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The use of a Blockchain-based System in Traffic Operations to promote Cooperation among Connected Vehicles

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Abstract

This paper intends to present some ideas for the implementation of cooperative ITS systems based on the Blockchain Technology (BT) concept. Blockchain technology has been recently introduced and, in this paper, we discuss a system that is based on a dedicated blockchain, able to involve both drivers and city administrations in the adoption of promising and innovative technologies that will create cooperation among connected vehicles. The proposed blockchain-based system can allow city administrators to reward drivers when they are willing to share travel data. The system manages in a special way the creation of new coins which are assigned to drivers and institutions participating actively in the system. Moreover, the system allows keeping a complete track of all transactions and interactions between drivers and city management on a completely open and shared platform. The main idea is to combine connected vehicles with BT to promote Cooperative ITS use and a better use of infrastructures.

Keywords: Intelligent Transportation Systems (ITS); Floating Car Data (FCD); Blockchain Technology (BT), traffic management; connected and autonomous vehicles.

Introduction

Two innovations in vehicle technology are universally acclaimed as the future of road traffic management: connected and autonomous vehicles (CAV).

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Connected vehicles are also part of another innovative trend which is called the Internet of Things (IoT) and that possibly will include also traffic signal and other road infrastructures.

Classic road traffic engineering practice was founded on efforts to allocate demand on transit systems [1] and on better road traffic control by adopting tools such as: traffic simulation [2–7] dynamic network loading equilibrium and dynamic models [8–11] and the implementation of efforts to influence user route choice [12–16]. CAV may help to manage and control road traffic in many new different ways,

Road traffic management systems could potentially use CAV information providing driving directions to reduce congestion. In addition, other traffic control strategies could be implemented such as adaptive traffic signal control based on the use of Floating Car Data (FCD)[17]. Adaptive traffic signals are presently based on traffic flow measures obtained with magnetic loops embedded in road pavement. This is a fixed infrastructure which is very expensive. Connected vehicles that would communicate their position to a central server could make it possible to regulate traffic signals according to the real vehicle positions on the transportation network in a more sustainable way. These systems which have been defined as Floating Car Data Adaptive Traffic Lights FCDATL or FCDATS in [18] have, in fact, the two following advantages: no need for costly infrastructures and the adaptive traffic signal control algorithms could profit of an augmented data set, offering better control results than traditional adaptive traffic signal systems.

In some research works the penetration rate of connected vehicles to obtain good results for traffic information systems was established: in [19] it is asserted that just 5% of the connected vehicles would be sufficient to estimate the journey times on a motorway network with an accuracy of 95%, Ferman et al. in [20] showed that an information system on real-time traffic based on probe vehicles is feasible and should work for motorways with penetrations above 3%, while other roads would require more than 5%. Other works have been a real implementation in the field of combined Global Navigation Satellite System (GNSS) and data transmission [21],[22],[23]. The idea of using radio receivers to estimate traffic conditions was foreseen in the patent Astarita [24] and received real field implementations in 2008 when the Bluetooth protocol was used to detect radio signals from Bluetooth cellular phones with an external Bluetooth device. The results of the first implementation of Bluetooth monitoring were presented starting from June 2008 in [25] and [26], followed after 2010 by [27],[28] and [29].

All the research and inventions described above show the great advantage of involving drivers to share their position with the administrations that deal with road infrastructure management and traffic control.

This advantage, however, is not well perceived by users as a personal utility and the problem with all the described systems is always that of encouraging drivers to share their travel information with the administrations and with the other drivers.

Another universally claimed innovation in informatics is the blockchain: a distributed ledger technology. This technology originated from the efforts of anonymous developers in creating a secure digital currency. Digital currencies that are based on a blockchain are defined cryptocurrencies since they are based on cryptographic mathematical tools. The first cryptocurrency that was developed was Bitcoin originated from a paper anonymously published in 2008 on the cryptography mailing list at metzdowd.com [30].

Since 2008 a great development of initial concepts has brought to the creation of many distributed and active blockchains. The blockchain concept involves different knowledge and many researchers anticipate many applications of this innovative concept especially in the logistics sector and in the CAV networks [31],[32],[33][34],[35].

The paper presents a potential application of the blockchain-based technology in traffic operations to promote cooperation among vehicles.

1. A system to promote cooperation among drivers

The proposed system has the final scope to reward and motivate drivers (or owners of vehicles) to share vehicle position (obtained from satellite localization) in real time with road traffic management organizations, this would allow institutions who are responsible for traffic control and traffic management to gather an enormous quantity of FCD.

