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Blockchain-based Distributed Framework for Automotive Industry in a Smart City

Pradip Kumar Sharma, Neeraj Kumar, and Jong Hyuk Park

Abstract— **The digitalization and massive adoption of advanced technologies in the automotive industry not only transform the equipment manufacturer's operating mode but also change the current business models. The increased adoption of autonomous cars is expected to disrupt government regulations, manufacturing, insurance, and maintenance services. Moreover, providing integrated, personalized, and on-demand services have shared, connected, and autonomous cars in the smart city for a sustainable ecosystem. To address these issues in this paper, we propose a blockchain-based distributed framework for the automotive industry in the smart city. The proposed framework includes a novel miner node selection algorithm for the blockchain-based distributed network architecture. To evaluate the feasibility of the proposed framework, we simulated the proposed model on a private Ethereum blockchain platform using captured dataset of mined blocks f[1]rom *litecoinpool.org*. The simulation results show the proof-of-concept of the proposed model which can be used for wide range of future smart applications.**

Index Terms— **Smart City, Blockchain, Automotive Industry, Supply Chain Management**

I. Introduction

In today's world, the automotive industry demands more personalized, integrated, and on-demand services including shared, connected, and autonomous environment, for example smart parking system, e-healthcare etc. The automotive industry is closely linked to new technologies. In fact, autonomous cars are the most anticipated and notable revolution in the automotive industry. A recent study predicts that around 250 million connected cars -- each of them carrying more than 200 sensors to collect information -- will be on roads worldwide by 2020 [1]. The increased adoption of autonomous cars in the automotive industry is seen to disrupt government regulations, manufacturing, insurance, maintenance services, etc. The integration of innovations in cars is a time-consuming process in terms of investment, development, and validation in the current business model of automotive industries.

Considered one of the most advanced sectors with participants ranging from government regulatory parties, manufacturers, suppliers, and vendors to spare parts suppliers, the automotive supply chain becomes a complex and wide-ranging ecosystem. However, one of the biggest issues in the automotive supply chain industry is counterfeiting products, which is currently estimated at several billion dollars' worth of spare parts. Counterfeit spare parts often have poor quality, as they enter directly into the supply chain or through online channels, and have an impact on the original equipment manufacturer and spare parts suppliers. This leads to dissatisfied customers and affects trust in the brand. In addition, the sharing economy is no longer a stranger to the automotive industry. Effective planning of production capacity, tracking and tracing of individual parts across the supply chain, and accurate and real-time information become essential in building a sustainable framework for the automotive industry in the smart city.

Recently, Blockchain technology becomes a revolution and attract the attention of many shareholders who recognize the benefits of this disruptive technology, influencing the financial industry as well as other sectors [2-4]. Some of the most common applications of blockchain technologies are their use in the transfer of assets and digital applications and distributed information records created using smart contracts, considered an ideal way to program logical business and operations. It has an impact on all sectors of the industry, and it is not surprising that the automotive industry has also been influenced by this revolution. In the current business scenario, many intermediaries needed such as banks, notaries, administrations, associations, etc. who can be redundant using this technology. Thus, it translate directly into considerable savings in terms of time and money and providing a platform for organizations to build sustainable business models. The integration of the automotive industry and Blockchain technology offers interesting solutions to some of the most pressing automotive problems, especially those related to the connected automotive industry. The power of this technology can drive innovation and solutions across the entire automotive ecosystem. Motivated from the facts, in this paper, we propose a blockchain-based distributed framework model for the automotive industry in the smart city to build a sustainable platform for the automotive ecosystem. The main research contributions of this paper are summarized as follows:

- We propose a distributed framework model for the automotive industry using blockchain technology.
- Then an algorithm for selecting miner nodes in the blockchain-based distributed network architecture is designed.
- The simulation is performed on a private Ethereum blockchain platform, and the proposed framework is examined using real-time data statistics based on the captured dataset of mined blocks from *litecoinpool.org*. The experimental result shows the effectiveness of the proposed model.
- We also discuss the different directions of research that we need to conduct to build a sustainable automotive ecosystem.

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The rest of this paper is organized as follows: Section II discusses the key requirements of the blockchain-based framework for the automotive industry and related research works; Section III describes the proposed framework model architecture for the automotive industry; Section IV presents the experimental analysis and discusses the future research direction; and Section V presents the conclusion of this research.

II. Preliminaries

A. Key requirements for the automotive industry

In the era of digital world, the automotive industry is shifting to digitalization, which is changing the entire business model. Recently, many automotive industries and stakeholders have used the blockchain technology in autonomous vehicles, cybersecurity, and connected cars to achieve scalability, auditability, and real-time monitoring. Manufacturing industries, supply chain logistics, retailing, and leasing are some of the automotive industry's key functional areas which can be leveraged through blockchain technology. Here, we discuss the key requirements of the blockchain-based framework for the automotive industry in the smart city.

