PEER-TO-PEER TRADING WILL INCREASE PARTICIPATION IN CARBON CREDIT TRADING

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ABSTRACT

Earth is battling a historical rate of adverse climate conditions like drought, flood, wildfire, and biodiversity and animal migration changes. Addressing climate change has become more critical than any time before. Green House Gas (GHG) emission is a significant cause as it traps the heat within the atmosphere. Many countries have tried different methodologies to curb the emission, and currently, Cap-And-Trade (CAT) program is the most widely accepted one. The goal of CAT is to limit the max amount of emission by overall industries and reduce the capped amount by some margin each year. As with any other application, CAT has shortcomings and sections to improve, and a standard global adaptation is of utmost importance. Each region and country has laws and regulations preventing the establishment of a stable international structure for trading carbon credits. Blockchain, a distributed system, is inherently based on Peer-to-Peer technology. With features like decentralization, increased privacy capability, consensus mechanism, and a smart contract, blockchain provides an excellent alternate pathway for CAT implementation. With the recent global adaptation of blockchain technology, Peer-to-Peer (P2P) technology offers a practical solution for addressing the shortcomings of CAT. With no centralized authority catering to a specific region or country, a peer-to-peer transaction technology will help increase people's participation in carbon credits trading.

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LIST OF ABBREVIATIONS

CAT	Cap-And-Trade
P2P	Peer-to-Peer
CCS	Carbon Capture and Storage
ETS-EU	Emission Trading System-European Union
CCE	Chicago Climate Exchange
DLT	Distributed Ledger Technology
PBFT	Practical Byzantine Fault Tolerance

CHAPTER 1

INTRODUCTION

The first chapter provides an overview of the concepts and terminologies relevant to the thesis. Section 1.1 highlights how climate change is affecting the general population. Section 1.2 describes how countries are addressing this challenge through the Cap-And-Trade model. Section 1.3 explains what peer-to-peer technology is and how it is used. Section 1.4 highlights what blockchain is and goes through its characteristics. Smart contracts are used in conjunction with blockchain, which will be discussed in section 1.5. Lastly, Section 1.6 gives the synopsis of the thesis.

1.1 Climate Change

Climate change is a reality that humans are aware of, but the rate and severity of climate change have always been in question. Nonetheless, there has been unequivocal evidence that climate change affects several parts of the world. It has risen above an issue concentrated to specific regions or countries to the Earth issue. The world is battling with changes in biodiversity, drought, flood, wildfire, rise in sea level, and extreme weather. The root cause of the change comes down to one significant factor, the emission of Green House Gases (GHG). GHG can absorb heat on a larger scale; thus, it is essential to tackling climate change. Out of all the GHG, Carbon dioxide is the primary gas. Therefore, we will use GHG and Carbon interchangeably. During the peak of the spread of the Covid-19 virus in 2020, human activities were restricted significantly, and a significant improvement in climate conditions was observed worldwide. Different human activities, like burning fossil fuel, manufacturing goods and services, transportation, farming, and deforestation, contribute to emissions in one way or another. Cap-And-Trade was proposed in the Kyoto protocol of 1997, which provided the option to reduce greenhouse gases emission [1]. Many countries have stepped up and implemented different regulations to curb emissions. The cap-and-Trade (CAT) program has been the most widely accepted one.

1.2 Cap-And-Trade program

Cap-and-Trade is regulatory compliance developed to curb carbon emissions by limiting overall emissions permitted and lowering the cap over the years. The governing body sets an overall carbon emission limit for the participating organization in CAT. Each organization is given a fixed number of permits that dictates its carbon emission allowance. The key is also called carbon credit. One tonne of Carbon emission is permitted for one carbon credit. The distribution of numbers of credit could be done through free allocation, past emission data, production capacity, or auction [3]. There are two main aspects of CAT.

