A Literature Review of Blockchain and its Applications in Stock Exchange

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Abstract *– The traditional centralized stock exchange systems are plagued with a number of issues, such as steep transaction costs, centralized control and governance, and vulnerability to various forms of attack and abuse, including front-running. Therefore, a system that guarantees the accessibility, integrity, reliability, and security of stock transactional data in such a trading environment is very crucial to overcome these problems. Blockchain is an emerging technology that is used for sharing data in a transactional and decentralized manner in a huge network of untrusted participants. Blockchain-based systems guarantee accessibility, availability, integrity, reliability, security against tampering and malicious attacks, smooth integration, and easy management of data. By utilizing smart contracts, this system facilitates various stock trading-related requests and inquiries, including the execution and settlement of orders, effectively eliminating the need for a central governing body in the stock trading process. All the stakeholders in this system must be able to access the transactional data stored in its distributed ledger without compromising its authenticity. A decentralized solution replaces the central authority and broker commissions with a mining fee that is used to compensate the miners for their contribution in maintaining the integrity of the system, thus reducing the transaction fees. In this survey, we examine the previous research work implemented by various authors on implementing blockchain in several aspects of decentralized stock exchanges.*

Keywords—Blockchain, Stock exchange, Distributed systems,Private ledger, Smart contract, Cryptocurrencies.

I INTRODUCTION

Blockchain is a relatively new technology that has become increasingly popular in recent years. The features of blockchain are that it allows us to perform online transactions like digital payments, decentralized exchanges and other important transactions between two parties without the intervention of a central authority.

Because of the distributed and decentralized nature of the blockchain network, it can be used for building a trusted decentralized stock exchange platform.

Traditional stock markets have “so called” trusted intermediaries who execute transactions for the traders. But the main problem with this type of exchange is that the data of the trader is at risk because the middleman can use it for various illegal activities such as front- running, back-running and insider trading.

With the advent of smart contracts, the possibilities of creating decentralized ecosystems have been simplified and have been made easier to manage, maintain and operate. Ethereum is such a platform which offers ways to code a smart contract using its core language called Solidity. This language is like any other programming language but with extra features specific to the Ethereum network.

A stock trading platform that is implemented on the blockchain can be used for decentralized stock exchanges. First, a design of the decentralized trading platform is created and like

any software application, this application also goes through stages of Design, manipulation, testing and deployment except for the fact that the tools and the programming languages are different.

Doing so will eliminate the various disadvantages that exist in the traditional stock exchange system and will also make it less vulnerable to the various attacks and abusive practices performed by middlemen as all the operations are performed by the smart contract and there is no central authority of governance involved in this decentralized system.

The goal of this study is to review the different ways in which blockchain is being applied to stock exchanges and highlight some of the challenges that come with it. Our research focuses on the following points:

• A survey of existing studies that explore the use of blockchain technology in decentralized stock exchanges.

• An examination of the various techniques that have been proposed in these studies, presented in a clear and straightforward manner.

II LITERATURE SURVEY

Zibin Zheng et al.,[1] provide a succinct summary of the blockchain architecture, including its key features and the difficulties it poses. The features of blockchain technology are highlighted as decentralization, immutability, anonymity, and transparency. The authors also discuss the challenges such as scalability, privacy concerns and selfish mining that arise when using blockchain. In addition, they explain how consensus is reached on the blockchain network using specific protocols, such as proof of work and proof of stake.

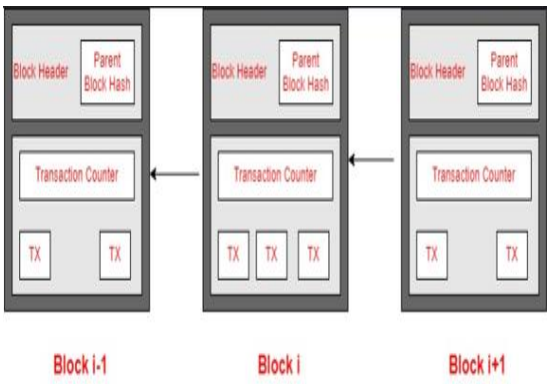

Fig. 1: blockchain which consists of a continuous sequence of blocks

Bayu Adhi Tama et al.,[2] provide a basic overview of the key concepts of blockchain technology, its functioning and use cases. It highlights the workings of the decentralized ledger and the process of adding new blocks through mining. This process of mining is resource-intensive and hard to hack, making it secure. The authors also discussed the different consensus mechanism used for mining such as proof of work and proof of stake. They further discuss how Blockchain can be applied in various areas such as finance, healthcare, business, and various other domains.