1) *Supply chain management:* We can apply blockchain technology for each phase of the supply chain from government regulation and manufacturing to maintenance and the recycling phase of the automotive industry. For instance, in case of automotive part failure or accident, the blockchain-based framework can provide unique identification that will help us determine the root cause as well as who should assume the cost and so on.
2) *Unparalleled security:* As connected cars become more and more self-driving autonomous cars, so addressing the challenges of connected car data security is a necessity. By inheriting secure means of sharing and storing data through blockchain technology, we can provide different levels of security in the automotive industry.
3) *Evidence integrity and secure storage:* The framework must ensure that previously submitted evidence remains unchanged despite any attempt to modify historical data to deny liability in case any event occurs.
4) *Mobility solution:* The framework should provide a platform to allow data, resources sharing, and carpooling services in an autonomous system.
5) *Ability to audit records:* A blockchain-based automotive framework can do audits because of the immutable nature of the information in the blocks.
6) *Automated maintenance services:* A blockchain-based automotive framework can be used to automate payments, insurance claims, and provision of maintenance services. It will also provide a platform for facilitating vehicle tracking.
7) *Transparency:* Due to the decentralized nature of the blockchain and lack of centralized control by a single party, all authorized parties have access to the same immutable information.
8) *Execution speed and cost reduction:* Numerous computing resources processing each transaction simultaneously due to the distributed nature of the blockchain accelerate the execution compared to the traditional centralized network wherein each transaction must wait for its turn to be processed. It also translates into reduced costs since there is no need for a single party to bear the burden of costly backup servers and remote storage.

B. Related works

Brousmiche *et al.* [5] presented a framework for automating the life cycle of vehicles using the consortium blockchain. They highlighted the initial phase of implementation and the challenges to be addressed in the future. A study was carried out by Supranee *et al.* [6] to illustrate that the blockchain technology can help to improve the supply chain process of Thailand's automotive industry. The research by Daniel *et al.* [7] presented the challenges and a framework for knowledge exchange among organizations in the automotive industry. Pinheiro *et al.* [8] proposed a decision-making process model in the multi-agent systems approach to the industry using blockchain. On the other hand, an abstract idea of the reward-based smart vehicle data sharing framework is proposed by Singh *et al.* [9] for intelligent vehicle communication using blockchain. They also presented a crypto IV-TP intelligent vehicle communication to improve privacy [10]. According to Ortega *et al.* [11], content-centric networking combined with blockchain can be effective in handling tasks in the automotive industry. To guarantee the execution of energy recharges, Pedrosa *et al.* [12] presented an algorithm with a refuelling use case scenario for autonomous vehicles using blockchain. In our previous research work, we presented a vehicular network architecture based on the blockchain in the smart city [13]. Dujak et al. [14] presented the concept of using blockchain technology in logistics and supply networks. They stated that the challenges such as the secure and authenticated logistic system, the control of trust issues, and the ability to exchange supply chain information in supply networks could be solved through the blockchain. Mondragon et al. [15] investigated the applicability of blockchain technology in the supply chain, particular in the manufacturing of structures. Providing an inviolable history of manufacturing, provenance, transportation, and storage, blockchain technology has proven to be effective. In addition, Hofmann et. al. [16] studies reveal opportunities in terms of decentralization, self-regulation and efficiency for the current status as well as for future logistics prospects. We discussed the use case scenarios and design principles to meet the requirements for building a sustainable network of smart cities. We have also proposed various blockchain-based distributed architectures for sustainable IoT and smart city network [17-20]. To the best of our knowledge, most of the researchers focused on the very specific phase of life cycle in the automotive industry. There is a need to design a complete framework to provide on-demand, customized services meeting all key requirements as we discussed above for the automotive industry in the smart city.

III. Proposed Framework Model

The main focus of this research is on digital transformation, mobility, and automotive consumer in the future digitalized smart city. The future automotive market needs more on-demand, personalized, and integrated services which are different from the current automotive market having shared, autonomous, and connected cars. The digitalization era can transform the automotive industry in the manufacturing process and change the current business model as well. In future smart cities, vehicles will demand a new way of interacting with the environment and enable the delivery of integrated services and transactions. With the growth of on-demand and e-mobility services, consumer behavior is changing; consumers are increasingly willing to share data and use technology to enhance their experience. Using a transparent, shared and validated transaction process, blockchain has the potential to play a bigger role in supporting transformation by combining

