
Blockchain in Accounting: Challenges and Future Prospects

Asif Iqbal Baba*, Subash Neupane, Fan Wu

Department of Computer Science,
Tuskegee University,
Tuskegee, AL, USA
E-mail: {ababa, sneupane2127, fwu}@tuskegee.edu
*Corresponding author

Fanta F. Yaroh

KPMG LLP,
Atlanta, Georgia,
USA
E-mail: fyaroh@kpmg.com

Abstract:

Blockchain technology has the potential to disrupt the existing business models in virtually every sector, including finance, legal, manufacturing, healthcare, government, supply chain, insurance, tourism, agriculture, etc. Because of a myriad of benefits surrounding this technology such as decentralization, persistency, anonymity, and auditability - every business wants to adopt the technology. Although this technology can be applied to any sector, it is fundamentally considered as accounting technology. It can improve efficiency and significantly change the face of traditional accounting and bookkeeping processes. The accounting systems of the present are still in their digital infancy in comparison to other industries, largely due to the exceptionally high regulatory requirements concerning the validity and integrity of data. In this paper, we give the blockchain taxonomy, introduce typical blockchain consensus algorithms, discuss smart contracts, and analyze how features like transaction immutability, distributed ledgers, consensus, etc., of this technology, will empower the accounting profession and expand the scope of accounting professional. More importantly, we will discuss the impact of blockchain technology on the accounting profession. Since the technology itself is in its early stages, there are, however, some technical and regulatory concerns, which we will discuss in this paper and indicate the directions for the future of blockchain-based accounting.

Keywords: Blockchain, Blockchain Architecture, Accounting, Decentralization, Distributed Ledgers.

Biographical notes: Asif Iqbal Baba has received his PhD in Computer Science at Aalborg University, Denmark. Currently, he is Asst. Professor at Computer Science Department, Tuskegee University, USA. His research currently focuses on security and privacy issues in IoT, Indoor tracking and navigation, and Big Data management. He published several peer reviewed papers in prestigious journals/conferences such as ACM SIGMOD, ACM SIGSPATIAL, ACM SIGCSE, IEEE MDM, WirelessDays, Elsevier, InderScience and IGI.

Subash Neupane is a graduate research assistant at Tuskegee University, Alabama, USA. He is currently pursuing his master's degree in Information Systems Security Management. Before joining Tuskegee, he worked at Tandem Corp, Mulgrave, Victoria, Australia in the capacity of Telecom Network Engineer. He has more than 7 years of experience in the IT industry.

Fanta Yaroh is a senior Auditor Associate at KPMG US. She completed her Masters in Information Science and Security Management from the Department of Computer Science, Tuskegee University, USA. She received her Bachelors in Accounting from the Collage of Business and Information Science, Tuskegee University, USA. She has been work in financial industry form several years now.

Fan Wu received his Ph.D. degree in Computer Science from Worcester Polytechnic Institute (WPI) in 2008. He is a professor of Computer Science and the Director of Tuskegee University Center of Academic Excellence in Information Assurance Education. His teaching and research interests lie in primarily in the area of Information Assurance, Software Security, Mobile Security, High Performance Computing and Artificial Intelligence. He has led several cybersecurity related projects funded by NSF, DHS, and DoD. He has served as the associate editor of the International Journal of Mobile Devices, Wearable Technology, and Flexible Electronics (IJMDWTFE).

1 Introduction

Recently blockchain technology has received global recognition across the industries and is seen as a technology that could potentially revolutionize businesses. However, most people heard about blockchain technology probably in the context of cryptocurrencies like Bitcoin and Ethereum (Alladi et al. 2019). The momentum is slowly but surely shifting towards building practical business applications. Besides, the landscape is changing rapidly as blockchain is used in many industries including finance, telecom, healthcare, supply-chain, insurance, education (Meng et al. 2018), technology, and government (Casino et al. 2019). While the technology is novel many stakeholders have come to the forefront offering a blockchain platform. The most recent and prominent industry to engage in the blockchain domain is Google (Johnson 2020).

In a 2019 survey on the blockchain, Deloitte, one of the world's leading financial companies, polled over 1000 senior executives of the companies across seven different countries (Delliott Insights 2019). Over 70% of those senior executives mentioned that they already see a business case in their organizations where blockchain can be used. Some of them have already moved forward with the use of technology. About a third of responding executives (34%) say their company already has some production blockchain system. In contrast, another 41% of respondents say they expect their organizations to deploy a blockchain application within the next 12 months. Moreover, nearly 40% of respondents reported that their organization would invest \$5 million or more in blockchain technology in the coming year. The report also states that 53% of respondents went on to say blockchain technology has become a key priority for their institutions in 2019, a 10-point surge over their 2018 survey.

Blockchain, at its core, is a complex, distributed ledger system. The ledger contains connected blocks of transactions for all the participants of the network. Network participants manage and approve transaction updates through a sophisticated consensus protocol. This ensures that a single, agreed version of the transactional record spreads to all network users as part of a permanent record, even without a central authority or a brokerage, such as the financial institution or clearinghouse (Sloane and Bhargav 2016). This mechanism generates an impression of ‘universal entry bookkeeping’, where a single entry is shared identically and permanently with every participant (ICAEW 2017). Substantial use of cryptography has become a critical feature of blockchain networks, which brings trustworthiness behind all network interactions. While the smart contract, a self-executing script that resides on the blockchain, integrates these concepts and allows for accurate, distributed, programmed workflows (Konstantinos and Micheal 2016).

In this paper, we examined how this emerging technology could transform accounting and create value for the industry. With the advent of technology, automating business processes is in high demand. In the context of the accounting profession, blockchain can further enhance this industry by reducing the costs of maintaining and reconciling ledgers and providing absolute certainty over the ownership and history of assets. For example, for auditing, blockchain presents one of the greatest opportunities by harnessing big data to make audits more insightful, faster, and efficient.

Some of the key benefits that blockchain brings to accounting are: **Efficiency:** With blockchain pushing data into and out of the system will be much faster than traditional accounting software. **Reliability:** With the automation of transactions, forming a chain, smart accounting function will drastically reduce human error. **Cost-effectiveness:** Improved efficiency and error reduction with consequently reduce the cost. Firms will have to bear a cost upfront for initial adoption. **Fraud reduction:** With blockchain implementation, it is difficult to manipulate the records. Since blockchain is a distributed ledger, making a chain to record means the same change needs to be made on all the copies, which is almost impossible to do simultaneously.

The rest of this paper is organized as follows. Section 2 reviews the background of blockchain. Section 3 describes the blockchain architecture. Section 4 details the impact of blockchain in accounting. Section 5 discusses the challenges blockchain is posing. Future directions are given in Section 6. Finally, Section 7 concludes the paper.

Recently blockchain technology has received global recognition across the industries and is seen as a technology that could potentially revolutionize businesses. However, most people heard about blockchain technology probably in the context of cryptocurrencies like Bitcoin and Ethereum (Alladi et al. 2019). The momentum is slowly but surely shifting towards building practical business applications. Besides, the landscape is changing rapidly as blockchain is used in the finance sector and in telecoms, healthcare, the supply chain, insurance, technology, and government (Casino et al. 2019). While the technology is novel many stakeholders have come to the forefront offering a blockchain platform. The most recent and prominent industry to engage in the blockchain domain is Google (Johnson 2020).

In a 2019 survey on the blockchain, Deloitte, one of the world’s leading financial companies, polled over 1000 senior executives of the companies across seven different countries (Delliott Insights 2019). Over 70% of those senior executives mentioned that they already see a business case in their organizations where blockchain can be used. Some of them have already moved forward with the use of technology. About a third of responding executives (34%) say their company already has some production blockchain

system. In contrast, another 41% of respondents say they expect their organizations to deploy a blockchain application within the next 12 months. Moreover, nearly 40% of respondents reported that their organization would invest \$5 million or more in blockchain technology in the coming year. The report also states that 53% of respondents went on to say blockchain technology has become a key priority for their institutions in 2019, a 10-point surge over their 2018 survey.

Blockchain, at its core, is a complex, distributed ledger system. The ledger contains connected blocks of transactions for all the participants of the network. Network participants manage and approve transaction updates through a sophisticated consensus protocol. This ensures that a single, agreed version of the transactional record spreads to all network users as part of a permanent record, even without a central authority or a brokerage, such as the financial institution or clearinghouse (Sloane and Bhargav 2016). This mechanism generates an impression of ‘universal entry bookkeeping’, where a single entry is shared identically and permanently with every participant (ICAEW 2017). Substantial use of cryptography has become a critical feature of blockchain networks, which brings trustworthiness behind all network interactions. While the smart contract- a self-executing script that resides on the blockchain, integrates these concepts and allows for accurate, distributed, programmed workflows (Konstantinos and Micheal 2016).