1.2.1 Carbon credit trading

The initial offering of credits dictates the amount of emission permissible for a company. If the emission from the company exceeds the allowable limit, a penalty is laid on it depending on the emission. To refrain from paying the fine, organizations that need extra carbon credit can buy it from an organization with a surplus. Some industries need more recognition than assigned, maybe due to the inherent nature of business and production, or high cost to switch to new technology, or the high setup cost. Meanwhile, some industries need much less than their competitors due to efficient processes or innovative technology. Trading permits are allowed under CAT to maintain the balance in emissions without going over the capped limit. One organization can sell the excess credits to those in need at a defined price and earn some money. It offers an opportunity to incentivize investment in green and optimized technologies and sell surplus credits [9]. This creates an ecosystem that collectively curbs emissions without affecting any single entity. The cap amount is then reduced each year, proportionally reducing each organization’s permit value to promote the shift to a more optimized or cleaner process. It also gives them enough time to adapt to new requirements without adversely affecting their production cost[5][6].

1.2.2 Carbon credit offsetting

Changing a company's production methodology to reduce carbon emissions could be a high-risk or prolonged process. It may be impractical to keep emissions below the set limit. The organization has another way to compensate for the extra emission, apart from credit trading, through carbon offsetting. Carbon offsetting is the process through which an organization makes an effort to reduce the atmosphere carbon through methods it would not normally do and receive credit for it. It is also treated as a tradeable commodity [29]. One such way is to invest in projects that conserve nature, which instead is destroyed. Forestation is widely considered an efficient way to reduce carbon from the atmosphere. Organizations can promote forestation or prevent deforestation from receiving equivalent credit in return. They can also set up renewable energy plants and receive credits. The idea behind this feature is that, even if the exploitation of nature and resources is local, its adverse effects can be seen throughout the earth. This provides an opportunity to set up a carbon offset program worldwide and still gain carbon credits.

There has been a recent development in capturing carbon directly from the atmosphere and storing it underground. Many industries capture carbon dioxide generated within it, securely transport it, and dispose of it. This process is called Carbon Capture and Storage (CCS). Though this process is efficient in providing the exact amount of carbon captured, secure disposal of such a large amount of carbon is a task. There are a few cases where the captured carbon is reused to produce something else, conflicting with the primary purpose of reducing carbon emissions. This is a relatively new development and, thus, is still under scrutiny and observation.

1.3 Peer-to-Peer technology

Combined efforts are needed to have a critical impact on the climate. Without global participation, actions will have no significant effect compared to the rate at which climate change is being observed. A common platform is needed, but we need a stable infrastructure and fair rules. P2P provides a good structure without a centralized controlling authority to alleviate the possibility of a single point of control. Peer-to-Peer (P2P) is a decentralized network of independent but interconnected devices that can communicate directly with one another. These devices are known as nodes or peers. The traditional network consists of multiple clients and one server, called the Client-Server model. The client is the one requesting the server, and the server responds. In a P2P network, each connected node can take on the client and server roles. As each node acts as a separate entity on its own, irrespective of the processing capacity, it can be anonymous. Opposite the traditional client-server model, each node can be a client or a server. These nodes can be dynamic and join or leave the network as needed. Each node maintains a list of its neighbors. When a new node joins the system, it is connected with several other independent nodes, and the corresponding node list is updated. Each node may or may not contain the entire data. When a clients request data, the request is transmitted to the network. The proposal is then propagated from node to node until it finds multiple nodes fulfilling the requests. These nodes will then act as a server and respond to the recommendations. The client then receives a part of the data from each server, thus reducing the single point of failure. As no single network path is used for all the responses, there are significant increases in bandwidth and speed. This is also an excellent way to achieve parallelism and avoid network congestion.

