Intelligent Transportation Systems Applications: Safety and Transfer of Big Transport Data

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Abstract. The distributed ledger technology (Blockchain) offers a fast, scalable solution for tracking and authentication. Implementation of Blockchain is expected to emphasise the use of technology to decrease or eliminate third-party costs, better protect devices and systems' data, and enhance transparency and security. It also offers a highly secure platform that enables quicker operation and payments, and more precise data record of transportation vehicles (in all modes). This feauture plays a significant role in the supply chain by providing access to shared information. This will possibly allow to decrease or eliminate redundant communication and information, avoiding data transmission errors. It is feasible to spend less time verifying data and more time analysing and managing data, which will improve the quality of the interaction between participants, control or reduce costs, or both. In the collection, analysis, and secure sharing of big data with relevant parties, technological advances and the efficient use of smart transportation systems in urban and rural transportation take priority. Particularly in recent years, the loss of data from hacker attacks or the inability to determine where data is transported demonstrates that Blockchain technology may be used successfully in this field. This paper examines in depth the "Smart Cities Traffic Safety" project, which is one of the largest Intelligent Transportation Systems (ITS) projects in Turkey and is being implemented by Samsun Metropolitan Municipality. In these ITS-based transportation applications, Blockchain technology is used to protect against cyber-attacks on the data of intelligent signalised intersections, average speed corridors, parking violation detection, and red-light violation detection systems. Additionally, the research focuses on the secure sharing of these transportation Big Data with third parties and the step-by-step monitoring of every data transfer history. In the context of this project, the first step is to propose a framework that is based on the technology of Blockchain. Then, a platform was developed, and the principal purpose of this platform is to enable the authentication, validation, monitoring, and protection of information efficiently to address the challenges.

Keywords: Blockchain, Intelligent Transportation, Data Safety, Big Data

1 Introduction

Blockchain technology is a very efficient system commonly used to simplify complex processes in transportation-related systems such as mobility as a service (MaaS), data control and transfer, and supply chain management. In the last few years, various transport-related companies have started integrating Blockchain technology to their operation, control and management processes on data tracking and transfer systems [1]. In a Blockchain system, digital ledger records transactions in a series of blocks, and all knowledge and data exist in multiple copies spread over multiple users. Thus, Blockchain technology supplies to track all system records [2]. All these properties of Blockchain technology make it one of the most promising and popular technologies worldwide [3]. This popularity benefits it to offer different applications in multiple areas to propose tracking and transfer systems solutions.

Blockchain technology was originally developed from the cryptography exchange, i.e., digital transactions. It has been used in various areas like crypto money, healthcare, financial systems, cybersecurity, smart grid, energy management and intelligent transportation systems [4]. It can distribute a database which is shared among the Blockchain nodes or related partner organisations. In the previous development, Blockchain technology was only effectively used in the finance sector. However, its capacity and current possibilities have proved that Blockchain is a great technology to use in many other areas because of its ability to store data in a distributed database after verification steps [5]. In fact, it is a good technology to record transaction information among trusted partners' data, and it can be used in many legal processes. Therefore, digital assets for the chosen study area, which is data stored in Blockchain, can be presented as digital proof because of the Blockchain's secure, transparent and immutable property [6]. The encountered problem in Blockchain generally becomes the size and safety of storage and transfer of the existing data. It is not feasible for the data with a higher number of dimensions and storage and transmit data to other parties safely. Thus, many researchers conduct studies to develop solutions to these problems [7-11].

With the rapid increase in accidents, longer travel times and colossal waiting times on roads in the last three decades, and despite notable developments in road infrastructure, the existing transportation solutions that have been developed and applied previously have become insufficient to solve today's traffic problems. Thus, Intelligent Transportation Systems (ITS) have started to find solutions to traffic problems in roads of many cities worldwide [8]. The technological developments and the effectiveness of ITS to reduce traffic chaos, enhance traffic efficiency, and make a positive contribution to the development of smart cities and roads made the utilisation of these systems more popular. IT systems supply valuable information regarding many traffic conditions and systems. Current results on ITS applications have shown that these systems are very effective tools for finding chaos solutions and can supply safety and comfort in urban and rural traffic problems [12]. Thus, ITS supply a profound effect on every aspect of our life with smarter transport facilities and vehicles, as well as safer and more convenient transport services. On the other hand, ITS have shown high social complexity instead of the expected intelligence, leaving many long-standing issues unsolved or even worsened.