In this paper, we examined how this emerging technology could transform accounting and create value for the industry. With the advent of technology, automating business processes is in high demand. In the context of the accounting profession, blockchain can further enhance this industry by reducing the costs of maintaining and reconciling ledgers and providing absolute certainty over the ownership and history of assets. For example, for auditing, blockchain presents one of the greatest opportunities by harnessing big data to make audits more insightful, faster, and efficient.

Some of the key benefits that blockchain brings to accounting are: **Efficiency:** With blockchain pushing data into and out of the system will be much faster than traditional accounting software. **Reliability:** With the automation of transactions, forming a chain, smart accounting function will drastically reduce human error. **Cost-effectiveness:** Improved efficiency and error reduction with consequently reduce the cost. Firms will have to bear a cost upfront for initial adoption. **Fraud reduction:** With blockchain implementation, it is difficult to manipulate the records. Since blockchain is a distributed ledger, making a chain to record means the same change needs to be made on all the copies, which is almost impossible to do simultaneously.

The rest of this paper is organized as follows. Section 2 reviews the background of blockchain. Section 3 describes the blockchain architecture. Section 4 details the impact of blockchain in accounting. Section 5 discusses the challenges blockchain is posing. Future directions are given in Section 6. Finally, Section 7 concludes the paper.

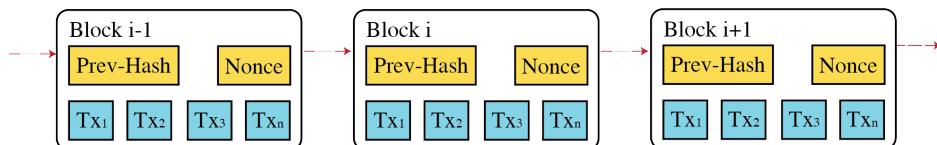


Figure 1 A Blockchain snippet

2 Background

Blockchain technology's existence goes back to 2008 and has recently taken the industries by storm. Many industries have started to implement blockchain solutions in some of their business cases. The first blockchain technology was founded shortly after the US financial collapse in 2008. Satoshi Nakamoto in 2008 introduced Bitcoin (Nakamoto 2008). Bitcoin is a cryptocurrency that uses traditional cryptography to manage the production and transfer of money. It uses a peer-to-peer (P2P) Bitcoin network to send decentralized digital currency from one user to another.

Blockchain can be visualized as an open book that contains a record of all the exchanges and interactions between users that took place through it. It consists of a peer-to-peer network and a decentralized distributed database (Khan 2017). There is no central authority to supervise the blockchain ledger. In other words, blockchain is simply a chain of blocks, each block is made of a header and body. It exists on a P2P network where every node stores a local copy of the public ledger. Each record in the ledger is called a block and includes details such as the transaction timestamp, hash pointer to its previous block, as shown in Figure 1. The hash pointer makes it impractical for anyone to change information about the transactions retrospectively. Also, the technology is safe by design, as the database system of multiple nodes records the same transaction. In this manner, the information can never be altered or erased. Blockchain systems are categorized into three types, private, public, and consortium blockchain (Zheng et al. 2018). The comparisons between three kinds of blockchain systems based on different features are listed in Table 1.

Feature	Private Blockchain	Public Blockchain	Consortium Blockchain
Access	Private	Public	Private/Public
Consensus	Organization Based	Public	Selected Nodes
Efficiency	High	Low	High
Centralization	Yes	No	Partial
Consensus Process	Permission-based	Permission Less	Permission-based
Immutability	Not completely tamper-proof	Completely tamper-proof	Not completely tamper-proof

Table 1 Comparison between private, public, and consortium blockchain.

Bitcoin was the first real-life blockchain application (Peck 2017). Bitcoin can solve the problem of “double spending” in the traditional payment method without a trusted third party's aid. Usually, when people make payments, a trusted third party is involved in verifying the transaction's validity before putting them into action. For example, to complete an electronic transaction, there must be a way to validate the funds transmitted have not been already spent. Conventionally, this problem is solved by using trusted third parties like

Propay, Paypal, and Venmo, which verifies and validates each transaction and maintains a public ledger of the user's transaction to prevent double-spending (Pacy 2014).

However, it is the third party that is mostly in doubt as to whether it could be exploited to commit fraud (The Economist 2015). The problem comes from formal centralization, in which everything depends on a single organization, causing the trust to be insufficient. Bitcoin offers a different solution to this problem, using cryptographic proof instead of trust. To create and maintain the public ledger, known as the blockchain, bitcoin relies on a peer-to-peer network and decentralized distributed database. This is in contrast to a centralized database that is in use presently. Each transaction contains two public keys- one each from the sender and receiver- proving that the funds were transferred. Both parties have to sign the transaction with their private key, and the transaction is recorded in the block. The block is then verified by the network before adding to the blockchain (Pacy 2014).

Several business houses, including brick and mortar stores, recently began accepting Bitcoin as payment. Some of the well-known Bitcoin acceptors are Microsoft, Subway, Overstock.com, Expedia, and Newegg. People used Bitcoins to buy drinks at pubs, cars from the dealerships, even as real estate payments (Beigel 2020). Since 2009, many Bitcoin variants have been introduced, including Ethereum, Bitcoin Cash, Ripple, and many others. As a currency, Ethereum features smart contracts, also known as Ether. It enables users to publish censor-secure software programs that can be operated infinitely in the absence of its creator. Together with the smart contract, Ethereum proved to the world that blockchain technology could be a viable option to many real-world situations other than being an alternative to the conventional financial system. Not only has this technology been implemented in sectors including consumer products, finance, manufacturing, media, telecommunications, but also in healthcare, travel, and government since 2014. IBM has teamed up with the Linux Foundation on the Hyperledger project, which is developing an open-source, standardized, and production-grade digital ledger.

3 Blockchain Architecture

A blockchain is composed of a network of nodes and databases. Its database is distributed and follows an append-only notion. In the high-level blockchain architecture is divided into six different layers, including, data layer, network layer, consensus layer, contract layer, service layer, and application layer as illustrated in Figure 2 (Lu 2018).

Data and network layers are bottom-most, and these lower layers are responsible for generating, validating, and saving data and information. The consensus layer includes consensus mechanisms such as Proof of Work (PoW), Stake Proof (PoS), and Delegated Proof of Stake(DPoS), and Practical Byzantine Fault Tolerance (PBFT), which helps the interconnected nodes to reach consensus. This layer also functions as a bridge between the lower and upper layers. Similarly, the contract layer includes smart contracts (a set of a predefined set of rules), control logic, consensus protocols, and incentive mechanisms. The top-most layer is the application layer, which mainly covers applications and services (Khan et al. 2020).

3.1 Data layer

The data layer includes various elements, for instance, data block, chain structure, timestamp, digital signature, hash function, and Merkle tree.

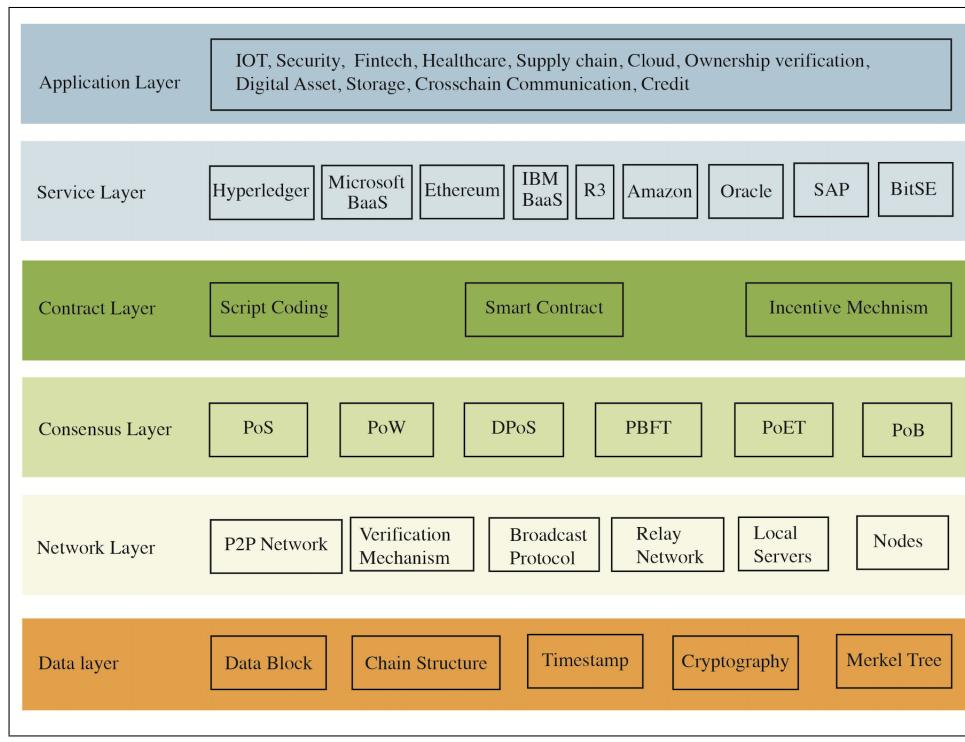


Figure 2 Blockchain Architecture

Data Block: It is used for the recording of interactive data and information. In the blockchain ecosystem, the raw data at the bottom level has to be further processed for storage in the block. A block contains a block header as well as the block data. The block header contains metadata for this block as shown in Figure 3.