1.4 Blockchain

Peer-to-Peer enables transactions without prior mutual trust but is also susceptible to malware. The P2P network connection can bypass the firewall, and the malicious node can attack the system. Nodes can be anonymous in P2P systems, making them a regulatory nightmare. Some of the challenges it needs to identify are Denial-of-service, a dispute among the nodes, and impersonation. This might quickly turn into an unreliable platform with privacy concerns. Due to the absence of a centralized authority, the responsibility of rules, regulations, and security is delegated to the entire network [14].

Blockchain technology is inherently a Peer-to-Peer network that maintains a distributed ledger and is managed by the nodes involved. Each transaction executed on the web is logged onto an immutable ledger. Nodes can also take responsibility for the verification of the transaction. These nodes can be termed miners. Blockchain uses a consensus mechanism such that no single node can verify the transaction. Each transaction needs a consensus of the nodes to be termed as valid and then locked onto the block of verified transactions in the ledger. Blockchain offers many features that can be loaded into the system to overcome the shortcomings of a traditional P2P network. They are listed below.

1.4.1 Double spending

In the blockchain, each coin or token is backed by some assets. These tokens can then be traded as a commodity. Each token can be used for a transaction. As there is no central authority, these tokens are signed by digital signatures to prove ownership of that token. Each transaction takes some time to process, and a single token can be used multiple times, as only recipients can verify only the associated transaction. In addition, some transactions might even be invalidated. Blockchain offers a feature like Hash function and consensus that helps prevents double-spending [15].

1.4.2 Carbon credit trading

Blockchain is capable of making a large number of transactions per second, each consisting of some amount of information. All the details of the transaction need to be stored on the ledger. Blockchain creates a hash of each transaction instead of the complete transaction, and only the hash is stored in each block. The hash function is a one-way function that converts an input of any size to fixed-length output. This output is called a hash value. Each block consists of many valid transactions. The block's hash is then fed to the next block, creating a chain of valid transactions. This makes it easy to verify the validity of any transaction.

1.4.3 Carbon credit trading

There is no central authority to create trust and determine the validity of any transaction. Thus, the responsibility of maintaining trust and reliability of the network fall onto the nodes. The transaction is termed valid if most nodes term it valid. As the nodes can be added and removed from the system, the network can be attacked by malicious nodes. Different consensus mechanisms can make the system tolerant to such attacks. Some consensus algorithms are Proof-of-Work, Proof-of-Stake, Proof-of-Authority, Practical Byzantine Fault Tolerance, and Proof-of-Reputation. It is a core part of any blockchain and helps reach a standard agreement among peers.

1.4.4 Carbon credit trading

The whole idea of a decentralized system is that the transactions are transparent to everyone. All the transactions are available publicly and can be traced in the system. Some blockchains might use anonymous addresses for confidentiality, but the level of identity exposure is utterly dependent on the implementation of the blockchain.

1.5 Smart Contract

A smart contract is a contract that is programmed and deployed onto the blockchain. These can be auto-invoked on the trigger of any event. Smart contracts can be programmed to perform any specific operation. The major characteristic of a smart contract is that it is immutable and recorded permanently. It can be triggered on the initiation of a transaction, capturing the initiators' information, verifying, and generating value. These can then be made to perform automated tasks like identifying the contract that is of value most close to it. These can also act like an algorithm or a protocol that will perform auto-validation and update the blockchain ledger [16][17][18]. Most smart contract characteristics closely resemble the characteristics of blockchain. A few of them are as follows.

1.5.1 Immutable

Once the smart contract is deployed on the blockchain, it cannot be altered or changed. Thus, it must go through various checks before it is deployed.

1.5.2 Secure

The intelligent contract supports cryptography and is an integral part of it. Its immutability nature makes security much more important. If the hacker can find any vulnerability, it can be exploited, resulting in loss of money, as we have seen with Ethereum hacks.

1.5.3 Self-enforcing and autonomous

The intelligent contract invocation does not need human intervention and is triggered by specific events.

