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PROTOTYPE FOR TRACEABILITY OF SUPPLY CHAIN WITH MULTIPLE BLOCKCHAINS

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Abstract: *Blockchain's growth in supply chains, since Satoshi Nakamoto's 2008 introduction, offers secure, immutable, and decentralized storage, drawing industry and academic attention for its transformative potential. Blockchain's hashed transaction chain ensures data integrity and immutability, addressing supply chain challenges: data collaboration, synchronization, and product traceability. We aim to create a Prototype for supply chain members, leveraging multiple Blockchains and IoT sensors for data integration and traceability. This software offers dashboards to manufacturers, suppliers, shippers, warehouse providers, distributors, and retailers, allowing them to monitor product statuses, verify using Blockchains, and save data securely. Using Sigfox sensors and LPWAN technology, our prototype connects with Ethereum, Solana, Tezos, Polkadot, Avalanche, and Stellar Blockchains. It enables two-way communication, eliminating third-party verification, and offers tailored interfaces, authentication, and authorization. This prototype also supports integration with other existing blockchain networks.*

Key words: *Blockchain, Supply Chain, Traceability, Prototype, IoT Sensors, Multi-Blockchain Gateway API.*

1. INTRODUCTION

A Blockchain is a decentralized, secure, and reliable network that enables recording of transactions, data storage, and value exchange in a distributed ledger without the need for a central authority. It serves as the foundation for cryptocurrencies and smart contracts, providing trust-minimized and permissionless value exchange. Blockchain technology was first introduced in 2008 through a whitepaper titled "Bitcoin: A Peer-to-Peer Electronic Cash System" by an individual or group using the pseudonym Satoshi Nakamoto [1]. This whitepaper outlined the concept of a decentralized digital currency and introduced the underlying technology known as Blockchain.

Initial implementation of Blockchain was with the launch of Bitcoin in 2009, which remains the most well-known and widely used cryptocurrency. Bitcoin's Blockchain is a public, distributed ledger that records all transactions made on the network. It operates on a peer-to-peer network of computers, known as nodes that collectively maintain and validate the Blockchain. Blockchain technology is characterized by several key features that distinguish it from traditional centralized systems:

- Decentralization: Blockchain operates on a decentralized network of computers called nodes, with no central authority governing the system. This decentralization ensures that no single entity has control over the entire network, enhancing security and resilience.
- Distributed Ledger: The Blockchain utilizes a distributed ledger that is replicated and maintained across multiple nodes. Each node in the network possesses an identical copy of the ledger, ensuring transparency and preventing a single point of failure.
- Transparency: All transactions recorded on the Blockchain are transparent and visible to all participants in the network. This transparency promotes trust and accountability, as anyone can independently verify the integrity of the data.

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- Security: Blockchain utilizes cryptographic techniques to secure transactions and data on the network. The use of cryptographic hashing and digital signatures ensures the integrity and authenticity of the information stored on the Blockchain, making it highly secure against tampering and fraud.
- Immutability: Once data is recorded on the Blockchain, it is extremely difficult to alter or delete. The immutability of the Blockchain ensures the permanence and integrity of the stored information, making it well-suited for applications requiring auditable and tamper-proof records.
- Smart Contracts: Blockchain platforms such as Ethereum support smart contracts, which are self-executing agreements with predefined rules written directly into the Blockchain's code. Smart contracts enable the automation of processes, eliminating the need for intermediaries and enhancing efficiency.
- Trust and Consensus: Blockchain employs consensus mechanisms to achieve agreement among network participants on the validity of transactions and the state of the ledger. This consensus mechanism eliminates the need for trust in a centralized entity, as the consensus rules are collectively enforced by the network.

These features collectively make Blockchain technology a powerful tool for secure, transparent, and decentralized applications, with applications ranging from cryptocurrencies and financial services to supply chain management, voting systems, and more.

2. LITERATURE REVIEW

The literature review focused on articles displaying Blockchain solutions based on Ethereum, Bitcoin, and Hyperledger Fabric. These three platforms have gained significant attention in the realm of Blockchain technology. The review encompassed a wide range of articles, including academic research papers, industry reports, and expert opinions. The primary objective was to analyse the performance, scalability, security, and usability aspects of these Blockchain solutions.

