Leveraging efficient Blockchain for a trustworthy data sharing in V2x

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Motivation & issues

Currently, the automotive industry is undergoing a very significant technological transformation. Not only is there a shift from traditional combustion engines to electric engines, but vehicles are actually becoming complex sensor networks. Equipped with various communication technologies such as Bluetooth, WiFi, DSRC (Dedicated Short Range Communication), and Cellular technologies (4G-5G), vehicles can interact with their environment, as well as with services and entities operating on the Internet (e.g., road infrastructure). This has led to the development of the Internet of Vehicles (IoV) [20], a part of the emerging Internet of Everything (e.g., V2X).

These advancements have opened the door to driving automation. In the near future, smart vehicles e.g., connected vehicles are expected [1] to achieve SAE driving automation level 3, which means that under certain conditions, automated driving will engage, but the driver must be prepared to take control of the vehicle. In the long run, levels 4-5 are expected, meaning that the vehicle is able to perform all driving functions under most or all conditions, leading to fully autonomous vehicles.

In order to provide driving assistance and automation, smart vehicles gather data from a large number of sensors, analyze them, and interact with their environment (other vehicles, road infrastructure, cloud services). These data and interactions enable vehicles to make decisions (in particular to address safety issues), and provide personalized services to their users. Furthermore, these interactions make connected vehicles become important and active players in the "smart city", a digital ecosystem made up of communicating smart "things" and services [5, 18].

As an example, Intelligent Road Signage (IRS) systems [21] use sensors and data coming from smart vehicles to detect changes in road conditions and automatically adjust the signage to give drivers the most up-to-date and relevant information. IRS can provide drivers with real-time information about the speed limit, lane closures, road works, traffic levels and more. It can also be used to alert drivers to potential hazards, such as a stalled vehicle or an animal crossing the road. This system can help to improve road safety by providing drivers/vehicles with the information they need to make safe and informed decisions.

Consequently, smart vehicles by sharing the acquired information contribute to the development of a large spectrum of applications: crowdsourcing-based applications, energy trading, traffic congestion reduction, collision, accident avoidance, infotainment and content caching. Those applications need sometimes a local data sharing (e.g., infotainment) thank to IoV network while others (dealing with IRS, navigation, emergency, safety, etc.), require more storage and computing resources, to be able to aggregate and analyze data in order to produce accurate decisions or recommendations [22] that could be transferred back to vehicles [23]. This is made possible in addition to vehicles' contribution, to the support of road infrastructure servers situated in the edge of the network and to fog/clouds infrastructures for more demanding tasks. In this last situation, vehicles cooperate using the entire V2X networks.

Those applications require a *safe, trustful and confidential* data sharing among vehicles and between vehicles and the continuum (IRS at the edge), fog and cloud computing). Moreover, some applications (e.g., accident avoidance for example) which manages real-time situations require a *fast data retrieval*. Finally, vehicles produce a huge quantity of data that necessitates a large capacity of storage.

In addition, successful V2X-enabled emerging applications need to guarantee reliable payment (e.g., remote parking payment) and incentives (e.g., road data sharing), trustworthy vehicles/collaborators and authenticated and high quality shared data, especially in case of road safety applications, to avoid bias in the resulting decisions.

Blockchain has recently emerged as a prominent candidate infrastructure for implementing accountability and trust procedures, primarily because of its intrinsic properties of immutability, integrity, availability, and non-reputability, as well as its ability to implement a shared distributed ledger of data, thus guaranteeing high availability, and to operate smart contracts, thus enabling complex, rule-based, and robust operational processes and applications (aka dApps). It represents then a good solution in response to V2X application requirements.

In practice, Blockchain technology offers a very large range of solutions regarding the type of ledger (permissioned, permissionless, consortium-based), the consensus protocol (Byzantine-Fault-Tolerant type, Proof of Work, Proof of Stake, Proof of Reputation…), the system's architecture (use of a side chain, use of oracles to collect external data…), the operational costs and incentives, the way smart contracts are operated, etc. These features have a very significant impact on the scalability of the system, its capability to meet real-time constraints, its robustness, its operational costs and the computing resources it needs, and the fees applications have to pay. Current BlockChain consensus protocols are computationally intensive. Moreover data retrieval time do not suit real-time constraints of V2X applications.

