Development of a Blockchain platform for logistics order management using IoT technologies

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Abstract

The article discusses the integration of the Internet of Things (IoT) and Blockchain technologies into logistics processes in order to create a decentralized platform for managing logistics projects. The approach allows for decentralized control and automation of processes at all stages of the supply chain, which has not previously been used in such a comprehensive form. The introduction of smart contracts in logistics ensures automatic registration of loading and unloading operations, as well as tracking the movement of goods, which significantly increases the transparency and reliability of operations. The work formalizes system requirements for information technology, proposes the architecture of a decentralized platform based on the use of Blockchain and IoT. The developed system ensures effective data exchange and transparency between participants in logistics processes, reduces risks and increases customer confidence.

Keywords

Blockchain technology, Internet of Things (IoT) technology, ERP (Enterprise Resource Planning), CRM (Customer Relationship Management), peer-to-peer (P2P), AMQP (Advanced Message Queuing Protocol), ABI (Application Binary Interface)

1. Introduction

Analyzing the role of logistics and information technologies in the modern world, it can be noted that the integration of advanced IT solutions, in particular IoT and Blockchain platforms, into logistics processes significantly transforms the industry. This not only improves the efficiency of management of transportation and supply chains but also opens up new opportunities for optimizing logistics projects and meeting the needs of stakeholders at all stages from production to the end consumer.

Information technology facilitates better integration and transparency between the various participants in the supply chain, enabling efficient inventory management, delivery planning and cost optimization. The Internet of Things, in particular, expands the possibilities of monitoring and management in real time, ensuring the reliability of supply and high quality of customer service.

Modern logistics projects are becoming increasingly integrated and technologically equipped, which requires industry specialists to constantly improve their skills and knowledge in the field of IT and innovative logistics solutions. This creates the basis for the development of a more sustainable, efficient and customer-oriented logistics management in the future.

The growing role of decentralized platforms points to the industry's desire for greater data security and information sharing efficiency. The use of Blockchain technologies and IoT can

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significantly change the way logistics projects are managed, ensuring transparency, reliability and efficiency at every step of the supply chain. In the world, strategic logistics decisions on the study and implementation of Blockchain and Internet of Things (IoT) technologies in logistics activities are just beginning. That is why the task of developing the information technology of the decentralized logistics project management platform is urgent.

The purpose of the article is to provide decentralized tracking of projects using the example of a transport company by developing a Blockchain platform for logistics project management using IoT. Achieving the goal of the article necessitates solving the following research tasks: to perform an analysis of the main existing methods of building information technologies of decentralized logistics project management platforms based on modern scientific works of Ukrainian and foreign authors; to formalize the system requirements for the information technology under development based on the analysis of the transport enterprise's activities; create the architecture of a decentralized logistics project management platform; justify the choice of hardware and software tools for the implementation of the Blockchain architecture of the logistics project management platform with the help of IoT.

During the research, theoretical methods (namely, abstraction, formalization), universal (analysis, synthesis, deduction and modeling) and intuitive methods ("brainstorming") were used. The article implements an approach to the integration of Internet of Things, Blockchain and smart contracts technologies into the information technology of a decentralized platform in the field of logistics project management. This approach includes processing data from IoT devices in real time, automatically updating data in the database thanks to events generated by smart contracts, and ensuring the immutability of the most important records in the Blockchain. This approach allows you to create more transparent, reliable and automated processes for managing logistics projects or digital projects in general.

The developed platform will have a qualitative impact on the activities of enterprises, increasing the trust of clients, because before the development of this technology, the enterprise did not have the opportunity to track the transportation of goods, to be sure of the reliability of this data and to assure the client of it.

2. Literature review

Logistics order (project) management platforms provide tools for planning, monitoring and analyzing various aspects of logistics projects, allowing supply chain participants to work together to achieve their goals. These may include features for inventory management, route optimization, cargo tracking, and integration with other systems such as ERP or CRM. A decentralized platform is a platform that operates without a centralized governing body or a single point of control, distributing data processing and management across the network. In the context of logistics, decentralized platforms can promote greater transparency, security and efficiency by using technologies such as Blockchain to ensure reliable data exchange and transactions between participants.

IoT allows physical objects (such as vehicles, containers, warehouse equipment) to be connected to the Internet to collect and share real-time data. In logistics, IoT can be used to track cargo, monitor the condition of goods, automate warehouse operations and optimize logistics processes, increasing efficiency, reducing costs and improving service quality.