Blockchains usually operate with a consensus mechanism which can be a Proof of Work (PoW). The PoW generally consists in performing computationally complex operations on each new block that is added. The way PoW is performed guarantees that nobody can easily add an altered block at some point of the chain since it would be necessary also to add all subsequent blocks and that is computationally unfeasible. PoW in cryptocurrencies has been criticized since it requires an enormous calculation power which turns into an enormous electricity power (see Fig. 1).

Fig. 1. Countries that consume more or less electricity than bitcoin mining in late 2018 (source: powercompare.co.uk/bitcoin-mining-electricity-map/)

The concept of combining Blockchain Technology (BT) with connected vehicles is not new [36–41], already paper x [36] discusses the idea of influencing transportation users on the base of "tradable mobility permit".

In this work, we merely propose ideas that can stimulate a useful scientific discussion on some topics that eventually could lead to a more accurate specification for an actual system to develop in the future.

In detail, in this paper, we introduce the idea of developing a new specific cryptocurrency inspired by Bitcoin and yet different in the way it performs the PoW. In our proposed system the PoW, for the servers that are operated by traffic management organizations and independent servers, becomes the completion and certification of an established number of travelled kilometres certified by the on-board devices. The motivational force for the users to adopt and promote the system is thus the generation of a "traffic coin" as a reward for using a connected vehicle and for sharing trip information. The blockchain takes care of storing data and at the same time rewards anyone who is creating and sharing data. This "traffic coin" is generated similarly to the Bitcoin system, on the base of a PoW, with the difference that the Bitcoin classical PoW is modified in the system by mixing the hash calculation with a PoW based on the vehicles trajectories. Dedicated servers that are operated by the traffic management organizations will be node of the blockchain system. The system is able thus to reward "cooperating" drivers with the emission (creation) of a dedicated cryptocurrency. Cooperating drivers would be drivers who carry on the effort to activate, while travelling, some on-board device and to share positions with the community in real time. The on-board device would be a sealed device that could certify travelled/kilometres.

The system consists of a group of devices connected on the internet network. In detail it is made up by (see Fig. 3): connected vehicles (1), computing servers of road management organizations (2) and common blockchain servers for common currency transactions (3) for verification, signing and monetary transaction insertion in the blockchain. Vehicles (1) can be normal vehicles with an on-board mobile device such as a smartphone or new "connected" vehicles can participate in the system). Servers (3) are similar to normal Bitcoin network servers (nodes). Technically servers (3) are optional and the system could also work without them, leaving the task of monetary transaction entry in the system to the servers of road management organizations (2 in Fig. 3). The reason for having them in the system is to help keep it decentralized.

The system here described is able to reach the above-described final scope by working in the following way: on-board devices should have an electronic card with a microprocessor, a circuit for wireless phone data connection, a memory chip for local data storage, a backup battery in case the electrical supply from the vehicle fails, a satellite receiver for geographic localization of the device and last, but not least, (since this is the characterizing and innovative element) a private key for signing electronic documents and specifically for signing monetary transactions. The private key coupled with on board device would be analogous to private keys that are used in cryptocurrency blockchains to verify and sign crypto currency transactions. For each vehicle, this private key corresponds to a public address that is also the address for the vehicle owner to receive system payments. The on-board devices on vehicles can: establish, through the GNSS satellite receiver, the vehicle positions in time, take a record of position data, validate position data with electronic signature and send signed position data to the road traffic management organization server that is responsible for the travelled local road network.

Road traffic management organization servers (2 in Fig. 2) work with two different functions: to generate and propagate the blockchain of the cryptocurrency and manage vehicle positional data received from on-board devices.

The generated cryptocurrency and the corresponding blockchain are structured in a specific and different way with respect to Bitcoin and other similar cryptocurrencies. In a cryptocurrency system the blockchain contains all the history of the monetary transaction transfers. In the system presented here the blockchain stores not only all the monetary transfers of the cryptocurrency ("traffic coin") but also data relative to positions in time (trajectories) of on board devices.

