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A Proposed Blockchain-Based Solution for a Data-Driven Vehicle Lifecycle Management

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Abstract: *Vehicle lifecycle data and stakeholders' data related to it have a non-open approach to data access. The lack of accurate, reliable, transparent, and accessible data consequently leads to a lack of trust, but also a risk analysis that is not always relevant. This paper consists of analyzing the factors to determine if a blockchain-based solution could increase trust and collaboration between different stakeholders in vehicle lifecycle management and the insurance industry. The goal is to model a data-driven approach on a blockchain-based solution that helps reduce barriers to finding data on all vehicle transactions. The methods used are based on the analysis of the current systems and platforms of vehicle lifecycle management and insurance policies from the business model perspective and security aspects. The proposed technical solution consists of a general architecture for a permissioned blockchain-based vehicle lifecycle management used by manufacturers, insurance companies, and other stakeholders.*

1. INTRODUCTION

This paper consists of analyzing the factors to determine if a blockchain-based solution could increase trust, and collaboration, and initiate a data-driven approach business model between different stakeholders in vehicle lifecycle management and the insurance industry. The possibilities that blockchain offers in addressing the problems of lack of data will be analyzed. A data-driven model, a solution based on blockchain, and "smart contracts" will be conceived. The proposal is to digitize all transactions in a decentralized, accessible, and distributed ledger which could initiate new initiatives in the insurance policies like the pay-as-your-drive or bonus-malus concept. Modeling and building a decentralized database of customers and products leads to a data-oriented business model and more concrete opportunities for analyzing those data. The current approach has risen issues that the blockchain-based solution must address because they continue to cost manufacturers, insurance companies, and customers a considerable amount of money. In this paper key issues identified are mileage fraud, accident fraud, IoT update vehicle usage, vehicle production, and usage location traceability, parts functioning and traceability, data analysis from manufacturers and other stakeholders, ownership traceability, insurance policies traceability, data-driven risk analysis, and predictive maintenance.

This paper presents a general architecture for permissioned blockchain-based vehicle lifecycle management. The proposed technical solution consists in a permissioned blockchain platform that helps break down border barriers to find data on manufacturers, vehicles, users, and all other stakeholders, following the entire product lifecycle. These data can be used by a range of users such as manufacturers, insurance companies, and other stakeholders. The main objective

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is to securely digitize and share vehicle lifecycle data. This will enable the stakeholders to securely collaborate over a permissioned blockchain network using vehicle data for different business model approaches. This could create a growing ecosystem of services around the proposed solution. The purpose is to store in a distributed ledger and provide evidence of all transactions committed for a vehicle from different stakeholders as needed while addressing the security concerns between participants in the network.

2. LITERATURE REVIEW

Relevant and accurate data about a vehicle impacts its value and the insurance policy related to it. Today's vehicle industry is spread over different manufacturers, dealership companies, vehicle repair services, and others. All this amount of data is not shared between different stakeholders. Issues and fraud related to vehicles rise, directly impacting their value and stakeholders. Zafar et al. (2022) underline the fact that due to a lack of records, insecure records, or lack of verified data, the purchaser of a used vehicle remains unaware of the maintenance and transfer history of the vehicle.

Willemarck et al. (2014) in their joint appeal to members of the European Parliament addressed the issue of vehicle odometer fraud which has become a growing problem internationally. Known more commonly as mileage fraud, it affects a considerable number of used cars in Europe - estimates go as high as 30%, costing European consumers approximately €5.6 to €9.6 billion. One of the reasons is the lack of unified vehicle life-cycle management. Vehicle data are currently spread across multiple stakeholders that do not trust each other or collaborate. Brousmiche et al. (2018) present another example of vehicle fraud that has great economic and societal impacts concerning rolling wrecks. Vehicles declared as wrecks by an insurance expert are put back onto the second-hand car market, with the help of corrupt professionals. These rolling wrecks are often the cause of severe accidents, involving injured people, and costing insurance companies and consumers a lot of money.

Pan et al. (2020) stress the need to introduce trust mechanisms in organizations to solve the problem of trust to improve information sharing. Lack of data transparency and trust arise since the only link to the information across different stakeholders is a paper-based vehicle logbook which in some cases, is corrupted or not updated with all transactions. Bringing all participating stakeholders under a common digitized platform is a challenge. Recently launched new initiatives for digitizing vehicle logbooks using blockchain technology, secure-by-design, and decentralized ledger. Abbas et al. (2020) explore the potential of blockchain technology in enhancing trust among the stakeholders based on blockchain technology's key attributes: distributed and sustainable; secure and indelible; transparent and auditable; consensus-based and transactional, flexible and orchestrated.

