

Innovative Distributed Ledger Technologies for Local Product Traceability in Agro-Touristic Economies

Carmelo Felicetti^{1,*}, Antonella Guzzo¹, Domenico Sacca^{1,2} and Francesco Pasqua²

¹DIMES Dept, Università della Calabria, 87036 Rende, Italy

²Relatech SpA, 87036 Rende, Italy

Abstract

The integration of innovative technologies, particularly Distributed Ledger Technologies (DLT), holds significant promise for enhancing traceability in local product supply chains, particularly within the context of territorial agro-touristic economies. This paper explores the potential of DLT-based solutions in bolstering traceability for local products, focusing on their role in fostering transparency, trust, and economic development in agro-touristic regions. The paper exploits a recently proposed requirements methodology, called GOREM (Goal Oriented Requirements Methodology), to support the conceptualization and subsequent implementation of DLT-based framework for Local Product Traceability in Agro-Touristic Economies.

Keywords

DLT, blockchain, traceability, agrifood, supply chain

1. Introduction

Traceability in local agrofood product supply chains is a pivotal element that ensures not only the safety and quality of food but also the preservation and appreciation of agricultural heritage and biodiversity. This comprehensive system documents and links various stages in the food's journey, from production to consumption, providing a transparent path back to its origins. Its significance is multifaceted, encompassing food safety, consumer confidence, market access, and compliance, while also delving into the evolutionary and cultural dimensions of agriculture.

Firstly, traceability is crucial for food safety and public health. It allows for swift identification and action in the event of food safety issues, reducing health risks and safeguarding public trust. For consumers, traceability offers a transparent window into the origins and journey of their food, enhancing trust and enabling informed choices. Moreover, it is essential for market access and compliance with regulatory standards, ensuring that local producers can compete and thrive in broader markets.

Beyond these practical benefits, traceability plays a vital role in the evolutionary reconstruction of local crop varieties. By tracking the history and development of these varieties, traceability systems help preserve unique genetic resources and the cultural heritage tied to traditional foods. This aspect is crucial for maintaining biodiversity and the authenticity of regional specialties.

Additionally, traceability enriches the cultural and traditional dimensions of agrofood supply chains. It highlights the historical and cultural significance of plant genetic resources, connecting products with their ancestral roots and the communities that have nurtured them. This connection not only adds value to the products but also supports the conservation of invaluable agricultural traditions and knowledge.

In the development of traceability systems, Requirements Engineering (RE) [1, 2] plays a crucial role. RE is a discipline within systems and software engineering that focuses on determining the needs or conditions to meet for a new or altered product. This process involves the identification, documentation, and continuous maintenance of system requirements, ensuring they align with the possibly conflicting needs of various stakeholders, such as end-users, regulators, and technology providers.

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*Corresponding author.

✉ carmelo.felicetti@unical.it (C. Felicetti); antonella.guzzo@unical.it (A. Guzzo); domenico.sacca@unical.it (D. Sacca); francesco.pasqua@relatech.com (F. Pasqua)



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To effectively model and communicate the complexities of traceability systems, graphical notations such as the Unified Modeling Language (UML) [3] and Business Process Model and Notation (BPMN) [4] are employed. UML is primarily used to visualize the design of a system, particularly software systems, through diagrams that depict elements like interactions, processes, and lifecycle of system components. BPMN complements UML by providing a graphical notation focused on the logical steps of a business process, thus enabling a clear depiction of process flows and decision points that are essential in managing the traceability of products from farm to consumer.

The integration of Distributed Ledger Technologies (DLT) in our approach, combined with these methodologies, aims to fortify traceability and enhance transparency, trust, and economic development in agro-touristic regions. The adoption of innovative technologies, particularly DLT, holds significant promise for enhancing the efficiency and transparency of local product supply chains.

Distributed Ledger Technologies (DLTs), such as blockchain, are revolutionizing traceability in local agrifood product supply chains by providing a secure, transparent, and immutable record-keeping system. This technology's relevance to the agrifood sector stems from its ability to enhance the integrity, efficiency, and transparency of the supply chain, fostering trust among consumers and stakeholders while promoting sustainability and ethical practices.