Blockchain technology supplies rapid development and has the full potential to revolutionise the increasingly centralised ITS in applications. It is a very effective and promising technology, and it can benefit significantly from this vital technology to save and keep data as digital proof [5]. ITS also have some critical security problems with data storage and transfer. The technologies used in ITS, such as Internet-of-Things (IoT) and computing via Artificial Intelligence (IT), make big data possible. It may result in many attacks from hackers to get this data and delete it from the central server of all systems. The second issue in these systems is the safety of data transfer from these systems to the main server or from operator to third parties. Following this problem, this study mainly aims to contribute to previous studies with a real-site application. For this purpose, the study investigated ITS data storage, control and transmission methodology with the help of Blockchain technology by using real ITS applications data for Samsun City in Turkey.

The following is the rest of the paper: Section 2 includes a number of relevant case studies related to the study's field. Section 3 includes briefing information for Samsun ITS project, while Section 4 provides methodology of the paper. Section 5 presents an implementation procedures and a platform for Blockchain-based data record of ITS systems. The conclusion and future work are provided in Section 6.

2 Literature Review

When moved from their original destination to their focus destination, the goods and services take a product, a carrier, and a middleman who might be irrelevant and disappear. So, Blockchain technology supplies a relevant feature to the transportation system without any involvement of a third party. The current traditional transport systems use electronic data and some developed application program interfaces to provide and record transportation data manually or digitally [13]. This obtained data can be changed, modified and manipulated by a third-party authorised person, which can have critical consequences on the global transportation system.

2.1 Blockchain and Transportation Relation

Blockchain technology no needs the involvement of a third-party authorised person. Therefore, it does not meet with failure in the systems. It is used for data authentication where the whole network can contribute and validate data, which makes the system tamper-proof and transparent. Thus, it could save and transmit the saved data securely. Blockchain technology in transportation systems has many benefits, such as breaking down silos, better traceability, faster payments, easier audits, easier identification of attempted frauds, greater consumer trust, real-time consumer feedback, and better scalability [2]. Blockchain technology also has great significance in improving transportation control, operation and management and how the public ledger benefits this management such as better accountability, need for more back-office, and access to more information about the transportation system. Integrating Blockchain technology and transportation management will also lead to significant adoption. This technology's used attributes in transportation include transparency, traceability, immutability, trust, distributed governance and cost-saving. All these attributes can be used in the ITS sector effectively, and they have a great potential to use in ITS.

In the last decade, many companies in the world have started using new technologies such as Blockchain, the Internet of Things, and artificial intelligence. They have started developing cyber-physical systems that can change the competitive environment [14]. The features provided by Blockchain technology make the utilisation of this technology more prominent day by day. For example, [15] investigated the strategic importance of the transport sector in creating economic, environmental and social values. They found that Blockchain technology can be good support for supply chain operations. In a different study, [16] studied the risk of attacker threats to intelligent devices of transportation systems. They examined an example of IoV and proposed a security mechanism for the infrastructure of services of connected autonomous vehicles using Blockchain technology. They saw that Blockchain technology allows confidentiality and transparency among customers and taxi drivers by tracking and recording each action of objects relative to vehicles or IoT devices in Blockchain. In a Blockchain security study, [17] explored how Blockchain can be used as an effective technology for distributed and secure storage of big data obtained by ITS network. According to the analysis, they reported that Blockchain technology could potentially be a good application for data distribution and secure storage.

In the last years, there is also high interest in electric vehicles, which is growing daily. Thus, many researchers have focused on using Blockchain in charging infrastructure. [18] suggested a new and safer e-vehicle charging system based on the Blockchain. This new charging system provides some features such as key security, safe mutual authentication, anonymity and direct secrecy for efficient charging. For the testing process of the new system, they compared the proposed system with an old one and reached those proposed systems more effectively than the existing one. In another study, [19] proposed an intelligent contract Blockchain for the e-Vehicles' safe charging to maximise the battery performance. For this aim, they integrated the Blockchain system between the EV and the vehicle's charging system and obtained optimised battery capacities for e-Vehicles. In a similar study, [20] examined the Blockchain system's contribution to calculating the sale and purchase of electricity in the charger. They found that it can allow partial or full decentralisation of the process and full automation without involving the intermediate device. They also obtained that Blockchain systems are very effective in modelling the electricity metering system during the charging process.

2.2 Internet of Things (IoT) Combination with Blockchain

The Internet of Things (IoT) is one of the most significant technological developments. It is a logical progression for the Internet (of computers) to evolve into integrated and cyber-physical systems, "things" that, although not computers, contain computers. With a network of inexpensive sensors and networked objects, it is possible to gather information about our planet and environment at a finer resolution. Indeed, such in-depth information will increase efficiency and enable the delivery of sophisticated services across various application fields, including ubiquitous healthcare and smart city services. Nonetheless, the more invisible, dense, and widespread collecting, processing, and distribution of data in the middle of the private lives of individuals give rise to major security and privacy issues [21].

