Coalition Game and Blockchain-Based Optimal Data Pricing Scheme for Ride Sharing Beyond 5G

Riya Kakkar, Rajesh Gupta, *Student Member, IEEE*, Sudeep Tanwar, *Senior Member, IEEE*, and Joel J. P. C. Rodrigues, *Fellow, IEEE*

***Abstract*—This article proposes a blockchain and coalition game theory-based secure and reliable optimal data pricing scheme for ride sharing. It mainly focuses on securing data sharing between vehicle owners and customers. It employs beyond fifth-generation (5G) as a communication network that facilitates vehicle owners and customers with low latency, high throughput, and high availability for communication. We also formulate a coalition game-theory approach to optimize the payoff of vehicle owners and customers by forming coalitions. The performance of the proposed system beyond 5G is estimated by comparing it with 5G and LTE-A networks. The various performance parameters considered are network latency, throughput, and profit for vehicle owners. The performance results show that the proposed system is efficient and beneficial for both vehicle owners and customers in terms of low latency, high throughput, and profit.**

***Index Terms*—Beyond fifth-generation (5G), blockchain, coalition game, data pricing, ride sharing.**

I. Introduction

NOWADAYS, people are more fascinated with ride sharing schemes rather than traveling via personal cars or vehicles. It offers various advantages such as cost-efficiency, minimizing traffic congestion, and reducing energy consumption [1]. It also facilitates customers and vehicle owners with the flexibility of booking/accepting rides as per the destination with minimum cost. It also offers a social environment for both customers and vehicle owners to interact with new people and acquire some knowledge [2], [3]. The aforementioned benefits attract users for ride sharing. Many researchers/organizations have given their ride sharing schemes with data processing at the centralized location, i.e., cloud and fog, which are highly vulnerable to security and privacy issues such as data modification, spoofing, and denial of service, [4] and also possess high latency. These issues can mislead both vehicle owners and customers during their ride booking.

It is necessary to ensure the security, privacy, reliability, and timeliness of the ride sharing data, so that the users can be treated fairly without any manipulation [5]. To meet the aforementioned issues, a decentralized, immutable, and trusted platform, i.e., blockchain, is required to secure the data [6]. Researchers proposed blockchain-based systems to overcome the security, privacy, and trust issues of centralized systems [1]. For example, Xu *et al.* [4] formulated a Stackelberg game for optimal pricing in car sharing with consortium blockchain to secure data transactions. Then, Wang and Zhang [7] also proposed a consortium blockchain-based secure ride sharing framework to ensure security, privacy, and transparency of the system.

Later, Amar and Basir [8] presented a bargaining-based system to solve the territory allotment issues between users using cooperative game theory. Then, Yuan *et al.* [9] conducted a case study on the blockchain-based ride sharing system to compare it with the centralized systems. They discussed a blockchain-based model in transportation systems to deal with the various security issues in the system. Many of the security solutions given by the researchers can encounter various issues like latency, cost-efficiency, scalability, and profitability. For example, Baza *et al.* [1] have discussed the blockchain-based secure ride sharing scheme for fair payment among the users using the pay-as-you-drive approach. But, there is no focus to optimize the price for drivers and riders for ride sharing. These issues can be resolved using blockchain with a coalition game-theory approach over the beyond 5G network. Motivated from this, we introduced a coalition game-theory profit maximization scheme for both vehicle owners and customers with security and privacy. The game players can form coalitions to maximize their payoff values. To tackle the latency and reliability issues, a beyond 5G communication network is preferred that ensures ultralow latency (< 1 ms) and ultrahigh reliability (99.99999%) [10], [11].

The aim of the proposed system is to ensure security, privacy, ultralow latency, and ultrahigh reliability of the ride sharing system. We analyzed from the literature and there is less focus on the maximization of payoff, i.e., profit for the game players. Also, the traditional blockchain-based approaches have much focused on the security, privacy, and trust of the ride sharing system, but the transaction cost-efficiency was ignored. The

Manuscript received 1 July 2021; revised 28 August 2021 and 31 October 2021; accepted 6 November 2021. Date of publication 1 December 2021; date of current version 9 December 2022. This work was supported in part by Visvesvaraya Ph.D. Scheme for Electronics and IT by the Department of Electronics and Information Technology (DeiTY), Ministry of Communications and Information Technology, Government of India, in part under the unique awardee number MEITY-PHD-2828, in part by FCT/MCTES through National Funds and when applicable cofunded EU funds under Grant UIDB/50008/2020, and in part by the Brazilian National Council for Scientific and Technological Development - CNPq under Grant 313036/2020-9. *(Corresponding author: Sudeep Tanwar.)*

Riya Kakkar is with the Department of Computer Science and Engineering, Institute of Technology, Nirma University, Ahmedabad 382481, India (e-mail: kakkarriya29@gmail.com).

