Conceptualization of Blockchain-Based Applications: Technical Background and Social Perspective

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Abstract

There has been an increasing amount of research into blockchain when blockchain is receiving increasing enthusiasm from both the practitioners and scholars. It has been revolutionary in bringing trustless computing and immutable decentralized ledgering of digital assets and transactions to businesses, organizations, and individuals. The decentralized nature of blockchain-based systems and applications eliminates intermediaries, saves costs, and enhances efficiencies. In its infancy, blockchain demonstrates great disruptive potentials in many areas such as finance, healthcare, education, and real estate among others. This research presents the conceptualization of blockchain-based applications from the Information Systems perspective. The concepts of blockchain, smart contract, ICO, Dapps, DAOs, DAC, DAS, and AM are discussed and analyzed. The technical background and social perspectives of the blockchain based applications are discussed and analyzed as well. The paper contributes to a framework of blockchain level from the Information Systems perspective.

Keywords: Blockchain, Decentralization, Cryptocurrency, Bitcoin, Conceptualization, Smart contract.

1. INTRODUCTION

Blockchain, a distributed ledger technology, is attracting attention from industries to academics as a disruptive technology with tremendous potentials throughout a vast range of applications. With a short history of less than a decade (Gupta, 2017; Schlegel, Zavolokina, & Schwabe, 2018; Sompolinsky & Zohar, 2018), blockchain is believed to have brought an unprecedented decentralization revolution to not only the technology field, but also to the structure of human society (Baruffaldi & Sternberg, 2018; Lu & Zheng, 2018; Sadhya & Sadhya, 2018; Swan, 2015; Tapscott & Tapscott, 2016a).

As the underlying technology of bitcoin and other cryptocurrencies introduced by Satoshi Nakamoto (Nakamoto, 2008), blockchain is an open-source technology with tremendous successes regarding worldwide acceptance, trading volumes, and applications (Joseph Cook, 2014; Mandjee, 2014; Tapscott & Tapscott, 2016b; Underwood, 2016). Some researchers suggest that blockchain is expanding as a disrupting force with applications in finance, health, government, society, business, politics and more (Agyepong, 2016; Beck & Müller-Bloch, 2017; Eldred, 2016; Hurlburt, 2016; Lee, James, Ejeta, & Kim, 2016; Mougayar, 2016; Post, Smit, & Zoet, 2018; Sadhya & Sadhya, 2018; Swan, 2015; Wörner & Bilgeri, 2016; Yue, Wang, Jin, Li, & Jiang, 2016).

Recently, increased attention has been paid to big data analytics (Günther, Rezazade Mehrizi, Huysman, & Feldberg, 2017; Loebbecke & Picot, 2015). Blockchain serves as the backbone of big data analytics and its unparalleled potentials and challenges should never be underestimated. As blockchain startups emerge and the involvement of major technology companies increases, the technological ecosystem has significantly evolved with the support of venture capitalists and organizations (Friedlmaier, Tumasjan, & Welpe, 2016). In 2016, a stunning $500M venture capital was fueled into blockchain initiatives which indicates high confidence in this area of investments (Asatryan, 2017).

Researchers from engineering, business, and the social sciences are investigating the innovations of the fast-evolving blockchain industries. While opportunities exist with the adoption and innovations surrounding blockchain, others call for clarity of the revolutionary issue of blockchain. Challenges exist in the rise of blockchain development, especially after scandals like bitcoin stealing, abuses in the areas of illegal drug trading, and money laundering.

These instances have often created a negative reputation of both bitcoin and cryptocurrencies. The dark side of blockchain together with the fluctuations in bitcoin values have led some to believe in a conspiracy theory that bitcoin is a Ponzi scheme that only benefits the initial investors.

However, as a cryptocurrency, bitcoin has been built upon the confidence and adoption of all investors. It does not fit the Definition of a Ponzi scheme in many ways, especially given the fact that the bitcoin ecosystem does not pay rewards for new recruitments or participation. The value of bitcoin only depends on supply and demand. Just like other technologies, the underlying technology of blockchain does not take side and is not controlled by any other party, including the initial investors.

Therefore, it is essential to clarify the misunderstandings and to build confidence for blockchain decision makers (Beck & Müller-Bloch, 2017). This confidence requires more research into blockchain and its innovative ecosystem (Lindman, Chalmers, & Rossi, 2017), including the archetypes and the economic perspective of blockchain (Catalini & Gans, 2016; Walsh, O'Reilly, Gleasure, Feller, Shanping, & Cristoforo, 2016).

