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Blockchain Technology on the Way of Autonomous Vehicles Development

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Abstract

The article describes the main trends in the field of intellectualization of transport systems and mobility. The possibility of using the Blockchain technology in transport systems is considered. The article proposes to use Blockchain technology for increasing cybersecurity through the creation of a safe and reliable system for sending parameters of the current state of each vehicle using the signals of neighboring vehicles. The authors have developed a tracking system for car actions using the Blockchain system based on the Exonum platform. Mathematical foundations of this system are presented in the article. Data input and confirmation of their acceptance of the transaction is carried out using an Elliptic Curve Digital Signature Algorithm (ECDSA). ECDSA security is related to the complexity of the private key search task described in the article. This largely relates to the management of large-scale systems, such as transport system. Failure to follow simple rules and recommendations can lead to serious consequences, such as road accidents and congestion. Therefore, the proposed system can assist in making decisions with autonomous cars and in investigating crimes as well as traffic offences.

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Keywords: Road safety; traffic accident; blockchain; Exonum; autonomous vehicles

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1. Introduction

Intelligent automotive technology is developing very rapidly, and recent advances suggest that autonomous car navigation will be possible in the near future. Modern intersections, traffic lights and brake lights help drivers to cross the intersections safely (Goryaev et al., 2018; Gorodokin et al., 2017). However, will it make sense in the future for cars driven by on-board computers, not humans? Considering the advantages of intelligent autonomous vehicles (more precise control, better sensors and shorter reaction time) car trips in the future can be not only safer and simpler, but also much more efficient.

The use of on-board computers and electric mobility can help reduce the negative impact of vehicles on the environment. In particular, smoother acceleration and deceleration and energy recovery will lead to a decrease in the consumption of brake mechanisms and, as a result, a reduction in particulate matter emission from disc brake and drum brake mechanisms of motor vehicles (Chłopek et al., 2014; Skrúcaný et al., 2019).

It has been confirmed that the original production factors, i.e. labor, land and capital have been extended by an additional important factor, namely information. The information are getting to the forefront, other factors have limited sources, especially in the future (Bukova et al., 2018). Given the transition of the global economy to Industry 4.0, methods for secure information management come to the fore.

Together with intellectualization of vehicles and appearance of fully autonomous vehicles on the roads the society will face new problems and challenges. For example, the maintenance and repair methods and technologies have to be developed, new solutions have to be implemented in logistic (Stopka, 2019; Stopka and Chovancova, 2018), as well as the problem of ensuring the safety of transmitted data. One of the new trends of protecting data is the blockchain technology that today is used in different areas.

In this regard, we believe that absolutely all vehicles will have a full-fledged on-board computer with the ability to install secure applications with access to navigation and other sensors in read mode. Therefore, the implementation of blockchain solutions will be quite affordable without additional hardware modifications (Madhushan and Farook, 2020).

2. Methods and tools of dealing with Big Data and transport intellectualization

According to experts (Makarova et al., 2017), by 2020, 250 million connected cars will appear on the roads worldwide. Since each of them will be equipped with more than 200 smart sensors, an on-board computer and a cloud-based information base, the need for data management will be as important as manoeuvering during rush hours (Tsybunov et al., 2018). The combination of blockchain and automotive technology provides solutions to some of the most pressing problems, especially those related to reliability and security. The capabilities of blockchain technology, which have already been developed, will stimulate innovative solutions throughout the automotive ecosystem. The more the car is connected, the more it is susceptible to potentially deadly cyber attacks. The blockchain will be able to provide data streams from hackers with the highest available level of security. In the automotive industry, the use of distributed ledgers can ensure that counterfeit parts cannot be inserted into the supply chain, which is ensured by transparency in the supply chain for production, delivery and suppliers. In addition, in the automotive industry associated with the automotive business, smart contracts can be embedded in production blockchains to automatically issue purchase orders at certain stages of the production process.