1.6 Thesis Overview

As the market matures, laws and policies become more stable, and carbon credits are traded as commodities [29]. Thus, having a stable trading platform has become imperative. Different regions like Chicago, CA, and even countries have their trading model and platform. This prevents a unified model and rules that everyone can participate equally. On top of that, many countries with stringent laws and regulations exploit the resources of the countries with lenient laws. This further adds to instability and uncertainty. Thus, apart from continuous improvement in the policies, a good, solid technical foundation for trading in required. Using technology for stock market trading was a turning point. We want to explore a similar possibility for carbon credit trading through blockchain technology. We must consider economic and technical systems to develop such a vast system. For research, we will dwell more on the technical system and keep the financial section for some other time. In our paper, we will explore the different implementation techniques of blockchain used today to facilitate carbon trading. The rest of the article is organized as follows. Chapter 2 summarizes the background by giving an overview of the Adaptation of Cap-And-Trade in Section 2.1, followed by Challenges with Cap-And-Trade in Section 2.2. This chapter then ended with Section 2.3 explaining the Necessity of the blockchain. Chapter 3 highlights the Literature survey done for the usage of blockchain in Cap-And-Trade. It summarizes the previous study on implementing Bitcoin and Hyperledger blockchain. Chapter 4 gives a brief overview of the work I am proposing, and the Conclusion is given in Chapter 5.

CHAPTER 2

BACKGROUND

2.1 Adaptation of Cap-And-Trade

Kyoto protocol was established to have a market-oriented environmental policy that promoted the market's involvement in the betterment of nature. Though it came up with the regulation and goal, it provided no single trading platform to establish a firm trading structure, management, and contract rules. There is no unified international trading market as well. The emission Trading System (ETS-EU) was established by Europe to implement the CAT. A department EUA regulates and monitors the trading. The US, Canada, Australia, and Japan followed. Among many, EU Emission Trading System and Chicago Climate Exchange (CCE) are relatively mature. Shenzhen officially started trading in 2013 [9][1][12][13].

In [1], the author created a trading model by considering the established trading platform for carbon trading in China. It identified the entities involved in creating the model and highlighted their role. The model is similar to the stock market if we consider the part of the entities involved. It offers a system for the operation of CAT and project trading. [2] highlights that the demand for green consumption is the primary factor in companies' willingness to adopt policies that adopt green technologies, changes in production technology, and the importance of CAT.

2.2 Challenges with Cap-And-Trade

The Carbo offset program is necessary but has been scrutinized for its authenticity. Many fraudulent projects project the already conserved environment under threat only to later establish it as an environment saved through efforts. The exact amount of carbon reduced through forestation is also difficult to quantify. The authenticity and credibility of any offset project can be determined based on the following three factors. It is also known as the Carbon offset triangle.

2.2.1 Permanence

The permanence represents the longevity of the effects of the carbon offset project. For a project to claim credits for the offset, it must ensure that the GHG is permanently reduced. The results of the balance should be long-lasting. If the GHG is reduced for 100 years, it is considered high value. Forestation is one of the most relied methods for the sequestration of carbon. It helps by sucking carbon dioxide from the atmosphere and trapping carbon within the high-density vegetation [19].

There are multiple challenges to ensuring the permanence of an offset project. For a project to make a significant and permanent impact, it needs to ensure that it does not release more GHG in case of failure, adversely affecting the nature more than the credits it received

2.2.2 Leakage

The effects of climate change can be observed worldwide, and each country has a different stand on the actions related to it. The exploitation of resources in one part of the world also affects the rest. This allows the organization in strictly regulated countries to outsource the offset projects to less regulated countries, often developing nations. Such projects also have a low setup cost compared to setting it in a stringent law-following country. This opens the door to inefficiently recording the authenticity and impact of the project. This allows them to exploit a specific region, exhausting the resources and affecting the lives of the people of that region while the part utterly isolated from it reaps all the benefits. Thus, there is a need for a novel approach to monitoring carbon [20].