On the one hand, this data may be utilised to deliver various sophisticated and individualised user-beneficial services. In contrast, this data contains information that may be utilised to algorithmically generate a virtual history of our activities, exposing private behaviour and lifestyle trends. The absence of essential security measures in many IoT gadgets of the first generation exacerbates the privacy threats associated with the Internet of Things. Several security flaws have been discovered in interconnected devices, from smart locks [22] to vehicles [23]. Several inherent characteristics of the Internet of Things exacerbate its security and privacy concerns, including a lack of central management, heterogeneity in device resources, various attack surfaces, situational and context-aware hazards, and scalability.

Various end devices transfer large amounts of data in IoT networks. This means that attacks against the IoT might potentially target either data or devices. Whether it's from a medical IoT system [24] or a national application such as the IoT-based smart grid [25], the sensory data in an IoT system might be private or sensitive [26]. Data privacy and security are indeed important. Security, data integrity, and dependability issues in IoT networks may be solved through Blockchain [27]. In addition to its use in the cryptocurrency industry, Blockchain has attracted significant interest in a wide range of Internet of Things (IoT) applications (including management of supply chains [28] and smart cities [29]). Risks to both sensory input and end devices may be mitigated by using Blockchain technology.

Several major characteristics of Blockchain make it a viable solution for addressing security and privacy issues on the Internet of Things: Security, Anonymity, and Decentralization. This paper proposes a Blockchain-based architecture for the Intelligent Transportation System (ITS) with IoT that delivers lightweight and decentralised security and privacy. The design preserves the advantages of Blockchain while solving the obstacles of integrating Blockchain into IoT (for example, mining blocks is time-consuming, and IoT applications require low latency). It is utilised that ITS data record example to demonstrate the use of these technologies in the field of transportation and smart cities.

Existing literature clearly shows that Blockchain technologies and related systems are developing very fast in various fields of activity. All these systems, such as transport systems, logistics and electric or autonomous vehicles technology, are based on big data processing. Thus, Blockchain utilisation greatly increases many big data and intelligent systems-related sectors. All the previous study results clearly show that Blockchain technology has great potential for safely storing, controlling and transmitting important data to third parties.

3 Smart City Traffic Safety-ITS Project of Samsun City

The increase in the population and the number of vehicles in traffic results in vehicle densities, delays, long vehicle queues, and many traffic accidents on urban and rural roads all over the world. Unfortunately, this chaos in traffic results in an increase in the emission of more CO_2, NO_x, PM2.5, etc. harmful gases to nature from fossil fuel-consuming vehicles and this issue cause climate change. This uncontrolled increase in traffic may also lead to traffic accidents, aggressive driver behaviours, disobedience to rules, etc., and adversely affect human health in traffic. To develop a solution to the problem, which is among the top priorities in the United Nations (UN) Action Plan, many cities worldwide are trying to control and manage existing urban and rural roads with innovative IT systems. In addition to using these intelligent and environmentally friendly systems, many cities also aim to initiate and expand the use of e-vehicles, micro-mobility or mobility as a service (MaaS) systems instead of fossil fuel vehicles in their public transportation systems, commonly. For this purpose, Samsun Metropolitan Municipality of Turkey has started to implement the "Smart City Traffic Safety" project throughout the city in June 2021 with the biggest technology and defence company "ASELSAN" in Turkey and got the best ITS City project awards in Turkey in 2022.

In the scope of the project, a total of 78 "Intelligent Intersection Systems" have started to install at signalised intersections, "Average Speed Detection System" in main corridors, "Parking Violation Detection System" in roadside parking areas, "Red Light Violation Detection System" in sections with signalised lights, and total 20 e-Buses are started to use for the public transport system of the city. Therefore, this ITS project has become one of the biggest projects in Turkey. After the contract was signed, Smart City Traffic Safety-ITS started to be implemented in July 2021 and will be completed in 2023. In the project, firstly, the geometric and technologic infrastructure transformation of a total of 78 intelligent intersections has started, and then many intelligent intersection systems and violation detection systems will be implemented to manage traffic and air pollution throughout Samsun city. For public transport, new e-buses developed by ASELSAN, a partner in the "Smart City Traffic Safety" project, are used in Samsun city instead of fossil fuel buses (Fig.1).

Fig. 1. New fully electric and supercharged e-Buses in Samsun City [30].

4 Determination of Methodology Steps

Blockchain is a cutting-edge technology that combines various fields, including encryption, IT, economics, and politics. Therefore, there are few application examples and case studies in most industries, including construction and transportation.