In the paper [1], the main emphasis of the authors is on logistics management in peer-to-peer (P2P) mode. The essence of their P2P approach is that the logistics management system is completely distributed among the computing resources of the actors. The platform combines three new technologies: IDS, Blockchain and IoT. All of these technologies have been tested and used in their specific fields, but never combined in this way. Thus, the proposed framework provides logistics with a completely new approach to management, opening up opportunities for new innovations and businesses using this platform. IDS technology allows the exchange of data between different participants in the logistics chain. Its key feature is data management in the sense that it allows parties to work together without disclosing confidential information to each other. The proposed P2P

framework allows to support interaction between different participants in logistics chains, to securely exchange data between different parties and use it for optimal planning on based on IoT data.

The paper [2] proposed the use of Blockchain technology for the simplification and transparency of the processes of monitoring and managing the movement of goods between different equal participants in information systems of the logistics supply chain. A prototype of a supply chain information system based on the use of Blockchain technology and smart contracts using the Ethereum decentralized virtual machine was developed and investigated in comparison with traditional approaches. There are several disadvantages of such a decentralized system, such as the problem of updating the software and choosing the right consensus type and algorithm for the Blockchain network on which the system will run. The work is useful for designing and creating more detailed and complex information systems in a decentralized way, using Blockchain technology and smart contracts to monitor and manage the shipment of resources, goods and products and other supplies with the participation of a large number of participants in the logistics supply chain processes. The result is increased tracking transparency, reliability and process automation in the supply chain.

In [3], a revolutionary approach to the evaluation of scientific achievements is proposed. They propose to use Blockchain technology to create a new scientometric index. This index will not only count how many times a paper has been cited, but also analyze how ideas from that paper have evolved in subsequent research. Thus, it will be possible to evaluate both the immediate impact of the work and its long-term contribution to science. This method is useful both for evaluating the activity of individual scientists and for evaluating the effectiveness of scientific organizations.

Article [4] describes a system based on Blockchain and IoT, designed to increase the efficiency of tracking and management of high-value cargo in cities. The authors propose a reliable, scalable and sustainable solution suitable for smart cities, emphasizing the importance of real-time tracking and transparent data management. The article describes how this system can optimize logistics operations, reduce risks and promote trust among stakeholders, providing an example of the integration of Blockchain and IoT in logistics.

Work [5] focuses on the agricultural sector, presenting a blockchain-based system for tracking the transportation of fruits and vegetables. The proposed system ensures that all participants in the supply chain, from farmers to retailers, can trace the origin and processing of products.

Article [6] considers the potential of integrating Blockchain and smart contracts with IoT devices in logistics. In the paper, they explore the synergy between blockchains, smart contracts and IoT, demonstrating how these technologies can significantly improve logistics management. The authors highlight the importance of data integrity and contract enforcement in the logistics sector, illustrating how Blockchain and smart contracts can automate operations, reduce fraud and increase transparency.

A study [7] examines the challenges faced by pharmaceutical supply chains during the COVID-19 pandemic and proposes a solution that combines IoT and Blockchain. The system improves supply chain resilience by providing real-time data on drug movement and storage conditions.

Article [8] presents a logistics tracking system based on a decentralized IoT and Blockchain platform, its architecture is presented in Figure 1.