Casino et al. (2019) in a systematic review of blockchain applications emphasize that blockchain has found widespread applications including insurance, payments, asset management, supply chain, banking transaction, etc. providing security, scalability, reliability, and trust among stakeholders and participators in the network. Some notable work is presented by Brousmiche et al. (2018) addressing vehicle life cycle management and odometer fraud prevention through blockchain technology based on J.P Morgan Quorum. They consider the involvement of different stakeholders and emphasize the need and the efficacy for secure management of vehicle data over its life cycle with blockchain technology. The authors presented the idea of a

digital car logbook to prevent odometer fraud and provide a secure cryptographic protocol to provide access to vehicle data to interested stakeholders. Another notable work by Masoud et al. (2019) addresses information integrity with a framework called CarChain, a novel public blockchain-based history reporting system in used motor vehicles. CarChain provides vehicle owners, repair service companies, and insurance companies to register, add and store vehicle data in a distributed ledger that broadcasts transactions through a peer-to-peer (P2P) network. Addressing the cost issue Zafar et al. (2022) analyzed the memory and monetary costs of implementing Hyperledger Fabric a decentralized permissioned blockchain-based secure automotive supply chain and underline that memory and monetary cost are acceptable in their implementation and do not pose a challenge. Previous notable work addresses certain issues like digitizing, sharing, and controlling access to vehicle data but does not address the need for a comprehensive blockchain-based solution over the complete vehicle lifecycle management and fully integrated with manufacturers, insurance companies, dealership companies, and repair service companies.

3. METHODOLOGY

The approach used is the analysis of the current systems and platforms of vehicle life cycle management and insurance policies, highlighting the problems of the actual solutions not only from the point of view of the system and security but also from the business model side. After identifying the current problems, blockchain technology is proposed to address them while considering information security. Concluding on the conception of a blockchain-based solution for the creation of a data-driven business model. The aim is to increase transparency, trust, and collaboration, to enable pay-as-your-drive insurance policy initiatives, price determine mechanism based on risk analysis, predictive maintenance, vehicle and supplier part traceability, and data-driven new initiatives. This is achieved by proposing a decentralized distributed ledger with users, manufacturers, vehicles, and transactions generated from the moment of production and the entire life cycle of the vehicle, and the history of user transactions related to them. The analysis of security aspects from the part of identity management and access privilege is taken into consideration in this paper.

4. USE CASE OVERVIEW

In this blockchain-based vehicle lifecycle management, several actors are contributing and sharing data in a secure blockchain network. The major actors in this network are the manufacturer companies, providing digital vehicle logbooks and embedded IoT devices, insurance companies, dealership companies, and vehicle repair garages. The solution will provide flexibility, scalability, and ease of participating in the blockchain network for new actors.

Vehicle life cycle processes proposed in this solution, presented in the figure 1 schema, highlight some main steps. The schema presents a real-life scenario for a vehicle. The vehicle begins its journey to a permissioned blockchain when a manufacturer/authorized service provider creates a digital logbook in the blockchain containing all vehicle details. Manufacturer/Authorized service provider may choose to install embedded IoT devices that will perform updates of mileage and maintenance warnings in the blockchain as configured. During step two vehicle is sold and vehicle ownership is updated in the blockchain. The current owner has access and can securely share temporary access with third parties (such as insurance companies, garages, and other participants in the network). In step three insurance companies based on historical data of

vehicles provided in the blockchain issue an insurance policy considering a bonus-malus system or the pay-as-your-drive approach since data are transparent, auditable, and with high integrity. In step four based on warnings and incidents reported by IoT devices and sensors vehicle owner securely shares vehicle data with a vehicle garage. Maintenance report is stored in the blockchain network and vehicle data are updated in-vehicle digital logbook. In step five vehicle is resold and ownership changes. Access to the previous owner is denied, and the current owner is granted access and ownership of the vehicle. An insurance policy is reissued by the insurance company and based on previous data stored in blockchain risk analysis is more accurate and price more realistic to performance. In step six an accident occurred, and data are stored in the blockchain. Considering that the insurance company decides after an analysis from an insurance expert if the vehicle will be repaired or will be asked for vehicle wreckage, thus ending the vehicle's life cycle. These steps in a real vehicle life cycle scenario are repeated many times and traceability of transactions for vehicles is transparent, and accurate and resolves issues like mileage fraud and rolling wrecks that are present in the current system.