State of the art

Meijers et al. In [14] and [15] explores potential applications of blockchain technology in the V2X space, categorizing and analysing use cases based on their underlying blockchain requirements. [4] provide a taxonomy in the field of BlockChain for IoV and reviews the recent work in the field. There are three key services provided by BlockChain in V2X applications [15] : (i)payment and incentives; (ii) vehicles' reputation and authentication management and (iii) data Authentication and time stamping. In this PhD we are interested in the last category of services which targets real-time applications (e.,g., real-time inter-parties data dissemination)

Several research works have addressed the issue of trustworthy data sharing in Internet of Vehicles (V2V) leveraging Blockchain properties as reviewed by [7,24]. In the context of BlockChain for V2X, performance and storage issues are highlighted in a lot of recent surveys [8, 9, 3, 16, 19] but no concrete work has been done yet on the field. Using the Blockchain to secure data shared among vehicles and IRS infrastructures requires to rethink the BC protocols (PoW, PoS) to let them act in lighter way. This can be obtained by using hybrid BC architectures (e.g., public & private) [11], where the protocols part consuming a lot of resources are executed in the private part requiring less resources. Jivthesh et al. In [6] proposes Smartverse, a blockchain technology-based authentication method to validate messages in the V2X ecosystem using the Ethereum blockchain platform, Interplanatary File System (IPFS). Submitted data (e.g., vehicle collision) is validated by other users in the V2X network by a voting mechanism. Only messages marked as valid are received by other users, but the space and scalability aspects are not addressed. Javed et al. In [10] propose a secure blockchain-based data sharing mechanism. They addressed the storage issue by using IPFS storage. They propose a lightweight protocol for transaction validation (Proof of Authority (PoA)). But the context is slightly different as they do not consider real-time constraints. On the other hand ,some research work have addressed [2, 12] the scalability aspects in Blockchain healthcare systems which do not have the same constraints as per V2X environments.

Scientific Approach

The first step in this project will be to conduct an extensive state of the art study on the following items:

- real-time V2X applications : produced data rate and type, response time constraints and so on.
- data trust models proposed in V2X context and how they are compliant to the targeted V2X applications' requirements.
- blockchain-based trust solutions architectures in the V2X context. With a particular interest in secure data storage and data sharing validation scalability.

This first step will lead to the submission of a systematic mapping publication [25] where the main research questions will be identified and the way existing work has answered a part of them, will be reviewed.

The second step is to work out and publish our research contributions:

- A hybrid BlockChain architecture that allow a fast access to reliable and authenticated data shared among vehicles and that allow the storage of a huge data produced by vehicles. The hybrid architecture shall dynamically partition data based on access frequency, relevance, and sensitivity. We use a strict smart contract governance. Smart contracts enforce access control policies and data validation rules, enabling fine-grained control over data sharing permissions and ensuring compliance with the regulatory requirements in this domain. This first contribution will lead to the writing and submission of a first research publication.
- The subsequent contributions will be devoted to the definition of an efficient trusted data sharing protocol and a data storage solution that respects real-time constraints explained above while preserving data integrity and immutability. A first trial will be to adapt solutions found in the literature among them those proposed by [2,10,12], thus to prioritize data processing, optimize blockchain consensus, off chain processing and caching and data pre-fetching.

All our contributions will be published in international ranked conferences and journals.

Technical Realization

The proposed architecture and the proposed trusted data sharing/data enforcement protocols will be simulated and the results will be compared to concurrent solutions. Extensive experiments will be conducted using realistic datasets: [26,26,28].
Technical contributions, i.e., trust scenarios and attack models, trust models and source code of operational trust computing processes, incl. blockchain infrastructure design and smart contracts, will be openly published on commonly used platforms (GitHub or a similar suitable platform).

Embedding of the PhD thesis

The PhD thesis will be conducted in the scope of IRIXYS (http://irixys.org) a european collaboration built by INSA Lyon, University of Passau in Germany and University of Milan in Italy. IRIXYS is a fully-integrated center of excellence "without walls", organized around a comprehensive common research agenda. PhD students in this context, benefit from its network of academic and industrial relations, and its stimulating environment focused on fundamental research and disruptive technological innovation. In addition, the selected PhD student will have the opportunity to present his/her work each semester during the IRIXYS workshops which enables him/her to have feedback from eminent researchers/industrials who are usually invited in these workshops.

By addressing trust and by leveraging blockchain technologies in an application domain closely related to V2X, this PhD proposal lies at the heart of the research agenda of IRIXYS.

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