A literature review of academic articles, conference proceedings, textbooks, technical documents and reliable online resources was conducted to better understand emerging technologies. In this context, the scope, features and use of Blockchain and other technologies in various industries were determined by analyzing online resources as well as case studies, whitepapers and other published materials. Critical analysis of the literature and comments by public experts allowed us to identify the most common problems in transportation. Within the scope of the identified problems, a methodology framework was prepared comprehensively on a solution with Blockchain technology for the examined IT systems. For the usability and validation of this framework, smart contracts were prepared and integrated into a frontend web platform. It has been seen that obtained ITS data was successfully recorded to Blockchain via frontend web platform. The proposed steps for the study can be summarized given flowchart in Fig. 2.

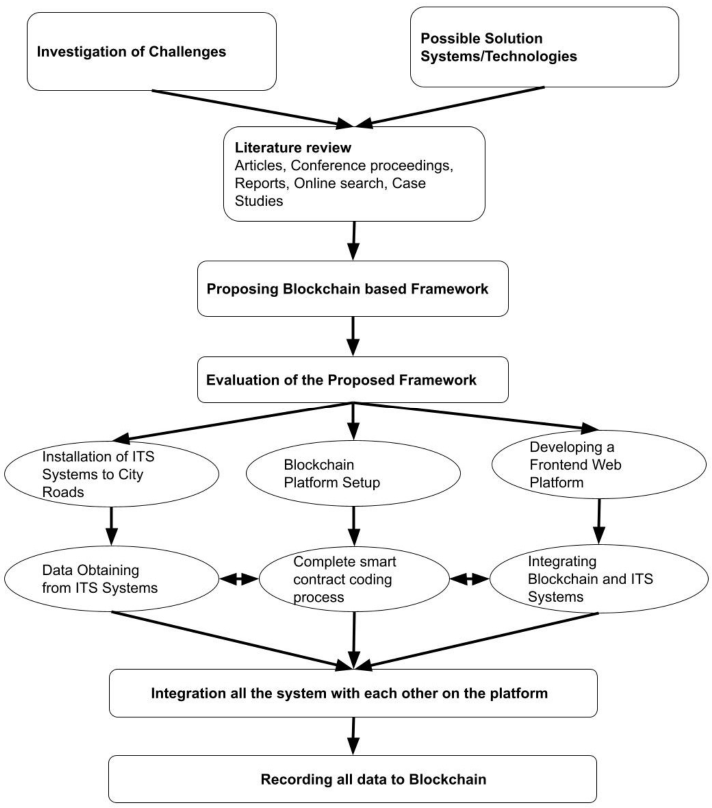


Fig. 2. Methodology diagram of the proposed study.

5 Evaluation of Dealing with Big Data Records of ITS

The evaluation was conducted with datasets from the Smart City Traffic Safety-ITS project of Samsun City, which involves interdisciplinary, collaborative efforts utilising ITS systems for Blockchain technology integration. The provided structure was used throughout the ITS systems based on Blockchain. As a consequence of a process initiated by ITS systems, those are an Intelligent Signalized Intersection System, Park Violation Detection System, Red-Light Violation Detection System, Speed Corridor System and e-Bus system, was recorded in the Blockchain for reporting offences this information. Data from ITS systems are stored on the digital platform developed when the smart contract was implemented. The user may then register using Blockchain if any modifications are made to these details. Due to the structure provided by the Blockchain, none of the prior records created can be altered and cannot be tampered with.

In collaborative work with users, the security and dependability of information are crucial. Inter-disciplinary collaboration, trust, and cooperation are the most significant aspects impacting the design process. The reason for changes or disagreements and any difficulties that arise often result in extra delays and expenses; however, with smart contracts, this process becomes more autonomous. Users can monitor and have confidence in any changes. Consequently, the growth of the process, its roles and duties, as well as inter-disciplinary cooperation will be feasible in the digital environment.

Once the data has been coordinated in the first phase, the Blockchain-based solution generates its own documentation, which is then made available to all users. This enables a transparent, automatic process since everyone knows their fundamental duties and remedial methodology, as well as the significance of capturing all actions as trustworthy data records in the Blockchain database. Since each dataset has its own identity, every issue may be identified and linked to the appropriate individual. Identifies the author using metadata assigned to the file, report, and user levels. This develops a complicated filtering mechanism inside the models to discover coordination issues in multiple disciplines and make them visible to the public in order to improve efficiency (Fig. 3). When a user signs into the system, a timestamp is appended to each activity that is logged on the distributed ledger as evidence of registration.

