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Review article

INTEGRATION AND IMPLEMENTATION OF BLOCKCHAIN TECHNOLOGIES IN THE AUTOMOTIVE INDUSTRY

Nexhibe SEJFULI-RAMADANI[1], Borislav POPOVSKI[2], Aleksandar RISTESKI[3]

[1]Department of Informatics, Faculty of Natural Sciences and Mathematics, MK*
2 Faculty of Electrical Engineering and Information Technologies, MK
3 Faculty of Electrical Engineering and Information Technologies, MK
**Corresponding Author: e-mail: nexhibe.sejfuli@unite.edu.mk*

Abstract

This paper provides an overview of the blockchain models implemented in the automotive industry, including energy trading and charging models, vehicle communication models, material tracking models, and lease history models. It explores the effectiveness of these ideas, as well as their respective advantages and disadvantages. Additionally, the paper discusses the latest advancements in the digitalization and decentralization of critical automotive data, including car registration, maintenance history, prices, and standards, as well as tracking and navigation. It highlights the potential of blockchain to increase transparency and reduce fraud. Specific examples of companies and organizations using blockchain technologies in the industry are also provided, and potential future developments and emerging use cases are discussed. Lastly, this paper addresses potential criticisms and challenges to the use of blockchain technologies in the automotive industry. Through this comprehensive examination of the topic, readers will gain a deeper understanding of the role of blockchain technologies in the automotive industry and its potential impact on the future of the industry.

Keywords: blockchain, distributed ledger technology, decentralization, digitalization, automotive industry, electric vehicles, supply chain management.

1. Introduction

As individuals, we often tend to isolate ourselves within our own experiences, especially as we age. At a young age, we may be quick to adapt to the latest technology and gadgets, but as we get older, we become more resistant to change, preferring to stick to what we know. However, in doing so, we risk falling behind the times and missing out on important advancements that could improve our lives. While we may not always be interested in the latest innovations, it is crucial to periodically check for new findings that could enhance our safety and well-being.

One such innovation that has recently gained significant attention is blockchain technology. While it has been embraced by science enthusiasts, many businesspeople have been understandably wary of this new idea [1]. As with any novel concept, it is crucial to wait and see whether it will withstand the test of time, however, for any idea to work, people must be willing to take the risk and experiment with it.

We will first inform the reader on what blockchain is and how it works in section 2 of this paper, before moving to the integration of cryptography for securing blocks and making them private, as we will see in section 3.

Interestingly, it was Asia that first embraced and implemented blockchain technology in their company and government systems, with other nations following suit at a cautious pace. This serves as a reminder that progress is not always immediate, but with careful consideration and effort, we can embrace new ideas and ultimately benefit from the advancements they bring.

Section 4 of this paper will delve deeper into this subject, splitting the usage of blockchain into five main problems that it has solved, with examples from news, websites and published papers on many individual innovations in the field.

2. Understanding Blockchain

Blockchain is a distributed ledger of digitalized data. What this means is, that if you made and want to sell a product, you can create a 'block' the moment that you sell it, and that block will contain information about the product's state, how much it was sold for, who paid, etc. If the buyer damages the product and takes it somewhere to be fixed, the moment they pay for the repair, another block is to be added to the product's blockchain.

Blockchain is similar to Google Docs in the way that multiple people can view and edit the same document without having to download and pass multiple copies. It relies on hash values, nonces, and proof of work to tie blocks together.

Hash values are generated by a hash function that takes a block of data and produces a fixed-length output. The output is unique to the data input and acts as a digital fingerprint. For example, an image file can produce a hash value like this: 21d51d6813047d0d9ea7aee462abc42d, but changing even one pixel in it will completely transform it to 21d51d6813047 d0d9ea7aee462abc42d. Each block in a blockchain contains its hash value and the hash value of the previous block, creating a chain of blocks. This makes it virtually impossible to modify a block without affecting its predecessor, providing security and immutability to the system.

To create a particular type of hash value, a nonce (number only used once) is added to the block data. So, after a message is converted to binary, a random number in binary is added at the end. We know that a one-pixel change is enough to transform the hash value (or one period added at the end of a message or even changing the font of a text document), but what miners try to generate are hash values that begin with a specified number of zeros. The chances of transforming the hash in such a way are slim and the more zeros required, the harder it is to be lucky. This difficulty level is adjusted periodically, depending on the number of miners and their computational power, to maintain a stable block generation rate.

