Blockchain and IoT based Vehicle Tracking System for Industry 4.0 Applications

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Abstract. Vehicle automation is one of the main applications of industry 4.0 especially for tourism companies who provide their vehicles to migrants for traveling purposes. It is difficult to maintain trust among the travel agency and the customers. Although there are many existing solutions in the research that addresses the trust issues, but most of the solutions are based on centralized architecture such as cloud computing where the data is prone to various security threats. Motivated by the aforementioned discussion, the authors have proposed a vehicle tracking system based on the integration of blockchain and IoT in this paper. The proposed system will increase the trust among the entities by providing them transparency in tracking details of the vehicle. As the trip details are immutable and decentralized in nature, so, blockchain is used to store the details. Also, the system will generate the trip summary that contains the route detail, the number of kilometres travelled and the total cost of the trip. Tools such as Ethereum, Remix IDE, MetaMask, and RinkeyBy have been used to measure the performance of the system.

1. Introduction
Smart technologies such as Artificial Intelligence, Internet of Things, Machine Learning, Augmented Reality and Virtual Reality have revolutionized manufacturing and engineering sectors [1]. Smart technologies enable us to maintain trust among the business entities by increase the transparency of the data [2]. With the use of smart technologies like blockchain and the internet of things, the process of communication and transparency can be enhanced [3]. Tourism is the fastest-growing industry. In smart cities, migrants hire a taxi or driverless car to visit different places in the city. Almost all leading rental service providers are using mobile applications from the booking of the car to the payment. In order to make these facilities more efficient and increase the trust among both parties, various researchers have come up with different solutions based on the Internet of Things (IoT), roadside unit, Vehicular Adhoc Network (VANET) and Radio Frequency Identification (RFID) tag [4].

However, most of the solutions rely on a centralized architecture where the data is prone to security threats. To surmount security threats, blockchain technology has been proving to be useful for storing data in a decentralized manner. Blockchain is a distributed, decentralized ledger and immutable in
nature. Rula Amjad Hamid et. al. (2020) proposed a Global Positioning System (GPS) tracking system that uses mobile sensors as a source of information. All the track data will be store in the mobile application. The stored data can be modified easily and it is prone to various security threats [5].

To overcome the aforementioned issues, the authors have proposed a system based on the integration of blockchain and IoT. In order to increase the trust among both parties, location will be tracked by RFID and shared among the participants of the network. Also, at the end of the trip, auto bill generation process will take place that will generate the bill with a detailed trip summary with the help of smart contracts. Ethereum blockchain is used for the deployment of smart contract [6].

Blockchain is the trending technology that enables us to store data in a decentralized environment [7, 8]. All the events are maintained by some set of rules that are called as a consensus mechanism. The data stored in the blockchain is immutable in nature and not prone to security threats [9]. Decentralized technology is not controlled or managed by a single entity of the network. With the amalgamation of IoT and blockchain, the trust can be maintained among the network of tourism [10]. The proposed solution will help to improve the trust model as well as the existing model of tourism.

1.1 Blockchain Technology

In past few years, technologies like blockchain and smart ledgers are gaining popularity due to its emergence of crypto currencies, such as Bit Coin and Ethereum. Blockchain stored the data in decentralized and distributed environment. The data stored on blockchain is immutable in nature. Blockchain does not require a centralized authority for the verification of transactions [11, 12]. Blockchain provides a transparent and less complicated way to access ledger-based transactions over the network [13]. Blockchain technology comprises of various services and techniques that are introduced as follow:

- **Hash Cryptography:** Blockchain technology uses SHA3 hash for encrypting the transactions. SHA256 will convert an arbitrary length input into a fixed length value that is 64 characters long.
- **Consensus Protocol:** In blockchain network, certain users have access rights to verify the transactions with some set of rules, known as consensus protocols.
- **Distributed Peer-to-Peer Network:** All the transactions are distributed among all the participants of the network.
- **Mining Process:** In blockchain, miners use nonce value of blocks to generate hash value in the network. This process needs high computational power.

1.2 Advantages of Blockchain Technology

Blockchain data is distributed over the network, and no one can tamper with the data. Each block that is added into blockchain network generates a new hash value therefore, no one can tamper with the data. The potential uses of blockchain are described as following:

- **Smart Contract:** A digital contract is developed with the coding on a blockchain network. It can be reversed or modified.
- **Consensus Mechanism:** All the transactions added into blockchain network after a verification process. In verification process when all the users agree to the condition of the transaction.
- **Distributed Ledger:** All the data is shared among all the participants of the network.
- **Provenance:** A complete history of the data is available on the network of blockchain.
- **Immutability:** Data stored in blocks is immutable in nature, thus the information is secure and trusted.