LWubing Chen et al.,[3] provide information on the different ways in which blockchain technology is being utilized. A prominent application of blockchain is in the area of cryptocurrency. They emphasize on its use in the financial sector, specifically in the realm of digital currencies such as Bitcoin and Ethereum. These cryptocurrencies enable fast and efficient cross-border payments without the need for a central intermediary. Blockchain is also used in various other sectors such as healthcare, advertising, insurance, copyright protection, energy and social applications, with one of the key advantages of blockchain is that it helps to prevent double-spending in digital transactions.

Dharmin Dave et al.,[4] explain why blockchain technology sometimes can cause problems such as scaling up, Interoperability, and replacement of databases. These problems are very critical and need to be addressed while developing a blockchain application and the survey on these problems prevents these issues in our application.

Tam T. Huynh et al.,[5] provide an understanding of the security challenges that arise in a blockchain network. They noted that the most common attacks on a blockchain network are carried out by dishonest nodes that seek to control the generation of blocks on the chain. One of the most prevalent attacks is the 51% attack, in which an attacker can solve a hash puzzle in a proof of work consensus mechanism and create a new block on the chain.

Another common attack is the double-spending attack, in which a dishonest node spends the same coin in one or more transactions. A less common attack is the selfish mining attack, in which a

dishonest node publishes private blocks to the network in order to create the longest valid chain. A specialized form of attack is the eclipse attack, where peers of the network are isolated from the victims and thus, can launch other types of attacks.

Types of security attacks	Defending Solutions
51 percent	Two-phase Proof of Work. Random mining group selection technique. Proof of Activity protocol.
Double spending	PoW scheme and a distributed time-stamping service. Waiting for more confirmations exponentially. Listening Period, Inserting Observers and forwarding Double-spending Attempts. Fair deposits.
Eclipse	Detereministic random eviction, Random selection, Test before evict, Feeler connections, Anchor connections, More buckets, More outgoing conections, Ban unsolicited ADDR messages, Diversify inicoming connections and Anomaly detection.
Selfish mining	Freshness Preferred mechanism. ZeroBlock scheme. Decentralized backward-compatible defence mechanism.
Distributed denial of service	Proof of Activity protocol.

Fig. 2: Various forms of attacks and protection methods

Xiaoqi Li et al.,[6] explain about blockchain propagation and synchronization. Advertising-based propagation is a method derived from bitcoin protocols in which when a node 'A' receives information about a block, 'A' sends a message to its peers. Another type of propagation is Send-headers propagation. For example, when a node 'B' receives information about a block, it will send a send-headers message to node A.

Another form of push propagation is known as unsolicited propagation, in which there is no INV message or send-headers message. This method was created to enhance the speed of block propagation. The last form of propagation is relay network propagation, in which all miners share a single transaction pool, and all transactions have a global identifier. This reduces the block size and reduces the load on the network, resulting in faster propagation speed.

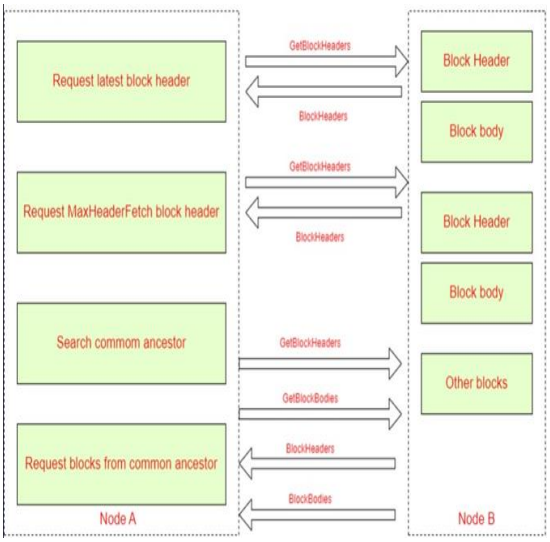

Fig. 3: The process of synchronizing blocks among nodes

Zibin Zheng et al.,[7] describe the idea and design of a smart contract. They explain that a smart contract is a computer program that is self-verifying, self-executing, and tamper-proof. The authors highlight that the use of blockchain and smart contracts allows for the rapid development, design, and implementation of solutions to real-world problems without the need for a third party. The authors also highlight some of the areas where smart contracts are being used, such as in supply chain, Internet of Things, healthcare systems, digital rights management, insurance, financial systems, and real estate.