Proof of work is the work required to generate the nonce that will give the desired hash value form (with a specified number of zeros at the front). The first miner to find the correct nonce broadcasts the block to the network for validation. Other nodes in the network verify the block's validity and, if accepted, add it to their copy of the blockchain. The successful miner is rewarded with newly created cryptocurrency and transaction fees.

Since generating the lucky nonce is hard and miners have to keep generating numbers, block mining is an energy-intensive process that requires a significant amount of computational power. This has led to concerns over the environmental impact of blockchain, particularly for cryptocurrencies like Bitcoin, which consume vast amounts of electricity.

A blockchain can be encrypted, which means if you're a potential buyer of the before-mentioned example product, the previous owner has to give you access to view the blocks and you can refuse to buy if otherwise, but most importantly, you will know exactly where this product came from, how badly it has been damaged before, what parts were replaced and for how much, etc. The blocks also require digital signatures, so whoever makes a transaction about anything regarding the product has to first verify their identity and that will also be stored in the block so that the person can't later deny what was charged and what was paid for [2].

3. Public and private blockchains

Rarely does a company benefit from having all their transactions and documentation publicly available, but it is also unlikely that anybody else needs to see this data except the potential buyer, loaner, or renter. It is in the common interest of both the organization and the customer to want their data readable only by them and by the people that they give access to. This is attained generally by public-private key pair encryption. To explain it with a really simple example of how asymmetric encryption works, we'll say that person A wants to establish a secure connection with person B. A's computer generates private key pkA, while B's computer generates pkB. A and B have previously agreed on a number or function g, but for the sake of simplicity, we'll say it's a number. A sends B the public key gpkA, while B sends A gpkB. Both parties raise this number to the power of their private key and both parties get gpkApkB. Now there are two opportunities here [2]:

- the parties can use symmetric encryption with gpkApkB
- the parties can use asymmetric encryption where the block is encrypted with a public key (for example gpkA) and decrypted with a private one (pkA).

In both cases, not only does the block get encrypted, but it also creates a sort of digital signature for the people involved in the transaction: If B decrypts the block with the key generated from A's private key pkA, there is no doubt that A has written that transaction.
However, this is not the end of it. A private blockchain also means the owner can choose who puts another block in and who mines the blocks.

4. Usage of blockchain in the automotive industry

The automotive industry has always been at the forefront of technological innovation, constantly seeking ways to streamline processes and improve efficiency. With blockchain, the industry can ensure greater trust and transparency between stakeholders, reduce fraud and errors, and enhance the overall efficiency of supply chain management. Sellers and buyers, lenders and loaners all benefit from using blockchain and this is especially needed in the automotive industry for the following reasons:

4.1 Removing doubts of fraud from both parties: Depending on what kind of services the company offers, not only will the transactions be securely stored and immutable, but most importantly, no party will be able to later deny that they sent or received the money, because of the public-private key pair exchanged to write the transaction. his feature can be incredibly useful for the automotive industry, where trust between buyers and sellers is critical. For instance, when buying a used car, the buyer wants to be sure that the car has not been in any accidents or undergone any major repairs, and that the seller is the rightful owner of the vehicle.

Aside from money problems, this trust in authority can be achieved in various other aspects. An unusual one is the case study of car registrations in Portugal and the decentralization of them through blockchain [3]. The authors realized that when cars were transported to other cities or countries to be sold in second-hand markets, sellers, lawyers and other governmental or non-governmental entities of one place communicate with sellers, lawyers, and other governmental or non-governmental entities of another place often through email or through a designated website to get information on car registry numbers so that they can add, delete or reuse them.
This of course has many problems starting from database attacks to fake websites to updated information much later than needed. Using Hyperledger Fabric, the team created a blockchain for worldwide car registry data where each block would be added by a trusted authority, and even in the case of misuse, the preparator would be caught immediately because of the public-private key encryption, which by the way in many kinds of literature is referred to as smart contract, however, this is just the standard, programming requires creativity and so smart contracts can be realized in different ways.
The cases taken into consideration for the models presented were:

- change of ownership
- creating a lease
- seizing a vehicle
- registering as a guarantee
- changing vehicle state

Each of these cases has its ordinary model and blockchain-based model to highlight how many steps in the ordinary process are redundant and create more problems than they should (e.g. adding on to the already big pile of paperwork that office workers already hate taking care of). According to the source [3], the resultant pilot software for car registration was tested on 100 vehicles, so 100 transactions in total but with a rate of 50 transactions per second. Then, the same was optimized and tested on 200 vehicles, so 200 transactions in total with a rate of 100 transactions per second. Lastly, 400 vehicles were registered, so 400 transactions in total with an amazing rate of 200 transactions per second.
For each of these three experiments, they measured the time needed for the system to validate the requests and register the car, also tracking RAM and CPU usage. The results showed that the system reached maximum speed with high efficiency with approximately 2MB block size for each transaction. This is a huge improvement considering that an average blockchain block is 1MB and the structure of the system also paves the way for other potential uses that are similar, such as registry of people or private property.
Having proved successful with such a relatively large number of test cases goes on to show that the problem lies not in the ability of blockchain technology, but in mankind’s hesitation to use it.

4.2 Removing doubts of authenticity: Even if the blockchain is private, you can get access to it if you are granted access by the owner. So, if you want to buy a car but the company is not a known name or you think they might be a fraud, you can ask them for access to their blockchain. Now not only are you sure that this company has a history of successful sales, but you are also sure that these records are genuine because modifying blocks or generating a fake blockchain is almost impossible.
The same can be said for a company that wants to, let's say, give car loans. They can ask for the customers' income history and credit history to check for late payments or problems with payments in general, other loans the customer might have and some companies even ask for monthly costs like bills [4]. In smaller cities, lenders might resort to just asking people they know for information on the loaner [5]. The number of papers gathered for each potential loaner gets too big and an article published in the Lightico webpage for loan fraud statistics

of 2019 [6] stated that "...a paltry 7% of income verification documents are validated. The vast majority are simply accepted at face value. In addition, lenders rarely look at applicants' credit reports.".
Blockchain removes the weakest link in this system - the human factor. Once transactions and identity verification documents get recorded on the blockchain, there are several software that can be built relatively easily to make these decisions without human intervention. [7] Mobi, a global nonprofit smart mobility consortium tried this approach with small local companies and had great results [5]. In the meeting held and documented in [5], an interesting case to mention is a car lease system based on blockchain technology that locks itself up if the lease payment has not been made in the required period.
Having tested and verified the usability of such systems in various projects, Mobi now has its own infrastructure MobiNET, made for its workers to build applications for the digitalization of many manual processes, starting from the identification of workers and their digital signatures.
Volkswagen is already ahead in this area with its partnership with Energy Web's blockchain to ensure powering electric vehicles with renewable energy, because although electric vehicles are the eco-friendliest option, there's no guarantee that the electricity source is renewable [8].

4.3 Providing secure and accurate car history: car industries, because many documents about the car's previous owners, accidents, changed parts and even performance are forged or not shown to the potential buyer. Many models have been proposed to handle this issue by digitalizing the data and uploading it in blockchain [9], out of which we will focus on a recent wide-range case study [10] done in Taiwan, where app compatibility was also taken into consideration, meaning the model was based on the requirements of various apps that China already has to try and keep track of things like this.
China already has an automotive industry alliance and a blockchain platform for it, EGCC, released in 2018 [11] and it brought a lot of advantages, as you could now get access to the car's block line and see its history of changed parts, accidents, where it was sent for repair and what was repaired and so on, but it had two disadvantages that the new 2021 model fixes, the first one being that you had to pay in EGCC coins to query data and the second one being that the new model provides record permission (people that can add blocks should first verify that they have the necessary competences, for example only a mechanic can add a record about car repair). This system had three main goals:

- To provide transparency of the information available on the vehicle condition
- To provide users access and control over smart contracts, while maintaining a blockchain system that is tamper-proof
- To provide user-friendly web and application interface designs

The final model works in such a way that the initial data required for each vehicle is provided by the manufacturer (this is the initial block in each car's blockchain). This data includes the car's model, the year it was released, its mileage, and engine capacity. After a potential buyer agrees to become the new owner of the car, the new block changing the ownership is written by the government branch, and the same entity updates the chain each time an accident occurs or the car is sent for maintenance, however, it can just permit the police department or maintenance service so that for a short period they have the authority to register these changes officially, with their signature. People uninvolved in this process can only view general information about the vehicle until the day that it is scrapped. When the vehicle is scrapped, the contract that represents the vehicle is also destroyed by the self-destruct function of the contract.
In the evaluation stage, the team concluded that the transaction throughput is enough for daily transactions.

