging policies set by the government are required with unified rules and standards for blockchain technologies.

The main purpose of blockchain in fintech is to create a decentralized and high-quality trust mechanism. The realization of such a trust mechanism relies on the core principles of blockchain technologies discussed in Section 2.1. In financial services, the solidity of trust mechanisms is closely related to technical performance and information security. Also, it is inseparable from rules. With the richness of financial products, blockchain technologies have more requirements for financial supervision in application to fintech. As far as Internet payment is concerned, it directly involves immediate interests of the user's property security at a micro-level. At the same level, it is also related to the stability of the national financial system. For example, third-party payment companies have huge deposits of funds and acquire the potential to carry out financial business. This may have an impact on the entire financial system. From the perspective of ensuring national financial security, government supervision is inevitable. Thus, an update on regulatory means becomes a new challenge.

Financial supervision in the field of inclusive finance involves information disclosure and sharing, standardized operation supervision of financial service providers, and personal credit supervision. The Chinese government plans to introduce laws and regulations (e.g., Personal Information Protection Law and Data Security Law) in 2020 to supervise and protect information security. The formulation of legal rules will also affect the application of blockchain technologies in the fintech industry. The rules of the new bill must be written into smart contracts and used for financial supervision.

In the field of supply chain finance, opacity of information on the supply chain is an important factor which restricts the development of supply chain finance. In the supply chain financial system discussed in Section 3.5, there are core companies with strong influence and other cooperative companies in the supply chain without the same right to speak. The development of cooperative enterprises should not rely on core enterprises to benefit from the construction of the capital chain. When the information is asymmetric and the credit mechanism is not perfect, multi-agent participation in supply chain finance can easily cause an imbalance in the entire supply chain finance. Blockchain technologies use shared ledgers as the basis for accounting when resolving the problem.

This allows the unification of information, funds, and logistics to be fully realized. Therefore, the core company's credit can truly serve as the core guarantee of supply chain finance and reduce risks of credit cooperation between the various entities as well as costs. In the cooperation of data sharing, the participation of all the nodes in the blockchain under supervision also becomes a new challenge.

Regardless the regulations in finance, the regulator needs to join the chain as a node in the blockchain and should become the main body on the blockchain in order to obtain the most authentic, reliable data, and rigid supervision.

## 4.3 Rules of Future Blockchain

Blockchain promotes the development of fintech, and the financial industry uses its own uniqueness to promote the development of blockchain technologies. In the industry, its domain characteristics and the

future development rules of blockchain are inseparable. The rules of the future blockchain should address the following.

### 4.3.1 Optimization of trust mechanisms in various financial fields

According to the new rules established for blockchain in the financial industry, it is required to use distributed technologies and consensus algorithms to rebuild trust mechanisms and smart contracts to write consensus programs in the system under the new rules. When the trust conditions are met, each link that requires review and trust should be automatically executed.

### 4.3.2 Fast transaction verification and improved throughput

In financial business, there is often a high frequency of transactions involving data transactions between any two nodes around the world, which requires transaction verification. If the consumption practice is too long, it is difficult to meet the high frequency of transactions. Thus, verification speed should be increased. Improving the verification speed in the future blockchain is a long-term research area, including the optimization of key links such as signature algorithms, data operations, ledger structures, consensus mechanisms, and message diffusion.

### 4.3.3 Massive financial data storage and fast synchronization of node data

The amount of financial data is increasing day by day. The storage method of historical and active data directly affects the synchronization of node data. Under the unified consensus, the operating cycle of newly added nodes is shortened, and synchronizing a small number of transaction sets can synchronize node data effectively.

Multiple privacy protection schemes (e.g., encryption of private keys, hardware private key products, encryption of the bottom layer of blockchain, encryption of middleware, data encryption when entering data in upper-level applications, and secondary encryption of user-generated encrypted data) are possible technical solutions to protect privacy.

The API interfaces that are suitable for a variety of financial business scenarios as well as custom interfaces under special rules make it easier for the secondary development of financial services. The standard API interface provided during primary development is open to secondary developers, making it easier for financial companies quick docking. Through the encapsulation of the underlying blockchain, the application difficulty is reduced, and the consensus algorithm and the underlying distributed technology are continuously optimized.

In the financial field, the ever-changing financial rules lead to changes in the technical rules of blockchain. The rules, however, are still centered on trust optimization with the goal of improving the efficiency of data transactions. They also provide multiple privacy protection and applicable interface solutions as elements.

## 5. Conclusion

Blockchain brings a transformation from information network to value network in the field of financial services. In this transition, blockchain provides an innovation at both the technical level and the institutional level. At the same time, blockchain has brought a series of challenges to be addressed in

economic and social development. Blockchain is not only a series of new technology applications, but also an innovative attempt at the system and rule level. This paper has presented a comprehensive survey of the development of blockchain technologies in financial services, including equity crowdfunding and credit investigations in inclusive finance, cross-border remittance, Internet financial payment, P2P lending, and supply chains Finance, and application of blockchain in the field of Anti-money laundering. We also discussed the architecture under different financial service application scenarios from the perspective of financial trust mechanism to help readers understand the latest efforts of blockchain technologies in the field of fintech.

It further described the technical performance, security risks, and rules of blockchain in fintech. Key issues encountered in blockchain in fintech was identified. These include (1) issues with throughput and verification speed in large-volume data processing, (2) data storage and node synchronization speed issues, (3) smart contract vulnerabilities in information security, (4) encryption algorithm security issues, and (5) financial regulatory issues under the influence of the blockchain technology rules and financial rules. The regulatory challenges were also analyzed in different financial service fields and proposed a scheme for the supervision of blockchain technologies in the fintech industry by writing rules into smart contracts. Finally, the basic rules and research directions for future blockchains were proposed.

## Acknowledgement

This work was supported by the Ministry of Education of the Republic of Korea (No. 2019R1I1A3 A01060826).

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