With the use of blockchain the security issues can be reduced and transparency can be increased among the parties. As there is no third party at any stage of transaction.
The rest of the paper is arranged as follows: Section 2 encloses the methodology of the proposed solution. The result outcomes of the proposed solution are discussed in Section 3. Section 4 concludes the paper.

2. Related Work
In this section the authors have highlighted the relevant related work. In past few years, there has been a boom of area of privacy and preserving the applications of Industry 4.0.

In order to track the vehicle location, Anne Hardy et. al. (2017) proposed a system for tracking tourist travel location with smart phone based GPS technology. The system using mobile GPS for tracking the location of the tourists via an android mobile application [14]. But the GPS will track only if the tourist will have a smart mobile phone.

Yeong Lin Lai and Jay Cheng (2017) proposed a location tracking system based on cloud storage. The proposed solution is using RFID tag to track the location of the vehicle. The authors have also used technologies such as Location Tracking Algorithms (LTA), Wireless Sensor Network (WSN) and Cloud Computing technology. The location will be tracked by the RFID and send to the cloud storage [15]. Cloud computing is a centralized environment for the storage of the data. The data in centralized environment of prone to security threats. Therefore, we need a decentralized and secure environment to store the data.

Kanza et. al. (2019) proved how blockchain is enabling the feature of decentralization for preserving pseudonymity and privacy [16]. Yuan et. al. (2016), had presented a vision for amalgamated the intelligent transport system and blockchain technology [17]. Shiver et. al. (2019), presented a model for autonomous vehicles that allows the user to store the data in decentralized environment [18], but the results can be applied in the settings of pre-autonomous vehicles. In [19], the authors have proposed the first privacy keeping blockchain based incentive network in VANETs. The authors had proposed an incentive mechanism called as CreditCoin to share network information through VANETs. Both Singh et. al. and Javaid et. al. have analysed the use cases of blockchain technology for securing and transforming the existing applications of Industry 4.0 [20, 21].

3. Proposed Methodology
To achieve the aforementioned objectives, a solution is proposed that is based on the integration of IoT and blockchain. In the proposed system architecture, the RFID tag is used to track the location and the data will be stored in the blockchain network. The proposed architecture is discussed below.

3.1 System Architecture
There are three layers in the proposed model, namely, Blockchain layer, Participants, Sensing layer as shown in Figure 1. The location of the car will be tracked with the help of RFID tag. All the track data will be stored in blockchain in the form of blocks.
The block will contains the hash address of previous block, time stamp, time threshold, random number and object as shown in Figure 2. The systems work flow is simple to understand as shown in Figure 3. Firstly, the customer will book a car and after car booking process, the documentation verification takes place. In document verification, all the documents of car such as insurance documents, RC, pollution will be verified by the customer and agency will check the driving license card of the customer. If all the documents are valid at both the ends then the car keys will be handover to the customer and the trip will be initiated. RFID tag will track the location of the car. After completing the trip, bill generation process will takes place. In this step, according to the number of kilometers travelled by the customer, a bill slip and a trip summary will be generated. Both the bill and trip summary will be share to the customer and the agency so that they can check whether the customer gone onto the right place as mentioned in the contract or not. If all the things are ok, then the payment step will be done by the customer based on the bill shared.
3.2 Proposed Algorithm

The precise execution of the proposed system is shown in Algorithm 1. After the trip initiation, the process will get started. The vendor will initialize the process first by giving some inputs to the algorithm. Algorithm input data such as car id, security amount, starting point, ending point, kilometre readings before starting the trip. The device will generate transaction regarding the location of the customer every time the RFID tag gets scanned. All the track data is stored into blockchain and shared with the agency so that they can check whether the client is going to the mentioned location or not. After the end of the trip, bill and a detailed trip summary will be generated and shared with both the participants. Table 1 lists all the acronyms that are used in the Algorithm 1.