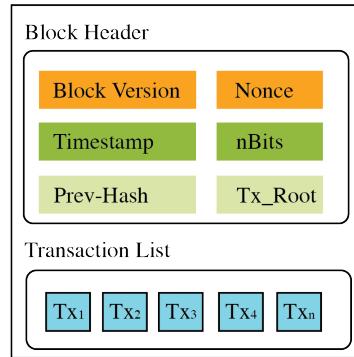


Figure 3 Block Header

Chain Structure: The name is derived from the structure of each record, called blocks, which is linked to a single list, known as a chain (Christensson 2018). A block contains

the header of the block and the body of the block. The header is made up of several other components, while the body of the block has a transaction counter that records every transaction. As blocks are added to the list it forms a sequential chain-like structure as depicted in Figure 4.

1. **Block version:** Specifies which set of rules to follow for block validation.
2. **Merkle tree root hash:** The hash value of every block transaction. is also known as the Tx_Root. It includes the hash value of all validated transactions of the block. As illustrated from the example in Fig. 4, all the transactions are hashed into a hash value; then, they combine pair-by-pair and are inputted to another hash function. This work is repeated until there is only one single entity, which stands for the Merkle root.
3. **Timestamp:** Time in seconds between the current time and the Unix Epoch, that started on Jan 1, 1970. It refers to the time when the block was found.
4. **nBits:** The target threshold for a valid block hash.
5. **Nonce:** A field of 4 bytes usually starting at 0 and increasing with any calculation of the hash. This field is used in PoW, which demonstrates the efforts made by a node to obtain the right to append its block to the chain.
6. **Parent block hash:** A 256-bit hash, pointing to the previous block.

A mathematical algorithm is used to map the data in the block to a fixed-length binary digit string known as the cryptographic hash. For integrity and event order, blockchain uses the SHA-2 hash function. SHA-256 and SHA-512, are the most commonly used versions for hashing. SHA-256 algorithm produces a 256-bit cryptographic hash.

The first block of the blockchain is called a genesis block. The blockchain is envisioned as a vertical stack, and the blocks are stacked on top of one another, with the genesis block being the base of the stack. The block body is composed of a transaction counter and transactions. The maximum number of transactions that a block can contain depends on the block size and the size of each transaction (Zheng et al. 2017). Blockchain uses asymmetric encryption and hashing algorithms to verify the untrusted network and ensure security in such networks (Lu 2018).

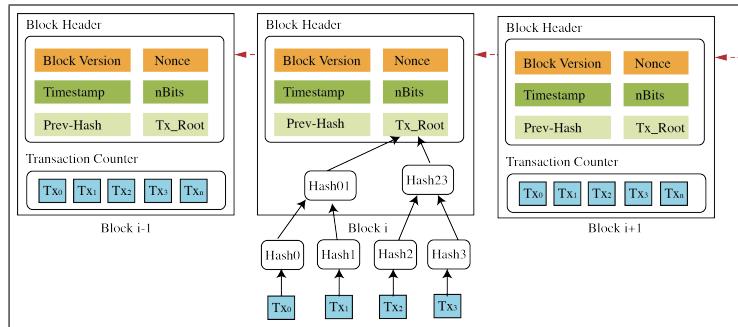


Figure 4 An example of a sequential chain of blocks in the blockchain.

3.2 Network Layer

Blockchain nodes are interconnected by a peer-to-peer network. P2P network is an overlay network built up over the Internet. The P2P blockchain can be modeled as structured, unstructured, or hybrid depending on the type of blockchain and its parameter. However, a synchronization protocol is needed to publish a newly created block in the chain, but routing protocol may or may not be needed. For example, Bitcoin does not require a routing protocol, as a peer can receive information at most in one hop in the network (Raikwar et al. 2019). A broadcast protocol is needed to broadcast two types of information: information about interactions and information about blocks. Unlike bitcoin, which uses unstructured P2P networks, Fintech companies should adopt the use of structured P2P networks. Using a structured network will enable companies to locate resources easily as each node has an identifier with the routing table.

3.3 Consensus Layer

Adversaries can act maliciously in many ways in an open, trustless, and distributed network. Bitcoin uses the Proof-of-Work (PoW) protocol to reach consensus, which requires a node to try and solve a hard-computational problem to validate a batch of transactions and add them to the blockchain as a new block. Many variants of proof-based consensus algorithms have been proposed, which are based on PoW, Proof of Stake (PoS), and their hybrid form. The other variants that are made independently from PoW and PoS are shown in Figure 5. The basic concept of the proof-based consensus algorithm is that the node that performs sufficient proof will get the right to add a new block to the chain and receive the reward among many nodes that join the network. We have opted to define the PoW consensus algorithm in this paper as it is the most commonly used at present.

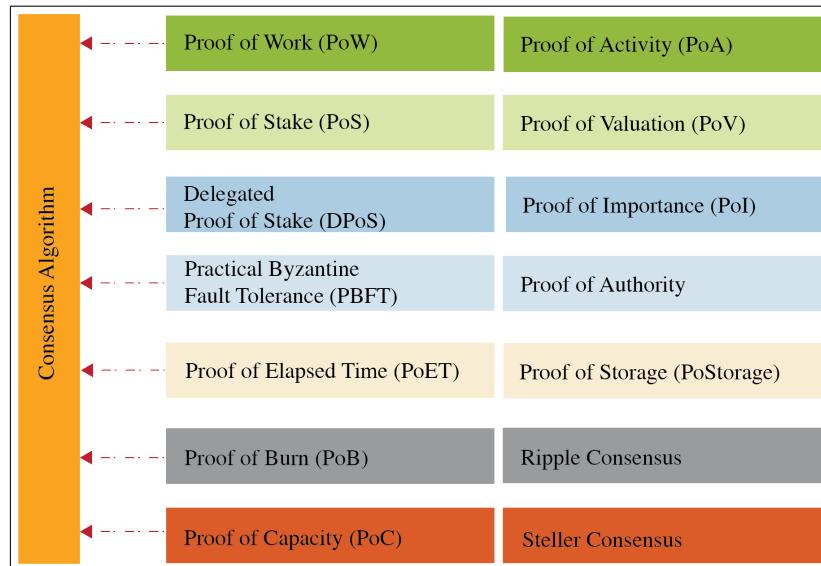


Figure 5 Consensus Algorithms

3.3.1 PoW-based consensus algorithm

Each node needs to show a certain amount of work done, also known PoW to add new blocks to the blockchain. In the blockchain network, if every node tries to broadcast their blocks containing the verified transactions, a possible ambiguity is created. For instance, if a transaction is verified by several nodes, placed in their blocks, and then transmitted to other nodes, this transaction may be duplicated into different blocks, then the ledger becomes meaningless. The participating nodes would have to put their verified transactions, as well as other information like Prev_Hash and Timestamp, into a block before they start solving the puzzle. The puzzle (secret value) is a nonce field that is put back into the block after the node successfully finds it. After this, all the information inside the block header will be combined and inputted into an SHA256 hash function. The secret value is accepted if the output is below the given threshold T , designated by the difficulty; otherwise, the nodes will still need to devise the secret value (Nguyen *et al.* 2018). For Bitcoin, the node must consider a hash value that is less than a certain number, often referred to as the network's fixed level of difficulty. The degree of complexity is automatically determined by the Bitcoin algorithm, which means that a new block is generated every 10 minutes. The process of solving the PoW puzzle to find a winning hash value is called mining. The first node to find a winning hash adds the block to the blockchain and claims the mining reward as well (Baliga 2017). When a node solves the problem, it broadcasts its proposed block with this value to other nodes to notify them that the problem has been solved. Right after that, all the miners receiving this message, who still have not resolved the problem, will stop solving. Instead, they start checking the validity of the broadcasted block. The validity is checked by comparing the hash value of the previous block. This ensures integrity in the chain. Once validated by every node in the network, the proposed block is finally appended to the chain. This process repeats over and over again. Given that this process is distributed and concurrent, several nodes can find a winning hash at the same time. The winning nodes typically add their block and broadcast it to the blockchain via a peer-to-peer network. In this case, there is a temporary fork, as shown in Figure 6, the chain is branched out, and new blocks are added to different branches. The miners will continue mining new blocks to the forked branch, but the protocol will ensure that the longest branch with PoW will be included in the chain while shorter ones are discarded subsequently. This ensures coherence between all the nodes regarding the state of chain (Baliga 2017).