Rajesh Gupta and Sudeep Tanwar are with the Department of Computer Science and Engineering, Institute of Technology, Nirma University, Ahmedabad 382481, India (e-mail: 18ftvphde31@nirmauni.ac.in; sudeep.tanwar@nirmauni.ac.in).

Joel J. P. C. Rodrigues is with the Senac Faculty of Ceará, Fortaleza-CE, BrazilInstituto de Telecomunicações, 6201-001 Covilhã, Portugal (e-mail: joeljr@ieee.org).

Digital Object Identifier 10.1109/JSYST.2021.3126620

cost of storing data into the blockchain, i.e., Ethereum, is too high, restricting organizations from adopting the system. To overcome this issue, we have incorporated an interplanetary file system (IPFS) to keep records, which are immutable, distributed, and free of cost storage [12]. The performance of the proposed system is evaluated using the parameters profit, throughput, and network latency. Many research works have not considered the latency, scalability, reliability, and optimized price issues in the blockchain-based system. Implementing a coalition game-theory approach with IPFS over the 5G network highlights the importance of the proposed system and its performance, such as scalability, profitability, reliability, and security due to its low latency, high throughput, and high availability performance.

A. Motivation

The motivation of this article can be defined as follows.

1) The importance of implementing a blockchain-based decentralized framework with a beyond 5G network makes the ride sharing system highly secure and reliable. Implementing IPFS with 5G enhances the system's scalability and availability due to their low-latency and high-scalability features.
2) Some of the existing research works mainly focused on securing data in ride sharing. Baza *et al.* [1] only focusing on providing fair payment to users but have not considered the optimal data pricing with a blockchain-based framework. Therefore, this raises the requirement of a blockchain-based optimal data pricing scheme using a coalition game-theory approach for ride sharing.

B. Research Contributions

The research contribution of this article are as follows.

1) We propose a blockchain and IPFS-based secure and cost-efficient data pricing scheme for ride sharing underlying beyond 5G network.
2) We implement a coalition game-theory approach for optimal pricing between the vehicle owners and customers.
3) Lastly, we estimate the performance of the proposed system considering the factors such as latency, throughput, and profit for vehicle owners.

C. Organization

The rest of this article is organized as follows. Section II presents the related works. Section III shows the system model and problem formulation. Section IV shows the coalition game formulation for optimal pricing. Section V presents the coalition formation solution. Section VI presents the results and discussion. Finally, Section VII concludes this article.

II. Related Works

This section highlights the existing literature works on the blockchain-based scheme for ride sharing. Some of the research works are as follows. Kim *et al.* [13] discussed a decentralized blockchain-based framework to authenticate and secure the user's identification and privacy by performing the security analysis in the ride sharing system. Then, Bathen *et al.* [14] proposed an authenticated self-driving car sharing system, i.e., RiderS. They introduced a proof-of-matching algorithm to verify the data transactions and to remunerate the vehicles participating in the blockchain. Pal and Ruj [15] proposed an Ethereum-based system to ensure security and transparency in ride sharing systems. Then, Zhou *et al.* [16] presented a blockchain-based secure framework for car sharing by executing the smart contracts in Internet-of-Vehicles base stations. The performance analysis has been performed to provide security when users are communicating in the system. Later, Aïvodji *et al.* [17] discussed a secure solution to implement dynamic ride sharing systems to resolve the matching problem. The experimental results have been performed to secure the user's privacy.

Manjunath *et al.* [18] proposed a cooperative-based strategy with an ant colony optimization algorithm for a car sharing system. They experimented on the ride dataset of chicago to measure the success rate of car sharing. Then, Hariz *et al.* [19] presented a decentralized multitransportation system to enable secure communication among users using a Stackelberg game-theoretic approach. All these research works were focused on the system's security, and they have were concerned about optimal pricing. Qadir *et al.* [20] proposed a carpooling framework to recommend a vehicle to the passengers with the highest aggregated score. They did not consider the security of the system. These issues are the reason to propose a blockchain-based secure system with a coalition game-theory approach.