2.2.3 Additionality

Forestation, shift to clean energy technology, and trapping GHG on land all provide a way to reduce carbon emissions to the atmosphere. Still, all these options are based on asymmetric information. The origin of the offset and the private information about the project is only known to the seller. Thus, it provides a straightforward approach to setting up unfair practices. For many offset projects, the effects and carbon reduction are difficult to quantify and authenticate. This raises a concern for 'additionality.' These need to be verified that these are additional and reduce emissions that would have been possible without it. [21] [22].

There has been increasing in fraudulent projects that project a safe and conserved area under threat and receive credits for it. Few of the projects have gone up to produce cash from it along with gaining carbon credits, conflicting with the purpose of offset.

2.3 Necessity of Blockchain

Gan et al. [10] highlight that getting a fair price for trading is very important. The trading model will work optimally when the cost for a reduction in emission and the market price of an equivalent carbon emission permit is equal [3]. Lin et al. [34] proved that the low trading price for carbon permits is due to the lack of a free market. The permit rate is so low that companies should buy credit instead of investing in emission reduction. A free market can be created through a decentralized blockchain governed by a set of rules coded in it.

Wei et al. [23] analyzed how P2P through blockchain can enable data trading. According to the author, data can be copied and sold to multiple buyers in an unregulated market. Such transactions on the blockchain are known as 'Double spending.' Before blockchain technology, we need to establish trust between the parties involved in the transaction to prevent double-spending. A centralized trading strategy was based on building trust and ownership. As discussed in the 'Additionality' section, having centralized authority with no universally accepted norm gives rise to information asymmetry. The author proposed a data trading mechanism based on blockchain to overcome this drawback. Blockchain can be used to facilitate P2P transactions, and Smart contracts can be used to facilitate automated assessment mechanisms.

The cost associated with blockchain is often compared to the cost and advantage of having a centralized system. In [24], authors have identified how the transmission cost can be reduced significantly if the central authority is removed and the peer-to-peer transaction is promoted. A similar analogy can be drawn for the marketing of carbon credits.

In [25], authors have studied and evaluated that having a smart contract to enable transactions on the blockchain can be automated and reduced the human dependency for verification and completion. This reduces many human hours and guarantees the process execution.

Zhang [3] highlighted that in the international carbon permit trading platform, the developed countries have control over the pricing and most benefit from the information asymmetry. Carbon trading will provide the most value when the permit rate equals the investment needed to generate credits. Developed nations import credits from countries where the difference between marginal cost and the credit trading price is significant. Thus, exploiting the model to achieve their own carbon emission reduction goal at the expense of others. Having a decentralized system for carbon trading could alleviate this problem

CHAPTER 3

LITERATURE SURVEY

With the recent rise in popularity and adaptation of blockchain technology in Fintech, there has been increased interest in identifying other application areas for blockchain. Carbon trading is no exception to it. In this section, we will go through research on the usage of blockchain technology in carbon trading.

Britto et al. [27] proposes a token bases system for carbon trading that is decentralized and transparent. The main advantage it offered was tracking of credits and a repellent to hoarding credits. The system consists of three participants: Generator, Consumer, and Issuer. The generator is the seller selling credits either saved from the allocated limit or obtained through offset, and the consumer is the buyer. The issuer could be the organization overlooking the entire system. The advantage blockchain offers over the centralized system is that it can be independent of a controlling authority. Blockchain inherently contains a feature that might alleviate the problems identified by the author, but no method has been proposed to tackle them.

Yuan et al. [26] proposes a framework for carbon trading among power plants in China. The study is focused on how a platform can be developed on the blockchain for carbon trading between power plants. It will be used for transparent carbon trading. It had a provision for an independent carbon credit buyer and seller, and the individual or market could determine the price. The framework for the trading platform consists of buyers/sellers, block nodes, an administrator account known as a system supervisor, and a smart contract. The transaction between buyer and seller is done through the smart contract and handled by the nodes. The system receives a buy order, and the node identifies the best suitable seller and uses a smart contract to generate a transaction settlement. This record is then transferred to all the nodes, and the transaction is updated. One good thing about this is that it required a few tokens for any trade.