The literature revealed that Ethereum for Agri-Food Traceability System, with its smart contract capabilities, has become a popular choice for decentralized applications, but faces challenges related to scalability and transaction fees [2].

Bitcoin, as the first and most well-known cryptocurrency, has demonstrated resilience and security but is limited in its functionality beyond digital currency [3].

Hyperledger Fabric, on the other hand, offers a permissioned and modular framework suitable for enterprise use, with a focus on privacy and flexibility [4].

The literature review also highlighted ongoing developments, future challenges, and potential use cases for these Blockchain solutions in various industries such as finance, supply chain management, and healthcare. Overall, the review provided valuable insights into the strengths and weaknesses of Ethereum, Bitcoin, and Hyperledger Fabric, serving as a foundation for further research and development in the field of Blockchain technology.

2.1 Benefits of Blockchain within Supply Chain

In this section we have reviewed multiple research papers which was about the benefits of Blockchain in Supply chain Traceability in Smart Manufacturing, Sustainability & Recycling and Agri-food:

Blockchain technology streamlines processes, enhances efficiency, and reduces delays by eliminating intermediaries and automating trust in areas like supply chain management, transaction verification, and data sharing. Blockchain enables real-time tracking and proactive insights in the supply chain, empowering timely decision-making, risk identification, process optimization, and issue resolution. Blockchain's transparency and immutability enable manufacturers to make smarter, secure decisions based on accurate data, improving decision-making and reducing errors or fraud risks. Overall, the implementation of Blockchain technology in the industrial sector offers benefits such as improved efficiency, proactive insights, and enhanced decision-making capabilities [5].

Blockchain is a powerful tool to address false recycling by promoting transparency, traceability, and tamper-proofing. By analysing implementation costs and effectiveness, optimal conditions for Blockchain adoption are identified. The cost thresholds for implementing blockchain vary across recycling models, platform commission rates, and salvage sharing ratios. Manufacturers show greater acceptance of higher implementation costs in categories with lower platform commission rates, while platforms increase their investments. Additionally, the urgency for Blockchain implementation rises with larger disparities between actual and projected recovery volumes.

The recycling industry experiences three significant effects as a result of implementing blockchain technology, as emphasized in this study. It creates a decision incentive effect by motivating platforms to enhance online marketing and recyclers to increase their recycling efforts. Furthermore, it leverages marketing capabilities by building consumer trust, promoting waste product recycling, and improving brand goodwill, which boosts demand and brand premium. Lastly, it establishes an incentive alignment effect, where manufacturers and platforms mutually benefit from blockchain implementation, leading to a balanced and improved recycling channel. Overall, blockchain brings about positive impacts on decision making, marketing leverage, and incentive alignment in the recycling sector.

According to the study findings, manufacturers typically opt for the manufacturer recycling channel to preserve the complete salvage value in cases where blockchain implementation is absent. However, this choice hinders the platform's profitability and online marketing, negatively impacting the long-term sustainability of the closed-loop supply chain (CLSC). On the other hand, blockchain implementation promotes recycling and demand, benefiting both the backward and forward directions of the CLSC. By defining a cost range for blockchain implementation, manufacturers and platforms can reach an agreement on recycling, optimizing the triple benefits of the CLSC. The efficiency of manufacturer recycling determines the extent of stable cooperation, while blockchain enhances the platform's market expansion capacity and fosters sustainable CLSC development. Overall, blockchain effectively addresses conflicts among recyclers, raises consumer awareness, and motivates recycling behaviour [6].