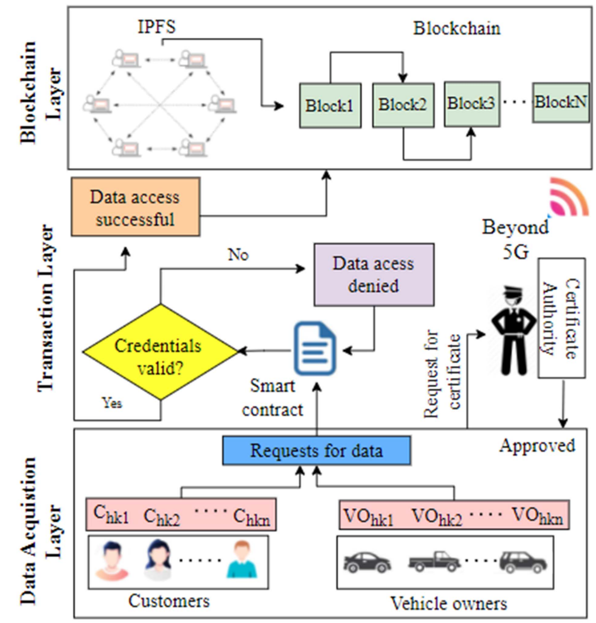


Fig. 1. System model.

III. System Model and Problem Formulation

A. System Model

Fig. 1 presents a blockchain-based optimal data pricing scheme for ride sharing. It comprises of a set of vehicle owners (S_{υ}), the set of customers (S_{Cu}), and the set of certificate authorities (S_{CA}). The communication network, i.e., beyond 5G, is used to make the system efficient and reliable. An IPFS protocol is used for data storage to make the system cost-efficient. The proposed scheme aims to enhance the security and privacy of data in the ride sharing system. We have introduced the idea of a certificate authority (CA) to authenticate the vehicle owners and customers. CA receives a request from S_v and S_{Cu} for the credentials (χ) if they want to become an authentic member of blockchain. A smart contract verifies the authenticity of vehicle owners and customers by viewing the validity of the χ issued by a CA. Only after verification they are allowed us to add their data transactions to the block of a blockchain. A coalition game-theory approach has been formulated to optimize the data pricing between the vehicle owners and customers. They can form multiple coalitions to increase the payoff by cooperating with each other. The employed beyond 5G network and its features ensure that transactions between vehicle owners and customers are efficient (ultralow latency) and ultra-high reliable for ride sharing.

It will lead to a reduced communication overhead, while adding data to the blockchain by implementing IPFS with the beyond 5G network with latency, i.e., Network_latency < 1 ms, high throughput, and high availability, i.e., Avail $< 99.99999\%$ with a huge number of transactions between vehicle owners and customers as we have to store only hash of data instead of whole block. Low latency and high throughput will also improve the convergence time so that data can be added to the blockchain efficiently without any delay. A blockchain and IPFS-based framework is implemented to ensure the security and reliability of the ride sharing system. Fig. 1 shows the working of a three-layered proposed system in detail. It comprises of the following three layers:

1) data acquisition layer;
2) transaction layer; and
3) blockchain layer.

These three layers are described as follows.

1) Data acquisition layer: This layer consists of the set of entities vehicle owners and customers associated with their hash keys, which can interact with the help of their wallets. Customers can book the rides according to their destination and their willing price. Similarly, vehicle owners will provide information about the rides with their allotted prices in the system. Now, vehicle owners and customers request to store their data about the rides in the IPFS. For that purpose, CA in the transaction layer authenticates the vehicle owners and customers. If they are valid users, then χ will be issued to them by the CA, ensuring the authentication and privacy of the system. After authentication, vehicle owners and customers have their χ to store data in IPFS, for which they have to go through the transaction layer to fulfil certain conditions.

2) Transaction layer: It is the communication layer of the proposed system through which all the data transmission about the rides can be performed securely over the beyond 5G network. The beyond 5G communication network ensures the system's reliability due to its low-latency and high-reliability features. After authentication by CA, this layer involves executing a smart contract to verify the issued χ of vehicle owners and customers. If the χ are valid, then their data can be securely stored in the IPFS over the beyond 5G communication network; otherwise, the request to store data will be denied.

3) Blockchain layer: The proposed system considers the Ethereum blockchain to ensure security and transparency in the ride sharing system. It ensures secure data transactions between vehicle owners and customers. The blockchain layer mainly involves storing the data in IPFS securely, and then any users can request to add that data to the blockchain. For that, they have to fulfil certain conditions. Algorithm 1 shows the detailed procedure of storing the data in IPFS and then adding it to the blockchain. Smart contract verifies the authenticity of vehicle owners and customers to store their data in IPFS, which is free of cost and reliable data storage. If they contain the valid χ, then data can be stored in IPFS.

Algorithm 1: Algorithm to Add Data in Blockchain.