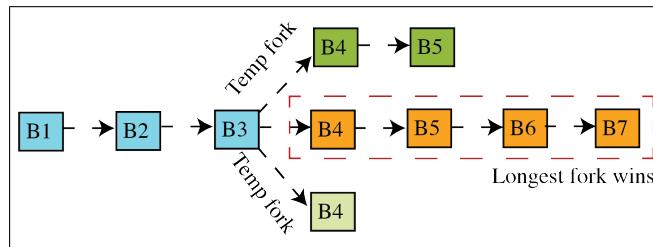


Figure 6 Forking Problem

3.4 Contract Layer

The contract layer contains multiple script codes and algorithms that are required for blockchain operations and smart contracts. The contract layer is a rule-based protocol that

has been developed to allow flexible programming and operational data functions (Puthal et al. 2018).

3.4.1 Smart Contracts

In the blockchain context, smart contracts are much more comprehensive than traditional transactions to buy and sell. Apart from the purchase and sale, they may have extensive sets of instructions integrated into them. A contract is a more formal way of using Bitcoin for concluding agreements with individuals through blockchain. A traditional contract is a deal between two or more parties to do something or not in exchange for something. Each party must have confidence in each-other to meet their side of the obligation for the exchange. Smart contracts have the same sort of agreement to act or not to act, but they eliminate the need for one kind of trust between the parties in an agreement. This is because the smart contracts are both defined and executed by the code automatically at no discretion. Three elements of smart contracts that make them distinct are autonomy, self-sufficiency, and decentralization (Swan 2015).

The decentralized blockchain ensures that honest parties obtain adequate compensation in case of contractual breaches or abortions. There is, however, a lack of transactional privacy in existing systems. Every transaction in the blockchain is exposed, which includes cash flow between aliases and amounts transacted (Kosba et al. 2016). A solution to transactional privacy for accounting firms is to adopt a private smart contract that does not store transactional details in plain text on the blockchain rather applies a cryptographic solution to parties in a contract.

3.5 Service Layer

The service layer is a mixture of computational resources and lower-level data that provides services for top-level specific application services (Gupta et al. 2018). Companies build a service platform independently. Some of the examples of a blockchain platform developed by companies today include IBM Azure BaaS, Ethereum, and Hyperledger (Castillo 2020).

3.6 Application Layer

The application deals with how blockchain can be used across different platforms. Some of the blockchain's use cases include accounting, supply-chain, medical care, insurance, government, cloud services, etc.

4 The Impact of Accounting

Blockchain technology has the potential to impact a wide range of industries. It is expected that blockchain will improve collaboration among businesses, the transparency of business processes, and, ultimately, the productivity and sustainability of the economy. Blockchain works even better with applications which involve the transfer of value and asset between parties. At present, such transfers in businesses are cumbersome, costly, and take one or more centralized organizations. For example, securities settlement generally includes multi-day clearing and settlement processes between several financial intermediaries. Some financial services specialists believe that the financial services industry is on the brink of disruption: advances in emerging technology like blockchain are projected to transform the industry

and its workforce by automating many of the activities currently performed by humans (Bible et al. 2017).

Blockchain can be viewed as accounting technology. It is concerned with the transfer of ownership of assets and maintaining a ledger of accurate financial information. The accounting profession is largely concerned with the measurement, communication, and analysis of financial information. Most professionals work to ascertain or measure property rights and obligations or to plan the best allocation of financial resources. For accountants, the use of blockchain brings transparency about ownership of property and bonds. By knowing obligations and transparency in transactions, an employee can function better and become more productive. This will dramatically improve work efficiency in turn. Blockchain has the potential to enhance the accounting profession by reducing the costs of maintaining and reconciling ledgers and providing absolute certainty over the ownership and history of assets (ICAEW 2017).

To understand how blockchain can be beneficial to traditional bookkeeping systems, we need to understand how transactions are entered and kept by business organizations in the past and present. Three important methods of bookkeeping are discussed below to showcase how accounting information is stored, verified, reconciled, and audited.

1. **Single Entry System:** In single-entry bookkeeping each business transaction is recorded in only one account. Although this mechanism is fast and simple, it was fraught with errors, be it accidental or fraudulent. Errors and frauds are common in this method of bookkeeping because of the absence of cross verification (Grigg 2005).

2. **Double Entry System:**

To address the issue of inaccuracies and errors about single-entry bookkeeping systems, accounting today is based on double-entry systems. At least two accounting entries are required for recording and documenting each financial transaction in the double-entry accounting system. Such entries may be in the account of assets, liabilities, equity, expenditures, or profits. A debit amount for one or more accounts and a credit equal for one or more accounts results in total credits equal to all accounts in the general ledger. In case of an error-free recording of accounts, the total balance of all accounts with debit balances equals the aggregate balance of all accounts with a credit balance. Debit and credit accounts accounting entries normally have the same date and identification code in the two accounts so that every debit and credit can be traced to the journal and the transaction source and thereby establish an audit trail in the event of an error. These accounting entries are then entered in the journal. The basic accounting equation of Assets equal Liabilities plus Capital would hold regardless of which accounts and how many are affected by a given transaction. Public auditors often check and validate the financial details of the company to gain the trust of outsiders. This is a costly and rigorous process that will not only bind the human resources (accountants, bookkeepers, and financial officers) of the company but also take away their precious time to help auditors (Inghirami 2020). Grigg, in his paper on 'Triple Entry Accounting' (Grigg 2005) argues that "It adds an important property to the accounting system; that of a clear strategy to identify errors and to remove them. Even better, it has a side effect of clearly firewalls errors as either accident or fraud". This method may minimize human documentation errors and inconsistencies but may not provide full assurance of the financial statement of the company.

3. **Triple Entry System:** To enhance the reliability of corporate financial statements, this bookkeeping system has been suggested as an independent and safe paradigm. This method requires a neutral third party to oversee and record each accounting transaction meaning three entries were created, two entries were recorded by transacting parties, and third entry was recorded by an intermediary. However, there are concerns regarding the use of third parties as they are vulnerable to cyberattacks. The next step in the accounting process may be Blockchain Technology: rather than holding independent documents based on transaction receipts, businesses may write their transactions directly into a joint ledger and establish a continuously interlocking accounting system. Because all the entries are circulated and encrypted, it is almost impossible to forge or delete them or cover up activity. With blockchain's advent, processes can become automated, cheap, and even more cost-effective. A decentralized ledger supersedes the need for third parties who keep receipts centrally. Also, smart contract technology could enable rapid verification of transaction records per accounting standards or business rules. Transparency of Blockchain gives visibility for all authorized user's transactions, which can minimize auditor's work with sampling and validating transactions. This allows auditors to focus more time on inspections and anomalies. Meanwhile, CPAs have the potential to leverage Blockchain technologies to apply their assurance offerings to the fields of cybersecurity and sustainability (Inghirami 2020).

Blockchain can transform the way financial records are created, maintained, and updated. Instead of one owner, blockchain records are distributed to all users. This can be viewed as a “**Universal Entry Bookkeeping**” where each participant has access to every entry. As discussed earlier, it uses a system of consensus and verification to ensure that a permanent record is transmitted to all users. Unlike traditional ledgers, which are database focused and run by a single centralized party, it is decentralized and offers a different perspective to data and transaction. For instance, decentralized consensus could eventually improve the employee's engagement in accounting issues and verification of company transactions, shifting to more diversified controls by blockchain-led transparency (Ruckeshauser 2017)

Another critical issue that the accounting industry is currently facing is financial transparency. There is very little or no financial transparency between the transacting parties at the moment. Also, the fact that current systems lack real-time data and information. This issue could be addressed through the use of blockchain. The most important features of blockchain are propagation, permanence, and programmability. Propagation is the access ability to an identical full copy of the transaction records to all participants. Permanence signifies that past transactions cannot be edited without the approval of the majority, which makes blockchain records permanent. Programmability allows program code to be stored with the ledger entries to create automatic journal entries, also known as smart contracts. Propagation and permanence are essential to the blockchain. Any application based on blockchain has these key characteristics.