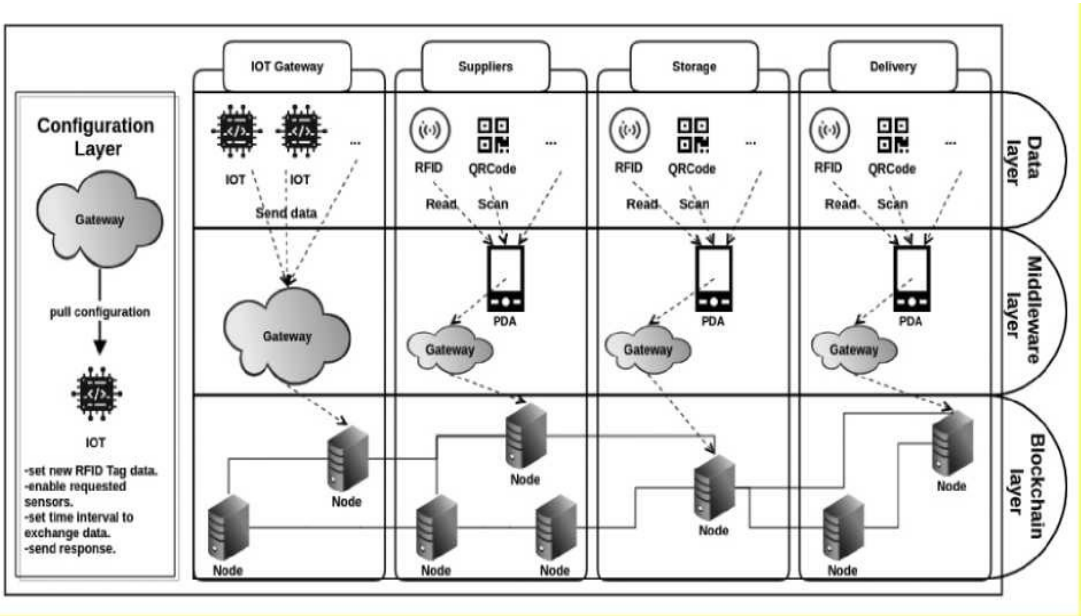

Figure 1: System architecture based on IoT and Blockchain by El Midaoui.

The work demonstrates how the system enhances the ability to track and manage data, which is critical for modern logistics operations. The paper provides a blueprint for integrating Blockchain and IoT into logistics, highlighting their potential to revolutionize the industry.

The work [9] investigates the application of an IoT-model based on RFID in the conditions of martial law to protect the health and life of both the civilian population and military personnel. The article examines the use of RFID tags to ensure the security of movement and identification of people in need of medical assistance or at risk in territories where hostilities are taking place or in occupied areas.

The article [10] proposes a new system that integrates IoT and Blockchain technology for monitoring and tracking agricultural products. The architecture of the web application of the system proposed by them is shown in Figure 2.

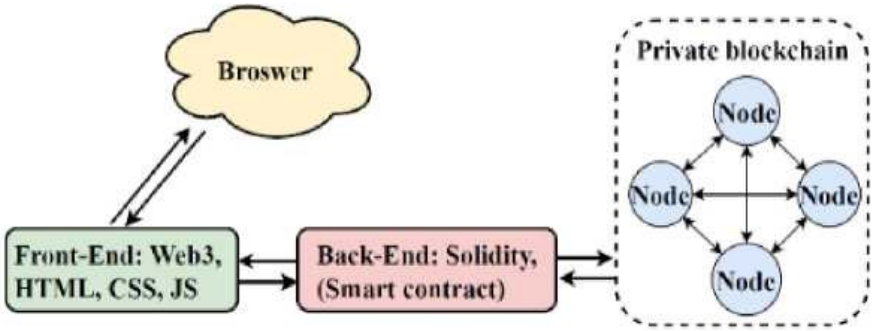

Figure 2: Truong's web application architecture.

The authors highlight the importance of farm-to-consumer traceability, demonstrating how the system improves transparency and data integrity to ensure the quality of agricultural commodities during transport from production to consumer, addressing key issues of food safety and supply chain transparency. The article provides insight into the integration of IoT and Blockchain in the agricultural sector, offering a roadmap for the implementation of such systems.

The paper [11] presents an IoT system for detecting and controlling movement during fitness exercises. The use of such a system in the format of a mobile application allows the user to receive an evaluation of the technique of performing exercises by demonstrating them in front of the smartphone camera, as well as recommendations that will contribute to improving the performance of exercises. This, in turn, will increase the effectiveness of training. The IoT system configures

business rules and scenarios, identifies required artifacts for users, the exercises they perform, and detects errors and anomalies during exercise execution. In addition, the system analyzes video files. An important aspect of pattern recognition is the individual anthropometric data of each user, which should be taken into account during the analysis.

A review of the reviewed works provides a deep understanding of how Blockchain and IoT technologies are integrated into various sectors [12-13], forming the basis of information technologies of decentralized platforms, especially in logistics and supply chain management, to solve complex challenges and improve operational efficiency.

3. Problem statement

Logistics management information systems usually work only within one company, managing logistics events only within its boundaries. When a company needs to receive goods and products from another, it does not receive all the previous data and metadata about those goods. Even if companies agree to share this information with each other without any automation, there is a technical problem with the different data structures used by different companies and adapting them to one of them. And this problem becomes even more complicated when more than 2-8 companies are involved. This problem can be solved by using one specific information system for the supply chain [14].

Thus, there is a need to create and launch a common platform where all parties share the necessary up-to-date information. Several attempts to implement such a platform have been made in several past EU-funded research projects (such as CONTAIN, FREIGHTWISE, e-FREIGHT or iCargo) and more recently through commercial products such as Uber Freight. On the other hand, if the system becomes centralized and fully controlled by one member, then that particular member will have full access to edit and delete data from the database. In some cases, this is unacceptable for other participants in logistics processes, as it gives too much power over the system to a participant or intermediary, creates a risk for diversity and fairness in the market.