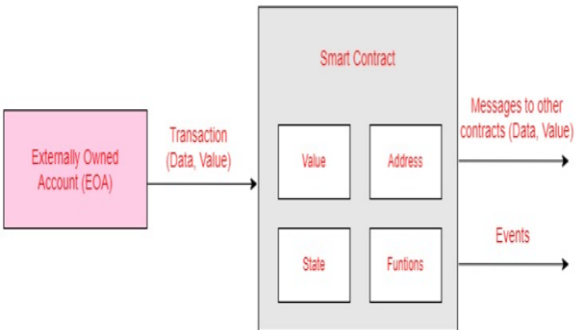

Fig. 4: Transaction process in a smart contract

Shafaq Naheed Khan et al.,[8] discuss the platforms that are used to execute smart contracts. They mention that the first platform is Bitcoin, which is a public blockchain platform that is used for digital currency transactions. Another platform discussed is NXT, which operates on a proof of stake protocol, and features the selection of active smart contracts. Ethereum is also noted as a blockchain platform that was the first to implement

smart contracts, and it allows for advanced and adaptable smart contracts to be created. The Ethereum Virtual Machine (EVM) is specified as the runtime system for smart contracts and all miners in the network run the EVM to execute instructions. The authors also mention that Decentralized Applications (DAPPS) can be built using Ethereum's programming language called Solidity.

Author	Year	Blockchain type	Consensus Mechanism	Implementation	Performance Analysis
Liu et. al. [21]	2019	Private Blockchain	Improved delegated proof of stake	✔	✔
Jiang et. al. [22]	2018	Two loosely-coupled Blockchain	Proof of Work (PoW)	✔	✔
Azaria et. al. [23]	2016	Ethereum based Blockchain	Proof of Work (PoW)	✔	✘
Griggs et. al. [24]	2018	Private Blockchain	Practical Byzantine Fault Tolerance (PBFT)	✔	✘
Dagher et. al. [25]	2018	Permissioned Ethereum Blockchain	QuorumChain Consensus algorithm	✔	✔
Han et. al. [26]	2018	Consortium Blockchain and Fully Private Blockchain as a Hybrid Blockchain	Proof of Work (PoW)	✘	✘
Purohit et. al. [27]	2021	Consortium Blockchain	Proof of Authorization (POA)	✔	✔
Zhuang et. al. [28]	2018	Private Blockchain	Proof of Stake (PoS)	✔	✘
Buzachis et. al. [29]	2019	Private Blockchain	Clique - Proof-Of-Authority (PoA)	✔	✔
Zhang et. al. [30]	2018	Private blockchain and consortium blockchain	Proof of conformance	✔	✔

Table : Blockchain types and consensus mechanisms along with implementation and performance analysis

Dr. Gavin Wood et al.,[9] provide an overview of the blockchain paradigm and its mathematical principles, specifically in the context of an Ethereum network. The author explains that in blockchain, a transaction is equivalent to a state transition and each transaction creates a valid link between two states. A valid state transition can be represented as A = Y(A(t), T) where Y is the transition function. The author notes that when Y is combined with A, it results in a system that is more powerful than any other existing systems of a similar nature.

Multiplier	Name
10^0	Wei
10^12	Szabo
10^15	Finney
10^18	Ether

Fig. 5: Multiplier Table

Claudia Antal et al.,[10] emphasize on the architecture of blockchain applications, it can be understood using a 3 tier architecture.

The first layer, referred to as the PN tier or Protocol and Network tier, includes technology for building peer-to-peer networks, replicating ledgers, and validating consensus. The second layer, known as the Scalability tier (S-Tier), operates in parallel with a Distributed Ledger Technology (DLT) network and aims to resolve issues raised by the PN tier. The third layer, Interoperability tier, built on the previous two layers, addresses the integration and cooperation of various system deployments and DLT applications.