2.1. Transport systems' intellectualization trends

Real-time traffic and travel information (RTTI) real-time information contributes significantly to the growth of population mobility. This information (increasingly in conjunction with satellite navigation services) is now offered as public and private sources. In the long term, it is expected that their systems will reveal their full potential, based on the principle of cooperation between moving participants and elements of infrastructure, including systems that provide the communication and exchange of information between V2V vehicles (vehicle-to-vehicle), between a vehicle and V2I infrastructure (vehicle-to-infrastructure), and between different elements of the I2I infrastructure (infrastructure-to-infrastructure). If necessary, these systems will be complemented by the Global Navigation Satellite System (GNSS) for positioning and timing (Khasanov et al., 2019). In order to perform the functions for which the telematics systems are designed, the data sent and received by them must be kept secure. Blockchain is ideal for protection against hacker attacks.

One of the main areas of ITS, which has been actively promoted in the past 15 years, is the implementation of the concept of an intelligent car. The international program “High Security Vehicles“ is operating. The first experiments using onboard intelligent systems already showed that they are able to reduce the number of accidents by 40 percent, and the number of accidents with a fatal outcome – by 50 percent. The transition from the creation of driver assistance systems to the development of semi-autonomous and unmanned vehicles is a global trend and is explained by the desire of developers to ensure the stability and security of the transport system. At the same time, it should be understood that the emergence of new technical and technological solutions is associated with the emergence of new problems, the solution of which may require new methods and tools. Thus, the emergence of a new type of car with fundamentally new control systems can cause problems in the field of safety and interaction with other road users. It is necessary to identify possible risks, to predict the probability of their occurrence, to determine the possible consequences. In addition, ways to prevent risk situations and reduce the severity of the consequences in case of occurrence should be developed. As smart sensors are increasingly used not only to monitor traffic, but also to communicate with it, the need for high data transfer speed and data security becomes apparent. Under these conditions, there is an increasing need to search for solutions in the field of cybersecurity that would eliminate or at least minimize the possibility of extraneous interference in the control system of both the vehicle and the system as a whole.

New additional telematics services can provide insurance companies with information on the driver’s location, duration of the trip, acceleration and braking modes, vehicle speed, cornering behavior and other information. Blockchain provides a reliable means of collecting this data and transmitting it in a secure unchanged state. Fleet management companies have already implemented technology for connected vehicles. As pioneers in their field, fleet companies will soon use blockchain technology throughout the industry for all the benefits it offers. The fleet management industry is also an excellent testing ground for consortium chains.

2.2. Blockchain technology in terms of applicability in transport systems

Let’s consider blockchain technology from the point of view of possibility to apply it to solve the problem. Blockchain is a technology for reliable distributed storage of records of all ever committed bitcoin transactions. It is a chain of data blocks, the volume of which is constantly growing, as miners add new blocks with records of the most recent transactions every 10 minutes. Blocks are written to the blockchain in a linear-sequentially chronological order. Each full node (computer connected to the bitcoin network using a client that checks and transfers transactions), stores a copy of the blockchain, which is automatically downloaded when the miner joins the bitcoin network. The registry stores complete information about all addresses and balances, starting from the genesis block (the very first transaction block) to the very last block added.

One of the models of cognition of the modern world is based on the paradigms of computing. A new paradigm arises about every decade. First, mainframes appeared – a large universal high-performance fault-tolerant computer with a significant amount of RAM and external memory used for intensive data processing, usually by large companies and government organizations, then personal computers (PCs), and after that, the Internet fundamentally changed our life. Mobile and social networks have become the next (fourth) paradigm. The paradigm for this decade may be the connected world of computing, based on cryptography of blockchain. It is possible that it is the blockchain technology that will become the upper economic layer of an organically connected world of various computing devices, including wearable computing devices, sensors of the “Internet of things” – the concept of a computing network of physical objects (“things”) equipped with built-in technologies for interaction with each other or with the environment. The organization of such networks is seen as a phenomenon that can restructure economic and social processes in order to partially exclude human participation: smartphones, tablets, laptops, digital self-fixation devices (for example, Fitbit - the market leader in fitness gadgets that are a part of a wider topic, so called “mobile health”), smart homes, smart cars and smart city. But the economy implemented by means of blockchain does not simply support the money flow, but the transfer of information and the efficient allocation of resources that this money provides on the scale of the economy of individuals and entire companies. With revolutionary potential of the Internet, blockchain technology will be deployed and implemented much faster due to the widespread availability of the Internet and mobile communications.