Mediation between autonomous agents representing nodes in the supply network is presented as a more natural approach to supply chain management. Autonomous management is seen as an option to address the increasing complexity and dynamics of supply chains. Autonomous management is the processes of decentralized decision-making in hierarchical structures. It involves interacting elements in non-deterministic systems that have the ability and ability to make decisions on their own. The goal of autonomous management is to achieve increased stability and positive development of the entire system due to distributed and flexible management of dynamics and complexity [15]. Real-time tracking in supply chains can help reduce confirmation wait times, and eliminating certain supply chain processes altogether through decentralization can improve overall efficiency, especially when ownership or shipment status changes between parties. A blockchain logistics project management platform has the potential to reduce shipping costs, increase logistics company profits, increase supply chain customer satisfaction, and reduce environmental damage through sustainable development approaches. This is a new innovative vector for logistics companies, which can provide them with a number of advantages: consistency and transparency of logistics processes; review and accounting of the history of goods transportation; reducing the threat of audit and payment errors.

The implementation of the platform and experimentation in the future will reveal additional features and characteristics that may arise in the context of logistics and the supply chain, such as different levels of the supplier hierarchy, different customer typologies and smart logistics scenarios, etc. This, in turn, can help identify new problems and formulate relevant research directions.

4. Methods and technologies

One of the key components for the implementation of the logistics project management platform architecture is Blockchain, which is why it is necessary to consider several of the most suitable Blockchain networks (platforms) for building this type of system.

Ethereum is a decentralized platform that opens up wide opportunities for creating decentralized applications and executing smart contracts [16]. One of the key aspects of Ethereum's work is the use of Blockchain technology, which provides a unique opportunity to store and exchange data without centralized control. Users interact with the network, sending transactions that contain data and instructions for performing certain operations. These transactions are verified and processed by the network to ensure they are valid and conform to protocol rules. For this, the Proof of Stake (PoS) consensus mechanism is used, which ensures the reliability and resistance of the network to attacks. Smart contracts are a key element of how Ethereum works. They are programs stored on the Blockchain and automate the execution of agreements between parties. Each smart contract is executed automatically according to certain conditions that are defined in the contract itself.

The IOTA blockchain is a revolutionary distributed ledger technology used to enable scalable transactions and data sharing in the Internet of Things. The main difference between the IOTA Blockchain and traditional blockchains is the absence of blocks and chains. Instead of transactions being grouped into blocks and chains, they are organized into the nodes of a graph called a directed acyclic graph (DAG). This allows the IOTA network to process transactions in parallel and for free, making it ideal for large-scale IoT applications. One of the key advantages of the IOTA blockchain is the low cost of transactions and their instant confirmation, making it ideal for applications in the field of micropayments and consumer IoT devices. Furthermore, due to its architecture and scalability, the IOTA blockchain can provide security [17] and reliability for a wide range of IoT applications.

EOS is a Blockchain platform based on the concept of decentralized autonomy. The main working principle of EOS is to provide speed, scalability and efficiency for the development of applications and smart contracts. This platform uses the Delegated Proof of Stake (DPoS) algorithm, which allows selected groups of nodes to make fast and efficient decisions, will allow a quick response to a DAO attack. If this happens to the EOS network, block validators will be able to vote to freeze the application until it is fixed, thus allowing the network to continue as normal [18].

Hyperledger Fabric is a private blockchain platform developed as part of the Hyperledger Linux Foundation project. The main principle of Hyperledger Fabric is to create high-performance and scalable distributed ledgers for enterprises and developers. Each organization has its own channel, which allows you to create private and confidential areas where only certain members can interact. Each channel can have its own consensus, privacy and security rules, making Hyperledger Fabric an ideal choice for enterprises with high data security and privacy requirements. One of the key features of Hyperledger Fabric is the ability to use smart contracts, which can be written in the programming language Go, Java or Node.js [19]. It allows developers to create complex business logic and automated processes, simplifying the deployment and management of applications on the Hyperledger Fabric platform.

By choosing Ethereum to execute the platform, we benefit from the most advanced platform for developing smart contracts. Ethereum is supported by a large developer community that provides a lot of information resources and tools that make the development process much easier. In addition, the transition to Proof of Stake (PoS) in Ethereum 2.0 has significantly increased transaction speeds and reduced energy consumption costs, making the platform more stable and efficient for implementing decentralized projects. In order for the decentralized platform to be able to provide an accurate association between the cargo and the truck, as well as to track the processes of loading and unloading in warehouses, we will use the capabilities of QR codes. The Zebra FX9600 RFID Reader was chosen for the platform because of its powerful technical characteristics and integration capabilities that meet our needs in the IoT project. A TP-Link AC1900 router was chosen to connect to the Wi-Fi network. An important aspect when developing the architecture of a decentralized platform is the choice of protocols for interaction between its software components. The work uses

and justifies the choice of MQTT, AMQP and HTTP(S) protocols, which are the most suitable for this type of system, taking into account the characteristics, advantages and prevalence.