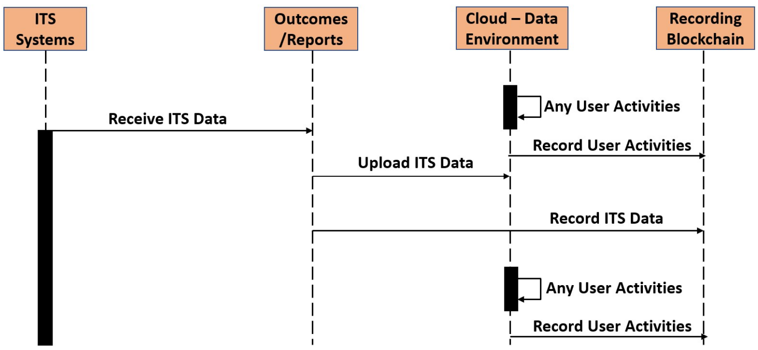


Fig. 3. Working scheme of the system.

Large enterprises and organisations' use of sophisticated analytical tools for storing, visualising, and analysing data has contributed to the exponential growth of big data technology. However, big data safety has become a major concern due to the massive data consumption and transportation. Despite significant security issues, cloud technology has been broadly used for applications involving vast volumes of data. When suitable security procedures are not used, third-party apps and intruders might readily engage in destructive actions such as stealing sensitive data and crashing the server. Big data has several challenges, including data collection, sharing, storage, and processing. This chapter evaluates the strategies and applications based on Blockchain technology for big data in the transportation environment. Fig. 4 illustrates an overview of Blockchain in a transportation environment, including data collection, storage, analytics, and privacy and security.

Reports, images and other data from sensors, cameras and other devices are available to many participants. Many participants share and record these data in an open environment, such as municipalities, control centres and academia. Although these data are in many forms, they are recorded in the system for each vehicle.

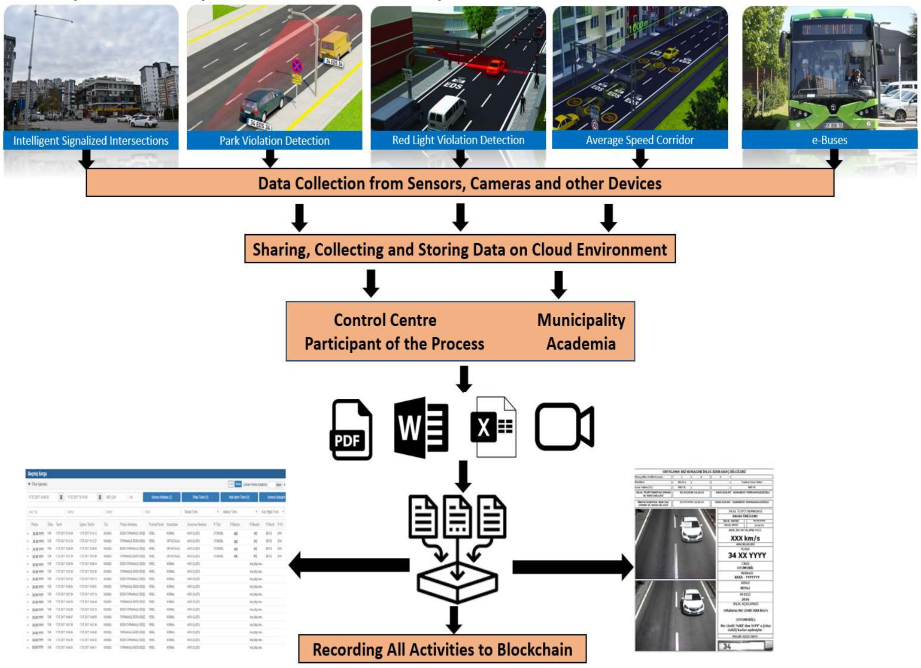


Fig. 4. Overview of Blockchain in a transportation environment, including all process steps.

5.1 Creating Smart Contracts and a Web-based Platform

The remix platform is used to compile and deploy smart contracts. The remix is an Ethereum Solidity (ES) development environment that makes it easier to build smart contracts. In the data structure to be used in the creation of the smart contract to be recorded, file name, provider, violation (red light, park etc.), location, date and time and timestamp of the data are used as seen in Fig. 5 (i), smart contract structure was design in solidity as - `struct ITSDataRecord {address sensorID; string violation; string location; uint32 reportID; uint32 timestamp;}`

Thus, when recorded data was recorded, where and how it was recorded can be stored as unalterable evidence. Second, digital data can be generated by creating a new smart contract for each vehicle. In this contract, information specific to the vehicle that commits violence is registered to the Blockchain by identifying the vehicle's Blockchain ID. In this way, each vehicle-specific data record can be created digitally through the Blockchain demonstrated in Fig. 5 (ii), smart contract structure for the Vehicle Data Record was designed as – `struct ITSVehicleRecord {address vehicleID; string violation; string location; address senderID; uint32 reportID; uint32 timestamp;}`.