Blockchain is a fast-evolving field with both excitement and doubt. Though this application is immature, there are many innovations that can harvest the uniqueness of blockchain. Several industries are leading the applications of blockchain, but gaps exist as well. Therefore, academicians have begun to address these gaps in research through a systematic and interdisciplinary approach from the fields of technology, economics, social sciences, business, and philosophy.

This research offers conceptualization of blockchain-based applications from the IS perspective. Overall, the research question is ***How to conceptualize constructs of applications based on blockchain from the IS perspective***?

The paper is organized as follows. After the introduction, the second section provides a conceptual perspective literature review of blockchain. Key concepts, including blockchain, smart contracts, ICO, Dapps, DAOs, DAC, DAS, and AM are introduced. The third section provides the technical background review of the blockchain. Different technical concepts, including distributed Nodes, proof of work, and security are discussed. The fourth section provides analysis of social perspective of blockchain. The fifth section presents different conceptual levels of blockchains. The paper ends with conclusion and future research.

2. TECHNICAL BACKGROUND OF BLOCKCHAIN

Blockchain is a database recording of all historical transactions with consensus among all parties, and without a central authority. Distributed nodes blockchain is a distributed ledger chronologically stored in nodes which provide verification and storage services for the entire network.

Distributed Nodes

The nodes can be any computing entities such as computers, servers in the cloud, Internet of Things (IoT) devices, or specifically designed chips running within mining pools. The nodes communicate with each other in a peer-to-peer method and gain rewards by providing confirmation services of transactions that are occurring within the network.

To fake transactions, one needs to control 51% of the nodes which is almost impossible for an active blockchain with a large number of nodes. The nodes are designed to run as a self-governed organization without relying on a specific central node, thus avoiding single point failures within centralized systems.

All distributed nodes maintain identical records ensuring that the transactions are stored equally and therefore are resistant to attacks and are free of traditional reconciliation and audition.

Proof of work

Proof of work is a computation of adding new transaction information into a blockchain. Using brute force, this process requires tremendous computing power. In bitcoin, it is compensated by rewarding bitcoins to the computers or miners. This process grants the economic values to proof of work for the mined coins. Since all transactions are required to be verified before merging into a block, the blockchain relies heavily on proof of work.

Thus, a single correct chain with all verified historic transaction records is guaranteed without the possibility of multiple blockchains with more than one version. For public blockchains like bitcoin, there are an abundance of nodes running as nodes anytime, while for some private blockchains, specific nodes are needed to be deployed and keep running in order to verify transactions happening in the network.

Proof of work provides a trustless consensus among multiple parties. However, it has shortcomings. For instance, proof of work requires a large amount of computing power consumption, slow speeds, and has a risk of a 51% attack. New consensus algorithms have been proposed, such as proof of stake, proof of activity, proof of capacity, etc., to address these shortcomings. For example, instead of providing computation services to get incentives in proof of work, nodes could be used to invest coins to verify new transactions in proof of stake.

Security

Cryptography provides the underlying security for blockchain. However, there are still security concerns. Verbücheln (2015) uses cryptographic proof to replace the need for the involvement of a trusted third party.

All previous transactions are hashed as well as all new transactions are also hashed as a Merkle tree. The Merkle tree is a tree of hashed values of pairwise transactions allowing a fast location of a specific transaction or the identification of a modified transaction.

A nonce is brutally calculated using SHA-256 begins with a number of zero bits (Gilbert & Handschuh, 2003). In this way, the proof of work is achieved by the CPU time and the consumed electricity. All blocks are linked by hash values in order of time, an attacker needs to modify one block and all blocks afterwards, thus making it practically impossible and uneconomical since the same computation efforts are required to create a fake blockchain.

Thus, rational choice would be an honest miner. Meanwhile the pseudonymous characteristic of blockchain ensures the users privacy and identity are protected without risk of exposure to potential attackers or trackers.

In the scenario of decentralized energy trading, Zhumabekuly Aitzhan and Svetinovic (2016) discussed an approach combining blockchain, multi-signatures, and anonymous encrypted messaging streams. This method indicates that blockchain-based systems can utilize other security and privacy methods to provide application level enhanced protection.

