2024 Fifth International Conference on Intelligent Data Science Technologies and Applications (IDSTA)

Intelligent Transportation Systems Based on Blockchain Smart Contract Technology in Supply Chain Management

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***Abstract*—The Intelligent Transport System has made transportation more efficient. With available traffic information and 5G technology, cars can effectively transmit relevant information to other road users, such as congestion, environmental forecasting, and accidents. This information is vital to designing a fast and efficient means of transport. However, many people do not participate in the sharing of information, even depending on the possibility, because this means that a lot of personal information about the car and its owner must be provided. The information systems used so far could not solve these problems. However, in the case of vehicles authenticated in the blockchain, the personal data of the car owner will remain secret and will not be made public. Due to decentralization, trust is based on blockchain technology and not on personal and sensitive data. To this end, the research goal is to create a blockchain where ITS data can be safely stored. Since the registration data can be efficiently saved in the blockchain, a smart contract is created without any special knowledge of its use by the end user. A smart contract always requires a simple registration, which is recorded in the contract. The data specified in the contract are automatically saved in the blockchain, avoiding all "traditional" centralized data storage solutions, thereby increasing the safe storage of data.**

Keywords—blockchain technology, smart contract, data security, Ethereum sidechain

I. INTRODUCTION

The 21st Century has been continuously digitalized, which gradually helped to introduce new and innovative technologies [1]. The rapid and dramatic development of information technology, over the recent decade, cannot be denied [2], which has seen many good and bad solutions in the past [3]. Blockchain technology and distributed ledgers are attracting massive attention and triggering multiple projects in different industries [4]. Traffic management and passenger safety are important domains where ubiquitous connectivity between vehicles can play a vital role [5]. This crucial and imperative need in our transportation system is not only important but also extremely essential for the present and future of road networks, vehicles, and user sustenance. Improvement in road and vehicle transport technology has continued to redefine the current expectations and subsequently prospects of sustainable transport and traffic management [6].

The application of blockchain technology makes it possible to transfer the ITS solution to a decentralized environment. Due to the structure of the blockchain called ITSB, the blocks are closely connected and form a high level of security suitable for data storage. Blocks of the blockchain contain all ITS-related data important for road users. The structure of the ITSB blocks is shown in the Fig. 1 below:

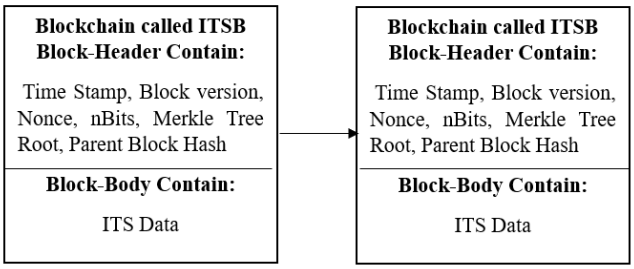

Fig. 1. Building the structure of the blocks of the blockchain called ITSB

The research questions that guided this study were as follows:

Research Question 1:

Is it possible to create a blockchain with private access to securely store data generated by smart intelligent transport systems?

Achieving this research goal is a big challenge because decentralized peer-to-peer data storage systems are much more complex than the centralized data storage solutions that have been frequently used and accepted up to now.

Research Question 2:

Can the data generated by intelligent transport systems be automatically uploaded to the private access blockchain by using a smart contract?

The motivational goal is to write a smart contract that can automatically upload data to the ITSB blockchain for supply chain management. Until now, such a solution has not been created in scientific life.

Trends are the results of economic processes that can even change development trends [7]. Centralized data storage solutions are widely accepted these days, but this is also a trend that will presumably change since newer and safer data storage can be implemented in a decentralized environment, which is one of the important motivational points of this research. It is typical of this research that it presents so many new solutions, the acceptance of which is not uniform even in the IT sector.

The research is structured according to the following structure:

- Modern solutions between ITS and blockchain technology,
- Creation of a blockchain called ITSB,
- Creating a smart contract for the automated storage of data for the ITS system.

It appears as an important aspect in the research that a real decentralized data storage solution that can be widely used in everyday life should be presented and created for the currently used centralized data storage solution.