Input: π_r, π_j, $IPFS_{(hash,key)}$, χ, Ψ^{bk}
Output: Data added to the blockchain network
procedure Adddata__blockchainπ_r, π_j, CA, υ_m, Cu_n
  if $S \in S_{\upsilon_m}$ **then**
    for $i = 1, 2, \ldots, o$ **do**
      $IPFS_{(hash,key)} \leftarrow$ DataReq(υ_m)
      $\upsilon_m \xleftarrow{\chi}$ CA
      Execute smart contract
      if $\chi == valid$ **then**
        $\upsilon_m \xleftarrow{\pi_j} IPFS_{(hash,key)}$
        $blockchain \leftarrow$ DataReq _ to_add(υ_m)
        if $\pi_j \in \Psi^{bk}$ **then**
Data added successfully
        else
Access denied
        end if
      else
        Invalid Credential
      end if
    end for
  else if $S \in S_{Cu_n}$ **then**
    for $j = 1, 2, \ldots, s$ **do**
      $IPFS_{(hash,key)} \leftarrow$ DataReq(Cu_n)
      $Cu_n \xleftarrow{\chi}$ CA
      Execute smart contract
      if $\chi == valid$ **then**
        $Cu_n \xleftarrow{\pi_r} IPFS_{(hash,key)}$
        $blockchain \leftarrow$ DataReq _ to_add(Cu_n)
        if $\pi_r \in \Psi^{bk}$ **then**
Data added successfully
        else
Access denied
        end if
      else
        Invalid Credential
      end if
    end for
  end if
end procedure

Now, vehicle owners and customers can request to add their data to the blockchain. After storing the data in IPFS, IPFS provides hash keys associated with them. These hash keys should be in accordance with the hash of blockchain, and then they can add their data to the blockchain successfully, otherwise, data access will be denied. After that, proof-of-work consensus protocol is used with blockchain to validate the data of vehicle owners and customers that need to be added to the blockchain. In the blockchain network, all the authorities, i.e., members, should agree on the same decision regarding validating data that is honest and acceptable. Then, miners generate the valid data block by solving the complex puzzle and get the reward for the same [21]. So, all the data transmission about the rides can be performed securely over the beyond 5G communication network using an IPFS data storage.

B. Problem Formulation

The proposed system consists of set $S \in \{S_\upsilon, S_{\text{Cu}}, S_{\text{CA}}\}$ in which S_υ is a set of *o* vehicle owners $\{\upsilon_1, \upsilon_2, .., \upsilon_o\} \in \upsilon_m$ and S_{Cu} is a set of *s* customers $\{\text{Cu}_1, \text{Cu}_2, \ldots, \text{Cu}_s\} \in \text{Cu}_n$, which can be associated with the number of *a* CA $\{\text{CA}_1, \text{CA2}, .., \text{CA}_a\} \in \text{CA}_k$ to request for χ. S_{Cu} can trade with any mth υ_m by spending amount from wallet. The abovementioned entities can be represented as follows:

$$\psi_{\text{Cu}_n} \rightarrow \psi\upsilon_m \tag{1}$$

$$\upsilon_m \xrightarrow{\beta} \sum_{n=1}^{f} \text{Cu}_n \quad \text{and} \quad \text{Cu}_n \xrightarrow{\beta} \sum_{m=1}^{g} \upsilon_m \tag{2}$$

$$\text{Cu}_n \xrightarrow{\beta} \sum_{k=1}^{f'} \text{CA}_k \quad \text{and} \quad \upsilon_m \xrightarrow{\beta} \sum_{k=1}^{g'} \text{CA}_k \tag{3}$$

$$f \leq s;\ g \leq o;\ f' \geq f;\ g' \geq g \tag{4}$$

$$n,\ m,\ k \geq 0 \tag{5}$$

where β signifies the relationship between a vehicle owner, customer, and CA, f and g, respectively, denote the number of customers and vehicle owners that are associated with each other, and f' and g' denote the number of CA related by customers and vehicle owners, respectively.

CA can issue χ to the S_υ and S_{Cu}, if they are the valid users. Now, S_υ and S_{Cu} have their χ to store the transactional data into the IPFS protocol. A smart contract verify the users authenticity. If they have valid χ, then they are allowed to store their ride data in an IPFS protocol. Then, the IPFS will facilitate with the hash keys associated with the S_υ and S_{Cu}, which are $\pi_j \in \{\pi_1, \pi_2, \ldots \pi_w\}$ and $\pi_r \in \{\pi_1, \pi_2, \ldots \pi_z\}$. The abovementioned entities can be represented as follows:

$$\upsilon_m \xrightarrow{\zeta} \sum_{j=1}^{w'} \pi_j \text{ and } \quad \text{Cu}_n \xrightarrow{\zeta} \sum_{r=1}^{z'} \pi_r \tag{6}$$

$$j > 0, w' \leq w, r > 0, z' \leq z \tag{7}$$

where ζ denotes the number of hash keys $\{w', z'\}$ associated with S_υ and S_{Cu}.