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with the automotive industry. In this section, we propose a blockchain-based distributed framework model for the automotive industry in the smart city to meet the current as well as future requirements. We discuss in detail the distributed framework model and its workflow as well as the miner selection algorithm in the following subsections:

A. Blockchain-based distributed framework model

As a competitive need, digitalization is widely considered. In recent years, the growth of IoT has been explosive; it continues to grow in both value and adaptation at a rapid pace, leading to smart ecosystems. In the automotive industry of smart cities, trusted suppliers in the supply chain lifecycle are carefully selected, managed, audited, and certified to deliver reliable, consistent, quality services. In this research, we propose how the blockchain structure model allows the development of secure digital product memory records, from raw material sources and manufacturing up to their maintenance and recycling phase in the supply chain lifecycle.

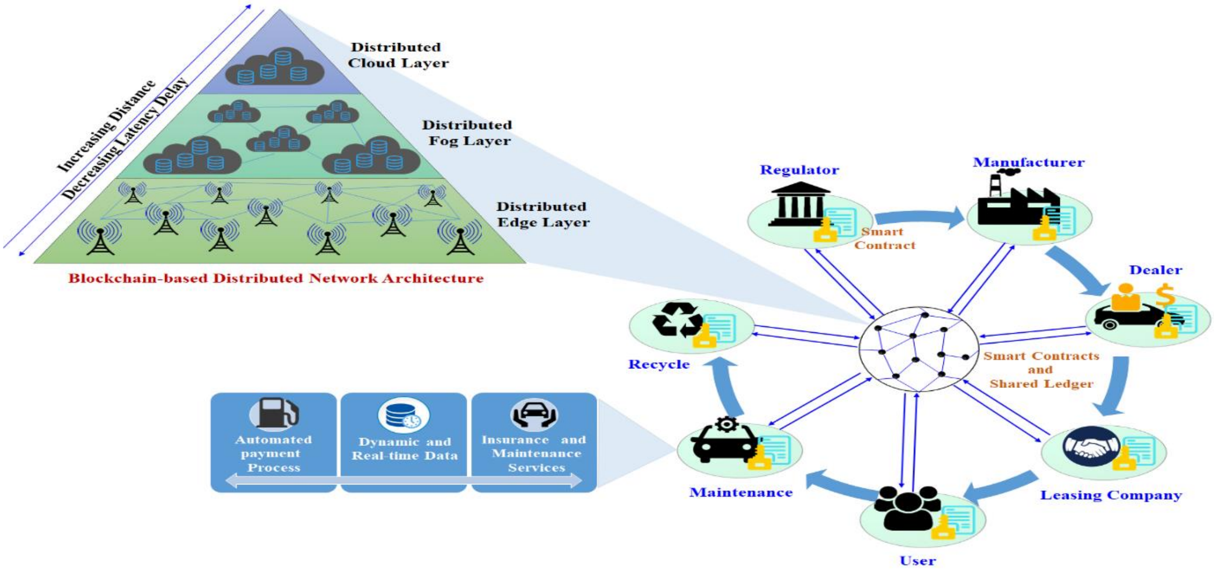

Fig. 1 Blockchain-based distributed framework for automotive industry in the smart city

Fig. 1 demonstrates the complete life cycle of the automotive industry framework model in a smart city using the distributed blockchain-based scalable network. In the proposed framework model, the entire life cycle is categorized into seven phases. Here, we leveraged the strength of the blockchain-based distributed network architecture from our previous work [17] [18]. In our previous work, we presented a distributed blockchain network architecture to provide secure, on-demand access and low-cost competitive computing infrastructures in an IoT network. It enables high-performance, cost-effective computing by putting computing resources at the edge of the IoT network and providing secure, low latency access to large amounts of data. Since then, we have inherited the blockchain-based distributed network architecture from our previous works [17] [18], so we are skipping the detailed description of network architecture. In the first phase, the regulator in the proposed framework model is responsible for creating the new vehicle registration based on government regulations and loading it into the shared ledger in the network. A smart contract ensures that only the regulator has the right to do so. In the second phase, the manufacturer receives the certified created ownership issued by the regulator, which is called a consensus between the manufacturer and the regulator. Upon receiving ownership, the manufacturer makes the vehicle model, ID, and template available in the network for all relevant parties with appropriate permission using smart contracts. In the third and fourth phases, the vehicle are transferred to the dealer and leasing companies with the execution of smart contracts in the supply chain. After the vehicle transfer to the leasing company, the car is finally released to the user, subsequently passing through the maintenance and recycle phases in the fifth, sixth, and seventh phases in the supply chain life cycle. In the maintenance phase, the proposed framework model provides services such as automated payment process, insurance and maintenance services, and dynamic and real-time data for the smart transportation system and personalized, on-demand, and automated services to meet user demands. In the recycle phase, the scrap merchant is allowed to scrap the car at the end of its life by executing a smart contract. The synchronization process continues throughout the supply chain of the car through the end user, maintenance, and scrap merchant. A detailed description of the methodological approach of the proposed framework model is discussed in the next subsection.