The main advantages of using DLTs for traceability are:

- *Enhanced Transparency and Trust:* DLTs create a tamper-proof record of each transaction or product movement within the supply chain, from farm to fork. This level of transparency enables consumers to access detailed information about the origin, processing, and distribution of food products, building trust in local brands and encouraging informed purchasing decisions.
- *Improved Food Safety and Quality Assurance:* In the event of a food safety issue, DLTs allow for rapid, precise trace-back to the source, enabling quicker responses to contamination, disease outbreaks, or quality concerns. This capability not only protects consumer health but also minimizes economic losses by reducing the scope of product recalls.
- *Efficiency and Reduction of Fraud:* By automating and recording transactions on a distributed ledger, the technology reduces the chances of human error and fraud. It eliminates the need for intermediaries, streamlining the supply chain, reducing costs, and increasing efficiency. This aspect is particularly crucial for local agrifood chains where resources are often limited.
- *Support for Local Producers and Authenticity Verification:* DLTs can empower local producers by providing a platform to showcase the authenticity and quality of their products. Consumers are increasingly willing to pay a premium for products that are locally sourced, organic, or produced using sustainable methods. Through DLTs, producers can provide verifiable proof of their product's provenance and production methods.
- *Facilitation of Compliance and Certification:* The immutable and transparent nature of DLTs simplifies the process of complying with regulatory requirements and obtaining certifications. Producers can efficiently demonstrate adherence to safety standards, organic certifications, or geographical indications, facilitating market access and consumer trust.
- *Encouragement of Sustainable Practices:* DLTs can support the promotion of sustainable agricultural practices by providing a transparent record of environmental impacts, resource use, and ethical considerations along the supply chain. This visibility can encourage producers to adopt more sustainable practices and enable consumers to make choices that align with their values regarding environmental stewardship and social responsibility.

In the face of the changing dynamics within the agritourism industry, we propose a comprehensive framework that capitalizes on the benefits of distributed ledger technologies (DLT) while also enhancing local resources for sustainable growth. The goal is to develop and test a traceability platform that not only enhances traceability and quality certification but also supports economic empowerment. By merging the capabilities of distributed ledger technologies with the strategic valorization of local resources, the activity aspires to cultivate a sustainable and robust agritourism economy and to realize the untapped potential of a region's agritourism sector.

Adopting a DLT-based framework for traceability in local agrifood product supply chains introduces new challenges that must be addressed during the management of its requirements. The process of eliciting these requirements often demands significant human engagement and pinpointing the elements crucial for success is a complex endeavor.

To navigate this complexity effectively, it is essential to accurately determine the key application scenarios and their corresponding requirements. For this purpose, we utilize the Goal Oriented Requirements Methodology (GOREM), a novel approach developed by the University of Calabria [5], designed to tackle requirements engineering in intricate software development endeavors.

GOREM, being a goal-oriented approach [6, 7], is adept at extracting requirements through the examination of the stakeholders' objectives, the business contexts, and the anticipated models of the applications. This methodology employs UML (Unified Modeling Language) graphical notation, facilitating a smoother communication and knowledge sharing process among stakeholders. GOREM's effectiveness has been demonstrated in previous industrial research projects [8, 9, 10], where its application with industrial partners shed light on several noteworthy aspects of requirements engineering.

In this work, GOREM is applied to assist in the conceptualization and the subsequent deployment of a DLT-based framework for enhancing traceability in local agrifood product supply chains. This application is intended to address the inherent challenges and ensure a structured and efficient implementation of this advanced technological solution.

The remainder of this paper is organized as follows. In Section 2, we explore the related works, comparing our approach that integrates the GOREM methodology with other significant research in the field. In Section 3 we describe the GOREM methodology. In Section 4 we describe the conceptualisation of DLT-based framework in GOREM. In Section 5 we provide some details on the adopted blockchain technology. Finally, in Section 6 we draw the the conclusion and discuss future work.

2. Related Works

The application of Distributed Ledger Technologies (DLT) in agricultural and agro-touristic supply chains has been explored by several researchers, but our approach integrates the GOREM methodology, which uniquely supports the system's conceptualization and implementation phases, ensuring that the requirements are meticulously addressed.

In comparison to El Mane et al. [11], who also deploy blockchain for agricultural supply chain management, our framework provides a more detailed integration with goal-oriented requirements engineering, enhancing the adaptability and effectiveness of the system in real-world scenarios.