4.4 Providing security to big companies: Ford, Tesla, BMW, Renault, and General Motors have expressed genuine interest in blockchain mainly because of the all-time famous problem big companies have, that is, tampering with their products. When you grow a lot and have multiple branches in different cities all around the world, it's hard to keep track of everyone's activity. Many company CEOs are not aware of worker exploitation or tampering with their products for profit. A very common problem, for example, is odometer fraud, where the seller rolls back the car odometer to make it appear like it has a lower mileage than it does, to get more money out of the buyer. If you bought a car like this from an official store point, you'll blame the company, for not being aware of this phenomenon.

Renault partnered with IBM to use blockchain to keep track of their cars and make sure that their parts are all up to date with the newest standard [12]. This project was called the eXtended Compliance End-to-End Distributed (XCEED) blockchain project and after testing this project at its Duoai plant, using blockchain made it possible to archive over one million documents at 500 transactions per second.

Meanwhile, Ford, in cooperation with Huayou Cobalt and IBM, did a pilot project in 2019 with blockchain [13], where it tried to trace Cobalt produced at Huayou's industrial mine site as it travels through South Korea and finally to the United States, to see if worker exploitation was happening. The real-time and secure data made a successful pilot and the same technology was later implemented in 2021 for cobalt, lithium, and copper [14]. Tesla quickly became part of this movement as well in 2021 and tested the model for cobalt tracing [15]. In the future, the sources report that:

"Work is expected to be extended beyond cobalt into other battery metals and raw materials, including minerals such as tantalum, tin, tungsten, and gold, which are sometimes called conflict minerals, as well as rare earths. Focus industries for the solution include automotive, aerospace and defense, and consumer electronics. There are plans for a governance board representing members across these industries, to help further ensure the platform's growth, functionality, and commitment to democratic principles." [15]

An interesting and less dark example is General Motors' idea of implementing blockchain in its activities [16]. The company uses blockchain to store data from the cars' various sensors to create an accurate and reliable navigation map for autonomous vehicles. The system starts with a candidate map that is then improved based on data added to the blockchain from GM cars. If many cars that pass through the same area report identical blocks, which means identical problems, then a change is made in the map. This data represents car defects or problems in the same situations. This can be caused by, let's say, a road pit or something more serious like a shortcoming of the car mechanism. In 2022, SAIC-GM-Wuling, the Chinese joint venture between General Motors, SAIC Motor Corp, and Guangxi Automobile Group, is pushing for blockchain to be used in more aspects, like banking, utilities, hospitals, and local government agencies [17]. 15 new pilot areas have already been selected to apply the newest blockchain technologies to various public and private institutions. These projects are expected to reduce paperwork by as much as 10 million sheets per year, reducing costs by $2.5 million annually.

4.5 Secure e-payments: In previous studies, payments were registered in the blockchain manually through a person in charge. For instance, a gas station worker would record the transaction after filling the car with gas. The worker and the car owner would both have their applications, or one of them would have a card that the other would scan with an application or terminal. However, with the advent of smart cars and even self-driving cars, the newest revolution in blockchain technology has made it possible to link the software directly to the owner's e-wallet, making the transaction process faster, easier, and more secure. With the evolution of cars and the dawn of smart cars and even self-driving cars, the newest revolution in blockchain technology makes it possible to link the software to the owner's e-wallet. Two terms to be explained here are:

- e - wallet: a type of electronic card linked to the owner's bank account, it is used for transactions made online through a computer or a smartphone. An e-wallet can also be linked to the user's Bitcoin balance.
- bitcoin: simply put it's a digital currency, but a misconception that many people make is that it's a digital representation of physical money. One Bitcoin is equal to 16,718 euros, but if you have a Bitcoin in your account, it doesn't mean you have 16,718 euros in your bank account. An easy way to think about it is like selling a made item. If you made a drawing and put a price to it, it is equal to that price, but that doesn't mean you have that money. You will get the money from someone else's bank account when that person is willing to buy it. Some banks or companies accept bitcoin as payment and the strategy is similar to how I might request 100 rings from one place and sell them for more in places where the economy is better and generally prices of items are higher.