B. Methodological approach of the proposed framework model

Fig. 2 illustrates the step-by-step methodological approach of the proposed blockchain-based distributed framework model for the automotive industry in the smart city. The government regulator in the first phase of the supply chain lifecycle creates registration for the new vehicle based on the government rules and policies and building a new block. With the help of the smart contract, we execute the block and ensure that it satisfies the smart contract terms and conditions and initiates the transaction of the new block. Once the transaction gets validated, the consensus and transfer ownership to the vehicle manufacturer are published in the blockchain-based distributed network. After transferring ownership to the vehicle

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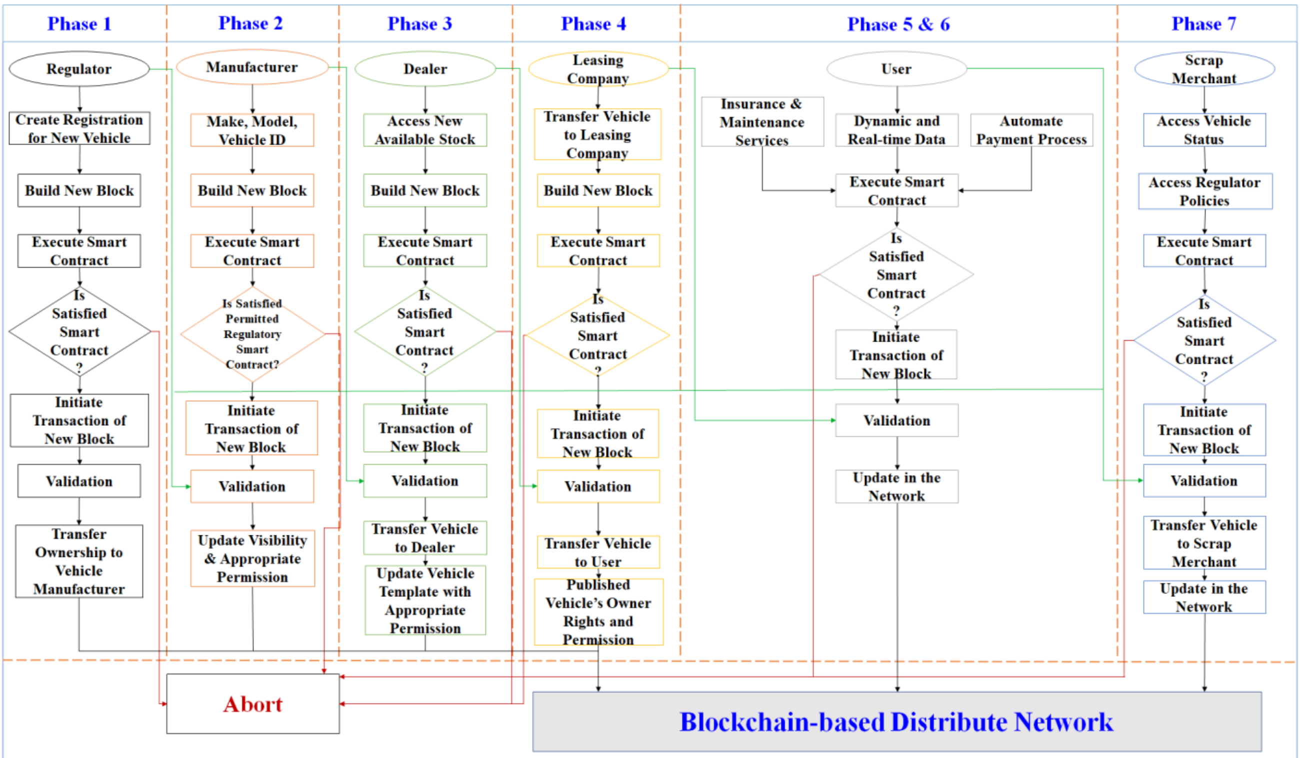