It prevents malicious users and frequently undervalued transactions. At the same time, the drawback is that it is permission controlled. It requires an intermediary for supervision of the transaction and settlement.

In [29], author studied the feasibility of blockchain in carbon trading. The author divided the model into five layers: data layer, network layer, consensus and incentive layer, contract layer, and application layer. Each layer is independent and has a specific task. It makes it easy to determine the feasibility of different approaches. The application layer provides the interface for users. The data layer is used to store all the information, and along with the network layer, it gives security and verification. The contract layer involves signing a smart contract and automatically invoking tasks. It also has a provision for a consensus mechanism that can make it independent of any centralized authority. It provides a mature solution as compared to other frameworks.

In [11], the author proposed a framework consisting of three modules. The blockchain module is responsible for the decentralization of reputation and carbon emissions. Distributed reputation module is focused on analyzing the reputation and assigning a reputation score to advocate trustworthiness. The third module, the Carbon emission module, is responsible for implementing CAT and P2P trading. The authors mainly focused on implementing the consensus mechanism, developing a decentralized reputation rule and policies, and avoiding a single point of failure. The reputation policies used are placid and need more real-world experiments. On the fairground, priority is given to entity with high reputation, but we need to address more about the scenarios where malicious seller tries to undercut the reputed seller. The overall framework suggested is focused more on the consensus mechanism and does minimal to address the structure of the blockchain. The author’s reputation mechanism could be extended to achieve consensus for the blockchain update to ensure that entities with high reputations have more significant weightage in the decision. This way, the core value of blockchain decentralization is maintained, and the weightage of entities with better reputations will develop the blockchain in the correct direction. The reputation-based consensus can have a particularly significant use case for offset credits. As discussed in the Background section, credits from offset are more likely to be fraudulent. Using a reputation score and the history of offset credits' origin could be pivotal.

In [28], the author takes an exciting step to reduce the systems' dependency on human interaction. Autor proposed integrating IoT technology in blockchain to track emissions and automate the entire process systematically. This approach resolves a few of the challenges we identified in the Background section. It utilizes the core feature of blockchain, Distributed Ledger Technology (DLT), to authenticate and verify transactions. DLT makes the information more transparent and consistent. The system is divided into different layers, the User layer, the Registration and Authentication layer, the Blockchain layer, and the data center. The smart contract is used in conjunction with this to execute automatic updates on the ledger and data center and can also be used for analysis. The system employed anonymized accounts to accommodate the privacy factor as well. To further add safety, the system has a private and consortium-led blockchain that allows only the permission node to execute the smart contract and work on the block. Validating nodes use Practical Byzantine Fault Tolerance (PBFT) as a consensus protocol. In developing countries like India, a strong movement is being made to make smart cities, and an application like this would lay the foundation for further use of blockchain.

Sadawi et al. [30] identified many gaps we have discussed and came up with a comprehensive solution to address them. The most important aspect it covers is the need for a consensus mechanism. The system is developed to ensure integrity, fair trade, and smart contracts for automated trading and control mechanisms. It is a research study on how a consortium blockchain can be developed in conjunction with a public blockchain to offer confidentiality for participating companies and transparency for the public. This will enable only the relevant data to be publicly available and increase confidence in the public and companies. It also has a provision for the consensus mechanism, which can be studied independently. It is a three-level design, Upper-level public blockchain, Low-level consortium blockchain, and the transfer level. Upper-level blockchain allows the participation of governments of all countries, companies, and the public. The allocation of credits depends on the respective government regulations but is transparent to the public. A low-level consortium blockchain is primarily used to track emission statistics using sensors for automatic updating and intelligent contracts for verification. The third level is responsible for an adopted protocol for operation and trading.