Wang et al. [12] introduced a smart contract-based system for agricultural food supply chain traceability. While their approach focuses on smart contract automation, our work further supports local economic development by enhancing the traceability and authenticity verification which is critical in agro-touristic markets.

Furthermore, Hu et al. [13] discuss the enabling of blockchain and edge computing technologies for organic agricultural supply chains. Our framework differentiates itself by not only addressing technological deployment but also focusing on sustainability and the socio-economic benefits within agro-touristic economies, ensuring that technology aligns with local cultural and economic objectives.

Moreover, our implementation using Hyperledger Fabric offers a contrast to the typical use of Ethereum-based solutions in similar frameworks, such as that proposed by Pranto et al. [14]. This choice is motivated by the need for a permissioned blockchain environment that is better suited for regulated and sensitive agricultural data, providing a higher level of security and control over the transactions.

In addition, Bistarelli et al. [15] explored the **-chain* platform for livestock product traceability, utilizing a different blockchain framework. Our solution, while similarly focusing on traceability, extends its functionality to encompass a wider range of products and integrates with local tourism sectors, promoting a broader economic impact.

Finally, the concept of using secure tag-based identification in supply chains has been extensively

explored and validated in [16], demonstrating the efficacy of tag-based solutions in enhancing the traceability and security of supply chains, which aligns with our use of DLT to enhance product traceability in agro-touristic economies. Additionally, the use of deep learning for identification purposes further reinforces the robustness of our proposed framework [17], which integrates advanced AI techniques to improve authentication and traceability within the supply chain.

This comparison highlights our framework's unique integration of DLT with a goal-oriented requirements engineering approach, its focus on local economic and cultural development, and the utilization of a permissioned blockchain, which collectively enhance the practical deployment and strategic value of the technology in agro-touristic economies.

3. Overview of GOReM

GOReM is a goal-oriented methodology [18] for Requirements Engineering that has been devised and experimented at the University of Calabria, with the initial aim to help establish requirements inside large industrial research projects where many different stakeholders cooperate regarding a specific context. GOReM is centered on the UML notation [3]; as a consequence, it is easy to employ and it simplifies the sharing of knowledge among a wide variety of stakeholders [19]. The resulting requirements modeling activity has been recognized by the users to be easy and effective. Typical activities of Requirements Engineering (RE) [1, 2], i.e. elicitation of requirements, analysis, validation, verification and management, are expressed in GOReM mainly in terms of: (i) stakeholders and their goals, (ii) use cases and involved processes and (iii) work-product documentations. The methodology consists of three main phases, each of which is devoted to modeling specific aspects of a RE process: Context Modeling, Scenario Modeling and Application Modeling (see Fig. 1).

These phases are repeated iteratively and feedback among them is allowed in order to support an incremental refinement process. Furthermore, scenarios and applications are specified concurrently. A BPM (Business Process Modeling) model [4] of the reference process for GOReM, along with its main work-products, is reported in Fig. 1.

Context Modeling aims at clearly representing the reference domain [20]. The work-products of this phase are: a **Stakeholder Diagram**, which shows a, often hierarchical, specification of all the stakeholders involved in the specific context, each of which is in turn characterized by a set of **Softgoals** [21] they intend to pursue; a **Softgoal Dependency Diagram**, which shows the relationships between the stakeholders and the softgoals, as well as the relationships among softgoals (i.e., contribute, hinder, include, specialize); moreover, the **rules and regulations** that govern the context are individuated and analyzed in a work-product.

Scenario Modeling specifies different business scenarios in terms of **roles** that are played by the involved stakeholders, their specific **goals**, and the **specific rules and regulations** that govern the business scenario.

The scenario modeling phase includes also “rules and regulations selection” activity that considers which rules and regulations, among those identified in the Context Modeling phase, must be considered in the modeled scenario, by specifying if they are laws, policies and best practices, coding them, identifying and highlighting possible links and timeline.

Application Modeling defines application scenarios in order to specify the functionalities which should be provided by a single business scenario resulting from the previous phase. Each application scenario is characterized by functionalities that are modeled by UML-based **Use Cases**, **Actors** and **Processes**. In particular, each main use case should be a functionality of the overall application scenario, to be developed in some way which should be specified at design and development time. In addition, some process can be specified using UML or BPMN notations [4], if considered useful to better understand requirements by specifying flow of activities. Every UML based diagram can be enriched with the UML comment symbol which allow to add a description to all the GOReM diagrams. However, a textual description and complete information is located in the corresponding work-product.