II. Building a Model of the Relationship between ITSB Blockchain and the ITS Smart Contract for Intelligent Transportation Systems

With the authentication of information on vehicular network events, it is important to authenticate the sender and forwarder of this information. The authentication is more critical with moving vehicles. As we know, the vehicular network is composed of different regions. Vehicles move continuously across these regions and lost their connectivity with previously visited regions. Because in every region another data center is installed and there are fewer chances of registration of nodes with this. So, it becomes more difficult for moving vehicles to authenticate in real-time. The authors proposed a system model in which volatile vehicles move from one data center to another. Each data center consists of a specific service manager who is responsible for managing the vehicular fog service. The data of vehicular fog service is stored in fog and the hash of this data is stored in the blockchain. The service managers are also responsible for storing the ledger with which the vehicles are authenticated. As the same ledger is present at each service manager database, the service manager of the different regions is now able to authenticate the vehicle easily. This will prominently reduce the time of authentication [8]. Fig. 2 below shows the more important steps in building a blockchain-based ITS system.

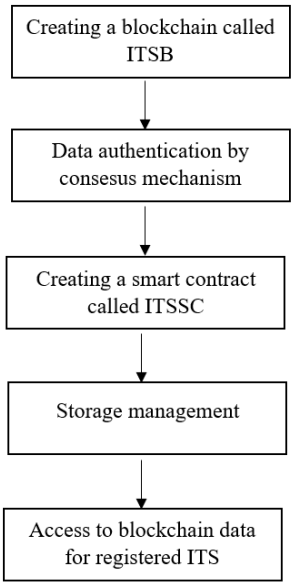

Fig. 2. More important steps in building a blockchain-based ITS system

To build the system, 3 layers are needed, which are closely connected. In the first step, the data is entered, the communication layer is connected to this, and then the layer responsible for security. Security is of paramount importance in this case, as this necessitates the use of blockchain technology. Without modern database security solutions, the available ITS information loses its relevance. According to my formulation, database security can be defined as follows:

Database security is defined as the ability to resist threats and attacks, and the totality of defending resources, which will avert all unauthorized natural and legal entities, as well as malicious computer programs' intentions in influencing the database's operation, as well as their causing any type of damage to database's rightful owners, or users. The security requisites of confidentiality, integrity, and accessibility, as well as undeniability and authenticity [9].

Fig. 3 below presents the layered architecture of the ITS and blockchain system.

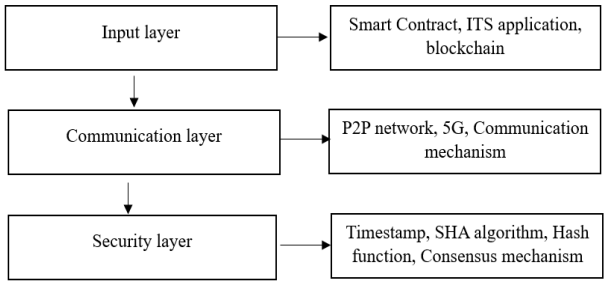

Fig. 3. The layered architecture of the ITS and blockchain system

III. Creation and Configuration of ITSB Blockchain Genesis Block

The first and most important step in creating a blockchain is to create a Genesis block. The Genesis block is essentially the first block in the blockchain. Fig. 4 below presents the close relationship between the genesis block and subsequent blocks.