The MQTT protocol is designed [20] with resource-constrained devices such as sensors, controllers, and microcontrollers in mind, and minimizes network bandwidth and header size requirements, ensuring efficient data transfer. At the heart of the MQTT protocol is the "subscribe-publish" model, which defines the way of organizing communication between clients and the MQTT broker Figure 3.

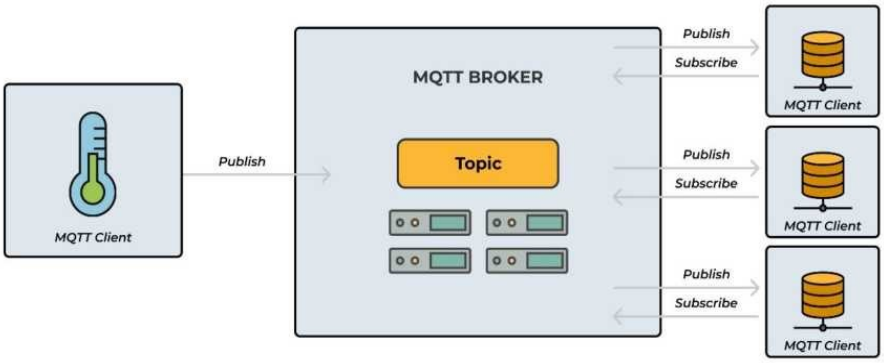

Figure 3: The principle of using the MQTT protocol.

AMQP is a messaging protocol designed to provide reliable and scalable data transfer. AMQP clients first connect to an AMQP broker using a network connection, usually over TCP/IP. Publishers create messages and send them to an AMQP broker, along with an indication of the queue or exchanger to which they want to publish the message Figure 4.

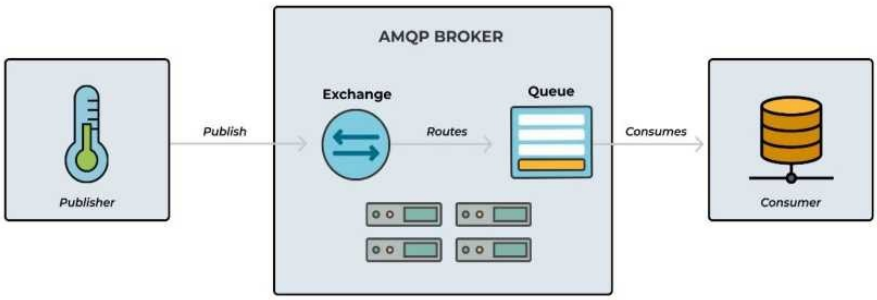

Figure 4: The principle of using the AMQP protocol.

An AMQP broker uses exchangers to route messages to appropriate queues based on client-defined routing rules. Subscribers connect to a queue and receive messages that are in that queue. Messages can be processed by a consumer who dequeues them, or automatically deleted if the consumer has successfully processed them. After successful processing of the message, the consumer confirms it with the broker. If the confirmation is not received, the broker can resend the message or have it processed by another consumer.

The HTTPS protocol, in turn, is an extension of the HTTP protocol, supporting encryption to protect the confidentiality and integrity of data during its transmission over the network [21]. Data transmitted via the HTTPS protocol is "packaged" in the SSL or TLS cryptographic protocol, thereby ensuring the protection of this data. Unlike HTTP, the default TCP port 443 is used for HTTPS. The advantages of HTTPS are the ability to ensure data privacy by encrypting information, as well as

reducing the risk of interception and alteration of data in transit. However, this protocol may require more resources to encrypt and decrypt data, which may increase server load and increase latency.