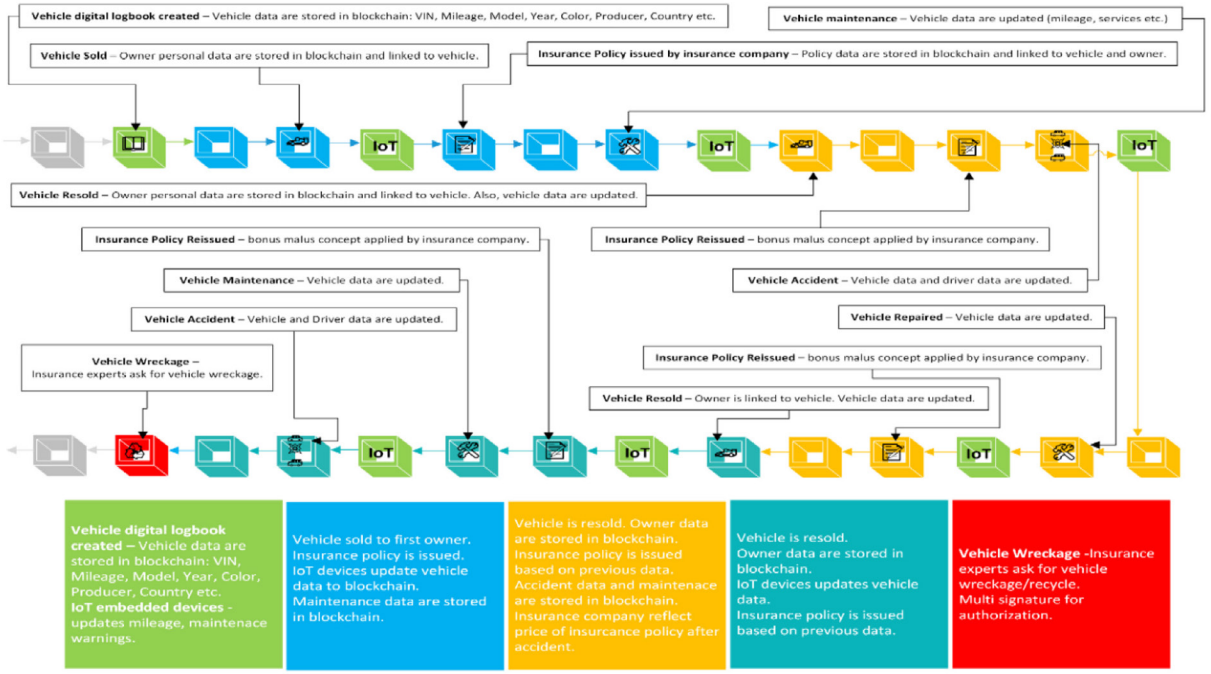

Figure 1. Blockchain-based vehicle life cycle

5. TECHNICAL SOLUTION PROPOSAL

Architecture for this blockchain-based system for vehicle life cycle management will be modeled from a business-level perspective. The architecture of the system will be modeled based on Hyperledger Fabric technology which is an enterprise-grade distributed ledger platform that offers modularity and versatility for a broad set of industry use cases. Working with Fabric directly involves modeling applications using Chaincode. The system will be modeled considering three main business levels: assets, participants, and transactions. There will be considered two main assets which are vehicle and insurance policy. The blockchain-based solution is scalable and in a real-life scenario, stakeholders will be able to agree to add more assets and participants to the network if needed. Assets are modeled in the form of key-value pairs. These key-value pairs represent the current state of the asset. The assets are stored in a state database, and individual fields of an asset can be updated by updating the corresponding key-value pair. In this

technical solution focus will be on the higher-level abstractions that are specific to the business use case by modeling resources whether they are participants in the network, the assets that are transferred, or transactions that are executed, and defining resource permissions.

A map representation of the main *assets* is presented in figure 2. Assets are modeled as objects with their attributes and may contain other objects as attributes. Vehicle as the main asset is modeled with attributes such as Digital logbook, IsSold, Insurance Policy, IsMaintained, and IsAccidented. Each of these is an object with its attributes. The focus of this asset is the digitizing process of the digital logbook, the history of insurance policies related to vehicles, and all vehicle issues and maintenance reports. All assets are subject to change if other assets and participants enter the blockchain.

Figure 2. General map of network assets and their attributes.

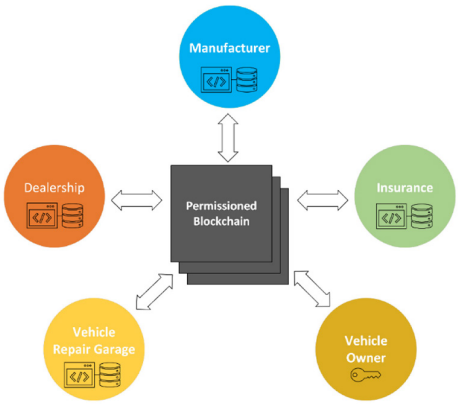

Figure 3. Participants in the Hyperledger Fabric network.