- Informational Security: Utilising of a blockchain based traceability system ensures reliable information storage through its consensus mechanism, enhancing data integrity and security. This system also provides high degrees of immutability and information integrity. In addition, if integrated into IoT devices (Internet of Things), it improves transaction efficiency.
- Technological Benefits: The information stored in the multiple ledger database is subject to encryption manipulation, making it challenging to be attacked. The implementation of consensus mechanisms guarantees that the information remains unhampered with as long as all participants in the traceability process reach an agreement.
- Improvement of collaboration and trust in the supply chain: Successful interoperability and integration of cross-organizational business processes depend on distributed, autonomous and heterogeneous services to carry out tasks. By leveraging blockchain technology, trust and collaboration between supply chain partners can be strengthened. The ability to trace a tamper-proof history of information throughout the traceability chain contributes to improved prediction and evaluation capabilities, thereby increasing the quality of information.
- Reduce economic loss and product waste: The utilization of a traceability system based on blockchain enables the acquisition of dependable data for each stage within the traceability chain. This, in turn, leads to a more precise determination of the shelf life of food products, resulting in reduced economic loss and food waste.
- Sustainability and transparency of traceability management: Blockchain

technology enables seamless end-to-end tracking and tracks the origin of products from farms to consumers. Each production step can be recorded in the blockchain, including farming details, lot numbers, quarantine dates, processing information, transportation data, storage conditions, and shelf-life. This fosters trust among stakeholders, allowing comprehensive inspection of the entire supply chain. Companies can use this information as legal evidence for traceability management and product authenticity. Overall, the adoption of blockchain significantly improves sustainability and transparency in the management of traceability.

The integration of blockchain with IoT devices has a profound impact on research and implementation of the traceability of agricultural products and addresses concerns related to information security and transparency. [7].

2.2 LPWAN Communication Technologies.

Low-power wide-area network (LPWAN) technology theoretically has the capacity to connect small networks, battery-powered devices for up to 10 years, making them well-suited for remote sensors and low-data-demand applications, even in underground or indoor environments. These LPWAN technologies can help in smart homes, smart retail, smart grids, and the industrial internet of things, it is necessary to connect devices that are located in remote areas without traditional LTE coverage [8]. We analysed Sigfox, LoRaWAN and Narrowband IoT to determine their suitability for item traceability. Sigfox is a proprietary unidirectional LPWAN communication technology that offers a very low data range. It operates in unlicensed ISM bands, and a Sigfox gateway can support millions of devices while providing coverage in more than 70 countries [9]. Sigfox takes advantage over NB-IoT and LoRaWAN as it provides longer range, longer battery life, cost effective deployment and global coverage. It provides simplified data integration on https protocol [10]. Sigfox cloud system provides HTTP based event notifications to be sent from IoT to integrate application, therefore, demonstrates the efficient use of Sigfox in a platform tracking system. The tracking platform's functions are verified, confirming the practical application of Sigfox in a real server-based system [11].

3. BLOCKCHAIN BASED MPLEMENTATION IN SUPPLY CHAIN:

Blockchain technology has the ability to fundamentally change supply chain management. It acts as a secure and transparent data management system, capable of establishing an immutable ledger for transactions and product movements. This not only cultivates trust among stakeholders but also facilitates end-to-end visibility. The integration of blockchain into supply chain management has the potential to enhance traceability, transparency, and security while offering solutions to persistent challenges like disruptions, opacity, and inventory control. Despite being in its nascent stages, the implementation of blockchain in supply chain management faces hurdles such as technical complexities, regulatory adherence, and stakeholder buy-in. Nonetheless, the advantages it promises are substantial, necessitating further research to uncover its diverse applications and implications [12], [13].

3.1 System Overview

We have developed a prototype which provides supply chain actors to integrate with existing or newly added blockchain networks. **Figure 1.** explains high level architecture of our prototype. It provides Distributed App to be accessible for Supplier, Manufacturer, Shipper, Auditor/compliance officer. As it is explained in below figure that backend application connects to Blockchain networks from Web API Gateway. This API Gateway provides blockchain uses blockchain specific programming libraries to create wallets, accounts, create keys, sign transactions and persist data on users' chosen blockchain network. As shown our prototype provides facility to connect/integrate with Ethereum, Solana, Tezos, Polkadot, Avalanche and Stellar Blockchains.

Figure 2. Presented below depicts a sequence diagram illustrating the interactions among various actors involved in the registration process of our proposed prototype.