3. CONCEPTUAL PERSPECTIVE OF BLOCKCHAIN

Blockchain

Blockchain originated as the open ledger of all transactions for bitcoins stored across nodes in the peer-to-peer decentralized networks that can exist beyond geographic boundaries and authoritative controls. Blockchain can be viewed as a giant public accessible registry to record information, assets, and transactions, which are verifiable and transparent for all (Beck, Avital, Rossi, & Thatcher, 2017).

Blockchain is a continuously growing time-stamped record. However, the conception of blockchain is far richer than the technology implementation as a distributed ledger technology. The richness of blockchain and the potentials for business as well as the political aspects of human society brings new level concepts like smart contracts, Dapps, DAO, DAC, DAS, and AM into play (Swan, 2015).

Smart Contracts

Smart contracts are digitized agreements between two or more parties programmed on a blockchain (Fairfield, 2014). Unlike the paper-based contracts, which are agreed upon by parties and legalized by authorities, smart contracts are coded as running programs that can be automatically executed once the preset conditions are met thus allowing exchanges of a digital or physical asset.

Due to the decentralized mechanism of blockchain, the contracts are ensured to be honored and the whole process is executed without relying on certain authorities that require validation. Smart contracts can be coded in commonly used procedural languages as well as logic-based languages (Idelberger, Governatori, Riveret, & Sartor, 2016).

Running on the underlying blockchain, smart contracts allow the parties to be humans, machines, organizations, and even other contracts. This feature dramatically enriches the concept of contracts and greatly increases the features of some applications. The disruptive potentials of blockchain largely relies on how innovative applications of smart contracts are (Peters & Panayi, 2016).

Initial Coin Offerings (ICO)

ICOs are known traditionally as Initial Public Offerings (IPOs) in order to sale shares in exchange of funds from investors. Similarly, for a cryptocurrency startup, it can sale its cryptograph coins or tokens to initial investors to raise funds for a certain product.

ICO is an innovative financing schema for blockchain-based startups and is different from crowdfunding. In an ICO, a preset target is identified and agreed upon by all investors. If, and only if the specified target is met, the ICO is declared a success and the startup formally becomes operational. Otherwise, the ICO fails and all investments are returned. The key for a successful ICO is the acknowledgment and acceptance of the campaign.

Considering the open competitions among ICOs and the driving forces of financial incentives, the market will automatically evolve a natural selection for competitive ICOs and eliminate inferior products. All is done through a blockchain without the involvement of traditional brokers, underwriters, central exchange markets, or regulating bodies, and without any significant costs.

The Ethereum (Wood, 2014), a project of a decentralized application platform, launched a successful ICO where 18 million dollars was raised that offered large returns for initial investors. The appearance of blockchain based ICOs provides hints for how traditional financing activities can be changed and how decentralized economies can work, thus requiring serious discussions of present business leaders, innovators, and regulators.

Decentralized Applications (Dapps)

Dapps are services running on blockchain and are decentralized applications. Applications range from finance, banking, e-commerce, social networks, file sharing, property sharing, among others (Agyepong, 2016; Guo & Liang, 2016; Peters & Panayi, 2016), which normally have respective counterparts in traditional centralized cyberspaces.

As innovations based on this blockchain technology are created, these Dapps demonstrate the enormous business potential in a much wider scope beyond that of the financial industry. Many startups are providing innovative Dapps solutions to disrupt the established business models and traditional business processes (Raval, 2016).

Dapps can also be designed to revolutionize sharing economical models (Puschmann & Alt, 2016) by merging blockchain with the IoT (Huckle, Bhattacharya, White, & Beloff, 2016).

Decentralized Autonomous Organizations (DAOs)

DAOs allow multiple parties to reach an agreement on internal structures, rules, and collective missions. The authority of the agreement can be enforced by internal organization constitutions and external laws.

Traditionally, it is difficult to build temporary, geographically distributed organizations. Powered by blockchain, the whole life cycle of an organization can be implemented as multi-party smart contracts. DAOs are innovative for societal issues by redefining and reconstructing the mechanisms of an organization.

DAOs are open-sourced, transparent, run in an automated environment by codes without controls from dominating centers, and thus the collective intelligence can be utilized and maximized into actions which are free of trust issues. Blockchain-based DAOs also provide trust and identity for sharing economically-based applications (Jarvenpaa & Teigland, 2017; Puschmann & Alt, 2016).