The main *participants* in the network are Insurance Companies, Dealership Companies, Vehicle Garages, Manufacturer companies with embedded IoT Devices, and vehicle owners. The system is modular and flexible for further development and changes for different participants. The blockchain network will be run into these participants and an access control list will be defined to determine roles and access right for each participant and for each channel. Every company which represents a major participant uses its applications and stores information in its databases as presented in figure 3. The proposed solution consists in sharing that information in a blockchain network accessible by all participants by integrating communication from participants' applications to the proposed blockchain Hyperledger Fabric network. Data are encrypted and only participants who have access and have the key or are provided with a valid key may view or write the data.

Transactions will be modeled as Read, Update, and Create access rights based on assets and participants. The read access of one participant is not allowed without providing the access key of the other. All transactions are encrypted. The transactions are not displayed in a detailed form in this paper but are displayed as what access rights have participants in table 1:

While defining the assets, participants and transactions are imperative to determine the relationship between participants and assets. Below are presented the main relationship between participants. Relationships in the Hyperledger Fabric network could be more detailed, elaborated, and subject to change based on new participants that join the network.

Table 1. Participants access rights

Assets\Participants	Insurance	Dealership	Garage	IoT devices (Manufacturer)
LogBook	Read	Create	Read	Update: Mileage, Consumption, Issues Detected
IsSold	Read	Create, Update Status	Read	No access
Insurance Policy	Create	Read	Read	No access
IsMaintained	Read	Read	Create	Read
IsAccidented	Create Update Status	Read	Read	Read

The main relationships are presented below:

- Insurance Company can issue one insurance policy for one vehicle. Until one insurance policy is valid, no insurance company can issue another one. Thus, the relationship between the insurance policy and the vehicle is one-to-one.
- One vehicle must own one digital vehicle logbook. Vehicle logbook fields are updated based on vehicle maintenance, embedded IoT devices, and further updates.
- One owner can have multiple vehicles. The owner is provided with access keys for each vehicle and may choose to grant temporary access to interested stakeholders.
- Vehicle Repair Garage can offer services to multiple vehicles and vehicle owners can choose between different vehicle repair garages.
- Vehicle Dealership Companies can offer services to multiple vehicles and vehicle owners can choose between different vehicle dealership companies.

The *identity management* process will be in a form of a chain of trust formed by a root certificate authority (CA) and intermediary CA. Fabric provides a built-in CA component that allows the creation of CA in the blockchain.

6. CONCLUSION

In this paper, a permissioned blockchain-based solution implemented with Hyperledger Fabric for vehicle lifecycle management is presented. Considering the lack of data and lack of collaboration between different stakeholders in the automotive and insurance industries we believe that blockchain technology could build trust and collaboration. There is a need to digitize vehicle lifecycle data in a secure and temper-prof technology. Blockchain key features such as immutability, decentralization, sustainability, security, and consensus-based provide an opportunity for a mutual agreement between participating stakeholders to share their data and integrate their systems with the blockchain network. In this blockchain-based proposed solution, the manufacturer enters into the blockchain each vehicle produced, or the authorized service provider enters into the blockchain each used vehicle creating a digitized vehicle logbook. During the vehicle lifecycle, the data is entered into the blockchain, and its usage is traced. All transactions through the vehicle lifecycle are stored in the blockchain network resolving issues like:

- Buying and selling a vehicle: the potential buyer verifies the property, and the doubt of buying a vehicle from a false owner in the case of a stolen vehicle is eliminated; it eliminates the possibility of duplicating the chassis number.
- Odometer fraud: it is possible to follow the kilometers traveled by the vehicle, avoiding that is illegally lowered by a dealer.
- Accidents fraud: they are all recorded, and this helps to determine a more accurate value in the market, reducing the information asymmetry that can occur when crashed cars arrive and the buyer is not informed.

- Maintenance services traceability: any maintenance performed on the vehicle is recorded in the blockchain by the service repair garage providing a higher level of transparency. This also helps to determine a more accurate market value in a trade and a price comparison between similar models.
- Data-driven model of the lifecycle of a vehicle: the existence of a platform with data on each type of vehicle, helps manufacturers and others to analyze the lifecycle of their product, and the quality of production since it tracks each event of how the vehicle responds in terms of safety and performance. This information is used by manufacturers to identify their production, advertising, and sales strategies.

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