Fig. 2 Illustrates the methodological approach of blockchain-based distributed framework model for automotive industry

manufacturer, the manufacturer begins to fabricate the vehicle model, identification, and model and build a new block, and execute a smart contract. If the newly created block satisfies the permitted regulatory smart contract, initiate the transaction of a new block and get validated by miner nodes in the network. Here, transactions are verified and validated by the regulator as well. Once the transaction are validated, the manufacturer publishes the vehicle template with updated visibility and appropriate permission for all the relevant parties in the network. After publishing the updated templates into the network, the dealer can access information on stock availability from the network and execute their smart contract to initiate transaction of the new block and transfer the vehicle to the dealer. Here, the manufacturer and regulatory participate in the validation process. In the end, the dealer publishes the vehicle template in the network for all members with appropriate permission to see. In this phase, the dealer can also issue loyalty points that can be used and exchanged as currency in the network. The dealer could complete the purchase of parts with loyalty points redeemed by the customer at a discounted price. Once the loyalty points have been redeemed, the dealer account will be updated so that participants in the network can see with appropriate permission. The leasing company accesses the updated vehicle template from the network, transfers the vehicle from the dealer, and builds a new block and initiates a new transaction if the created block satisfies the smart contract. Once the transaction is verified and validated by the regulator, manufacturer, and dealer, they transfer the vehicle to the end user and publish the vehicle's ownership, rights and permission into the network. The proposed framework model connects the entities involved when leasing a vehicle to a customer in a secure manner to perform Know Your Customer (KYC) customer checks such as credit check, ID, and license prior to leasing the vehicle and storage of leasing contract in the blockchain network. During phases 5 and 6, there are different personalized, on-demand, and real-time services offered for the user such as insurance contract, periodic maintenance contract, and automated fuel payment contract. In this phase, the proposed model allows insurance companies to create customized vehicle insurance contracts based on actual driving behavior and automate the payment of insurance and financial settlement following a claim. Driving behaviors and safety events such as mileage, speed, damaged parts, and collisions of a vehicle owner could be stored in the blockchain network, shared, and used to calculate insurance premiums and payments. Since the record is tied to the owner, the history of the vehicle owner remains available to the insurance company for future

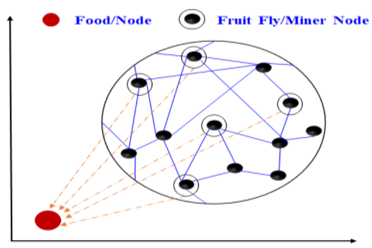

Fig. 3 Node finding behavior of fruit flies/miner nodes during mining process

Algorithm 1: Miner node selection algorithm

Input: $N \leftarrow Is\ the\ list\ of\ total\ miner\ nodes\ in\ the\ network$
M ← Is the list of newly added miner nodes (or didn't participate in mining process for long time)
K ← Is the list of active miners
$MaxGen \leftarrow Maximum\ generation$
$gen \leftarrow 0$
$index \leftarrow 0$
$FruitFlyList \leftarrow NULL$
$FruitFlySmell \leftarrow NULL$
$IsActive \leftarrow NULL$
$BestSmell \leftarrow NULL$
Output: List of selected miners to send transaction request

```
Begin
    For Each K Active Miner Nodes
        Calculate SD_i, LT_i, TL_i;
        Calculate Weight_i ← SD_i + 1/LT_i + 1/TL_i;
        Calculate Dist_i ← Weight_i;

        Calculate S_i ← 1/Dist_i;
        Calculate Smell_i ← Function(S_i);
        FruitFlyList[index] ← Add(K_i);
        FruitFlySmell[index] ← Add(Smell_i);
        IsActive[index++] ← True;
    End For
    For Each M Miner Nodes
        FruitFlyList[index] ← Add(M_i);
        FruitFlySmell[index] ← NULL;
        IsActive[index++] ← False;
    End For
    While (True)
        index ← 0;
        BestSmell ← FindBestSmellConcentration (FruitFlyList, FruitFlySmell);
        For Each N Miner Nodes Searching for the Food Source
            If (IsActive[index ])
                Set Weight_i ← BestSmell + RandomValue;
                Calculate Dist_i ← Weight_i;
                Calculate S_i ← 1/Dist_i;
                Calculate Smell_i ← Function(S_i);
                FruitFlySmell[index] ← Update(S_i)
            End If
            index++;
        End For
        gen++;
        If(gen > MaxGen)
                FruitFlyList ← SortIncreasingOrderSmell ((FruitFlyList, FruitFlySmell))
            Return Select Top L Miner Nodes with High Concentration Smell
        End If
    End While
End
```

insurance quotes even after the sale of the car. In case of on-demand mobility, fuel payment, and ride-sharing services, our proposed blockchain-based framework model records and executes agreements and monetary transactions to allow vehicle owners to monetize trips, pay at fuelling service stations, and exchange data in a seamless, secure, and reliable manner. At the end of the lifecycle, scrap merchant access vehicle status information, regulatory rules, and policies and execute a smart contract and check if the newly created block satisfies the smart contract, and then initiate the transaction of the new block, with the process validated and verified. In the validation process, all the relevant parties in the supply chain will participate in the process. Once the transaction gets validated, the vehicle will be transferred to the scrap merchant with appropriate permission to dispose of the vehicle at the end of the lifecycle and make the corresponding update in the network. In the next subsection, we discuss the miner node selection algorithm in the distributed blockchain-based network architecture.