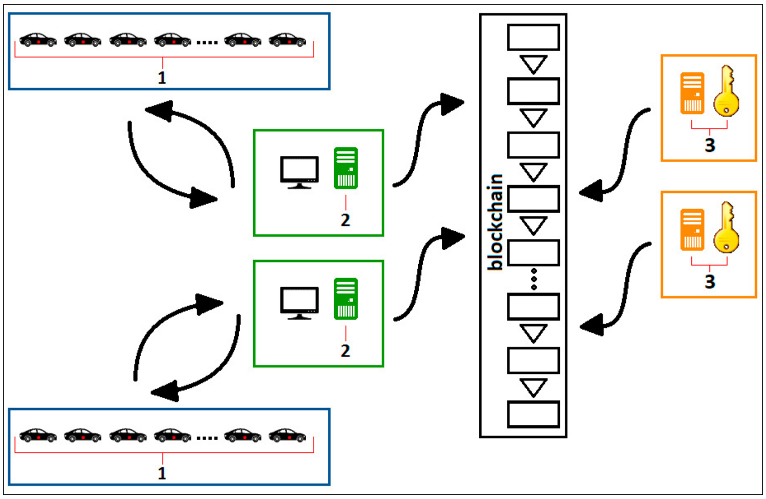

Fig. 2. The proposed system.

In practical terms, drivers (or owners of vehicles) by using the on-board devices send in real time trajectories data validated by electronic signature. Road traffic management organizations servers verify the signature and insert the trajectories data into the blockchain. In other wordsv the blockchain stores not only data of the monetary transactions, but also data relative to travels that have been completed by the on-board system devices.

In the proposed blockchain the generation of "traffic coin" is carried out by substituting Bitcoin hash calculation with a physical proof of work: the completed and shared vehicles trajectories. In practical terms the proof of work, for the servers that are operated by the traffic management organizations, becomes the completion and certification of the travelled distance of the on board devices.

As an example, a possible implementation of the above-introduced proof of work concept, but not the only one, is that of allowing the administrations to generate some "special" blocks of the blockchain, containing positional data of vehicles, without any onerous hash computation. The reward for generating such a block can then be divided among the administration, the drivers and the server that creates the next block of the blockchain. In this way the system would guarantee an immediate insertion of "special" blocks with positional data in the blockchain when the established number of travelled kilometres is reached by one of the administration servers.

The system would bring obvious advantages both for drivers and for public administrations since it would allow public administration to use the data in real time, received from on-board devices, applying vehicle traffic control strategies useful for the community to increase transport sustainability. The system would spread among drivers once the road users accept the validity of this system and of the related generated cryptocurrency and the public administrations adopt this industrial invention using the data received from on-board devices by applying vehicle traffic control strategies. Many control strategies can be applied from the generated data that can be useful for the community to increase transport sustainability such as: traffic signals real time regulation, car sharing, and better management of transit systems.

Among the possible strategies to incentivize the use of the system, administrations could reimburse the costs of on-board devices by accepting the cryptocurrency issued to drivers in exchange for city services such as parking, access to restricted traffic areas etc. The Floating Car Data obtained could also allow informing the drivers on the network in real time. This information can be provided in different ways and create other advantages for drivers such as: the ability to see the evolution of traffic on the road on the Internet in real time. The drivers could decide to use transit or postpone trips in cases of traffic over-saturation. The benefit of this system is therefore also the information service to users based on the data sharing among users themselves. These data can be the source of traffic forecasts and better traffic planning.

Moreover, if the cryptocurrency were to increase in value the same administrations would obtain a capital gain from just adopting the system even if there were no traffic management improvements.

2. Conclusions

Mobile devices and "connected" vehicles as a means of information collection and transmission enables a revolution that can be fully exploited in systems where the same administrations and citizens become involved in the process of gathering and sharing of information. This paper presents a system which aims to involve both drivers and city administrations in the use of promising and innovative technologies for a better traffic system management based on floating car data. The introduction of incentives to drivers who are willing to share travel data would be possible with a Blockchain that would allow keeping a complete track of all transactions and interactions between drivers and city management. The use of both mobile technologies and BT would promote Cooperative ITS use and a better use of infrastructures.

This paper introduces just some basic concepts which could lead to further scientific discussions. Many issues need to be further investigated before an actual implementation can be carried on such as:

-the real-time implementation of the proposed system could put a heavy load on the computing system. This issue evidences the need for a proper investigation of practical solutions to make the system feasible in large-scale situations;

-the details regarding the practical implementation of a PoW that is based on mixed: hash calculations and data coming from vehicles trajectories.

-the details regarding the dedicated on-board sealed device (we requested a patent on that).

This work, which intends merely to stimulate discussion at the hosting Conference, presents some ideas that could be the base for further scientific investigation especially in the evaluation of possible benefits of similar systems.

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