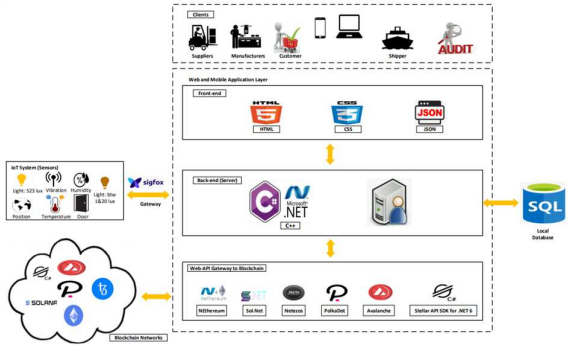

Fig. 1. Proposed Architecture of Multi-Blockchain & IoT-based DApp.

Upon successful completion of the registration process and subsequent verification of each entity by the Auditor within our system, user accounts are established on the blockchain. During the registration phase, each entity is required to provide specific details regarding the blockchain network they wish to utilize. Consequently, our prototype will generate a wallet, account, keys, transactions, and perform verification on the designated blockchain network accordingly.

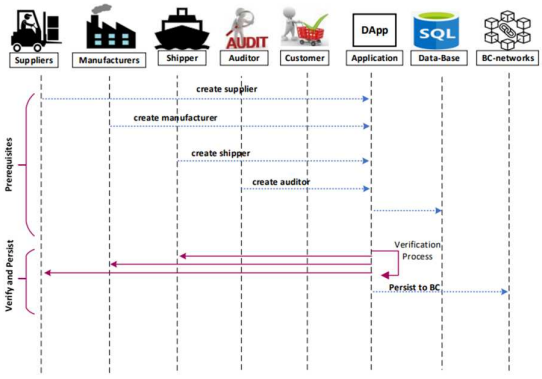

Fig. 2. Sequence diagram illustrating the registration process for various entities - Suppliers, Manufacturers, Shippers, Customers and Auditors.

4. CONCLUSION

In conclusion, the incorporation of blockchain technology into IoT devices and the adoption of low-power large-scale network communication technologies (LPWANs), such as Sigfox, present substantial opportunities to enhance traceability within supply chains. The advantages offered by Sigfox, including its extensive global coverage, extended battery life, and streamlined data integration capabilities, position it as a highly promising solution for implementing tracking systems in supply chain operations.

Furthermore, the introduction of a prototype that allows supply chain actors to integrate with blockchain networks showcases the practical application of blockchain in the industry. The prototype's architecture, which involves connecting to blockchain networks through a Web API Gateway, demonstrates the ability to create wallets, accounts, and transactions on the chosen blockchain network.

The implementation of blockchain technology in supply chain management has many advantages. These advantages encompass enhanced operational efficiency, improved decision-making capabilities, strengthened trust and collaboration among stakeholders, decreased economic losses and waste, and heightened sustainability and transparency. As continuous progress is made in blockchain technology, its potential for transformative impact is poised to reshape numerous industries, ushering in a future characterized by heightened security, efficiency, and decentralization.

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PROTOTIP PENTRU TRASABILITATEA LANȚULUI DE APROVIZIONARE CU MAI MULTE BLOCKCHAINURI

Blockchain, introdusă în 2008 de Satoshi Nakamoto, oferă stocare sigură și imutabilă, atrăgând interesul din industrie și academia pentru potențialul său. Acest lucru abordează probleme din lanțurile de aprovizionare, inclusiv colaborarea, sincronizarea și urmărirea produselor. Intenționăm să creăm un prototip pentru membrii lanțului de aprovizionare, folosind blockchain-uri multiple și senzori IoT pentru integrare și urmărire. Software-ul furnizează tablouri de bord personalizate pentru producători, furnizori, transportatori, furnizori de depozite, distribuitori și comercianți cu amănuntul, permițând monitorizarea produselor, verificarea blockchain-ului și stocarea securizată a datelor. Prototipul se conectează la blockchain-uri precum Ethereum, Solana, Tezos, Polkadot, Avalanche și Stellar, facilitând comunicarea bidirecțională și eliminând necesitatea verificării de terțe părți. De asemenea, susține integrarea cu blockchain-uri existente.

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