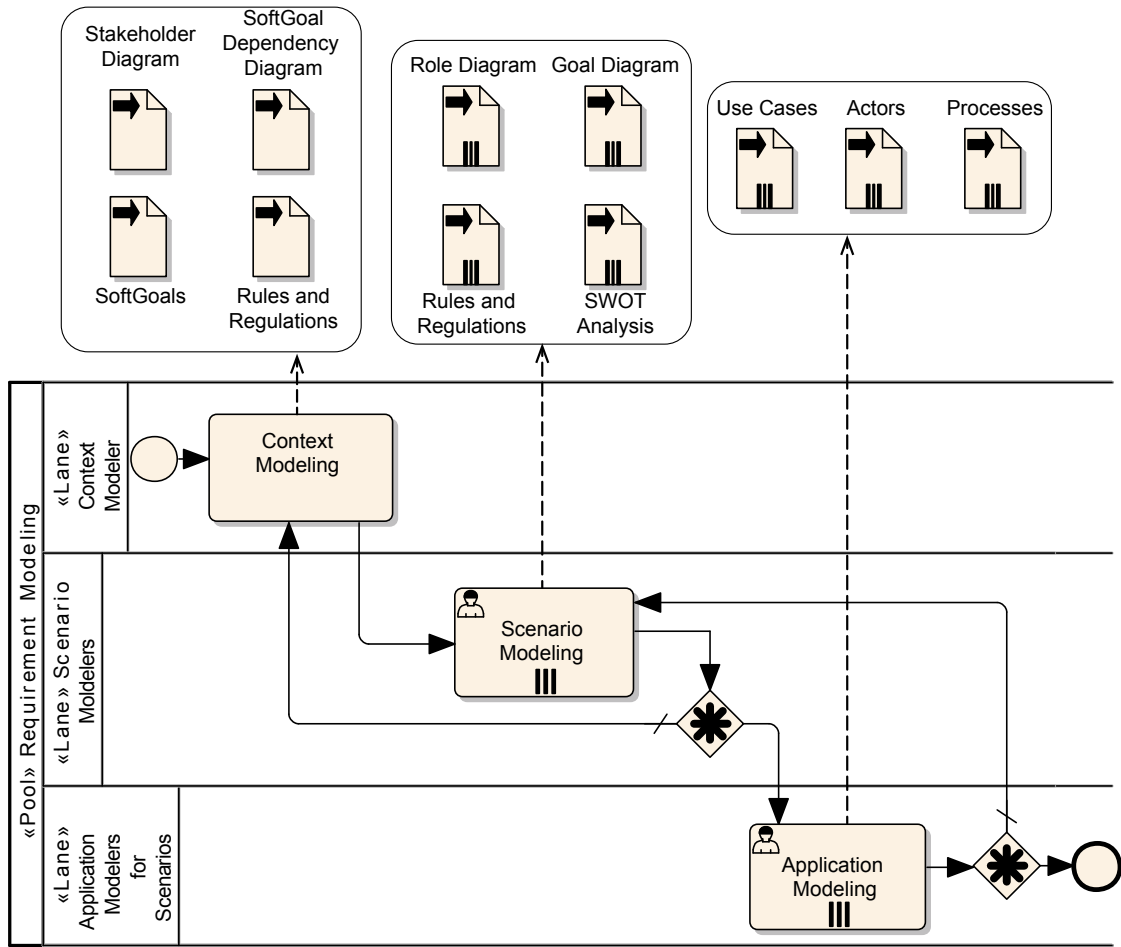


Figure 1: Reference Process Model of GOREM and Work Products

4. GOREM Specification of the DLT-based framework for enhancing traceability

4.1. Context Analysis

In the context of the DLT-based framework for enhancing traceability in local agrifood product supply chains, several key stakeholders have been identified, representing the primary actors involved, with the possibility of additional stakeholders. These stakeholders, depicted in Figure 2, are listed below:

- *Raw Material Supplier:* This entity is responsible for providing and delivering the essential inputs required for agricultural production, such as seeds, seedlings, water, fertilizers, soil, electricity, and packaging materials for product preservation and distribution, as well as fuels and lubricants for agricultural machinery and vehicles.
- *Agricultural Producer:* This individual is primarily focused on ensuring the quality and sale of agrifood products.
- *Retailer:* This company is interested in purchasing agrifood products from the agricultural producer to resell them.
- *Agricultural Credit Institution (CIA):* This institution provides financial support to agricultural producers and businesses.
- *Shipping Company:* Operating in the logistics sector, this company is responsible for the transportation of products, aiming to guarantee safe transit.