So, the IPFS protocol has shared the hash keys with S_υ and S_{Cu} with which they can request to add their data to the blockchain. For that purpose, the issued hash keys of S_υ and S_{Cu} should be in accordance with the hash of block header (Ψ^{bk}) in the blockchain. Algorithm 1 shows the detailed procedure to add data of S_υ and S_{Cu} to the blockchain. Smart contract plays a major role in authenticating the S_υ and S_{Cu}. If S_υ and S_{Cu} are authenticated, then they can store their data in the IPFS, which will give them the hash keys. These hash keys would be compared with the hash of the blockheader to add their data to the blockchain. The time complexity of Algorithm 1 will depend upon the *0* number of vehicle owners and *s* number of customers requesting to add their data to the blockchain by comparing their π_j and π_r with Ψ^{bk} and can be calculated as O(*0*) and O(*s*). The mentioned entities can be represented as follows:

$$\sum_{j=1}^{w'} \pi_j \xrightarrow{\kappa} \Psi^{bk}; j > 0 \tag{8}$$

$$\sum_{r=1}^{z'} \pi_r \xrightarrow{\kappa} \Psi^{bk}; r > 0 \tag{9}$$

where κ denotes the hash keys associated with S_υ and S_{Cu}. Now, the S_υ and S_{Cu} have access to add their data to the blockchain, in which customers can choose to select the ride from the number of rides made available by the S_υ.

IV. Coalition Game Formulation

A coalition game theory has been introduced to optimize the data pricing between the S_υ and S_{Cu}. It is implemented to form multiple coalitions among players to avoid any data pricing conflict and maximize their payoff for ride sharing. We have considered the case of a transferable utility game in which the payoff is transferable among the players. These two approaches can be defined as follows.

Definition 1 (Coalition game): In the proposed system, the coalition game G_c consists of a pair $\{N, \alpha\}$ where N is the number of players $\{1, 2, \ldots, p', \ldots, N\}$, which is $N = \{\upsilon_m, \text{Cu}_n\}$, α denotes the real-valued coalition function mapped as $\alpha : 2^N \rightarrow \mathbb{R}$ to each coalition $K_t \subseteq N$ [22].

Transferable utility: We have considered the transferable utility function for which $\alpha(K_t)$ is a value for each coalition $K_t \subseteq N$, which can be defined as the transferable utility that users get as an overall payoff for each coalition. For each coalition K, the S_υ and S_{Cu} get an overall payoff in the form of a function $\alpha(K_t)$, which should be distributed among the players according to their participation. In a coalition game $G_c = \{N, \alpha\}$, we have used the concept of the core as a solution to distribute the overall payoff to the involved users, which can be interpreted as [22].

$$\text{Co}(N, \alpha) = \left\{ \sum_{p \in N} \rho_p = \alpha(N) \sum_{p \in K} \rho_p \quad \geq \alpha\{K\}\ \forall\ K \in N \right\} \tag{10}$$

where $X = \{\rho_1, \rho_2, ..\rho_p.., \rho_P\}$ is the payoff distributed among the players, i.e., S_υ and S_{Cu}.

V. Coalition Formation Solution

In the proposed system, a coalition game-theory has been formulated to form coalitions among players υ_m and Cu_n, considering the core solution, to compare the increase in payoff of individual players while making coalitions. S_υ and S_{Cu} can make multiple coalitions but S_{Cu} have an opportunity to make more coalitions than S_υ as S_{Cu} can select to book the particular rides, thus increasing the payoff of the S_υ. Now, if S_υ and S_{Cu} want to maximize their payoff for ride sharing, then they decide on strategies, i.e., S'_{υ_m} and S'_{Cu_n}. We define these strategies in the form of equations in which S_υ can have number of available rides $\{\gamma_1, \gamma_2, \ldots, \gamma i\} \in \gamma_q$ associated with the prices $\{\eta_1, \eta_2, \ldots, \eta_i\} \in \eta_e$ for the number of routes $\{\lambda_1, \lambda_2, \ldots, \lambda_h\} \in \lambda_b$. The strategies $\{S'_{\upsilon_m}, S'_{Cu_n}\}$ can be represented as follows:

$$\{\, S'_{\upsilon_m}, S'_{\text{Cu}_n}\} = \left\{ \max \sum_{e=1}^{i'} \sum_{b=1}^{h'} (\eta_e, \lambda_b), \min \sum_{e=1}^{i'} \sum_{b=1}^{h'} (\eta_e, \lambda_b) \right\} \tag{11}$$

$$e > 0,\; b > 0,\; i' \leq i,\; h' \leq h \tag{12}$$

where i' denotes the number of prices associated with the rides and h' denotes the number of routes for rides.