Decentralized Autonomous Corporation (DAC)
For-profit organizations, especially those business orientated commercial corporations can be reinvented as Decentralized Autonomous Corporation, or DAC, on the blockchain. The essentials of corporation governance and operations can be fully programmed in contracts deployed on blockchain with a full set of functionalities and capabilities in order to conduct business with external entities.

The DACs are natural alternative business forms for people to conduct pure global or semi-business activities with self-defined corporation constitutions and autonomous business processing, while remaining free from bureaucratic costs. With the emerging of DAC, there is a lack of legal regulations for DACs. This remains a challenge for the blockchain community, government, and lawmakers.

Decentralized Autonomous Society (DAS)
DAS is a collection of entities connecting and interacting with each other in order to exchange resources within certain structures. Since the individual entities are based on blockchain, they are autonomously running as sets of smart contracts in a manner of decentralization, and without human interference.

This is not an updated highly autonomous system built today to speed up processes, but rather a massive and pervasive DAO and DAC that will define a fundamentally completely new DAS.

Automatic Markets (AM)
AM are the future driving forces through which resources can be allocated. Trades among DAOs and DACs can create an AM in which ownerships are exchanged and resources are consumed. For instance, and in relation to smart properties, the underlying resources encoded as smart properties can be rights, options, and utilities, as well as physical or non-tangible goods.

A trade in an automatic market is realized once a smart contract is satisfied with preset conditions. The signals can be outcomes of other smart contracts, output of legendary systems, as well as real-time data from machine networks or the Internet of Things (IoT). With emerging DAOs and DACs, automatic markets are inevitably bringing new business models and impacts to the traditional centralized economy paradigms.

4. PUBLIC, CONSORTIUM, AND PRIVATE BLOCKCHAIN

When designing a blockchain powered system, it is important to choose the right blockchain solution. In terms of permission and accessibility, it is possible to deploy the system over either a public chain, private chain, or a consortium chain.

Public Blockchain
The underlying blockchain of bitcoin is a typical public blockchain with equal accessibility for all participants. The identical version of blocks is stored in a distributive manner, crossing all nodes and not relying on specific nodes. The nodes are free to leave or join anytime without significant impacts on the running performance of the blockchain. The information stored on public blockchains are transparent without geographic or organizational restrictions.

Private Blockchain
Opposite to public blockchains, private blockchains are ledgers running in a closed environment and usually within an organization. Private blockchains are only transparent for permitted participants according to access controls.

The whole computation facilities and software is owned by organizations, providing an isolated and secure blockchain infrastructure that is built to support advanced applications. Since the blockchain is restricted to an organization, the data shared in the blockchain is suitable for sensitive data.

Consortium Blockchains
Consortium blockchain offers limited accessibility to selected organizations that are identified as consortiums. Consortium blockchain is maintained and accessible by participants within the consortium with possible controlled accessibility to outsiders.

	Public	Consortium	Private
Permission	Permissionless	Permitted	Permitted
Identity	Pseudonymous	Non anonymous	Non anonymous
Data confidentiality	Low	High	High
Nodes ownership	All	Members	Organization
Governance	Decentralized	Decentralized	Centralized
Maintenance	free	Shared by participants	Organization
Mining cryptocurrency	Bitcoin	Not necessary	Not necessary
Efficiency	Low	High	High
Use scenario	Public	Organizational collaboration	Internal process
Example	Bitcoin	Bank clearing services	City e-government

Table 1. Comparisons of public, consortium, and private blockchains

In Table 1, comparisons of public, consortium, and private blockchains are presented. The differences among these three kinds of blockchains require decision makers to decide which type of blockchain is suitable for their business models.

For private blockchains and consortium blockchains, the blockchain infrastructures are owned and controlled by pre-selected participants within in a single organization or organizations in the consortium, however, on the contrary, public blockchains are fully open for anyone and not owned by specific participants.

This difference of ownerships brings misunderstandings of believing the private or consortium blockchains are compromised blockchains, for the centralization of ownerships and controls which is against the nature of the decentralization of blockchain. However, this misunderstanding is rooted in the misinterpretation of meaning of decentralization which is more about the decentralized transaction processing rather than the technology implementation.