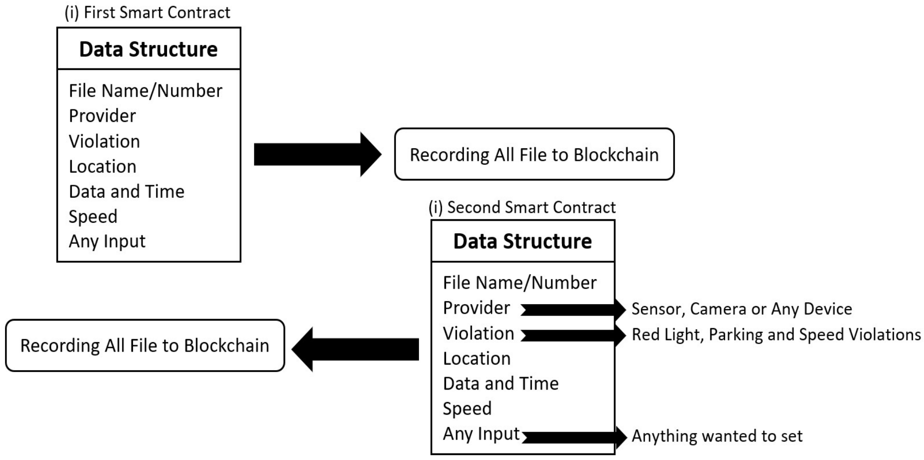
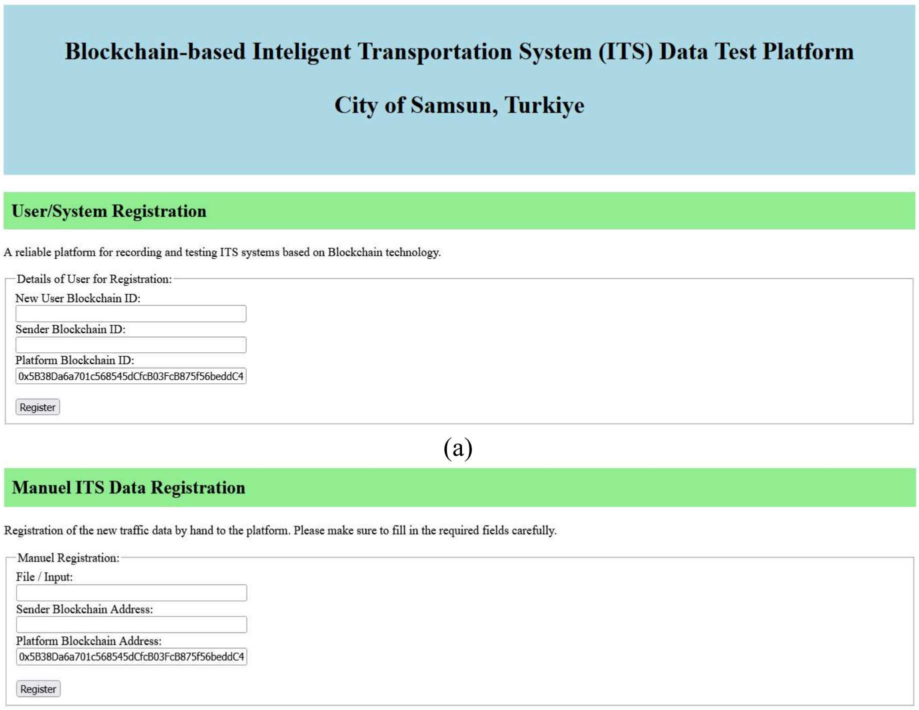


Fig. 5. Smart contract specific data record process of vehicles (ii) or report of systems supplied by ITS.

A platform that enables interaction with smart contracts using front-end websites was created. To generate the interactivity of the front-end website, a front-end JavaScript interface connecting the front-end website to the Blockchain system has been developed. The user interface allows users to engage with contracts, including the deployment of new contracts and contract processes such as recording or retrieving data from Blockchain. Three smart contracts are deployed to implement the outcomes of Blockchain-based ITS systems in the details provided in this research. Smart contract for registering new users/reports/updates: Each contract is identifiable by its unique number, which is stored in the mapping link to the most recent contract address. Using the new user(.) method, the contract is created and updated for each user so that other nodes may see all users' records (see Fig. 6). Smart contract for the outputs recording of ITS systems: It is a mechanism for recording outputs and seeing all outputs that have been recorded. When additional nodes are registered to the platform, the newData(.) methods may be used to inspect registered data. Smart contract updates with users: ITS systems are implemented following the original contract. After registering on the Blockchain network, each action should be recorded in the contract. With the updateUser(.) and updateData(.) methods, the end User/Client is able to see the whole transaction history for all data.