C. *Miner node selection algorithm*

To avoid the mining process during the block generation carried out by a unique miner pool and limited by miners, we propose an efficient algorithm for selecting miner nodes. In the proposed miner node selection algorithm, we used the fruit fly optimization algorithm (FOA) to select the list of the best possible miner nodes to compute the mining process during block generation. FOA is an evolutionary algorithm inspired by nature based on the food foraging behavior of fruit flies. The term was coined by Wn-Tsao Pan [21]. Using their sense of smell and vision, fruit flies have a better way of finding food compared to other fly species.

Table 1. Notations of mine node selection algorithm

Notation	Description
N	List of all miner nodes in the blockchain-based distributed network.
K	List of all miner nodes those are actively participating in the mining process.
M	List of all miner nodes those are newly added or did not participated in the mining process for a longer time.

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$FruitFlyList[]$	Array list to store the active and newly added miner nodes.
$FruitFlySmell[]$	Array list to store the smell of active and newly added miner nodes.
$IsActive$	Flag indicates that the node is active or not.
$BestSmell$	Indicates the miner node with best smell.
$MaxGen$	Maximum number of generation while searching for food.
SD	Standard deviation of the generation time of block by each miner node.
LT	It represents the time at which the last block created by a miner node.
TL	It represents the trust level of the miner nodes. The value of trust level increases as it successfully create new block. The trust level of newly added miner node or that did not participated in the mining process for longer time is set to zero.
$Weight$	Weight of the miner node which can be defined as $Weight \leftarrow SD + {}^{1}/_{LT} + {}^{1}/_{TL},$ When LT>0 and TL>0. In case of LT or TL value zero, we are omitting it from the calculation of the weight of miner node.
$Dist$	The distance is equivalent to weight of miner node.
$Smell$	The smell concentration of each miner node is inversely proportional to the distance of miner node.
$FindBestSmellConcentration$	It returns the smell value of miner node that has a high concentration.
L	It is the number of selected miner nodes to send transaction request.

In our proposed algorithm, we consider fruit flies as miner nodes and food as a transaction initiator node to create a new block. Fig. 3 shows the food/node finding behavior of fruit flies/miner nodes during the mining process when creating a new block. Algorithm 1 illustrates the proposed miner selection algorithm using FOA. Here, we have classified the miner mode into two different groups: group of active miner nodes and group of newly added miner nodes (or did not participate in the mining process for a long time). Table 1 shows the notations used in our proposed algorithm. In this algorithm, we take the list of all miner nodes as input and provide a list of the best possible miner nodes to send a transaction request in the mining process when creating a new block. Initially, in step 1, we calculate SD, LT, and TL of the miner nodes from the list of active miner nodes, and then compute the smell of each miner node. SD is the standard deviation of the generation time of each miner node and can be defined as follows:

$$SD_i = \sqrt{\frac{1}{N}\sum_{j=1}^{N}\left(M_j(t) - \mu\right)^2}$$

Where N is the number of miner nodes in the blockchain-based distributed network, $M_j(t)$ is the capture time taken by i miner node to generate the last block, and $\mu = \frac{1}{N}\sum_{j=1}^{N} M_j(t)$ is the mean; we assume that each miner has equal probability.

At first, the smell of each newly added miner node will be NULL. In step 2, we select a miner node with the best smell concentration using the FindBestSmellConcentration function. While all miner nodes search for the food source, we check whether the miner node is active or not. If the miner node is not active, then we set the smell of the miner node from the selected miner node with the best smell and random value, and compute the smell concentration using the smell function and update the miner node smell values in the miner nodes list. Once we have computed the smell concentration of all miner nodes, we check whether the number of iterations reaches the maximum generation or not. If the number of iterations reaches the maximum generation, we sort the list of all miner nodes based on their smell concentration and return top L miner nodes with high smell concentration; otherwise we repeat step 2.