Blockchain's distributed ledger for transactions can replace central authorities such as banks, clearinghouses, and lawyers. Also, the fact that parties can interact directly with one ledger, which means there is never a need for reconciliation; this in turn, could save money and time for a business. Moreover, tax authorities and regulators having access to blockchain could observe and monitor transactions in real-time, which will not only be cost-effective, but it will also increase the efficiency of regulatory and compliance activities. The permanent record of a blockchain reduces the risk of financial crime, which makes records trustworthy. The technology supports a fast clearing and settlement process. Once

a transaction is confirmed and submitted to the ledger, it also settled in the wallet. This fast settlement leads to cost reduction and lowers the risk of fraud. Blockchain protocol facilitates verification before each block is written to the ledger. Furthermore, it supports document retention. Any authorized participant can access and verify ownership records, including transaction information and procedures embedded in smart contracts. Blockchain also contains detailed information such as precise histories of asset movements and time stamping that can hugely benefit the auditing process. Another benefit is the operational improvements. Blockchain adoption can eliminate some middle and back-office processes, which include not only reconciliation, but it also aids in error correction and improve business.

To be effective, it is important to note that any accounting company which wishes to use technology blockchain needs to choose a private blockchain as its platform. Using private blockchain has various advantages over public blockchains. Any interested party may enter or leave the public blockchain network at any point that is undesirable in an accounting context. Another thing that accounting firms want to avoid is the transparency of financial and transactional records to the public (Appelbaum et al. 2018). The information is available for anyone interested, be it financial or transactional. It raises questions about the protection of privacy. To prevent this, accounting firms should consider using a private blockchain solution with shared access to agreed parties. The genius of a private blockchain is that it not only safeguards the confidentiality of the transaction among approved stakeholders but also limits who can join the network. Private Blockchain participants are granted specific network rights and restrictions so that someone has either full or limited access at the network's discretion. This feature of different levels of access rights provided to different users in private blockchain can be viewed as Role-Based Access Control (RBAC).

Thus, depending on the functionality of the organizer, the information types stored and circulated over the blockchain, and the different levels of access that different stakeholders need, private blockchains appear to be the most logical and business-friendly option for accounting firms (Intuit 2020).

4.1 How big four accounting firms use blockchain?

At this point, at least all big four accounting firms (Deloitte, Ernst Young, KPMG, and PwC) have shown some interest in blockchain, although they tend to differ in interest and approach. In this paper, we looked into the details of the blockchain adoption of each firm.

1. **Deloitte:** The earliest one to dive into the crypto space was among big four is Deloitte. Back in May 2016, they announced their first blockchain lab in Dublin, Ireland. It collaborated with the Bank of Ireland to conduct joint proof-of-concept based blockchain trial. Currently, three of the four largest banks in Ireland are reported to be using blockchain Deloitte's to verify the credentials of their employees (O'Neal 2019). They also launched Rubix, an enterprise blockchain in Toronto in 2014. Rubix offers advisory services and creates decentralized applications based on a blockchain platform for clients from different industries. It was initially catered to four specific types of applications: reconciliation, audits, land registry, and loyalty points (Vetter 2018)
2. **Ernst Young:** EY in Switzerland was the first of “big four” accounting firm to accept bitcoin for both auditing and advisory services. The firm introduced the EY Blockchain

Analyzer back in 2018, which has been developed utilizing experience gained from working with global clients in the US, Europe, and Japan. According to EY's press release (EY 2018) "EY Blockchain Analyzer is a suite of blockchain audit technologies that improve the ability to perform an in-depth review of cryptocurrency business transactions".

EY has been continuously developing blockchain based solutions. Some of the other blockchain applications created by EY include Nightfall, Dye Pack, and Smart Contract and Token Testing.

3. **KPMG:** Not only has PMG increased its presence in the blockchain space, but since 2017 it has also been part of the Wall Street Blockchain Alliance (WSBA) (Das 2017).

In 2016, KPMG launched a Digital Ledger Services Program to assist financial services companies to investigate blockchain. According to KPMG itself, the "Digital Ledger Services enable financial institutions to realize the potential of blockchain capabilities in the cloud, including faster and more secure transactions, streamlined and automated back-office operations, and reduced costs." KPMG also partnered with Microsoft Corp. to launch the "blockchain Nodes" initiative designed to create and identify new applications and use cases for blockchain technology. However, the latest survey by KPMG on blockchain showed that many tax and financial managers do not plan on blockchain technology adoption (Perez 2019).

4. **PwC:** PwC was the world's second largest accounting firms to accept bitcoin payments for its services in Hong Kong (Das 2017). The firm supported various blockchain projects and introduced a blockchain audit service that will encourage people to use the technology. According to the firm, the audit service needs an independent validation. The decentralized digital ledger can also be used for online identity verification, supply chain management, and auditing financial transactions, which is part of an auditor role. PwC also logs transactions on the blockchain and developed testing criteria and controls. Thus, users within a company can view, test, and monitor transactions on the blockchain in real-time.

PwC views blockchain as the software to structurally modify shared traditional practice between clients, competitors, and suppliers for the next-generation business process but also believes that development in blockchain solutions is not taking a rapid pace because of its regulatory uncertainty (PwC 2018).

4.2 Blockchain Adoption: Blockchain as a Service (BaaS)

"Blockchain as a Service (BaaS) is a type of blockchain service offering that allows business customers to use cloud-based solutions to develop, host, and adopt their blockchain applications, smart contracts, and other relevant functions on the blockchain while the cloud-based IT partner or service provider manages all the required tasks and activities to keep the infrastructure up and running" (Leewayhertz 2020).

Blockchain is becoming more and more accessible to businesses (small to large scale) because BaaS offerings like IBM's BaaS (Hyperledger) and Ethereum Enterprise Alliance (EEA) significantly reduce the cost and overheads of adoption. Essentially, BaaS involves a service provider that offers and manages various DLT infrastructure components.

IBM's BaaS is based on the open-source Hyperledger Fabric, version 1.0 from The Linux Foundation. It is a public cloud service that customers can use to build secure blockchain networks. EEA aims to build on and adapt Ethereum (which includes Ether, a token/bearer-asset) to address business needs such as permission management, whereas Hyperledger focuses on permissioned chains without a crypto-currency basis (tokens) (Singh et al, 2018). The precise nature of a BaaS deployment depends on embracing the company's end requirement, the service provider they choose, and application specifics. Today, many established tech giants such as Microsoft, IBM, Amazon, Oracle, and SAP offer BaaS. In this paper, we have compiled a list of some of the popular BaaS platforms based on the features such as major partners, major users, authentication and authorization, blockchain type, development facility, and scalability as illustrated in Table 2.

	Microsoft	Amazon	IBM	Oracle	SAP
Major Partner	Cords, Blockapps, GoChain, Consensys	Cisco, Intel, Corda, R3, Blockapps	SecureKey Technologies, Canadian banks	ICS FS, Vottum, myEtf, HACERA, Deloitte, Infosys	Intel, UPS, HPE and Airbus
Major User	Xbox, 3M	T-Mobile and Guide wire	Intelipost, Nigeria Customs	Circulor, SERES, and CDEL HealthSync	–
Authentication and Authorization	Active Directory	Identity and Access Management	IBM Secured Service Container	Identity Federation, OCI Identity Cloud Service	Service Key
Blockchain Type	Permissioned	Permissioned	Permissioned	Permissioned Consortium	Permissionless
Development Facility	High (with MS development kit)	Medium (limited only with AWS kit)	IBM mix development platform	Hyperledger Fabric SDK, Oracle Visual Builder Studio CS	Not released
Scalability	High (with all MS product)	Provide API for quick node creation	IBM Smart Cloud only	Dynamic scale-out and scale-up in the cloud and on-premise	–

Table 2 Comparison of BaaS Platform

5 Challenges

Blockchain technology aligns seamlessly with the accounting profession. It gives users the ability to create value and authenticate information quickly and precisely without the threat of being corrupted. Despite having many benefits and use cases, there are, however, some challenges and limitations. Some aspects of the technology may require further development to reach its full potential. In this paper, the challenges, both technical and business, are divided into five main categories as follows:

5.1 Scalability

Scalability is a characteristic of a system, model, or function that describes its capability to cope and perform well under an increased or expanding workload or scope. A system that scales well will be able to maintain its performance and efficiency even if it is tested by large and concurrent operational demands (Hayes 2020). In other words, it is defined as the capacity for a system to continue to function to its extent when the system considerably changes in volume or size-usually, to a larger volume or size. Scalability issues arise due to existing consensus methods and the size of the block where each node in the network sequentially authenticates the transaction before publishing it to the blockchain. This problem is compounded with the increasing number of transactions requiring more nodes to support the network, while at the same time increasing the number of steps for the transaction to travel and reaching full consensus with each node (Chauhan et al. 2018). Scalability has three major component **latency, size and storage, and throughput**.