Research papers discussed till now have shown how the basis of blockchain can increase the efficiency of the CAT system. This further motivated me to explore the challenges in implementing CAT on different blockchains like Bitcoin, a decentralized ledger, Ethereum, and Hyperledger. While bitcoin and Ethereum are permissionless, Hyperledger is permissioned. Permissionless blockchain allows entities to join and leave the system at will. Hyperledger provides space for creating modular architecture that is suitable for business applications. We will discuss the implementation mechanism and challenges for different blockchains.

3.1 Using Bitcoin

Kawasmi et al. [31] present a bitcoin-based Decentralized Carbon Emission Trading Infrastructure (D-CETI) focusing on privacy and system security. The author considered the constraints based on region and compliance type, which we identified in the Background section. Two main actors are the buyer and seller, who interact with the system through services like carbon credit generation, registration, and transaction initiation and management. The system can be decomposed into D-CETI Integrated Client (IC), D-CETI-

OT Coordinator, and D-CETI-OT Server. D-CETI IC is concerned with all the functionality on the client side. D-CETI-OT Server handles the security and contract creation to complete the transaction. D-CETI-OT Coordinator bridges the protocol used and integration with blockchain. The use of ***Smart meters*** is a very crucial step to reduce centralized organization dependency and automate carbon credit creation. This way, we can authenticate and have a credible source of offset credits. Essentially, the system works as a carbon credit issuing facility. It eliminates the need to validate and certify authority. For the integration part, D-CETI also allows issuing of carbon credits authorized by a certification authority. It has also clearly segregated the system's economic and technical aspects, enabling the integration of different systems into the chain. Thus, it can be used as an integration platform on a much larger scale. Like the similarities between bitcoin and newer technologies, this system can perform slowly compared to other technologies. Other technologies like Ethereum have come a long way to adapt to changing business needs with better throughput than bitcoin. Thus, it is natural to compare the framework with new technologies

3.1 Using Hyperledger

Yuan et al. [32] identified that having a public blockchain for CAT might be demotivating for companies that do not want to overshare the data. Thus, Hyperledger provides a good alternative, being a permissioned blockchain. A ledger is maintained with the entity having special permission and distribution. It provides a modular structure, enticing enterprise-level application development. It comes with an integrated SDK and allows a pluggable consensus mechanism. The framework is relatively similar to the legacy trading system, consisting of Traders, an Approver, an Environmental agency, and a Trading Centre. The trader is an entity that needs clearance from the Approver before the Environmental agency verifies the authenticity of a project. The blockchain network is integral to creating a consistent link between discussed network entities. It defines the customizable business and trading logic on blockchain and uses Smart contracts for access control and event invocation from different organizations and parts of the system. Though it addresses many legacy CAT issues, the only drawback compared to other research is that it depends on some governing organization and is not entirely decentralized.

Golding et al. [33] also explored the use of the Hyperledger blockchain for trading carbon credits. It talks about the tokenization of the right to emit carbon in a completely decentralized manner. The advantage it offers over the previous two frameworks is that it also considers the reputation. Reputation depends on ESG (Environmental, Social, and Governance) data available on-chain. It is not dependent on centralized authority, and the blockchain runs on Hyperledger fabric handling all the carbon credit trading. Policy contract defines the creation of credits that are subsequently loaded onto the blockchain. The business logic and reputation logic, dependent on ESG data, are loaded on the smart contracts. The framework works at three levels. Clients access the blockchain level through a central server. The central server offers identity management and secure blockchain access through an independent Web application and API layer. The framework overall has a good analysis for the automatic creation of carbon credits with credibility and security of smart contracts. The application is close to a completely decentralized operation but needs to consider the regulation differences based on region and country.