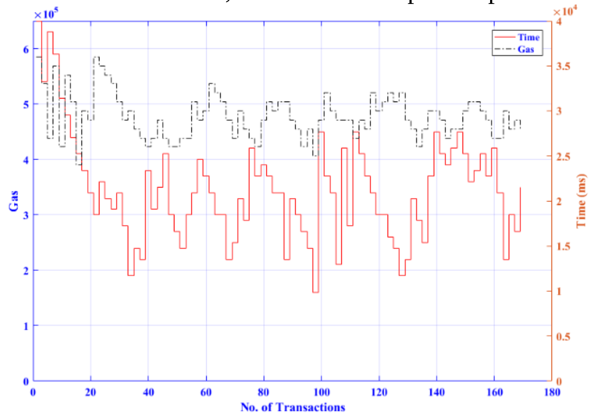


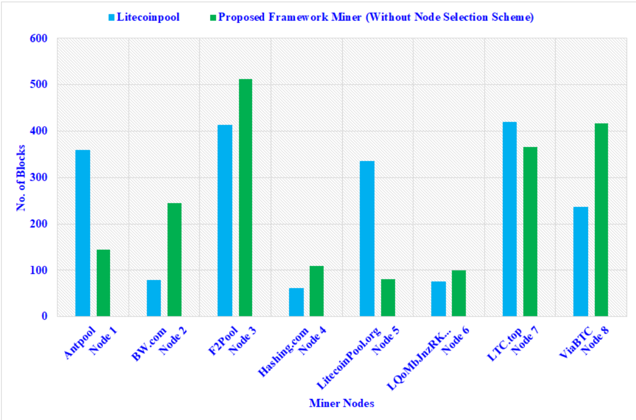
Fig. 4 Gas and time consumption with respect to the number of transactions

IV. Experimental Analysis and Future Direction

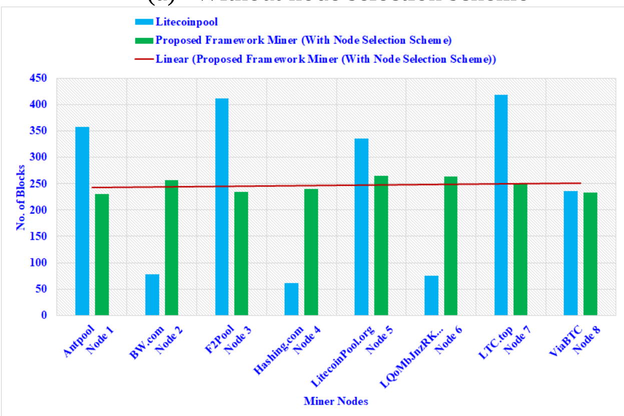
A. Experimental analysis

To validate the feasibility of the proposed framework, we simulated the prototype of the proposed framework using the Ethereum platform. We installed Geth, Node.js, PhPStrom, MinGW, and Truffle to build our own private network. *Geth* is a versatile command line tool that provides a JSON-RPC server and an interactive console to run a complete Ethereum node; Truffle is a development environment that has a test framework and an asset pipeline for Ethereum to compile, link, and deploy smart contracts and does automated contract testing. We have also installed the *Mist* browser to provide an end-user interface for navigating and using Dapps. To simulate the behavior of the client, we used testrpc Node.js based Ethereum client. To implement smart contracts, we used Solidity, which is a high-level contract-oriented language. To set up the proposed framework simulation prototype, we used 8 desktops each equipped with Intel i7 processor and 64 GB DDR3 RAM.

To analyze the use of gas and the time required in relation to the number of transactions, we observed the amount of gas and the time required to complete a transaction. Fig. 4 shows the gas consumption and the time with respect to the number of transactions. The price of gas is the price that the initiator of the transaction wants to pay to the miner node for the validation of the transaction. Speeding up the validation of the transaction requires a higher unit of gas; hence the higher transaction costs. The result signifies that how the proposed model varies in terms of time to complete a transaction when the gas consumption changes. It is important to shows the cost of the transactions in the proposed model. The result shows that the proposed model varies slightly over time as the unit of gas changes.



(a) Without node selection scheme



(b) With node selection scheme

Fig. 5 Number of blocks mined with and without proposed miner node selection approach