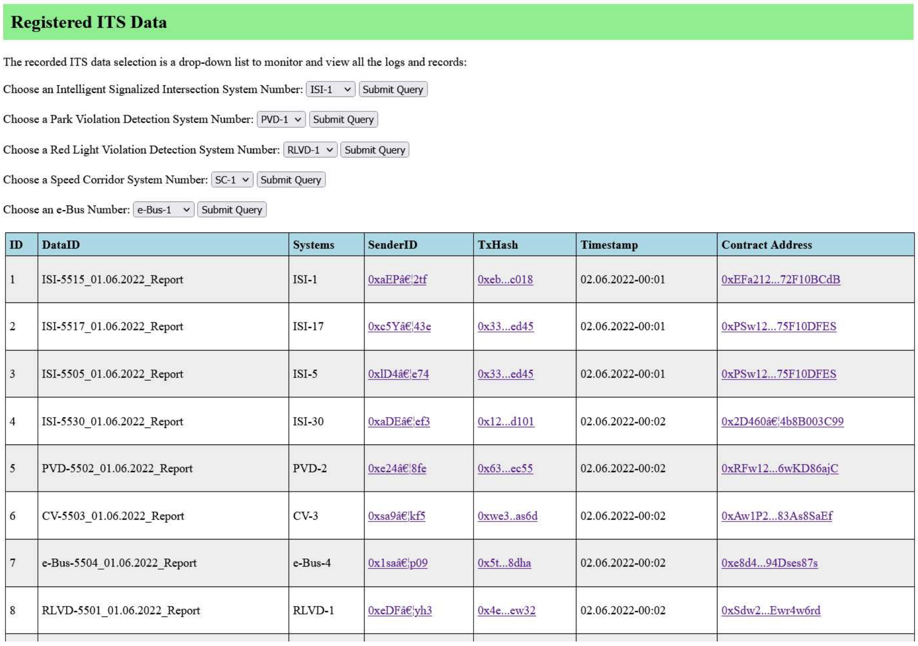
Big data applications, in general, gather data in various types from various sources (unstructured data). These documents cannot be processed in their original format. As a result, the data must be transformed into a structured format from which different application-domain predictions may be derived. With its capacity to efficiently manage large amounts of data, Blockchain offers organised data for generating predictions. Through consensus algorithms, Blockchain protects data integrity, reducing cybersecurity risks. This research focuses on two sub-areas of Blockchain technologies for big data collection: secure big data collection and secure big network infrastructure.



(b)

Fig. 6. Data test platform of the proposed system.

With this recorded platform, it is possible to track and monitor when and by which system any data is recorded, as illustrated in Fig. 7(a). If desired, records specific to these devices can be viewed separately, as it is seen in Fig. 7(b).



Registered ITS Data

The recorded ITS data selection is a drop-down list to monitor and view all the logs and records:

Choose an Intelligent Signalized Intersection System Number: ISI-1 Submit Query

Choose a Park Violation Detection System Number: PVD-1 Submit Query

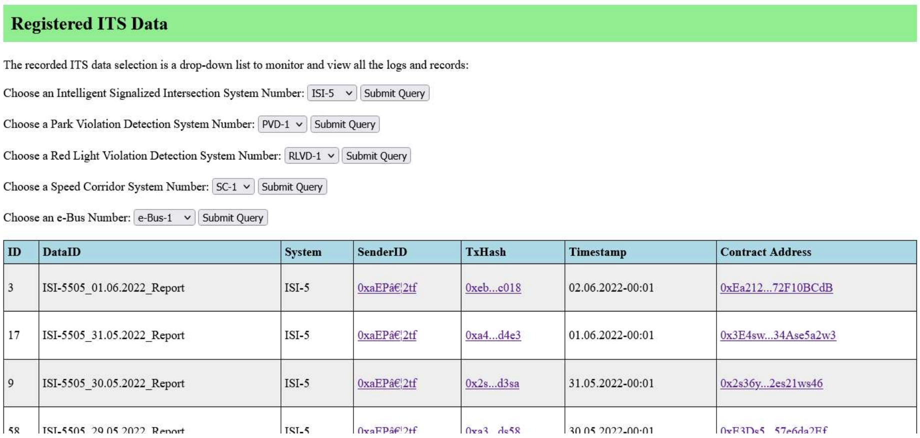
Choose a Red Light Violation Detection System Number: RLVD-1 Submit Query