CHAPTER 4

PROPOSED WORK

The Cap-And-Trade system is affected by economic policies, technical stability, environmental regulations, and political pressure, which takes a long time to mature. It isn't easy to shift from the established policy to a new one, especially considering CAT, which is used by many countries today. Creating an entirely new system might help resolve many issues, but the overhead of transitioning from the current to the new system is the biggest discouragement. Thus, the practical solution would be a system whose base is similar to the current CAT system and provides additional features identified in the Background and Literature survey section. Therefore, we aim to incorporate the established CAT mechanism into blockchain technology to offer a smooth transition and encourage countries to adopt it.

There are four types of blockchain, namely Public blockchain, Private blockchain, Hybrid blockchain, and Consortium blockchain. The goal of having the participation of global entities rules out the use of private blockchain. Having a public blockchain would be discouraging for the participating industries because of the possibility of market manipulation and volatility. Hybrid blockchain and Consortium blockchain offers a possible solution to our problems. Both offer a space where terms can be observed by chosen few. Consortium blockchain will allow a public blockchain, one of each country to work with other country's blockchains on a decentralized network. Few chosen nodes will overlook the consensus mechanism. Hybrid offers an opportunity of integrating a permissionless process in the blockchain while a few aspects are controlled by some authority. The authority could be a country distributing initial permits. The rest of the trading could be done on the permissionless side of the blockchain.

I am proposing a token-based blockchain for Peer-to-Peer trading. There will be two types of tokens, a primary token, and a secondary token. Each token will be backed by a permit issued by a regulated authority. The control of authority will be limited to the creation of tokens backed by emission permits, the rest of the trading will be peer-to-peer and decentralized. The primary token will be backed by the initial credits issued by the regulatory body, as it is currently created in CAT. The secondary credits will be the credits generated through the offset projects. The distinction is needed to tackle the issues identified in Section 2.2. The primary tokens have government backing and are thus cleared off from the possibility of being generated from unfair practices. The trading of secondary tokens will be influenced by the consensus mechanism.

The consensus mechanism plays a pivotal role in the working of any blockchain. The implementation of the consensus mechanism is a separate research area on its own and thus out of the scope of this paper. For the implementation part, we will assume that we are using a reputation consensus, as explained by Wang et al. [11]. While taking consensus, a node with a high reputation will have a greater impact than a node with no reputation. The reputation of the node is a slowly increasing function. It will prevent any malicious attempt of skewing the consensus by creating a high number of new nodes.

Each participating company will have a single unique address through which trading is allowed. Each transaction will be verified through a smart contract. Transactions of the secondary tokens will be more scrutinized than the primary. For each transaction of the secondary token, the smart contract will append the buyer and seller information along with the creator's information. A transaction record will be appended to the immutable ledger and available to the public. Some reputation will be assigned to participating entities in each 'fair' transaction. This delegates the responsibility of regulation and security to all the nodes and alleviates the need for central controlling authority, as discussed by Azim et al. [14].

CHAPTER 5

CONCLUSION

Peer-to-Peer technology-based trading will make carbon credits available worldwide, irrespective of the location and regulations. If the credits are available in plenty, companies will not necessarily have to bear the setup cost of offset projects at a remote location. Logically, companies are primarily concerned about profit [2, 4, 5]. Yuan et al. [7] showcased that Consumers are becoming more aware of climate change and prefer products that are less harmful to the environment, from manufacturing to the final product, even if the purchase cost is more. This incentivizes companies to invest more even if the initial adaptation cost is higher.

P2P and blockchain allow us to create a system that provides a platform to achieve the same. The European Union has developed a single database for tracking the emission trading system, which is a step in the same direction. However, the question often arises of data transparency and integrity. Quoting Kawasmi et al. [31], “By providing systematic decentralization, privacy, and security protection for the carbon emission traders, a decentralized platform (D-CETI) should increase their participation and the overall trading activity, which will help in the overall reduction of carbon emissions.”. If we have a system devoid of politics, and regional regulation and promote companies and people to join voluntarily, the platform will be more stable and attract more traffic.

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