The functionality of social and mobile networks of the fourth paradigm has become so natural that users now expect it from all technologies. So, mobile applications support the functionality that was previously implemented through web applications: “like” mark, commenting, inclusion into friends zone, participation in forums. In the same way, blockchain technology, related to the fifth paradigm, creates the expectation among users that the exchange of values should be available everywhere. The functionality implemented in the framework of the fifth paradigm may look like a connected integrated physical computing layer with many devices, on top of which is a layer for servicing payments (Dai et al., 2019).

2.3. State of the art: examples of the blockchain application in logistics and transport

Using new technologies, such as blockchain, the Internet of things, artificial intelligence, many companies are developing cyber-physical systems that change the competitive environment. Tanga and Veelenturf (2019) studied the strategic role of logistics and transport services to create economic, environmental and social values. Based on a literature review, the authors found that blockchain technology in the future could transform supply chain operations.

With the growing fleet of connected vehicles and the exponential expansion of the market for online taxi booking services, the need for a safe, uninterrupted and reliable exchange of information between vehicles of automobile networks is growing. However, according to Rathee et al. (2019), the risk of threats to smart devices by attackers is growing. This article examined an example of the application of IoV and proposed a security mechanism for the infrastructure of services of connected autonomous vehicles using blockchain technology, which allows for confidentiality and transparency among customers and taxi drivers, by tracking and recording in blockchain each action of objects relative to vehicles or IoT devices.

The rapid growth of Internet Vehicles (IoV) has led to enormous difficulties in the storage of large amounts of data, the intelligent management and protection of information for the entire system, especially when responding in real time. Since blockchain as an effective technology for decentralized distributed storage and security management has already demonstrated great advantages, Jiang et al. (2019) explore how blockchain technology can be expanded for use in transport networks, especially considering distributed and secure storage of big data. The authors performed theoretical modeling and performance analysis of vehicle network systems, as a result of which this article could potentially be used as a guide for studying blockchain technologies for IoV.

As interest in electric cars is growing, the authors of scientific studies devote their work to using blockchain in charging systems. So, Matthes et al. (2019) proposed a safe charging system for electric vehicles based on the blockchain, which ensures key security, safe mutual authentication, anonymity and perfect direct secrecy, as well as efficient charging. To test the effectiveness of the proposed solution, the authors compare it with existing ones. Asfia et al. (2019) indicate that research related to electric vehicles (EV) is mainly focused on hardware, such as the battery charging method, and there is still not enough software research, such as a billing system, that needs to be developed. The authors propose an intelligent contract blockchain for the safe charging of electric vehicles. Firstly, we consider a blockchain system integrated with EV and CS (charging system). Secondly, an algorithm is presented to achieve consensus for the efficient exchange of energy in the blockchain. Thirdly, many terms of the contract are analyzed in order to satisfy the individual energy consumption preferences of electric vehicles and maximize the utility of operators. The article of Zielińska et al. (2019) is devoted to the electric vehicle charging system, which presents the concept of using a model using blockchain technology when charging electric vehicles. The paper shows the concept of a model in which using chains of blocks it would be possible to calculate the sale and purchase of electricity in the charger. This technology can allow partial or full decentralization of the process, full automation without involving intermediate devices. The article also shows how such operations can be carried out automatically and without supervision, which allows the application of previously established principles, rules and assumptions based on smart contracts. The use of blockchain technology for modeling the electricity metering system during the charging process, as well as the possibility of participating in the market of infrastructure under construction, goes beyond the financial application of the technology. Aspects for which the blockchain can become a factor in changing business models are, first of all, more efficient and secure applications, elimination of unnecessary intermediaries or numerous innovations.

The article of Li, W. et al. (2019) presents a new decentralized and secure architecture for protecting data of connected vehicles, which is based on the blockchain paradigm. The authors believe that the study will serve as the first step for introducing blockchain technology from cryptocurrency systems to traffic management systems. The authors developed a prototype block network and an agreed protocol and showed how, by converting the original centralized car network to a decentralized network, the original vulnerable system can be protected from hacker attacks.