5.1.1 Latency:

Latency in the blockchain domain is defined as the time required for a transaction to commit. Currently, blockchain has a significant latency as compared to other e-payments giants such as VISA and PayPal. At the moment, Bitcoin blockchain guarantees mere 4.6 transactions per second, whereas VISA and Paypal process around 1736 and 193 transactions per second (tps) on an average, respectively (Li 2019).

5.1.2 Size and Storage:

The challenge is also that transactions can produce large volumes of data, but the blockchain isn't sufficiently scalable to store big data. One of the characteristics of blockchain is decentralization, and this means that every single node on the network processes every transaction and maintains a copy of the entire state. The number of transactions it can process has a limit, and as more nodes are added to its network, the blockchain becomes weaker. Therefore, as the size of the blockchain grows, the requirements for storage increase.

5.1.3 Throughput:

As of today, the theoretical peak throughput of Bitcoin is about 7 transactions per second (Blockplain 2018). Blockchain consensus technologies such as Proof of Work (PoW) and Byzantine Fault Tolerance (BFT) sit at the two opposite ends of the scalability spectrum. PoW-based blockchain offers good node scalability with poor performance, whereas BFT-based blockchain offers good performance for small numbers of replicas, with not-well explored and intuitively very limited scalability. Performance depends greatly on the

blockchain's deployment. For example, a hybrid blockchain can be designed to perform much better than a public blockchain. To solve the problems of performance, private blockchains are a viable alternative to the accounting industry (Vukolic 2015).

5.2 Privacy Leakage:

Most blockchains are massively distributed and publicly accessible databases. It is almost impossible to keep secrecy in public blockchains because those blockchains are meant to be public. Attackers can effectively use publicly available information to establish the link between the sender and the receiver. In this sense, blockchain adopters like Bitcoin are less private than traditional banking, where federal regulations mandate basic privacy protections (Henry et al. 2018). Research is still ongoing on cryptographic solutions that can prevent the leak of private and personally identifiable material about transacting parties.

5.3 Regulatory Issue:

Several states, the federal government, and international agencies have shown interest in regulating blockchain activities with a focus on virtual currencies. The widespread application and relative newness of blockchain technology make it impossible to conclude which agencies are likely to investigate specific blockchain activities. Mostly because the scope of regulatory authority in this field is yet to be defined, and blockchain activities may involve multiple agencies' jurisdiction. It is likely, a regulator will investigate any blockchain activity that falls within its traditional jurisdiction (Michael et al. 2018). PwC in its 2018 report suggests that regulatory uncertainty is the major hurdle of blockchain adoption (Stanley 2018). Blockchain's potential is much bigger than cryptocurrency; if regulatory uncertainty alleviates, the blockchain's value can easily increase by hundred-fold to \$3 to \$4 trillion by 2030 (Taskinsoy 2019).

5.4 Standardization:

Standardization provides a basis for technology investment and economic activity. Thus, these standardization efforts should be based on best practice and be readily applicable. Blockchain is novel and best practice continues to evolve rapidly. However, a major standardization initiative has been initiated on blockchain technologies through a technical committee of the International Organization for Standardization (ISO), ISO/TC 307. Other organizations like the Institute of Electrical and Electronics Engineers (IEEE) and the International Telecommunication Union (ITU) have also established standardization efforts on blockchains. The National Institute of Standards and Technology (NIST) has recently announced that it will collaborate with ISO to define blockchain standards. The United Nations Economic Commission for Europe (UNECE) is also studying the use of blockchain for trade-related use cases (Gramoli et al. 2018). Standardizing the blockchain's definition, its components such as clients and servers, consensus, pseudonymity, validation, transaction, smart contract, etc., will undoubtedly help the business organization adopt blockchain more efficiently and seamlessly.

5.5 Financial and human capacity:

Small accounting and financial organizations usually are resource-constrained. These companies, in general, do not have sufficient financial capacity to implement new technology

and must, therefore, rely on their legacy accounting systems to operate daily. In contrast to Delliot and PwC, the majority of companies do not have the financial capacity to examine emerging trends. Another concerning challenge is the human capacity within the organization. Regardless of the benefits, workers are so embedded in the legacy business models; it is quite daunting for their employer to alter their mindset in embracing new technology. There is also the fear of smaller companies not using technology at the same pace as bigger companies. This, in-turn, means larger organizations might have to wait for smaller parties to adopt blockchain. Unless the same blockchain platform is used by all trading organizations, we cannot fully evaluate blockchain's potential.

6 Future Directions

6.1 Blockchain With AI

Artificial Intelligence (AI) is expected to change the workplace and life in general. An AI-based business application will be groundbreaking to many organizations and allow them to transform their organization into innovative, efficient, and sustainable organizations. Leveraging the AI along with blockchain will help improve productivity and build a competitive value chain. To embrace the new technologies without business interruptions will be challenging for the companies. However, to make the transition smooth, companies need to deploy blockchain experts in core lines of businesses such as audit, tax, industries, etc. Blockchain, on the one hand, suffers from weaknesses such as security, scalability, and efficiency, while AI, on the other hand, has its fair share of issues with trustworthiness, explainability, and privacy. The integration of these two systems appears to be unavoidable; they could balance each other to revolutionize the next digital global age. Trustlessness, privacy, and explainability for AI are inevitably brought by blockchain. AI can, in turn, help build a blockchain machine learning system to improve security, scalability, governance, and personalization (Dinh et al. 2018).

(Kim et al. 2019) proposed a privacy-preserving DML (Distributed Machine Learning) model for a permissioned blockchain to resolve the privacy, security, and performance issues with DP (Differential Privacy). The model is based on the simulate-order-execute architecture of Hyperledger Fabric. Their method is based on two primitives, a differentially private stochastic gradient descent method and an error-based aggregation rule. The experimental results indicated the proposed model provides stronger resilience against adversarial attacks and has high usability because it has low complexity and low transactional latency.

(Salimitari et al. 2019) introduced AI-enabled blockchain (AIBC) with a 2-step consensus protocol that uses an outlier detection algorithm for consensus in an IoT network implemented on Hyperledger Fabric platform. According to the researchers, the outlier detection algorithm acts as the first step consensus and verifies the compatibility of new data and discards the suspicious ones to increase the fault tolerance of the network for the second step consensus (PBFT). They measured the latency, accuracy, and performance of their method. Experimental results suggested a significant increment in the fault tolerance of hyperledger fabric by their proposed detector.

6.2 Improving Scalability

Scalability is one of the main constraints of a blockchain. Blockchain systems like Bitcoin and Ethereum offer strong guarantees but have a limited capability of processing transactions with the same efficiency as other distributed systems. Throughput is also limited by the size of blocks and the rate at which blocks are produced. Blockchain transactions also suffer from high latency. A user has to wait for a confirmation block before the transaction is posted to the chain. Alternative consensus mechanisms can address the issue of latency but cannot improve throughput without making adjustments in blockchain design itself. Several other techniques have been proposed to improve blockchain throughput, including two broad classes such as block graph systems (Sompolinsky and Zohar 2018) and sharding (Zamani *et al.* 2018). Graph-based systems have explored generalizing the structure of the relationships between blocks from a strict chain to a graph. Other systems improve throughput by relaxing the constraint that every transaction is propagated to and processed by the entire network, known as sharding in the blockchain literature.