Choose a Speed Corridor System Number: SC-1 Submit Query

Choose an e-Bus Number: e-Bus-1 Submit Query

ID	DataID	Systems	SenderID	TxHash	Timestamp	Contract Address
1	ISI-5515_01.06.2022_Report	ISI-1	0xaEPâ€¦2tf	0xeb...c018	02.06.2022-00:01	0xEFa212...72F10BCdB
2	ISI-5517_01.06.2022_Report	ISI-17	0xc5Yâ€¦43e	0x33...ed45	02.06.2022-00:01	0xPSw12...75F10DFES
3	ISI-5505_01.06.2022_Report	ISI-5	0xlD4â€¦e74	0x33...ed45	02.06.2022-00:01	0xPSw12...75F10DFES
4	ISI-5530_01.06.2022_Report	ISI-30	0xaDEâ€¦ef3	0x12...d101	02.06.2022-00:02	0x2D460â€¦4b8B003C99
5	PVD-5502_01.06.2022_Report	PVD-2	0xe24â€¦8fe	0x63...ec55	02.06.2022-00:02	0xRFw12...6wKD86ajC
6	CV-5503_01.06.2022_Report	CV-3	0xsa9â€¦kf5	0xwe3..as6d	02.06.2022-00:02	0xAw1P2...83As8SaEf
7	e-Bus-5504_01.06.2022_Report	e-Bus-4	0x1saâ€¦p09	0x5t...8dha	02.06.2022-00:02	0xe8d4...94Dses87s
8	RLVD-5501_01.06.2022_Report	RLVD-1	0xeDFâ€¦yh3	0x4e...ew32	02.06.2022-00:02	0xSdw2...Ewr4w6rd

(a)



Registered ITS Data

The recorded ITS data selection is a drop-down list to monitor and view all the logs and records:

Choose an Intelligent Signalized Intersection System Number: ISI-5 Submit Query

Choose a Park Violation Detection System Number: PVD-1 Submit Query

Choose a Red Light Violation Detection System Number: RLVD-1 Submit Query

Choose a Speed Corridor System Number: SC-1 Submit Query

Choose an e-Bus Number: e-Bus-1 Submit Query

ID	DataID	System	SenderID	TxHash	Timestamp	Contract Address
3	ISI-5505_01.06.2022_Report	ISI-5	0xaEPâ€¦2tf	0xeb...c018	02.06.2022-00:01	0xEa212...72F10BCdB
17	ISI-5505_31.05.2022_Report	ISI-5	0xaEPâ€¦2tf	0xa4...d4e3	01.06.2022-00:01	0x3E4sw...34Ase5a2w3
9	ISI-5505_30.05.2022_Report	ISI-5	0xaEPâ€¦2tf	0x2s...d3sa	31.05.2022-00:01	0x2s36y...2es21ws46
58	ISI-5505_29.05.2022_Report	ISI-5	0xaEPâ€¦2tf	0xa3...ds58	30.05.2022-00:01	0xE3Ds5...57e6da2Ef

(b)

Fig. 7. (a) Recorded data of all system and (b) recorded data of a specific system.

6 Conclusion

Data integrity, privacy, database management, and availability may all be achieved through implementing ITS systems combined with Blockchain technology. Users and all interactions with the system may be tracked, and conflicts between users in terms of tasks and responsibilities can be eliminated by utilising Blockchain technology. Each participant in the system has their own user ID, roles and responsibilities, resulting in a well-coordinated network of requirements. ITS system data may be shared more effectively because of the immutability and traceability provided by Blockchain. As a trustworthy record of all transactions' history, the Blockchain can be relied upon to store proof of every execution in chronological order. It is possible to keep track of any changes to the transaction list using blockchains that store the ITS system's data as a distributed database on a global ledger, including transaction data on the network. To store encrypted data, cryptographic hash techniques incorporate a ledger containing the block header's root. The timestamp feature of the Blockchain platform is ideal as it automates the process, prevents participants from making unwanted changes and is ideal for secure data recording. An additional benefit of an open and decentralised procedure is the reduced time required for secure file sharing and accessibility. With the use of Blockchain, it will be possible to follow the registration processes of ITS systems and any vehicles, from the production of the vehicle until it is completely withdrawn from the traffic.

In the digitalisation process, IT systems and Blockchain integration can also transform the requirements and preferences of performers based on coded services. Blockchain applications can connect real-time data and systems throughout the whole lifecycle of all devices and participants involved in the process. In terms of limitations, while Blockchain is a novel technology, it should be taken into consideration that additional advancements might have an impact on the findings and converting IT systems to smart contract codes may also be problematic. Blockchain, computing, and the Internet of Things (IoT) will be further explored in future research to create more complex models based on real-world case studies.

In the future step, the primary focus will be on the creation of an advanced data record system that will be based on Blockchain technology for each vehicle and system. When using this record system, every vehicle and traffic system works in integration with one another. It will be capable of governing itself autonomously without the need for any intermediary. Also, when needed it will be monitored all the activities on a created platform.

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