Equation (11) shows that the S_υ want to maximize their payoff by maximizing the prices for rides and they want rides to take the long path. Alternatively, the S_{Cu} want to pay less price for its visit to the destination by minimizing the price for rides and it wants rides to take the shorter path. But, it is not feasible to satisfy both the conditions for vehicle S_υ and S_{Cu} to maximize their payoff. So, for players S_υ and S_{Cu} to be in the coalitions, the payoff $\rho_p(K_t)$ interpreted using core solution should be less than the payoff $\rho_p(K_{t'})$, i.e., $\rho_p(K_t) < \rho_p(K_{t'})$ gained for individual players by forming the coalitions K'_t. Now, we can consider the concept of preference order. It means that both the players can decide to join or leave the coalition based on the preference order. It can be defined as follows.

Preference order: A preference order $>_{p'}$ for any player $p' \in N$ can be defined as a complete, reflexive, and transitive binary relation over the set of all feasible coalitions that player p' can possibly form [23].

So any player can decide to join or leave the coalition based on the preference order. We can consider the case in which players prefer to be in coalition with $K_{t'}$ rather than K_t, i.e., $K_{t'} >_{p'} K_t$, due to the maximized payoff of players with coalition $K_{t'}$.

Algorithm 2 shows the detailed procedure to calculate payoff considering the coalition K'_t to optimize the price among S_υ and S_{Cu}. The time complexity of Algorithm 2 will depend upon the *0* number of vehicle owners and *s* number of customers to maximize their $\rho_p(K_{t'})$ by considering the η_e and λ_b by forming the K'_t coalitions and can be calculated as O(*o*) and O(*s*). The payoff calculated using the coalition core function is compared with the payoff of coalition K'_t for the gain of an individual player. A Nash equilibrium is created for the profit of both players in which the price for rides and distance of route would lie between minimum and maximum. The Nash equilibrium for the players can be represented as follows:

$$\min \sum_{e=1}^{i'} \eta_e < \sum_{e=1}^{i''} \eta'_e < \max \sum_{e=1}^{i'} \eta_e \tag{13}$$

$$\min \sum_{b=1}^{h'} \lambda_b < \sum_{b=1}^{h''} \lambda'_b < \max \sum_{b=1}^{h'} \lambda_b \tag{14}$$

$$\rho_p(K_{t'}) = \left\{ \sum_{e=1}^{i''} \eta'_e, \sum_{b=1}^{h''} \lambda'_b \right\} \tag{15}$$

Algorithm 2: Coalition Game for Optimal Pricing.

Input: $K_t, \eta_e, \lambda_b, \alpha, N$
Output: $\rho_p(K_{t'})$
Initialization: e=1, b=1
procedure Max_payoffN, υ_m, Cu_n
  if $N \in \upsilon_m$ **then**
    for $i = 1, 2, \ldots, o$ **do**
      $\upsilon_m = max \sum_{e=1}^{i'} \sum_{b=1}^{h'} (\eta_e, \lambda_b)$
    end for
  else
    for $j = 1, 2, \ldots, s$ **do**
      $Cu_n = min \sum_{e=1}^{i'} \sum_{b=1}^{h'} (\eta_e, \lambda_b)$
    end for
  end if
  for each $\{N, K_t\}$ with core solution **do**
    $\sum_{p \in N} \rho_p = \alpha(N)$
    $\sum_{p \in K} \rho_p \geq \alpha\{K\}$
  end for
  Form a coalition $K_{t'}$ to maximize the payoff
  for each $\{N, K_{t'}\}$ **do**
    $min \sum^{i'} \eta_e < \sum^{i''} \eta'_e < max \sum^{i'} \eta_e$
    $min \sum^{h'} \lambda_b < \sum^{h''} \lambda'_b < max \sum^{h'} \lambda_b$
    $\rho_p(K_{t'}) = (\sum^{i''} \eta'_e, \sum^{h''} \lambda'_b)$
    if $\rho_p(K_{t'}) \geq \rho_p(K_t)$ **then**
      $\{\upsilon_m, Cu_n\}$ gains max. payoff with coalition $K_{t'}$
    end if
  end for
end procedure