6.3 Improving Privacy

In the blockchain, every block and its associated data is propagated to and stored on every node of a chain in a peer-to-peer network. Each node of the blockchain then must be able to validate and execute each transaction, so transactions cannot be encrypted to maintain confidentiality, which eventually leads to privacy leakage. This type of privacy leakage may result in a breach of transaction information confidentiality. Confidentiality and privacy, therefore, pose a major challenge to blockchain and its applications, including sensitive transactions and private information (Zhang *et al.* 2019). To avoid such a scenario, accounting firms should utilize permissioned blockchain technology instead of a permissionless blockchain. A permissioned blockchain refers to a type of blockchain with restrictions in its membership and control procedures, which entails properties such as trade privacy, preservation, and noninvolvement. In such blockchain systems, the configuration intrinsically defines the role played by participants in which certain members can access, authorize new members in the system, and record the information on the blockchain(Liu *et al.*, 2019). Appropriate deployment of access-control layers in this type of blockchain has greater potential to maintain privacy. (Mitani *et al.* 2020) suggests that privacy protection and high transparency are achievable by modeling traceability based on the hidden Markov model. The model is encrypted with homomorphic encryption, and information is verified by applying the non-interactive zero-knowledge proof of the knowledge that the plaintext is equal to zero.

6.4 Regulatory Issues

The surge of blockchain cases around the world has attracted regulators in the United States, China, Japan, South Korea, Switzerland, Canada, United Kingdom, Australia, Singapore, Hong Kong, among others to regulate blockchain and protect consumers from illegal activities and fraud (Michael *et al.* 2018). However, regulatory challenges are manifold and will not only have a profound impact on existing regulations or even the policymaker 's current thinking, but they may also have to change their attitude towards technology. As technology is novel, the concepts around this technology, such as smart contracts and distributed ledgers, are different types of legal objects and can conflict with an existing legal framework, as traditional concepts of jurisdiction, liability, or compliance do not

easily fit. Dealing with blockchain will probably require re-defining certain fundamental principles of legislation and re-defining lawyers, policymakers, and regulators (Cermeño 2016). (Michael et al. 2018) argues that to avoid a regulatory investigation, blockchain-based organizations must be willing to demonstrate the compliance of blockchain networks with industry regulations and guidelines. (Michael et al. 2018) also suggests that some of the agencies that are likely to investigate and regulate blockchain systems are Securities and Exchange Commission (SEC), Commodities and Futures Trading Commission (CFTC), and Financial Institution Regulatory Authority (FINRA).

7 Conclusion

This paper introduced blockchain technology and its impact on accounting in general and pointed out some future directions. The advent of new blockchain technologies is not only helping businesses to transform their everyday operation, but also it is radically improving the efficacy of their processes. However, in the case of accounting industries, it still relies on traditional double-entry bookkeeping information systems. In our review, we found that there is ongoing research regarding the triple-entry bookkeeping information systems. Nevertheless, our finding suggests that even though the triple-entry system is desirable, it is not tamper-proof like blockchain. For instance, the trusted third party can never guarantee that the transaction between two parties will be safe from attacks or misuse; this is one of the accounting firm's major concerns. We believe that the adoption of blockchain technology will ultimately resolve this problem. In addition to the fact that information and data availability in real-time have a beneficial effect on business every day, it will also significantly help regulators make decisions. Contrary to the traditional financial practice, which is often erroneous and fraudulent, features that blockchain technology showcases cannot be ignored, such as smart contracts, transactional immutability, etc. Given that this technology is at its early stages of development, there are several challenges. One major technical challenge that's impeding the development of this technology is scalability. Undoubtedly, blockchain improves the accounting profession by reducing the cost of maintaining and reconciling ledgers. Nevertheless, blockchain is seen as a substitute for bookkeeping, and reconciliation could be seen as a threat to accounting professionals. This could have a considerable negative impact on widespread adoption in the accounting domain. It is safe to say that there are still many unknowns concerning how blockchain will impact the audit and assurance profession, including the speed with which it will do so, as the technology has not reached its maturity yet. Furthermore, regulatory uncertainty around the technology has contributed negatively towards its acceptance. If this technology is fully embraced, then the accounting business model's paradigm will surely alter radically. Also, we assume that the blockchain reinforced with a privacy-preserving deep learning system will make the audit process much smoother and error-free. The skill spectrum of the accountancy profession, however, will change to IT skills. At the current pace, blockchain technology will take years to reach its maturity. Either blockchain technology will thrive in the accounting domain or some sort of distributed ledger technology will appear in the future because the reward of reduced reconciliation, accurate information, real-time data, and the tamper-proof transaction is indeed too good to ignore.

Acknowledgement:

The work was partially supported by National Science Foundation grants #2000348, #1761735, #1723586, and #1663350. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the funding agencies.

References

Meng Han, Zhigang Li, Jing He, Dalei Wu, Ying Xie, Asif Baba (2018), 'A novel blockchain-based education records verification solution', *In Proceedings of the 19th Annual SIG Conference on Information Technology Education*, , pp.178-183.

Johnson C. (2020), 'Google Goes Blockchain- New Deal Opens A Door To Crypto', Forbes, viewed 6 June 2020, <https://www.forbes.com/sites/coryjohnson/2020/05/27/google-goes-blockchain/6d395a9b6593>.

Delliott (2019), *Delliott's 2019 Global Blockchain Survey*, [Online]. Available at: https://www2.deloitte.com/content/dam/Deloitte/se/Documents/risk/DI_2019-global-blockchain-survey.pdf, (Accessed: 4 May 2020).

Brakeville, S. and Bhargav, P. (2016), 'Blockchain basics: Introduction to business ledgers', *Issued by IBM Corporation*.

Institute of Chartered Accountants in England and Wales (2017), *Blockchain and the future of accountancy*, [Online]. Available at: <https://www.icaew.com/-/media/corporate/files/technical/information-technology/thought-leadership/blockchain-and-the-future-of-accountancy.ashx>, (Accessed: 15 March 2020).

Konstantinos, C. and Michael D. (2016), 'Blockchains and smart contracts for the internet of things', *IEEE Access*, Vol. 4, pp.2292-2303.

Nakamoto, S. (2008), *Bitcoin: a peer-to-peer electronic cash system*, [Online]. Available at: <https://bitcoin.org/bitcoin.pdf>, (Accessed: 15 February 2020).

Peck, M E. (2017), 'Blockchains: How they work and why they'll change the world', *IEEE Spectrum*, *IEEE*, Vol. 54, pp.26-35.

Khan N. (2017), *Demystifying Blockchain for Islamic Finance*, LinkedIn, viewed 8 June 2020, <https://www.linkedin.com/pulse/demystifying-blockchain-islamic-finance-nida-khan>.

Zheng, Z. and Xie, S. and Dai, H-N. and Chen, X. and Wang, H. (2018), 'Blockchain challenges and opportunities: A survey', *International Journal of Web and Grid Services*, *Inderscience Publishers (IEL)*, Vol. 14, No. 4, pp.352–375, DOI: 10.1504/IJWGS.2018.095647.

Pacy, E P. (2014), 'Tales from Cryptocurrency: On Biocoin, Square Pegs, and Round Holes', *New Eng. L. Rev.*, *HeinOnline*, Vol. 49, pp.121.

The Economist (2015), 'The great chain of being sure about things', The Economist, viewed 15 March,2020, <https://www.economist.com/briefing/2015/10/31/the-great-chain-of-being-sure-about-things>.

Beigel O. (2020), 'Who Accepts Bitcoin as Payment', viewed 29 May 2020, <https://99bitcoins.com/bitcoin/who-accepts/>.

Lu, Y. (2018), 'Blockchain: A survey on functions, applications and open issues', *Journal of Industrial Integration and Management, World Scientific* Vol. 3, No. 04, pp.1850015.

Khan, M. and Quasim, M. and Algarni, F. and Alharthi, A. (2020), *Decentralised Internet of Things A Blockchain Perspective: A Blockchain Perspective*, Springer Nature Switzerland, Switzerland.

Christensson, P. (2018) , 'Blockchain Definition', viewed 6 June 2020, <https://techterms.com/definition/blockchain>.

Zheng, Zibin and Xie, Shaoan and Dai, Hongning and Chen, Xiangping and Wang, Huaimin (2017), 'An overview of blockchain technology: Architecture, consensus, and future trends', in the *Proceedings of IEEE international congress on big data (BigData congress) 2017*, pp.557–564.

Raikwar, M. and Gligoroski, D. and Kralevska, K. (2019), 'Sok of used cryptography in blockchain', *IEEE Access*, Vol. 7, pp.148550–148575, 2019.

Nguyen, G-T., and Kim, K. (2018), 'A Survey about Consensus Algorithms Used in Blockchain', *Journal of Information processing systems*, Vol. 14.