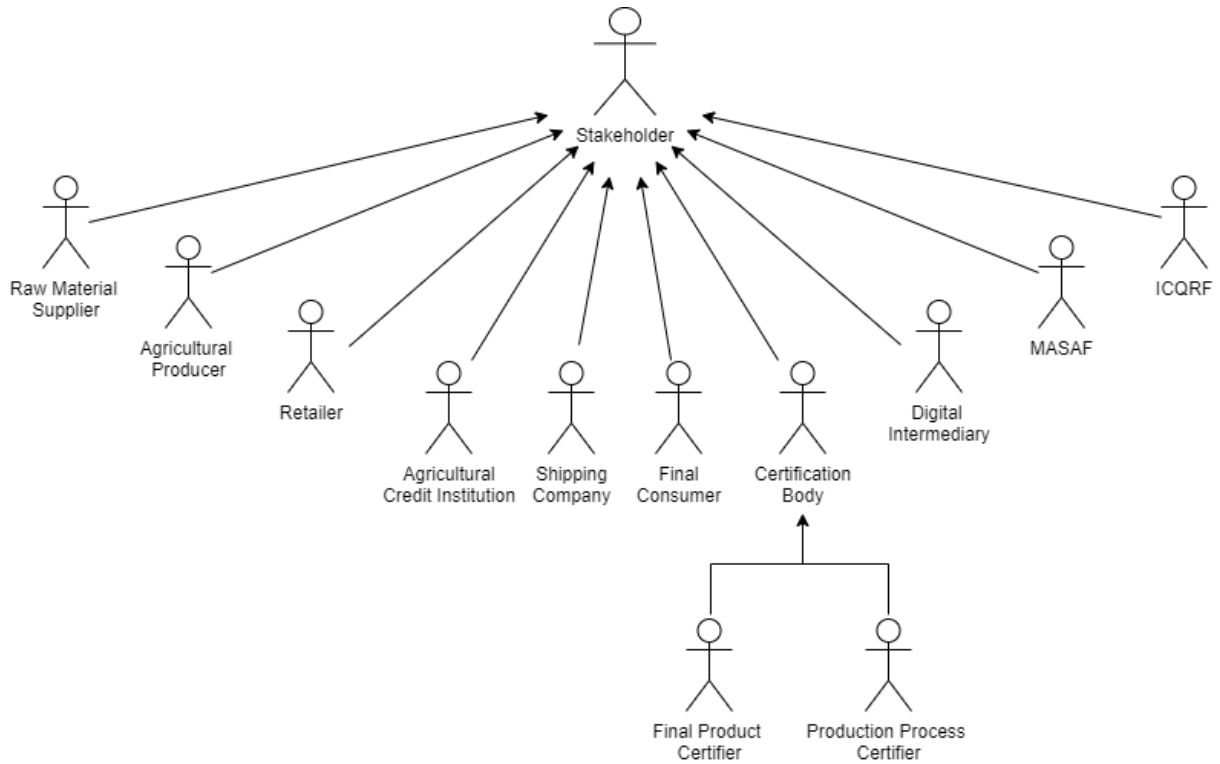


Figure 2: Context Model: Softgoal Stakeholder Diagram

- *Final Consumer*: This person purchases and consumes the products and is keen on verifying the quality of the agrifood items.
- *Digital Intermediary*: This stakeholder is involved in managing the platform implementing the DLT-based framework.
- *Ministry of Agriculture, Food Sovereignty, and Forests (MASAF)*: This governmental body addresses food safety legislation and product traceability.
- *Central Inspectorate for Quality Protection and Fraud Repression of Agrifood Products (ICQRF)*: As an Italian public entity under MASAF, ICQRF oversees the quality and authenticity of agrifood products and combats fraud and unfair trade practices.
- *Certification Body*: This independent organization verifies and certifies that a company or product meets certain quality, safety, or sustainability standards. It often adheres to nationally or internationally recognized standards, providing a certification mark that the company can use to demonstrate compliance. Specifically, two secondary stakeholders are identified:
 - *Final Product Certifier*: This entity inspects the final agrifood product to ensure it meets the set standards for quality, hygiene, safety, and regulatory compliance.
 - *Production Process Certifier*: This body certifies the entire production process, from soil quality control (conducted by agronomists) to process reviews and equipment inspections, assessing if the production meets established standards and quality requirements.