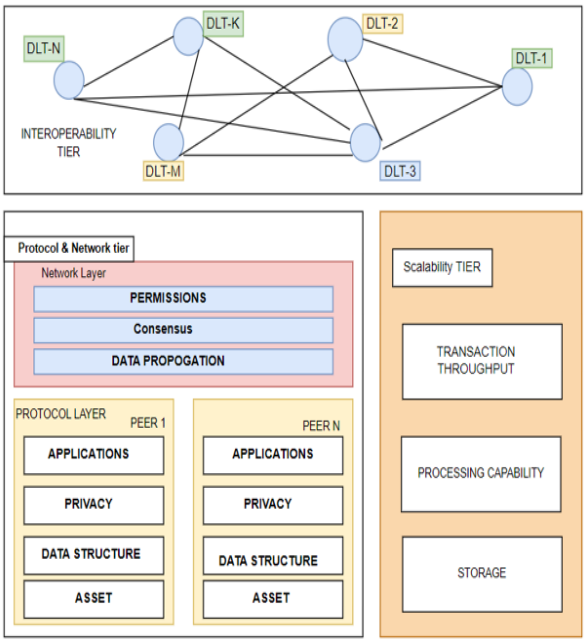

Fig. 6: A three-tiered architecture for the development of decentralized applications

Rajesh K. Aggarwal et al.,[11] give us a brief about how a stock market is manipulated at different levels. There can be more than one way to manipulate a market. The first type of manipulation is where an insider in a firm can take actions based on the placed orders that influences the price of stocks. Also, large block trades can influence the prices based on bulk orders. The more common type of manipulation is where a trader purchases a large number of stocks to drive the stock prices up and then later sells the same stocks at a higher price and thus the trader can profit from this price increase.

Chakrapani Chaturvedula et al.,[12] examine how stock prices can be manipulated through bulk trades and front running. They explain that in bulk trading, the parameters alpha and beta are determined over a specific period by performing an ordinary least squares regression.

The author also explains that front-running attacks, a practice in which a broker executes stock trades prior to large trades with the expectation that the stock prices will increase, resulting in a profit for the broker, causing manipulation in the stock market.

Thorsten Hens et al.,[13] provide an understanding of the market quality indicators, including price efficiency, short-term and long-term price fluctuations. They note that speculators in a stock market can contribute to price fluctuations by trading assets that are mispriced, with the goal of making money through aggressive trading. This makes them vulnerable to front-running attacks, which can lead to a reduction in price efficiency. The authors suggest that through the use of artificial intelligence, specifically Recurrent Neural Network techniques, it is possible to predict the price efficiency of stock markets.

The authors of this paper have also examined the asymmetric responses to positive and negative news for days with increasing Recurrent Neural Network (RNP). The second aspect considered is the short-term and long-term price fluctuations. Front running trades can cause significant volatility in the stock market by driving more frequent buying and selling, and could also lead to significant changes in the market over a longer period of time. These long-term fluctuations refer to buying and selling stocks over a relatively longer period of time, but it can still have an impact on the stock prices.

	BAS	HFT	p-Value
(1) Price Discovery			
Stock price	15.37	15.43	(0.486)
R^2(dp=a+b-dRNP)	0.874	0.874	(0.973)
R^2 down up	0.037	0.030	(0.270)
2)Short tierm price fluctuation			
volatility(annualized)	17.36	17.04	(0.369)
skewness	0.08	0.22	(0.434)
excess kurtosis	18.34	35.49	(0.149)
(3)Long Swings			
PEAK-to-through(%)	43.14	42.65	(0.209)
high	21.49	21.32	(0.628)
low	8.16	8.23	(0.514)
range	13.33	13.09	(0.551)
4)LIQUIDITY			
bid_ask spread (bp)	10.187	10.19	(0.948)
market impact (bp)	1.07	1.15	(0.087)
roundtrip cost(bp,ex.frontrunning	12.32	12.50	(0.484)
TURNOVER PER DAY	2.46	1.90	(0.000)
Days between trades	5.23	5.48	(0.0000)
order size(no. of shares	6067	4882	(0.0000)
Order Book Depth(market impact of 50K shares)	3.11	3.70	(0.0000)

Fig. 7: Indicators of market performance

Jean-pierre Danthine et al.,[14] describe how large investments such as mutual funds, institutional investors, and portfolio insurers, play a crucial role in impacting stock prices, which can be considered a form of front-running.

They also examine a market scenario where insiders act strategically, and prices are determined by market traders. They note that when investors lack information, the welfare loss due to insider front running will not depend on the degree of risk aversion represented by (p).

Claudia Pop et al.,[15] outline the drawbacks of the traditional centralized stock exchange system, and the necessity to move towards a decentralized stock exchange system. In the centralized structure of stock exchanges, all transactions are recorded in the central registry of the securities exchange platform. They are grouped by bid-offer and sorted by price. Transactions that are recorded on the market are held in the order book until specific conditions are met, this process is known as limit ordering.