Baliga, A. (2017), 'Understanding Blockchain Consensus Models', *Persistent*, Vol. 4, pp.1–14.

Puthal, D., and Malik, N., and Mohanty P S., Kougianos, E. and Das, G. (2018), 'Everything you wanted to know about the blockchain: Its promise, components, processes, and problems', *IEEE Consumer Electronics Magazine, IEEE*, Vol. 17, pp.6–14.

Swan M. (2015), 'Blockchain: Blueprint for a new economy', O'Reilly Media, Inc.

Kosba, A. and Miller, A and Shi, E. and Wen, Z. and Papamanthou, C. (2016), 'Hawk: The blockchain model of cryptography and privacy-preserving smart contracts', in the *Proceedings of IEEE symposium on security and privacy (SP) (2016)*, pp.839–858.

Gupta, Y. and Shorey, R. and Kulkarni, D. and Tew, J. (2018), 'The applicability of blockchain in the Internet of Things', in the *Proceedings of 10th International Conference on Communication Systems & Networks (COMSNETS) (2018)*, pp.561–564.

Castillo D M., Schifrin M. (2020) 'Forbes Blockchain 50', viewed 6 June 2020, <https://www.forbes.com/sites/michaeldelcastillo/2020/02/19/blockchain-50/49b761827553>.

Bible, W. and Raphael, J. and Taylor, P. and Valiente, I O. (2017), 'Blockchain technology and its potential impact on the audit and assurance profession', *Aicpa.org*.

Grigg, I. (2005), 'Triple entry accounting', *Systemics Inc.*

Rückeshäuser, N. (2017), 'Do we really want blockchain-based accounting?', *Decentralized consensus as enabler of management override of internal controls, Wirtschaftsinformatik und Angewandte Informatik*.

O’Neal S. (2019), *Big Four and Blockchain: Are Auditing Giants Adopting Yet?*, viewed 9 June 2020, <https://cointelegraph.com/news/big-four-and-blockchain-are-auditing-giants-adopting-yet>.

EY (2018), *’EY announces blockchain audit technology?’*, EY, viewed 6 June 2020, https://www.ey.com/en_no/news/2018/04/ey-announces-blockchain-audit-technology.

Vetter A. (2018), *’Voices Blockchain is already changing accounting’*, viewed 9 June 2020, <https://www.accountingtoday.com/opinion/blockchain-is-already-changing-accounting>.

Das S. (2017), *Big 4 Accounting Giant PwC Accepts its First Bitcoin Payment*, viewed 9 June 2020, <https://www.ccn.com/big-4-accounting-giant-pwc-accepts-first-bitcoin-payment/>.

Perez Yessi B. (2019), *’KPMG survey: 67% of corporates are not using blockchain technology’*, viewed 4 June 2020, <https://thenextweb.com/hardfork/2019/04/09/kpmg-survey-67-of-corporates-are-not-using-blockchain-technology/>.

PwC (2018), *Blockchain is here. What’s your next move?*, PwC, viewed 5 June 2020, <https://www.pwc.com/blockchainsurvey>.

Hayes A. (2020), *’Scalability’*, Investopedia, viewed 25 March 2020, <https://www.investopedia.com/terms/s/scalability.asp>.

Chauhan, A. and Malviya, O P. and Verma, M. and Mor, T S. (2018), *’Blockchain and scalability’*, in the *Proceedings of IEEE International Conference on Software Quality, Reliability and Security Companion (QRS-C) (2018)*, pp.122–128.

Li (2019), *Blockchain speeds the scalability debate*, viewed 6 June 2020, <https://blockplain.com/2018/02/28/transaction-speeds/>.

Blockplain (2018), *’The Blockchain Scalability Problem the Race for Visa-Like Transaction Speed’*, viewed 4 April 2020, <https://towardsdatascience.com/the-blockchain-scalability-problem-the-race-for-visa-like-transaction-speed-5cce48f9d44>.

Vukolić, M. (2015), *’The quest for scalable blockchain fabric: Proof-of-work vs. BFT replication’*, in the *Proceedings of International workshop on open problems in network security (2015)*, Springer, pp.112–125.

Henry, R. and Herzberg, A. and Kate, A. (2018), *’Blockchain access privacy: Challenges and directions’*, *IEEE Security & Privacy*, IEEE, Vol. 16, No. 04, pp.38–45.

Sompolinsky, Y. and Zohar, A. (2018), *’PHANTOM, GHOSTDAG: Two scalable BlockDAG protocols’*, Accessed, *IACR Cryptology ePrint Archive*.

Zamani M., Mahnush M., and Raykova M. (2018), *’RapidChain: Scaling blockchain via full sharding’*, in the *Proceedings of the ACM SIGSAC Conference on Computer and Communications Security (CCS’18)*, pp.931–948.

Michael, J. and Cohn, A. and Butcher, J.R. (2018), *’Blockchain technology’*, *IEEE Spectrum*, Vol. 1, No. 7.

Stanley A. (2018), *’PwC: Regulatory Uncertainty Is Largest Impediment To Blockchain Adoption’*, viewed 7 June 2020, <https://www.forbes.com/sites/astanley/2018/08/27/pwc-regulatory-uncertainty-is-largest-impediment-to-blockchain-adoption/6037dcf0b0144>.

Taskinsoy, J. (2019), 'A Misunderstood Digital Revolution', *Things You Need to Know about Blockchain*.

Gramoli, V. and Staples, M. (2018), 'Blockchain Standard: Can We Reach Consensus?', *IEEE Communications Standards Magazine, IEEE*, Vol.2, No.03, pp.16–21.

Appelbaum, D. and Smith, S S. (2018), 'Blockchain basics and hands-on guidance: taking the next step toward implementation and adoption', *The CPA Journal, New York State Society of Certified Public Accountants*, Vol. 88, No. 6, pp.28–37.

Intuit (2020), 'Role-based access control for CFOs accounting departments', viewed 14 June 2020, <https://quickbooks.intuit.com/r/growing-complex-businesses/role-based-access-control-for-cfos-accounting-departments/>.

Dinh, T N. and Thai, My T. (2018), 'Ai and blockchain: A disruptive integration', *The CPA Journal, Computer, IEEE*, Vol. 51, No.9, pp.48–53.

Cermeño, J S. (2016), 'Blockchain in financial services: Regulatory landscape and future challenges for its commercial application', *BBVA Research Paper*, Vol. 16, pp.20.

Zhang, R. and Xue, R. and Liu, L. (2019), 'Security and privacy on blockchain', *ACM Computing Surveys (CSUR), ACM New York, NY, USA*, Vol.52, pp.1–34.

Mitani, T. and Otsuka, A., 'Traceability in permissioned blockchain', *IEEE Access, IEEE*, Vol. 8, pp.21573–21588.

Alladi, T. and Chamola, V. and Parizi, R. M and Choo, K-K R. (2019), 'Blockchain applications for industry 4.0 and industrial IoT: A review', *IEEE Access, IEEE*, Vol. 7, pp.176935–176951.

Casino, F. and Dasaklis, T K. and Patsakis, C., 'A systematic literature review of blockchain-based applications: current status, classification and open issues', *Telematics and Informatics, Elsevier*, Vol. 36, pp.55–81.

Inghirami, Iacopo Ennio, 'Accounting Information Systems: The Scope of Blockchain Accounting', *Digital Business Transformation, Springer*, pp.07–120.

Liu, Manlu and Wu, Kean and Xu, Jennifer Jie, 'How Will Blockchain Technology Impact Auditing and Accounting: Permissionless versus Permissioned Blockchain', *Current Issues in Auditing, American Accounting Association*, Vol.13, pp.A19–A29.

Singh, Jatinder and Michels, Johan David, 'Blockchain as a service (BaaS): providers and trust', *2018 IEEE European Symposium on Security and Privacy Workshops (EuroS&PW), IEEE*, pp.67–74.

Leewayhertz (2020), *A Beginner's Guide to Blockchain as a Service*, viewed 12 November 2020, <https://www.leewayhertz.com/guide-to-blockchain-as-a-service/>.

Kim, Hyunil and Kim, Seung-Hyun and Hwang, Jung Yeon and Seo, Changho, 'Efficient privacy-preserving machine learning for blockchain network', *IEEE Access, IEEE*, Vol. 7, pp.136481–136495.

Salimitari, Mehrdad and Joneidi, Mohsen and Chatterjee, Mainak, 'Ai-enabled blockchain: An outlier-aware consensus protocol for blockchain-based iot networks', *2019 IEEE Global Communications Conference (GLOBECOM), IEEE*, Vol. 7, pp.1–6.