| Algorithm No. 1 | Working of Proposed Solution |
|-----------------|-------------------------------|
| **Input:** C_id, S_amt, S,D, T_km | **Output:** T_Sum, Bill_amt. |
| 1. | **VENDER** V (S,D) |
| 2. | **while** (true) |
| 3. | **if** (S ! =D) |
| 4. | **then**, ADD CURRENT LOCATION |
| 5. | **end if** |
| 6. | **else** |
| 7. | GENERATE BILL(C_id, S_amt, T_km); |
| 8. | **end else** |
| 9. | **end while** |
| 10. | **end VENDER** |
| 11. | GENERATE BILL(C_id, S_amt, T_km) |
| 12. | Var Bill_amt; |
| 13. | Var amt_Per_Km; |
| 14. | Bill_amt = (amt_Per_Km*T_km) - S_amt |
| 15. | **end GENERATE** |
Table 1. Abbreviations

| V   | Vender     |
|-----|------------|
| C\text{\textsubscript{id}} | Car ID     |
| S\text{\textsubscript{amt}} | Security Amount |
| S   | Source     |
| D   | Destination|
| T\text{\textsubscript{km}} | Travelled Kilometer |
| T\text{\textsubscript{Sum}} | Travel Summary |
| Bill\text{\textsubscript{amt}} | Bill Amount |
| Amt\_Per\_Km | Amount per Kilometer |

4. Result and Discussion

This section encloses the simulation tools, performance of smart contract and User Interface (UI) of the proposed solution.

Ethereum blockchain is used for the deployment of smart contracts as it is an open source platform. In order to develop Decentralized Application (DAPP), the authors have used Ethereum blockchain. For evaluating the performance of the proposed system, the authors had used RinkeyBy. Remix IDE and MetaMask facilitate development, execution and testing environment for a smart contract. Solidity language is used for the development of smart contracts. Etherscan test network (RinkeyBy) helps to establish the connection between them.

The system specifications that is used for the simulation are Intel core i5, processor 2.4 GHz, RAM 8GB and HDD 1TB. The following are the parameters that are used to evaluate the performance of the proposed system:

- Execution time versus Gas (Gas is the required fees required to complete transactions in Ethereum blockchain)
- Transaction fees (in terms of Gas) versus block size
- Gas required for the deployment of smart contracts.

![Figure 4. Execution time versus Gas consumed](image-url)
The execution time against the gas consumed is shown in figure 4. By plotting the graph between the execution time and gas consumed, the authors have concluded that as the more gas gets consumed, the less execution time will be required to complete a transaction.

Figure 5 encloses the relationship between the transaction fees (in terms of gas) and block number as shown. This relationship shows that as the block size increases, the transaction fees also increases.

Figure 6. Gas consumed versus No. of Transaction
In figure 6, the relationship of gas consumed against the number of transactions is shown. Also, it is clearly visible that the consumption of gas depends upon the number of transactions. The equations used for the conversion of transaction fees to ether and ether to US dollar are shown in table 2.

\[
\begin{align*}
\text{Cost in Ether} &= \text{Gas Consumed} \times 0.007742 \\
\text{Cost in USD} &= \text{Cost in Ether} \times 228.30
\end{align*}
\]

where 1 Gas is equal to 0.007742 and 1 Ether is equal to 228.30 US Dollars.

| Block No. | Gas Used | Cost in Ether | Cost in USD |
|-----------|----------|---------------|-------------|
| 7056495   | 7223     | 55.92047      | 12766.64    |
| 7056435   | 8907     | 68.95799      | 15743.11    |
| 7039383   | 8997     | 69.65477      | 15902.18    |
| 7039255   | 8974     | 69.47671      | 15861.53    |
| 7039249   | 9286     | 71.89221      | 16412.99    |
| 7039205   | 9863     | 76.35935      | 17432.84    |
| 7039104   | 9884     | 76.52193      | 17469.96    |
| 7038941   | 10245    | 79.31679      | 18108.02    |

5. Conclusion
Smart technologies such as blockchain and IoT have the potential to substantially transform the applications of industry 4.0. With the silent features of blockchain such as transparency, immutability, programmability, decentralized and distributed environment, it enables many innovative ways to design customer relationships with more trust. In this paper, the authors have proposed a tracking system based on the integration of blockchain and IoT for taxi vendors. The proposed solution will help to increase the trust among the vendors and the clients. Ethereum blockchain is used to store the tracked data of the location. The location will be tracked when the RFID chip will get scanned by the RFID reader. After completing the trip, a detailed trip summary will be shared with the vendor and the client. The authors have evaluated and analyzed the performance of the proposed system. The proposed algorithm has been implemented in smart contracts in solidity language and deployed it on etherscan (RinkeyBy) simulation tool. The simulation result shows the amount of gas which is consumed by the transactions in Ethereum. Hence, the proposed model is used to increase the transparency and trust between the venders and the clients. In future work, the authors can add decentralized wallet for the payment purpose.

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