The main drawback of the current system is that the entire network of the Stock Exchange is controlled and governed by a central authority, which makes it vulnerable to attacks and failure due to its centralized design.

Additionally, the central system facilitates transactions only through intermediaries referred to as brokers, who are trusted entities that conduct trades on behalf of traders in return for a fee.

To address these issues, the author proposes decentralizing the Stock Exchange platform. To create a decentralized exchange platform, a smart contract must be designed which will serve as an advanced order book. This smart contract would include data such as symbols, all-stocks, market price, bids, and asks. All orders are organized by the smart contract, by gathering information like the trader's address, timestamp, asset quantity, and buying/selling prices.

The smart contract that has been implemented on the blockchain acts as a decentralized repository, keeping track of all assets and maintaining duplicates of transaction data on the blockchain network.

Any changes made to the repository are overseen by its peers and any attempts at attack are futile since the state of the repository is recorded on the blockchain in a way that is tamper-proof.

Because of the unique properties of the blockchain network and smart contracts, it becomes very difficult to perform any types of malicious activities or attacks on this stock exchange system.

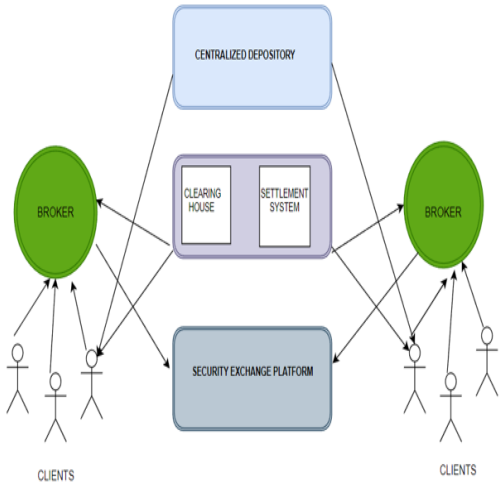

Fig. 8: Stock Exchange with a centralized design

Liyi Zhou et al.,[16] provide an understanding of the attacks that can occur in a blockchain-based decentralized exchange. They explain that a decentralized exchange platform allows users to trade assets while maintaining full control of their funds. However, decentralized exchanges have a latency in processing transactions, which can create opportunities for market manipulation. This can lead to adversaries performing practices such as front-running, which can alter the price of an asset and provide a benefit to the attacker.

In this paper, the author aims to analyze another form of front running, called a sandwich attack. A sandwich attack is a combination of both front running and back running. The study quantifies the likelihood of the attack being carried out by the adversary, based on the transaction's relative positioning within a block.

This results in huge gains for the adversarial trader. All through sandwich attacks under multiple adversaries that are competing are also taken in this scenario to account for the trading environment in the real world.

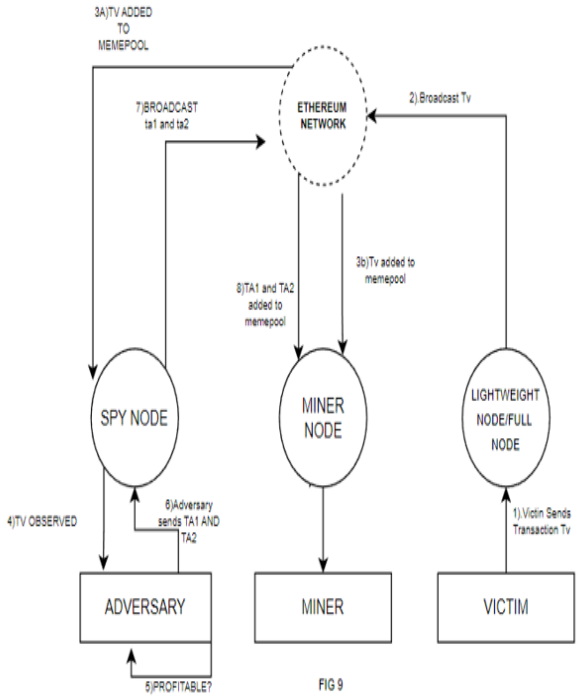

Fig. 9: A system that utilizes the sandwich technique for attacks

Hamed Al-shaibani et al.,[17] suggest a consortium-based stock exchange system with the goal of enhancing performance requirements of the stock exchange platform. The proposed system is based on the Ethereum blockchain, which enables the inclusion of all necessary business regulations and rules. The authors also elaborate on how the bidding process on a decentralized exchange would function. First, the seller posts the bidding details and starting price. The bidder's information is encrypted, akin to being in a sealed envelope, when it is received by the auctioneer, the information is decrypted as if the seal was opened, and the data is collected and stored.