In other words, the private and consortium blockchains are still decentralized ledgers. This is from the nature of decentralized transactions processing and how data is shared. The decentralization of underlying blockchain infrastructure is not a necessary and certain full or semi control of accessibility are necessary and indispensable for some scenarios.

5. SOCIAL PERSPECTIVE OF BLOCKCHAIN

Blockchain technology and innovative applications are pushing their way into many domains of human society with promising benefits. Before its full implementation into governments, businesses, and societies where individuals are relying on systems, applications, infrastructures, and algorithms powered by blockchain, it is important to study the impacts and implications related to both positive and negative consequences.

As a decentralized public ledger, the trust in an untrusted environment is achieved by algorithms running on machines without relying on human judgements. This machine trust can avoid any human or organization errors as well as malicious damages.

Additionally, this revolution is a strong advancement for human society which has been suffering the high costs and inconveniences of maintaining and ensuring hierarchic management structures that only provided authoritative trust systems. Now, due to the adoption of blockchain, current trust systems can be partially or entirely replaced by algorithmic ensured trust systems.

For example, by analyzing the functions of a cryptocurrency based monetary system, it can provide the monetary authority and work as the clearinghouse, while needs outside solutions for resort lender (Guo & Liang, 2016; Hayes, 2016; Peters & Panayi, 2016). Thus, a technocracy requires no human interventions and can be free of human weakness, frailties, and limitations.

Intelligent process automation

Intelligent process automation in relation to blockchain, allows for transactions and verification of digital assets which can be automatically processed by smart contracts and other decentralized applications.
This advantage can save time and cost for service providers and consumers as well as provide more efficiencies. A highly automatic environment can free employees from repetitive procedures and allow them to participate in more creative and fulfilling activities.

However, the automation process can also bring changes to job positions and responsibilities. Though the overall effects may appear positive and tempting and the changes also appear unstoppable, there are certainly challenges that exist.

6. CONCEPTUAL LEVELS OF BLOCKCHAIN

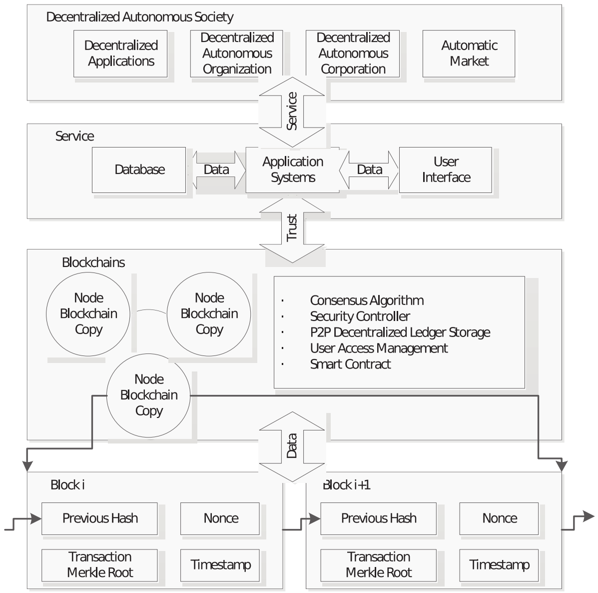

Figure 1. Framework of Blockchain Level

To summarize the above discussions of blockchain conceptions, we propose a four level conceptional framework.

In Figure 1, we illustrate the conceptional framework of blockchain in different levels from an underlying block structure to the decentralized autonomous society: (1) In the block level, blocks are chained in chronicle order with data of the previous block hash, the Merkle root of transactions, times- tamp, and the mining nonce. (2) In the blockchain level, the whole blockchain is verified by independent computing nodes providing consensus, security, ledger storage, access control, and the running environment of smart contracts. (3) In the service level, blockchain and a traditional database is integrated into application systems with user interfaces to provide services of certain functionalities. (4) All blockchain services then form the background to support the decentralized autonomous society level in which decentralized applications, organizations, corporations, and markets are gathered with unprecedented business, management, organizational, and social values.

7. CONCLUSIONS AND FUTURE RESEARCH

This research presents the conceptualization of blockchain-based applications from the Information Systems perspective. Based on the conceptional framework we proposed, there are many questions that remain unanswered. Based on the proposed conceptual levels of blockchain, we further plan to provide a systematic mapping and provide several potential research questions for IS researchers in the future.

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