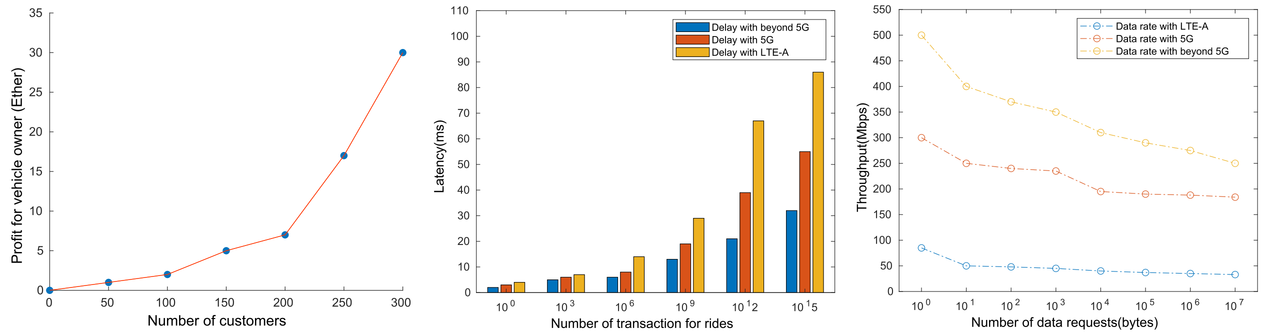
where i' denotes the number of prices for rides, which lie between minimum and maximum, and h' denotes the number of routes for rides, which lie between minimum and maximum. η'_e and λ'_b denotes the prices for rides will lie between minimum price and maximum price and routes for the rides will lie between short route and long route. Algorithm 2 shows the existence of Nash equilibrium that maximize the payoff of both the players, which is defined as follows.

Nash equilibrium: A coalition game consists of multiple coalitions, i.e., $\{K_1, K_2, K_3, \ldots, K_N\}$, which player can decide to join or leave based on their preference order. There exists a Nash equilibrium if $\rho_p(K_{t'}) > \rho_p(K_t)\; \forall\, p' \in N$ in such a way that no player can deviate from their strategies to increase their payoff $\rho_p(K_{t'})$ [24].

Therefore, $K_{t'}$ is a coalition with maximum payoff ρ_p after which the players cannot deviate from their strategy $\{S'_\upsilon, S'_{\text{Cu}}\}$ to be in the Nash equilibrium. So, existing Nash equilibrium converges to the point $\{\eta'_e, \lambda'_b\}$ with the maximized payoff of $\rho_p(K_{t'})$.

VI. Experimental Results

This section presents the performance analysis of the proposed system with the traditional LTE-A and 5G-based systems, considering the parameters latency, throughput, and profit for the vehicle owner. The analysis of the proposed system has been simulated over the Remix-integrated development environment (IDE) [25]. The smart contracts of the proposed system are developed, compiled, run, and tested over the Remix IDE using



(a) (b) (c)

Fig. 2. Performance comparison of the proposed system with the traditional approaches. (a) Profit analysis for vehicle owner. (b) Latency comparison. (c) Throughput comparison.

solidity source code. The results have been simulated on the proposed system to optimize the price for vehicle owners and customers by implementing the coalition game-theory approach by considering the different scenarios in which vehicle owners want to maximize the price for rides and take the long route for their benefits. In another scenario, customers want to minimize the price for rides and take a short route for their profit. Therefore, we have considered a Nash equilibrium so that the price for rides would lie between maximum and minimum and the distance of route would lie between maximum and minimum for the profit of both vehicle owners and customers. These scenarios are simulated using Python 3.2 to derive the maximized payoff using the coalition core solution. The simulated experimental results for the proposed system are as follows.

A. *Profit for Vehicle Owner*

Fig. 2(a) shows the profit for vehicle owners with the increase in the number of customers using the coalition game-theoretic approach. Initially, with fewer requests from customers for rides, the profit is minimum for selected vehicle owners. But, with the increase in the number of customers, the profit for vehicle owners will increase linearly. But, after a particular time $T = \tau$, their profit would increase exponentially as there will be more customers willing to book the ride for their travel.

B. *Network Latency*

Fig. 2(b) presents the comparison of latency of the proposed system with the increase in the number of transactions for the ride. The graph depicts the comparison of the proposed system with the traditional networks such as 5G and LTE-A. The comparison shows with fewer transactions, and the network latency would lie at the same level for all networks. But, as the number of transactions for rides increases, the latency of the proposed system beyond 5G becomes quite low than 5G and LTE-A. With beyond 5G, more customers will be booking the ride efficiently than 5G and LTE-A.