With modern cars being linked to the owner's e-wallet, the transaction process can now be automated. After the service is completed, the car software can make the payment automatically with digital currency if the service provider accepts it [18]. This is already happening in some places where digital currency like Bitcoin is accepted, and the car software supports making such transactions [19]. This automation makes the transaction process quicker, safer, and more convenient for both the service provider and the car owner. Additionally, the use of digital currency eliminates the need for physical cash or traditional credit/debit cards, reducing the risk of fraud or theft.

Recent CoinDance data show that this concept is still new and not widely adopted [20], but people seem to be investing immensely in Bitcoin because they believe this will be the future of society and the economy.

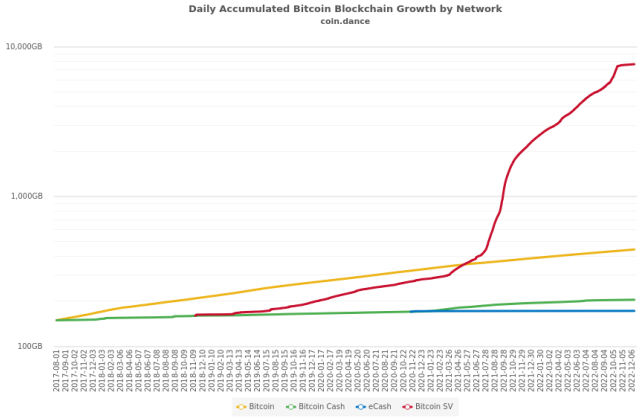

Figure 14: Daily accumulated bitcoin [20]

The numerous other statistics found in CoinDance show that Bitcoin has experienced significant growth since its creation in 2009, with its price increasing from a few cents to over $60,000 at its peak in 2021. However, like any investment, Bitcoin's price can be volatile and unpredictable, and there have been periods of sharp price drops, including a significant decline in 2018 and 2019.

Bitcoin's long-term potential as an investment is a subject of much debate among financial experts, with some arguing that it is a speculative asset with little intrinsic value, while others believe that it has the potential to become a store of value or even a global currency. It's important to note that investing in Bitcoin or any cryptocurrency carries significant risks, and investors should carefully consider their financial goals, risk tolerance, and investment experience before making any decisions. Investors should also be aware of the potential for fraud, hacking, and other risks associated with cryptocurrency investing.

In summary, while Bitcoin has shown strong growth in the past, its future performance is uncertain, and investors should carefully consider the risks and potential rewards before investing in it. It's always a good idea to consult with a financial advisor or do thorough research before making any investment decisions.

5. Conclusion

The notion that many ideas sound promising on paper but fall short in practice is not a new one. Over the years, countless concepts have been hailed as the solution to various issues, only to fizzle out when it comes time to put them into practice. However, blockchain technology seems to have dodged this fate and proven its worth in various fields. The versatility of blockchain technology is impressive, and its potential applications in the automotive industry are manifold. It has already proven itself to be a valuable tool in many aspects of the industry, with major car companies embracing it and making it an essential part of their system.

Blockchain has proven its worth by being integrated into nearly every subfield of the industry, from supply chain management to maintenance, making processes faster and more efficient. Blockchain has also had an impact on moral and ethical subjects, such as exploitation and deception, by providing a transparent, tamper-proof ledger of transactions that can help prevent fraudulent activity.

As more and more companies adopt blockchain technology, it is becoming clear that it has transformed the automotive industry and is not just a fad. The fact that major car companies have made it a standard part of their systems is a testament to its value and potential. It is not just a privilege for a select few, but a tool that is accessible and useful to all.

In conclusion, it is safe to say that blockchain technology has proven itself to be an invaluable asset to the automotive industry, and its potential applications are only continuing to expand. From streamlining processes to addressing ethical concerns, blockchain technology has revolutionized the industry and is here to stay.

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