5. Implementation

Let's consider the principle of operation of the Blockchain platform of logistics project management with the help of IoT. The process begins with project initiation. At this stage, the main parameters of the project are determined, such as the weight and volume of the cargo, initial and final compositions. This is followed by "Creating a smart contract". A smart contract is the basis for project management on the Blockchain, ensuring the automation and fulfillment of a number of different conditions of the business process. After that, the process includes reading the arrival of the truck at the warehouse with the help of the mechanism of using RFID technology that we described earlier, which allows you to automatically identify the truck and which warehouse it arrived at [9,11]. Reading of data on cargo in trucks and in the warehouse, as well as loading and unloading processes, is carried out using the previously described mechanism of using QR codes. Information about the specific loads that are in the truck is used to sequentially unload all the necessary loads from it. The unloading operation is recorded in the smart contract, and if the cargo has reached its final destination warehouse (that is, it is not unloaded at an intermediate warehouse, for example for transshipment), then "Smart Contract Closure" occurs. This documents the end of the project and provides traceability of the entire process, and the manager and/or client can later review the details of the shipment and the execution history of the corresponding smart contract. After unloading, the process of sequentially loading the necessary cargo from the warehouse into the truck begins. Before loading the next load, the system checks whether it can be loaded into the truck based on weight and volume. If so, the cargo is loaded and this event is recorded in the smart contract, otherwise, the warehouse employee receives a notification that loading is impossible.

The general architecture of the decentralized logistics project management platform is shown in Figure 5.

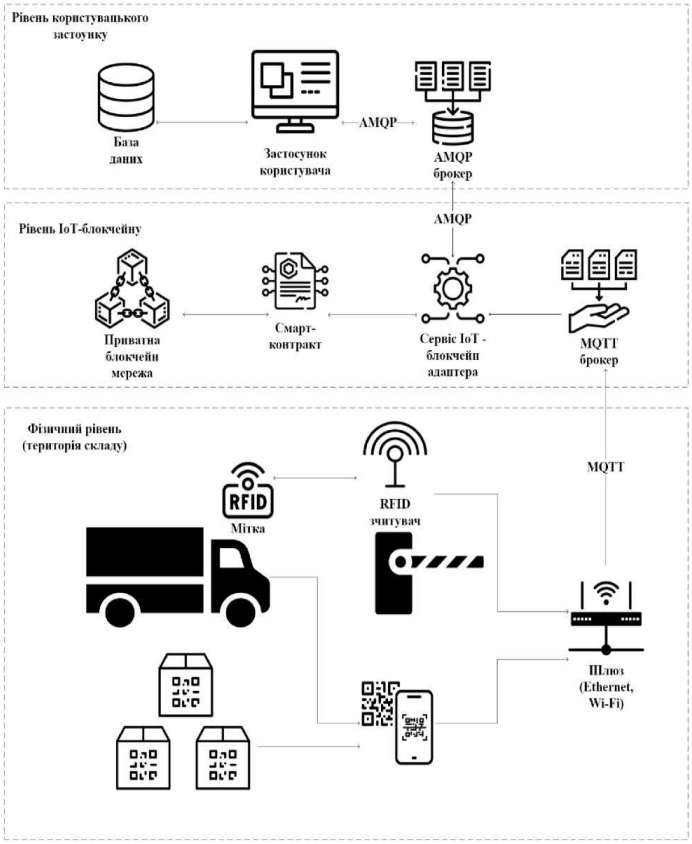

Figure 5: Architecture of a decentralized logistics project management platform.

The Blockchain-IoT Adapter is a program that:

1. On the one hand, subscribed via MQTT to messages from IoT devices.
2. On the other hand, AMQP interacts with the user's web application in both directions: the user's web application receives updated data from the Blockchain-IoT adapter and, based on it, adds or updates the corresponding records in the database tables; Blockchain-IoT adapter receives from the application data about the new logistics project, related cargo, all basic parameters.
3. Also, the Blockchain-IoT adapter interacts with the smart contract on the blockchain, calling the appropriate functions and processing events.

The user web application has its own API and web interface for manager and client use cases. The web application displays data from the database. The application sends the Blockchain-IoT adapter data about the new logistics project, the related cargo, all the main parameters. The user interacts with the web application using a web browser and the HTTPS protocol.

6. Results and analysis

A smart contract was created in the system for the selected Ethereum Blockchain [16], which is designed to track logistics projects and consists of the following main components:

Data structures:

- Cargo - stores information about the cargo, including its unique identifier (id), description, and current location (currentLocation, truck or warehouse).
- Project - stores information about the logistics project, including the unique project identifier (id), final warehouse (targetWarehouse), cargo mapping (cargos), list of cargo identifiers (cargoIds), and project activity status (isActive).
- VehicleStatus (vehicle status) - stores information about the current warehouse (currentwarehouse) and the status of being in the warehouse (isInWarehouse).
- HistoryRecord - stores information about events, including location and timestamp.
- ProjectHistory - contains an array of history records for each project.
- Features:
- CreateProject - creates a new logistics project with the specified parameters. Sets initial and target inventory, vehicle, and project activity status.
- AddCargo - adds a new cargo to the project. Sets the starting warehouse as the current location of the cargo and stores the cargo information in the project mapping.
- LoadCargo - loads the cargo into the truck after verifying that the truck is in stock.
- UnloadCargo - unloads the cargo from the warehouse after checking that the truck is in the warehouse.
- GetProjectHistory - returns the history of all events for a specific project.
- VehicleEnterWarehouse - records the arrival of the truck to the warehouse.
- VehicleExitWarehouse - records the exit of the truck from the warehouse.
- Events:
- ProjectCreated - generated when a new project is created.
- CargoAdded - generated when new cargo is added to the project.
- CargoLoaded - generated when cargo is loaded into the truck.
- CargoUnloaded - generated when cargo is unloaded at the warehouse.
- VehicleEnteredWarehouse - generated when the truck enters the warehouse.
- VehicleExitedWarehouse - generated when the truck leaves the warehouse.
- ProjectClosed - generated when the project is closed.

The smart contract provides decentralized management of logistics projects and tracking of cargo movement, recording the entire history of "ownership" transitions on the Blockchain, which allows for transparency and reliability of data storage for customers and participants in logistics processes.

To develop and test a smart contract on the Ethereum blockchain, we will use Remix IDE and the local Ganache blockchain environment. Remix IDE is an integrated environment for developing smart contracts on Ethereum, which works directly in the browser [22]. It provides a convenient interface for writing, compiling and deploying smart contracts. Ganache is a tool for running a personal Ethereum Blockchain on a local computer.

In Remix IDE, we will create a new Logistics.sol smart contract file, in which we will write its program code, using the Solidity smart contract programming language Figure 6.

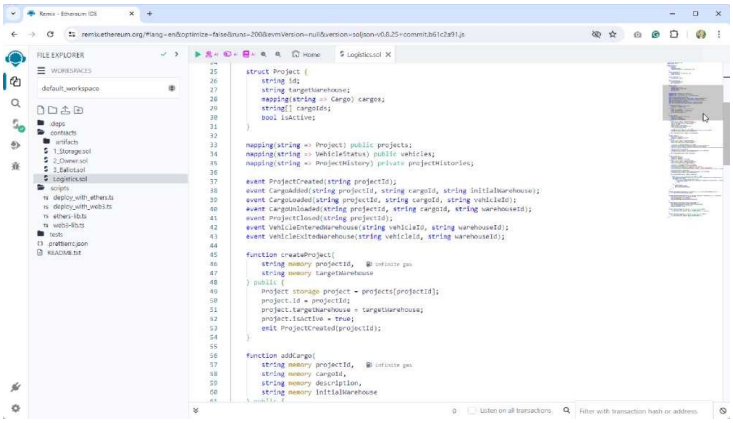

Figure 6: Writing smart contract code in Remix IDE.

After writing the code, we proceed to compilation. Compiling a smart contract in Remix IDE turns code written in Solidity into bytecode that the Ethereum Virtual Machine (EVM) can execute. This process also creates ABI files that describe the contract's interface to interact with other contracts and external applications. The Remix IDE compiler provides convenient tools for detecting errors and optimizing code before deploying it to the Blockchain. The next step is to set up your local blockchain using Ganache. Let's create a new local Blockchain workspace with several accounts and allocated funds. After successfully deploying the smart contract, you can see the list of contract functions. These functions can be used to call smart contract methods. For example, let's call the createProject function, having previously filled in all the necessary parameters, as shown in Figure 7.

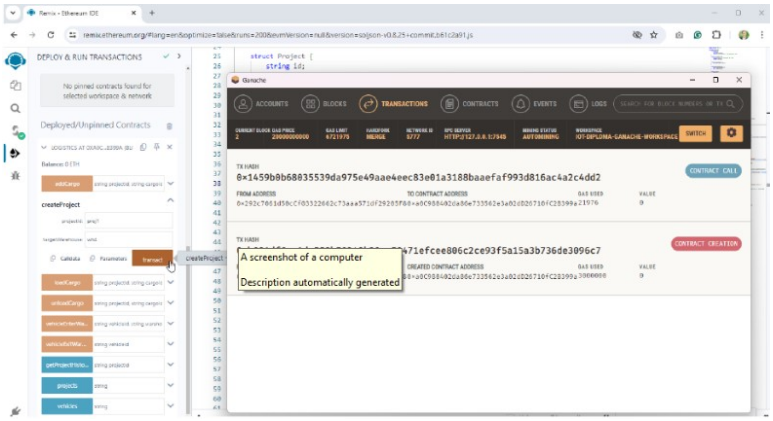

Figure 7: Calling the createProject function of a smart contract deployed in Ganache.