We observe that the approach proposed in [12] for tracking and executing transactions in the agricultural food supply chain identifies the following stakeholders involved in the entire process of the agricultural food supply: Agricultural Bureau, Farmer, Processor, Quality Supervision Bureau, Distributor, Retailer, Consumer.

4.2. Scenario Definition

The specific scenario to be analyzed concerns the production and transportation phase of products during which quality certification takes place. Below are the roles of stakeholders directly involved in

the specific scenario of the Project Idea:

- **Agricultural Producer** plays the role of:
 - *Producer*: ensures the production of high-quality agrifood products.
 - *Product Promoter*: promotes products to maximize sales.
- **Third-Party Certification Entity** plays the role of:
 - *Product Certifier*: guarantees that products meet established quality and safety standards, issuing valid certifications in accordance with the certification system.
 - *Production Process Certifier*: checks that the production process follows the guidelines.
- **Shipping Company**: manages the transportation of agrifood products from the producer to the retailers.
- **Intermediary** plays the role of:
 - *Platform Manager*: is responsible for the management and maintenance of the platform.
 - *Vertical Integrator*: focuses on a specific segment of an industry by adopting a targeted methodology and offering specialized solutions.
 - *Personnel Trainer*: trains staff who will interact with the system (operators who need to interface in a specific area).
- **Final Consumer** plays the role of:
 - *Quality Tester*: verifies the quality of the products.
 - *Purchaser*: buys the selected products.
 - *Reviewer*: reviews the manufacturing company.

The indirectly involved stakeholders are as follows:

- *MASAF*: responsible for the regulation and supervision of the Italian agrifood sector.
- *ICQRF*: oversees the monitoring and control to prevent fraud and ensure the quality of agrifood products. It is not directly involved in the specific scenario as it is not practical to interact directly with a public body.
- *Raw Material Supplier*: not directly included because the specific scenario focuses on product certification, which primarily concerns production, and therefore the producers. Furthermore, initially, the raw material suppliers may not be ready to use this technology, but later it could be useful to integrate them as direct stakeholders.

4.3. Use Cases

The main Use Cases are the following:

1. Vertical integration, installation, and startup of the platform.
2. Quality control of the production process and the final product with data recording on the blockchain and QR Code generation.
3. Transportation of products with information recording by the Shipping Company.
4. Scanning the QR Code to obtain product information and product reviews.

After the producer has provided detailed specific requirements related to the particular production sector, the Intermediary vertically integrates the platform to include the functionalities described by the producer. Moreover, training of the personnel who will interface with the platform is conducted, and the customized platform is installed, integrating it with the existing systems.

The Producer begins the production of agrifood products and logs onto the platform. They collect data related to production and record it on the blockchain. The Production Process and Final Product Certification Bodies log onto the platform and verify compliance with production standards to ensure

product quality. In particular, the Production Process Certifier records a video to attest to the production, which is uploaded to an offchain platform. The video's metadata and its hash value, however, are uploaded to the blockchain. Once the product certification phase is completed, a QR Code is generated that refers to all the information entered on the blockchain. Finally, the Producer affixes the QR Code on the finished product.

The Producer transfers his products to the Shipping Company, providing details regarding the destination of such items. Once the shipping company has taken charge of the shipment, it logs onto the platform and records this operation on the blockchain. Subsequently, the Shipping Company proceeds with recording the information regarding the traceability of the products, accurately noting the date and time of arrival at the final destination.

The Final Consumer in the role of Quality Tester selects the product and scans the QR Code to access the information that has been uploaded to the platform. After purchasing the product, the Final Consumer has the opportunity to review it based on their opinions.

4.4. Processes

In this section, the main processes involved in tracking agrifood products are described in detail.

The first process covers the entire journey of the products, beginning with their production, moving through quality control, and concluding with their delivery via a logistics company. This sequence is repeated for each product or package, depending on the type.