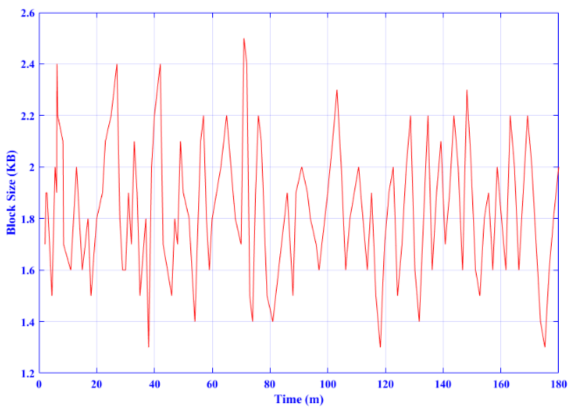


Fig. 6 Result of block size per KB

To analyze the miner node selection algorithm, we captured the dataset of mined blocks from litecoinpool.org [22], a pay-per-share (PPS) miner pool for Litecoin. We captured the latest 2016 block data on June 14, 2018 to evaluate the performance of the proposed miner node selection approach. We examined the SD, LT, and TL of finders "Antpool," "F2Pool," "BW.com," "LitecoinPool.org," "Hashing.com," "LQoMbJnzRK...," "LTC.top," and "ViaBTC". We install eight different miner nodes on our virtual machines and set the SD, LT, and TL values on all the different miner nodes based on the analyzed data captured from the dataset. Fig. 5 shows the results of a number of blocks mined by different miner nodes with and without the proposed miner node selection approach. Due to the lack of proper selection of miner nodes, the traditional approach consumes more electricity and drives the entire blockchain to a central system. The result shows the efficiency of the proposed algorithm in selecting miner nodes and can solve problems such as the waste of computing resources, the process of inverse decentralization and the time needed to reach a consensus.

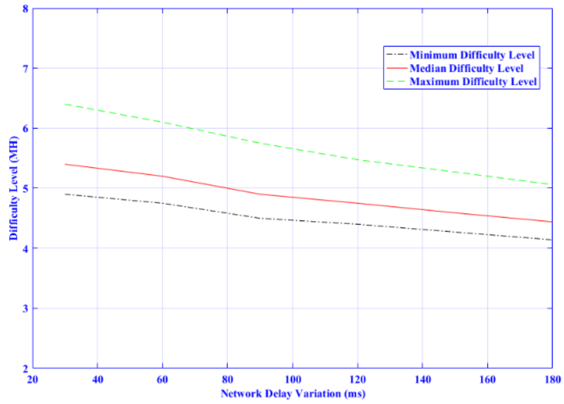


Fig. 7 Difficulty levels with various network delays

We performed the experiments to capture the block size and difficulty level. Generally, in Bitcoin, large blocks take longer to verify and propagate. To evaluate the performance of the proposed model, we recorded the size of blocks. Fig. 6 shows the result of the block size per KB. To check the adjustment of the proposed model's Poof-of-Work (PoW) difficulty, we also observed the PoW difficulty level with respect to various network delays. As the level of difficulty increases, transactions may become too difficult to validate for network delays; which results in additional cost in computing resources and processing time. Fig. 7 shows the result of PoW difficulty levels of the proposed model with various network delays. The result shows the effectiveness of the proposed model in maintaining transaction processing speed and shortening the block time by adjusting the difficulty level in case of network delays.

B. Future research direction

Blockchain is a technology that is ready to be explored by the automotive industry. As an emerging technology, the blockchain will continue to evolve due to its ability to disrupt industries and areas of research in various sectors. The blockchain works as a distributed value of the system, it depending heavily on collaboration with stakeholders, suppliers and competitors, etc. For the realization of a sustainable IoT network of smart cities, blockchain technology can wield positive impacts. Note, however, that there are still various research directions to take to address issues and challenges in the future.

- Co-integration with IoT platform: Co-integration of the automotive industry with the smart home, transportation, healthcare, etc. is required to create a single sign-on platform for making life easy, efficient, and smarter in the future.

- Virtual ecosystem: A virtual ecosystem for the individual user is needed to customize the services and balance power between users, automotive manufacturers, and tech industries.
- Structurally adaptable: The structural design of smart contracts directly affects the adaptability of the entire framework as an attribute of quality needed by many industries.
- Dynamic expandability: To maintain the performance and efficiency of the framework, the framework should expand dynamically alongside the increased size of distributed ledgers or organizations.
- Standardization: Currently, due to the lack of common standards, different organizations are developing their own blockchain and standards. In the public domain, blockchain-based applications are supposed to work within the regulatory framework.

V. Conclusion

In the automotive industry, inheriting the features of blockchain technology enables increasing the trust among organizations across the supply chain for reduction of business friction. Through the shared distributed record keeping structure, communication and collaboration among participants in the supply chain life cycle can be greatly enhanced; thus realizing significant time and cost savings and enabling manufacturers and suppliers to protect their brands against counterfeit products. In this research, we proposed a distributed framework model for the entire life cycle phases of the automotive industry using blockchain technology. We elaborated on the workflow of the proposed framework model in detail. We tested our proposed miner node selection algorithm using real-time captured data statistics. The experimental results show the effectiveness of our proposed approach and the feasibility of building a sustainable automotive ecosystem. Lastly, we discussed the future research directions that we will take in our future work. In the future work, we will extend the proposed model to address the open issues, as indicated in the future research direction.

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BIOGRAPHIES

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