As Li, M. et al. (2019) indicate, the joint vehicle use by passengers reduces travel time, carbon emissions and congestion. But, since passengers often look for drivers through a cloud server, this leads to unnecessary communication overhead and an increase in response latency. The advent of foggy computing for local processing of data with low latency has caused security and confidentiality problems, since when users share it, personal information of users can be disclosed. The authors believe that the consortium blockchain could provide a possible solution if the different carrier companies work together to serve users, and user privacy as well as company confidentiality will also be taken into account here.

3. Results: justification of blockchain applicability for cars tracking

Our work is devoted to the implementation of tracking the actions of cars using a modified blockchain platform, namely, a safe and reliable system for sending the parameters of the current state of each car through neighboring ones. In this system, vehicles confirm the messages of neighboring cars within a radius of 100-150 meters. Messages are signed by senders and every neighboring car equipped with such a system. An example of micropayments between devices is a car that automatically approves high-speed passage of a route on a highway in case of emergency, compensating inconvenience caused to other traffic participants by micropayments. Coordinating the air delivery of goods by unmanned aerial vehicles is another example of micropayment networks between devices where balancing individual priorities is needed.

Exonum is a platform that allows to create decentralized, secure and reliable applications using blockchain. The platform is intended for companies, organizations and even governments. Using the Exonum solution, these organizations can create their own private network that meets the needs of a particular company and provides unprecedented security by integrating the project with the blockchain. Exonum is the fastest private blockchain that can process up to 9000 transactions per second. Programs for the Exonum blockchain platform are written in the Rust language, which Bitfury experts call the safest programming language guaranteeing no memory management problems. A Rust program compiles directly into machine code, so it runs faster than a virtual bytecode. Currently, the Exonum platform is used to pilot projects in the state registries of three countries: Georgia, Ukraine, Russia. Further, we will consider the innovative blockchain technology and the mathematical foundations of this technology.

The blockchain elliptic curve is basically a publicly accessible repository into which participants enter data and confirm their transaction acceptance using the Elliptic Curve Digital Signature Algorithm (ECDSA). An elliptic curve is an equation of the form $y^2 = x^3 + ax + b$. In bitcoin and most other implementations, $a = 0$ and $b = 7$, so the equation can be written in the following form: $y^2 = x^3 + 7$ (Fig. 1a). These properties can be used to define two operations on the points that make up the curve: point addition and doubling. To add points, $P + Q = R$, it is necessary to draw a line through the points P and Q, which, according to the properties of elliptic curves, intersects the curve at some third point R'. Then, we find the point on the curve that is symmetrical to the point R' with respect to to the X axis. Point R is considered as the sum of P and Q. This can be easily understood from the image shown in Fig. 1b. A more complex option is the case when you want to add a point to itself. For this case, the operation of doubling the point, $P + P = R$, is determined. When doubling, one should draw a line tangent to a given elliptic curve at point P, which, according to the properties of the curve, should intersect it at another point R'. The point R, symmetric to R' relative to the X axis, will be considered as the doubling point P. It is shown in the graph (Fig. 1c). These two operations can be used to determine the operation of scalar multiplication, $R = a P$, defined as adding point P to itself a times:

$$R = 7 \cdot P \tag{1}$$

$$R = P + (P + (P + (P + (P + (P + P))))) \tag{2}$$

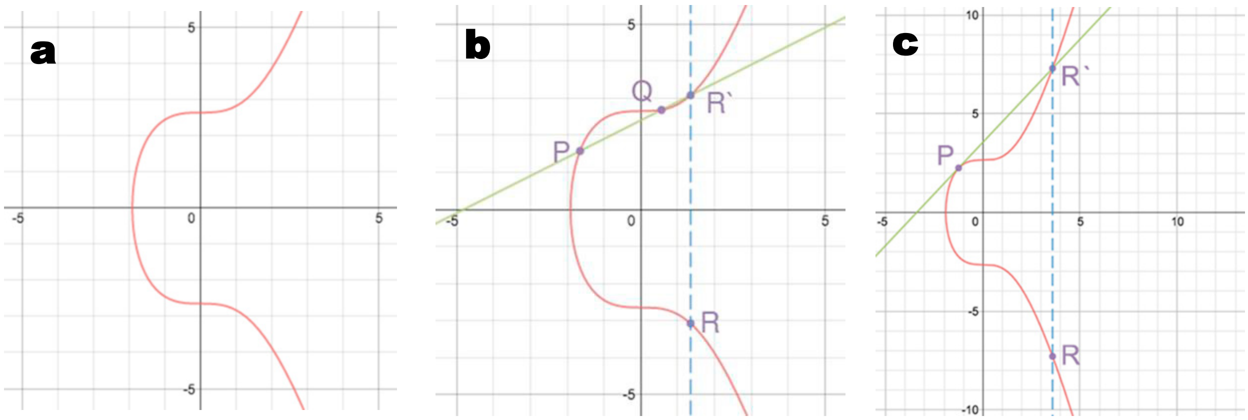

Fig. 1. (a) the equation $y^2 = x^3 + 7$; (b) $P + Q = R$; (c) $R = a \cdot P$.

The scalar multiplication process, as a rule, can be simplified using a combination of addition and doubling of points. Here, operation *7P* was divided into two stages of doubling points and two stages of adding points – in the end, instead of seven operations, you need to complete only four. Indeed, the “addition” can be defined on the curve, considering the third point corresponding to two given ones. This is basically what is being done at ECDSA. The calculation of the public key is performed using the same operations of doubling and adding points.

$$R = 7 \cdot P \tag{3}$$

$$R = P + 6 \cdot P \tag{4}$$

$$R = P + 2 \cdot (3 \cdot P) \tag{5}$$

$$R = P + 2 \cdot (P + 2 \cdot P) \tag{6}$$

This is a trivial task that an ordinary personal computer or smartphone can solve in milliseconds, while the inverse problem (obtaining a secret key by public value) is a discrete logarithmic problem, which is considered computationally complex. The best known algorithms for solving it, such as the ro-algorithm (ρ-algorithm) proposed by John Pollard (Sarnaik et al., 2015), has exponential complexity. For secp256k1, to solve the problem, you need about 2128 operations, which requires computation time of a regular computer, comparable to the lifetime of the Universe. The discrete logarithmic problem can be solved more efficiently by using other methods: for example, using pre-computation (Hong and Lee, 2019) or dynamic programming approach (Zielosko and Żabiński, 2018).

However, it should be emphasized that this example includes extremely modest integers. In a real Bitcoin or blockchain application, these are usually integers with a length of 256 bits, which leads to a significant increase in the cost of performing the above operations, however, it significantly increases the costs of the “intruders” to the system, which are required, for example, using computational attempts to recover the private key from the public one (Hull, 2017).

4. Discussion

Thus, the mathematics and necessary calculations for the implementation of these schemes, of course, are not trivial. However, we have an effective one-way function that allows a relatively affordable way to verify the signature, but creates obstacles to working with publicly available data, such as a public key, to obtain a critical private key. ECDSA safety is related to the complexity of the secret key search task described above. In addition, the security of the original scheme depends on the “randomness” of the choice of k when creating the signature. If the same k value is used more than once, then the secret key can be extracted from the signatures.Therefore, modern ECDSA implementations, including those used in most bitcoin wallets, generate k deterministics on the basis of a secret key and a signed message. ECDSA is the essence of how bitcoin and other blockchain applications work (Dresner and Stone, 2008). This scheme was resisting some fairly extensive testing of weaknesses, both mathematically and computationally. A few failures that occurred in practice, were caused by users lack of caution in protecting their private keys, in other words, they used a standard pseudo-random number generator to create secret keys that were later used by attackers.

5. Conclusion

Blockchain technologies are developing rapidly and find application in various fields of activity. All such systems as transport systems, logistics, automotive industry are based of Big Data processing, thus, these technologies will be developing. In addition, the work of large systems should be protected from malicious actions, since failures in such systems lead to fatal consequences. As with all technologies used in the digital age, the weakest points are users who are not vigilant enough. This largely applies to the management of large systems, including transport ones. Failure to follow simple rules and recommendations can lead to serious consequences, including transport collapse. This research will serve as an important step towards the development of a traffic control system for connected and autonomous vehicles, helping to solve the problem of cybersecurity, as well as in investigations of various kinds of crimes.

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