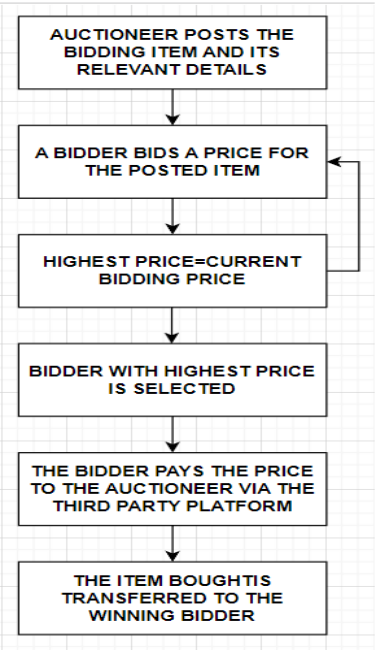

Fig. 10: Diagram illustrating the steps involved in the bidding process

Gaurang Bansal et al.,[18] describe how a smart stock market that can predict stock prices can be created by utilizing various elements of the blockchain network or decentralized ledgers. They highlight the potential of blockchain to simplify stock trading in a global market. The authors implement a Long-Short Term Memory (LSTM) architecture to predict stock prices, which achieved an accuracy rate of 99.71% during testing. LSTM is an enhanced version of Recurrent Neural Network (RNN) used in deep learning, and it defines how previous memories are integrated with new inputs. The concept is based on this multiplication where only a certain amount of input is "passed through". Input gates control the degree to which the newly calculated state is "passed through", while output gates determine an internal state that is exposed to upper layers.

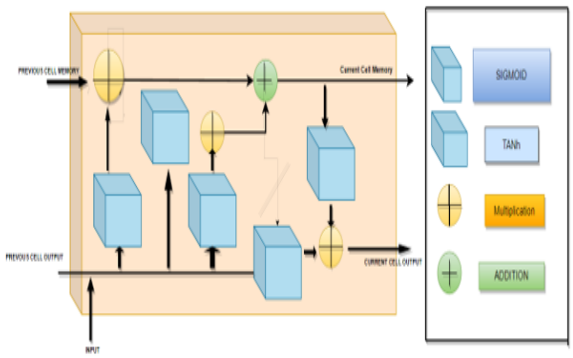

Fig. 11: Architecture utilizing Long Short-Term Memory

Agostino Capponi et al.,[19] propose a decentralized ledger-based exchanges and explicitly ethereum based stock exchanges, DeXs take in, manage, and execute orders through a blockchain-based platform. The validator that constructs the very next block of a network will make the high gas price orders as greater priority and the lower gas price orders are of low priority. Since every block has a size limit, the volume of orders a validator can include in a single block is limited.

L Stuart Haber et al.,[20] explain how digital documents or digital transactions are time-stamped. In certain scenarios, such as stock market transactions, time stamping is crucial in order to eliminate the risk of market manipulation and practices like front-running. One commonly used method for time stamping data involves daily entries and symbols, where dated entries are recorded sequentially on a digital ledger. A simple solution to this problem is the use of a "digital safety deposit box."

In this approach, when a client has a transaction that requires time-stamping, they send the transaction to a time stamping service (TSS). The service records the date and time the document was received and maintains a copy of the transaction for safekeeping. However, this method raises several concerns such as privacy, bandwidth and storage, incompetence and trust. These issues can be addressed by using a trustworthy party or a blockchain-based time stamping service provider.

III CONCLUSION

In this paper, we surveyed blockchain technology and how blockchain can be crucial in improving security, reliability, and protection of transactional data. Using the blockchain technology, we can create a shield against various attacks and illegal practices carried out on stock orders in a trading environment. It is also pivotal in making the process of managing such data with ease and efficiency. We realize that we can make use of smart contracts, one of blockchain's finest features, to process a large number of requests and queries related to stock exchange. All the stakeholders must be able to access the trading and order related data stored in a distributed ledger without compromising its authenticity.

We surveyed the relevant research papers on blockchain technology and how blockchain is being utilized in the field of decentralized exchange and mapped out all the relevant research into this literature review. The goal of this paper is to investigate the research topics of blockchain technology in stock exchanges, specifically its effects on the field of stock exchange and the main changes it is expected to bring. Our findings show that the blockchain technology has high potential in terms of being implemented as a platform for stock exchange and other forms of decentralized exchanges.

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