C. *Throughput*

Fig. 2(c) shows the comparison of throughput of the proposed system with the increase in the number of data requests for rides. It can be distinguished from the graph that the throughput of the proposed system beyond 5G is relatively high than with 5G and LTE-A. It is due to its low latency leading to the overall high throughput of the system.

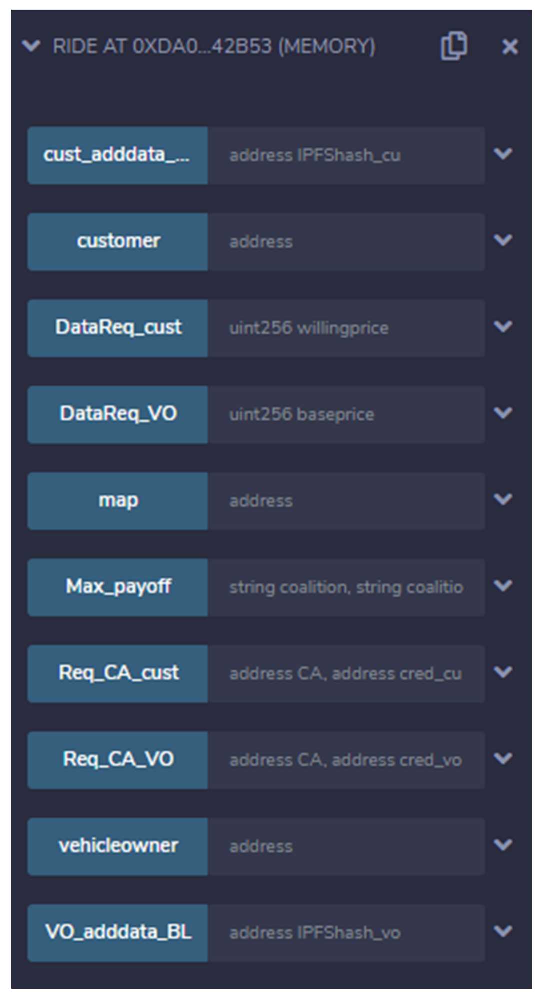


Fig. 3. Proposed system test interface on Remix IDE.

D. *Proposed System Implementation Interface*

The blockchain-based proposed system has been implemented on Remix IDE [25]. Consecutively, the smart contract of the proposed system is deployed and run on the Remix environment to test and validate its functionality. Fig. 3 shows the implemented test interface of the proposed system on Remix IDE along with their functions along with their input parameters.

So we have considered various parameters such as profit for the vehicle owner, latency, and throughput to analyze the effectiveness of the blockchain-based system using the coalition game-theory approach. Now, increasing the number of customers leads to an exponential increase in the number of rides booked after a time τ. As in the coalition game-theory approach, the payoff is directly proportional to the distance and price of the rides, as shown in (15). This led to the optimized payoff for a vehicle owner with more number of booking of rides. We are using a beyond 5G network, enabling customers to book the rides more reliably and efficiently due to the low latency and high availability beyond 5G. Also, the throughput of the proposed system with the beyond 5G network is way better than traditional networks. This leads to efficient and reliable communication between vehicle owners and customers with the increase in the number of rides requests. So the overall blockchain-based proposed system using the coalition game-theory approach contributed to the optimized payoff for players in terms of latency, throughput, and profit for the vehicle owner.

VII. Conclusion

In this article, a blockchain-based reliable and secure optimal data pricing scheme is proposed using an IPFS protocol over the beyond 5G network. We comprehensively investigated the traditional systems and got insights into their security, privacy, latency, reliability, and cost-related issues. We have analyzed that using a beyond 5G network with an IPFS protocol makes the system highly efficient with minimum blockchain transaction cost. We introduced the concept of the coalition game-theory approach to optimize the data pricing by maximizing the payoff of vehicle owners and customers. Implementation of smart contract of the proposed system on Remix IDE validates its functionality. Lastly, the performance of the proposed system with the beyond 5G has been estimated in terms of latency, throughput, and profit for the vehicle owners and compared with the traditional systems. It shows that the proposed system is highly secure and efficient.

In the future, the performance of the proposed approach would be evaluated under a heterogeneous environment considering real-time parameters. We will explore more about implementing the energy harvesting technology with the proposed scheme to show the vehicles' energy exchange and consumption by considering the different resources such as fuel, gasoline, or electricity for real-time communications.

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