Next, the data registration process by the producer is outlined. The producer logs into the platform using their credentials (username and password). Once authenticated, they can register information for each product or package on the blockchain. This involves activating a smart contract, which validates the transaction and allows data entry into the blockchain. Following this, the producer hands the product to the Certification Body for the next phase.

The third process involves product certification. The Certification Body records a video to verify product quality and uploads it to an offchain storage. Then, it accesses the platform to upload the video's metadata and hash value to the blockchain via a smart contract. After certifying the product quality based on the blockchain data, an intermediary generates a QR Code for the product or package, which the producer attaches. The products are then ready for delivery to the shipping company.

Finally, the shipping process is described. A shipping company operator logs into the platform to notify the blockchain of the delivery takeover. The operator records traceability data and the date/time of delivery, with data entry performed through a smart contract activation as previously described.

5. Blockchain Implementation Issues

The selection of an appropriate DLT framework is crucial for the success of any blockchain-based application. In this project, we considered both public and private blockchain architectures due to their distinctive characteristics and suitability for different types of applications.

Public blockchains, such as Ethereum, offer decentralization, immutability, and transparency. They allow anyone to participate and view transactions, which is ideal for applications that benefit from public scrutiny and full transparency. However, the main drawbacks include lower transaction throughput, higher latency, and less privacy, which may not be suitable for supply chain applications where business sensitivity and scalability are concerns.

Private blockchains, such as Hyperledger Fabric, provide controlled access and more privacy while maintaining many of blockchain's core benefits. They are optimized for high transaction speed and scalability, which are essential for managing the complex and large-scale transactions typical in supply chain management. The cons include less decentralization, which could potentially compromise the trust model that blockchain aims to enhance.

After evaluating both types of blockchains, Hyperledger Fabric was selected for the following reasons:

- **Performance and Scalability:** Hyperledger Fabric offers higher transaction throughput and lower latency compared to public blockchains. It is well-suited for the high demands of supply chain operations.
- **Privacy and Security:** Fabric's channel architecture and private data collections enable a more granular control over privacy and confidentiality, allowing businesses to share data selectively.
- **Modularity:** The modular architecture of Fabric allows it to be tailored to a wide range of industry use cases. It supports pluggable consensus protocols, which can be configured to balance between decentralization and efficiency.
- **Governance and Compliance:** Being a permissioned blockchain, Fabric enables better governance and adherence to compliance requirements, critical factors for applications within regulated industries such as agriculture and food safety.

These features make Hyperledger Fabric a compelling choice for our DLT-based framework intended for enhancing traceability in local agrofood product supply chains. Its ability to handle complex operations while ensuring data privacy and regulatory compliance aligns well with the goals of our project.

Hyperledger is an open source collaborative project initiated by the Linux Foundation in 2015 to promote blockchain digital technology and transaction verification [22]. It is the first distributed ledger platform for enterprise application scenarios. Fabric is the most important application project of Hyperledger technology, which is a general license blockchain with modular and extensible characteristics, follows the execution-sequence-validation paradigm and fundamentally deviates from the order-execution model.

Hyperledger Fabric has been used in [12] to establish consortium chains and smart contracts in their tracking framework for agricultural food supply chain.

It is proposed to adopt Hyperledger Fabric technology, which supports the existence of a varied and heterogeneous set of nodes, cooperating to support DLT services in business environments, by readjusting or eliminating non-relevant cost factors, such as cryptocurrencies or the proof of work paradigm. Indeed, Fabric operates on a voting-based paradigm to reach a consensus on the value of the recorded data. In particular, Fabric automates and internally manages many needs that need to be supported ad hoc in more public-oriented DLTs. Among these, the three most important are:

1. User Identity, managed autonomously via X.509 certificates within the network.
2. Lifecycle of Smart Contracts, including any code updates, so as not to report losses to data managed by old versions of the same contract.
3. Division of the network into areas of competence and management by different organizations, to better distribute governance skills, as well as the criteria for belonging and roles of users related to the same organizations.