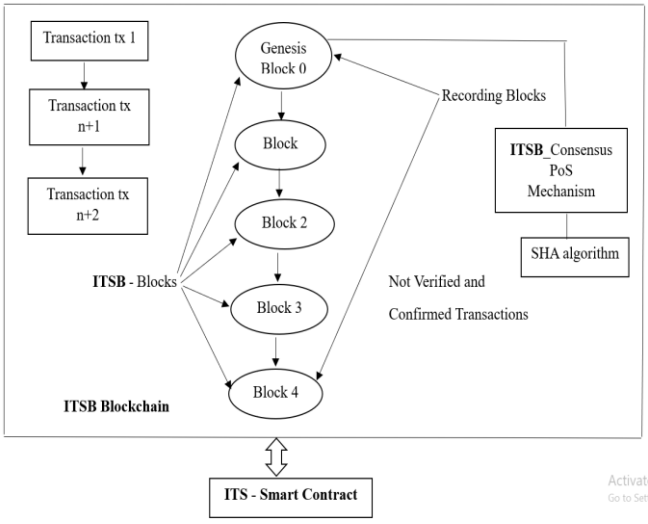

Fig. 4. Schematic block diagram of the blockchain base mode

The source code of the first block of the ITSB blockchain is demonstrated in Fig. 5 below.

```
{
 "config": {
  "chainId": ITS_100,
  "homesteadBlock":1,
  "ERC20Block": 1,
  "byzantiumBlock": 1
 },
 "difficulty": "200",
 "gasLimit": "50",
 "extraData": "0x00",
 "alloc": {
  "56c5kza8obv009756222087253469 8hjdsjcyq94n": {
  "balance": "2"
  },
  "hol84dpmv82554kpcneqfwwjm00054867596knz": {
  "balance": "2"
  }
 }
```

Fig. 5. Creation of ITSB blockchain Genesis block

The following are the most important commands used during the creation of the ITSB blockchain:

- Config: It defines the blockchain configuration and determines how the network will work.
- ChainId: This is the chain number used by several blockchains. The Ethereum main chain number is "1". Any random number can be used if it does not match with another blockchain number.
- HomesteadBlock: It is the first official stable version of the Ethereum protocol, and its attribute value is "0". One can connect other protocols such as Byzantium, eip155B, and eip158. To do this, under the homesteadBlock add the protocol name with the Block prefix (for example, eip158Block) and set the parameter "0" to them.
- Difficulty: It determines the difficulty of generating blocks.
- GasLimit: Gas is the "fuel" that is used to pay transaction fees on the Ethereum network. The more gas a user is willing to spend, the higher will be the priority of his transaction in the queue. It is recommended to set this value to a high enough level to avoid limitations.
- Alloc: It is used to create a cryptocurrency wallet for the private blockchain and fill it with "fake" ether [10].

IV. CREATING A SMART CONTRACT FOR AUTOMATIC DATA STORAGE IN THE BLOCKCHAIN DATABASE

Writing a smart contract requires not only legal knowledge but also IT knowledge. Broken down into skills, hard skills (textbook knowledge) are necessary for programming, as well as soft skills to understand how the system works [11].

In terms of Blockchain, a smart contract automatically enforces agreements between two or more parties without a trusted intermediary. These smart contracts are implanted as computer programs in Blockchain software like Ethereum and Hyperledger. Participants join the network depending upon the type of Blockchain and can request the execution of a particular contract for a transaction in the Blockchain P2P network. The history of these transactions is stored in blockchain is similar to digital currencies. The state of the contract and participants' assets are determined by the sequence of transactions in the blockchain [12].

The correct execution of smart contracts does not rely on a trusted third party similar to cryptocurrencies. Consensus protocols are there to resolve any potential conflict between contractual parties. There are different solutions available for conflict resolution depending on the platform [13].

Ethereum supports smart contracts. Blockchain platforms that support smart contracts are often referred to as programmable blockchains [14]. An Ethereum-based smart contract is a cryptographic box that stores information, processes inputs writes outputs, and is only accessible to the outside if certain predefined conditions are met [15].

Benefits of Smart Contract:

- Autonomy: Smart contracts remove the need for trusted intermediaries, enabling a higher degree of autonomy when it comes to transactions and other processes.
- Trust & Transparency: Since there's no third-party involvement and because transaction records are shared across the blockchain network, there's no need to question whether the information has been altered for personal gain.
- Efficiency: As soon as a condition is met, the contract wastes no time and executes immediately. Moreover, since smart contracts are digital and automated, they minimize the potential for human error.
- Savings: With smart contracts, intermediaries don't need to handle transactions, which removes associated time delays and unnecessary fees [16].

The smart contract conditions are called triggers. The following 4 conditions are required when concluding a smart contract:

- For the subject of the contract, which is the subject of the contract,
- To define conditions precisely. The provisions of the contract can only be implemented if they are fulfilled,
- For authentication. The subject of the contract and its conditions must be authenticated with a digital signature,
- Finally, a blockchain is also needed where the contract can be created [17].