In this way, a project (order) is created, cargo is added, ownership is transferred, and ownership history is obtained. To ensure the possibility of testing the system, a simulation model was created to generate IoT data. This model made it possible to simulate the processes of arrival and departure of trucks, loading and unloading of goods, as well as their association with the corresponding

warehouses. The smart contract is responsible for recording and storing data about logistics projects and their progress, ensuring transparency, immutability and availability of this data for users on the blockchain. To integrate data from IoT devices with smart contracts on the blockchain, an IoT blockchain adapter service program was created. This service automatically transmits data on cargo operations to the blockchain network, thereby ensuring their reliable storage and processing. In this context, some security aspects of the data recorded on the blockchain were also considered.

The final stage was the development of the frontend and backend of the custom web application, which also integrates with the IoT-blockchain adapter, and testing on the local information technology environment as a whole.

Table 1
Empirical data obtained from platform testing

Project ID	Cargo ID	Arrival time at the first warehouse	Processing time (minutes)	Time of dispatch to the next warehouse	Arrival time at the second warehouse	Processing time second warehouse (minutes)	Arrival time at final warehouse	Project closure time (smart contract)
Pr1	0001	08:00	6	8:12	11:10	6	13:25	13:30
Pr1	0002	08:00	5	8:10	11:10	4	13:25	13:30
Pr1	0003	08:00	5	8:10	11:10	4	13:25	13:30
Pr1	0004	08:00	5	8:10	11:10	3	13:25	13:30
Pr2	0001	08:00	7	8:13	11:10	6	13:25	15:30
Pr2	0002	08:00	6	8:11	11:10	5	13:25	15:30
Pr2	0003	08:00	5	8:10	11:10	4	13:25	15:30
Pr2	0004	08:00	5	8:10	11:10	4	13:25	15:30
Pr3	0001	08:00	8	8:13	16:10	5	19:25	19:30
Pr3	0002	08:00	6	8:11	16:10	4	19:25	19:30
Pr3	0030	08:00	5	8:10	16:10	4	19:25	19:30
Pr3	0004	08:00	5	8:10	16:10	4	19:25	19:30
Pr3	0395	08:00	5	8:10	16:10	4	19:25	19:30
Pr4	0001	08:00	4	8:10	16:10	4	19:25	18:30
Pr4	0002	08:00	4	8:10	16:10	4	19:25	18:30
Pr4	0003	08:00	4	8:10	16:10	4	19:25	18:30
Pr4	0535	08:00	5	8:10	16:10	5	19:25	18:30
Pr4	1236	08:00	5	8:10	16:10	5	19:25	18:30

The processing time in the first warehouse showed a significant decrease, especially in the Pr4 project, where it decreased to 4 minutes compared to previous projects Table [1]. This change is due to the decentralization of computing in the network. The processing time in the second warehouse stabilized at 4 minutes. The decrease in the processing time in the first warehouse contributed to the reduction in the overall completion time of projects. Projects with lower processing times, such as Pr4, are completed faster, confirming the success of process optimization. Overall, there is a clear trend towards a decrease in order processing times on the platform, which leads to an increase in the overall efficiency of project execution.

7. Conclusion

The scientific novelty of this study lies in the development of a platform architecture that uses modern blockchain and IoT technologies to manage logistics projects. This approach provides decentralized control and automation of processes at all stages of the supply chain, which has not previously been encountered in such deep integration.T he paper also proposes the implementation of smart contracts in logistics, which allows for automatic registration of loading and unloading operations, as well as tracking the movement of goods. This significantly increases the transparency and reliability of operations, eliminating the need for intermediaries and reducing the risks of data falsification.

The use of a decentralized approach to project management demonstrates a decrease in the processing time of operations and the overall optimization of logistics processes, which was confirmed during experiments and testing. The study formalizes system requirements that determine the acceptance criteria for the developed information system for a specific transport enterprise. The developed algorithm of the decentralized platform provides tracking of logistics projects, such as cargo transportation. A selection of hardware and software for the implementation of the architecture of this platform was also carried out. Software components of key architecture elements have been implemented, including a database, a smart contract, an IoT blockchain adapter, and a custom web application.

The developed system based on Blockchain IoT can significantly improve the quality of transport companies, increase the ability to track cargo shipments, verify the accuracy of information, and ensure customer confidence in the accuracy and reliability of data.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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