Furthermore, unlike other distributed ledger networks, Hyperledger Fabric has, structurally, different types of nodes:

- **Peer Nodes:** tasked with a dual role
 - Distributed storage of copies of the Ledger.
 - Parallel execution of smart contracts, following the invocation of a signed transaction towards a subset of peer nodes. The resulting value given by the invocation triggers cross-checks between the invoked peers, to ensure their identity and the non-dissimilarity of the result of the computation.
- **Orderer Nodes:** whose task is the temporal ordering of approved transactions into blocks, to be distributed to peers not involved in the initial assessment, for updating.
- **CA Nodes:** X.509 Certificate Authorities, for the distributed management of the Public Key Infrastructure (PKI), essential for the mutual authentication of the various messages circulating in the network, between users and between the different nodes. They are managed by the various present organizations, according to specifiable roles and hierarchical organization charts, in order to reflect the real interdependence of the present users.

- **MSP (Membership Service Providers):** microservices belonging to the various nodes, with the task of authenticating users through their certificates (issued by the CAs), with related roles, present on the certificates themselves.

We envision the creation of a dedicated Smart Contract, devoted to the tracking of the production process of certified agricultural goods. The process involves the interaction, at certain critical moments, of actors corresponding to an identity on Hyperledger Fabric. The corresponding data describing a precise critical moment will be incorporated into a Hyperledger Fabric transaction. While the actors responsible for that critical moment will sign, under their responsibility, the correct execution of the controls, at that particular critical moment, corresponding to a globally valid timestamp.

The responsibility for the blockchain infrastructure will be shared by the entire production chain, so as not to give full control of the data to a single entity.

For this type of certified interaction, it is plausible to include in the information flow of documentary files. They, in general, will always have a size of orders of magnitude greater than the data sent in the context of a transaction.

In this situation, the best choice is to generate a link between a unique identifier of the file (for example a hash), and store this last one in the context of a certified transaction on DLT, while the file itself will be stored in an off-chain repository. Obviously, this repository will have to provide some guarantee about its solidity and will have to be, as far as possible, protected from unwanted access. How to add to the described flow, levels of encryption, so as to make the file itself, deposited in the file storage, accessible only to one, or a group, of users. The unique identifier that will remain firmly guarded on the ledger will serve as control, both for the existence of the file at that precise historical moment, but also for validation at later times. In fact, it will be possible to verify if, in the meantime, the file has been modified. The issues of handling the integrity of off chain agricultural data has been recently investigated in [11].

In our approach, we add an additional level of trust by applying, together with the tracking via Blockchain Hyperledger Fabric, also the certified time-stamping of the data pertaining to the critical moment, files included. This last procedure will make use of a TSA.

Also known as a Time Stamping Authority, it is a centralized service that applies a timestamp to an electronic document to attest that an event has occurred at a specific time. The timestamp is a sequence of characters that indicates a time, but the marking does not certify the moment when the document was created; rather, it certifies the moment of its transmission and marking. The main goal of this service is to provide unequivocal proof of the temporal location of a document, enforceable against third parties. To achieve this goal, the service synchronizes its clock with an authoritative source to ensure maximum temporal precision. Furthermore, since the timestamp is issued by a reliable entity, it acquires legal value. The validity of a timestamp is limited in time, and the holder must request an extension from the TSA responsible for the issue to continue to benefit from it.

The result of the marking consists of a Time-stamp token (TST), which represents proof of the existence of the electronic document.

6. Conclusion

In this paper, we explored the potential of Distributed Ledger Technologies (DLTs) to enhance traceability in local agrifood supply chains, particularly within the context of agro-touristic economies. DLTs provide a robust framework for ensuring transparency, efficiency, and security in tracking local food products, which in turn bolsters food safety, supports local economies, and strengthens consumer trust. The adoption of DLTs is seen as a transformative step for the agrifood and agritourism sectors, enabling sustainable practices and economic empowerment.

Our proposed framework leverages DLTs to improve product traceability and quality certification while fostering the sustainable growth of local resources. This integration aims to unlock the potential of agritourism, promoting a sustainable, economically empowered sector that aligns with modern consumer expectations.

However, implementing a DLT-based traceability system presents its unique set of challenges, particularly in defining and managing the system requirements. To address these complexities, we utilized the Goal Oriented Requirements Methodology (GOREM), which aided in developing a structured and effective approach to integrating DLTs into the agrifood supply chain. This methodology facilitated the identification of crucial application scenarios and their requirements, ensuring a targeted and successful deployment of the DLT framework.

Current efforts are focused on deploying a DLT-based system for traceability and testing its application in the local agrifood and agritourism supply chains. The objective is to transform these industries by enhancing traceability, promoting sustainability, and fostering economic growth.

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