Fig. 6 below presents the connection between the ITS Smart Contract and the ITS blockchain.

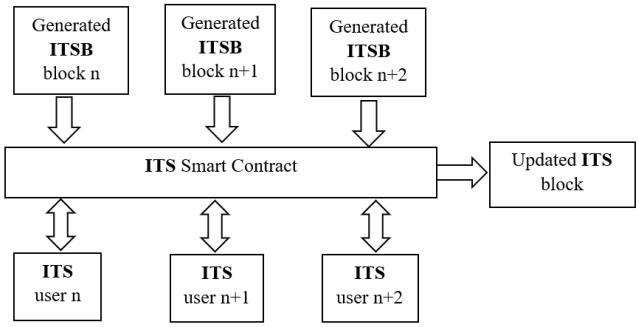

Fig. 6. ITS Smart Contract

A. Platforms for Smart Contract

In the case of the ITS system, it is advisable to choose from 3 different Smart Contract platforms. These are the following:

- Bitcoin is a public blockchain platform that can be used to process cryptocurrency transactions but with a very limited computing capability. Bitcoin uses a stack-based bytecode scripting language.
- NXT is a public blockchain platform that includes built-in smart contracts as templates NXT only allows developing smart contracts using those templates. It does not, however, allow customized smart contracts due to the lack of Turing completeness in its scripting language.
- Ethereum is a public blockchain platform that can support advanced and customized smart contracts with the help of Turing-complete programming language. Ethereum platform can support withdrawal limits, loops, financial contracts, and gambling markets. The code of Ethereum smart contracts is written in a stack-based bytecode language and executed in Ethereum Virtual Machine (EVM). Several high-level languages (e.g., Solidity, Serpent, and LLL) can be used to write Ethereum smart contracts. The code of those languages can then be compiled into EVM bytecodes to be run [18].

In the case of the ITS system, it is recommended to choose the Ethereum-based smart contract platform. The ETH blockchain is a stable blockchain on which the smart contract platform is built. In addition to security, reliable operation and continuous availability are very important aspects, that the ETH Smart Contract meets.

B. Creating a Smart Contract

The attitude towards innovation is a key factor, as it is through innovation that new solutions can be created. Such is the application of the smart contract in the intelligent transport system [19].

One of the most important steps when writing a smart contract is connecting to the ITS system. In the smart contract, it is necessary to enter the registration data, which the system stores in the private ITSB blockchain. This means that personal data is protected and can be stored safely.

Fig. 7 below presents the source code of the smart contract called ITSSC, which enables users to register in the system.

```
pragma solidity ^0.8.0;
contract name ITS Smart Contract {
  // Storage
  string firstName_Krisztan;
  string lastName_Balint;
  constructor(string memory _firstName, string memory _lastName) {
  mapping (address => vehicle1 address) balances;
 }
  function fullname (Krisztian Balint) private view returns (string memory) {
    return string(abi.encodePacked(lastName_Balint; firstName_Krisztian));
  }
}
functions send ITS data (ITSB blockchain address)
}
```

Fig. 7. ITS Smart Contract

CONCLUSION

The application of blockchain technology provides the opportunity to expand Intelligent Transport Systems and make them more efficient. Safe storage of data is a key issue in this sector. The efficient and safe identification of road users has been an unsolved problem until now, as many people did not want to provide their sensitive personal data during identification. As a result, building and expanding the system was an unsolved problem.

The ITSB blockchain ensures the safe and long-term storage of ITS system data. Due to the structure and consensus mechanism of the blockchain called ITSB, data can be stored more securely than in the case of their centralized counterparts.

The smart contract called ITSCC provides an additional opportunity in the development of the ITS system since the personal data of the registered ITS parties will never be made public, and they will not be known to the other participants, despite this, all smart contract members trust each other, since everyone must meet the same smart contract conditions based on a strict mathematical solution.

It can be concluded that the connection of the created ITSB blockchain with the smart contract may be an important part of the ITS system in the future, thus providing new opportunities in the field of further development.

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