LocalChain: Traceable and Certificated Agri-Food Local Supply Chains

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***Abstract*—This paper presents a blockchain-based prototype software for the agri-food supply chain, developed within the LocalChain project. The software aims to provide a secure and transparent way to track and verify the origin, quality, and sensorial characteristics of local products. The paper discusses the benefits and challenges of using blockchain technology in the agri-food sector and proposes a model for its application in a local supply chain.**

***Index Terms*—Blockchain in Supply Chains, Traceability, Agri-food certifications, Sensory analysis**

I. Introduction

Blockchain technology (BCT) is being increasingly adopted in agrifood supply chains to ensure transparency, traceability, and auditability [1]. IoT sensors are integrated with blockchain to collect and transmit data on environmental conditions, farming practices, and product quality, enabling real-time monitoring and efficient traceability, particularly for consumers' satisfaction. Furthermore, certifications are being integrated into blockchain-based traceability systems to ensure the authenticity and quality of food products [1]. BCT is also being explored for its potential to enhance sustainability in local food supply chains by promoting transparency, reducing waste, and improving supply chain efficiency [2]. All these considerations demonstrate how blockchain is becoming more and more a key enabling technology within a modern Smart City, to improve the citizens' knowledge about the origins, sustainability and quality of food.

Nonetheless, adopting blockchain in the agri-food domain still presents several challenges, in particular in local food supply chains, where actors are not used to interact with this technology. Storage costs are significant due to the vast amount of data generated, including transaction records and quality checks. To address this issue, actors should leverage a blockchain-based system that provides support to choose among information to be stored on-chain and information to be saved off-chain. On-chain data storage faces high costs, scalability issues, and inefficiency, while off-chain storage introduces security and availability concerns. Balancing both methods is therefore crucial. A second challenge concerns providing non-skilled actors with a simple interface to interact with the blockchain. A data-centric focus has fostered the adoption of resource-oriented approaches, leveraging the widely recognised REpresentational State Transfer (REST) architecture to model the interaction of actors with BCTs. By treating traceability data to be exchanged among actors as resources, rather than focusing on the specific storage technologies, it is possible to enable standardized interactions of actors with different BCTs through lightweight APIs. However, existing approaches [3], [4] propose ad-hoc solutions based on a specific BCT, they do not specifically address food traceability using RESTful APIs and they do not delve into details concerning on-chain data storage costs.

In this paper, we describe the application of BCT to traceability of products in a local food supply chain, as addressed in Localchain, a research project funded by Lombardy region. The research activity started from the definition of a data conceptual model focused on products/lots and a set of predefined activities performed by supply chain actors (e.g., creation, transformation, acquisition/provisioning, distribution). This data-centric approach guided the implementation of simple Smart Contracts for the interaction with the blockchain and the design of a tracking application on top of the distributed ledger, targeted to both supply chain actors and final consumers. The project topics matches the reference architecture of the CINI National Lab on Smart Cities and Communities, being BCT a modern distributed storage system to develop new smart agriculture applications for potentially untrustworthy environments.

II. Traceability Data Model

Figure 1 shows the traceability data model designed in the Localchain project. The model is built around the food supply chain for the production and retailing of a specific product, described by a `ProductType`. The supply chain is modelled as actors and phases, where in each phase `Lots` are created, transformed, distributed and transferred between actors. The above mentioned actions on lots are represented as `Activities` and determine the generation of new lots starting from existing ones (for example, bottling corresponds to the creation of a lot of bottles from a lot of wine stored in barrels). Actors perform activities on the lots within `Sites`, that correspond to the origins of the lots. Every element in this conceptual model, including lots, sites (origins), activities and actors, can be certified by attaching further information in

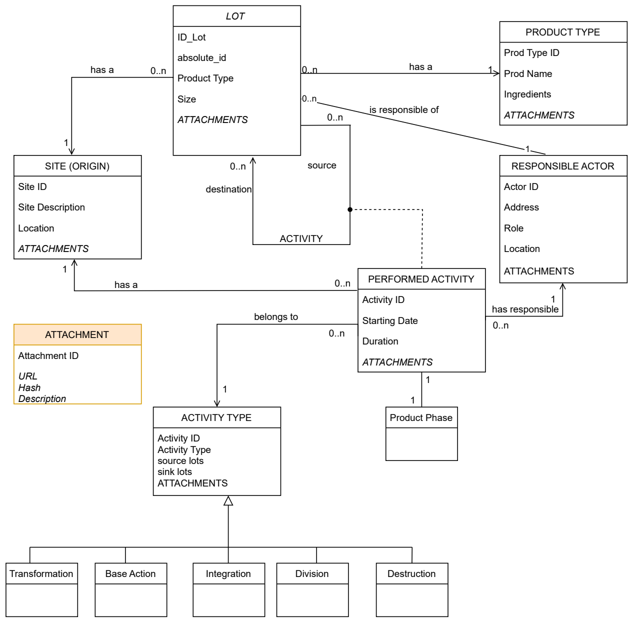

Fig. 1. Model of the traceability data.

the form of documental certifications (e.g., sensory analysis documents). Every actor is in charge of storing information regarding his/her activities on the blockchain, for traceability purposes. Moreover, in implementing RESTful APIs, the conceptual model is helpful for identifying and detailing resource requirements, particularly regarding their persistence, whether on-chain or off-chain. Examples of these requirements include scalability based on data size, audit requirements, and restrictions on the visibility of specific information.

III. Implementation

The Localchain implementation is articulated over the following steps: (i) *resources modelling*, which leverages a conceptual model to describe supply chain data to be stored on the blockchain as *resources*; (ii) *service modelling*, to design *Resource-Oriented Services*, exposed through a REST API, hiding the complexities of resource persistence; (iii) *software components definition*, as software components are responsible for handling invocations of the REST API regarding publishing/reading resources to/from the blockchain, and executing possible actions on resources, namely, POST component and GET component, respectively; (iv) *mapping of storage methods*, to implement the interaction of software components with the blockchain, in our case Ethereum, (e.g., to access Smart Contracts functionalities) as well as the interaction with other data stores or persistence providers (e.g., decentralised external file systems).

In the scope of a POST/GET request, depending on the desired type of resource persistence, the corresponding POST/GET component relies on: (i) methods of Smart Contracts, identified by their address on the blockchain, apt to store (resp., read) data on the blockchain; (ii) methods of External File Storage, to upload (in the case of POST) or retrieve (in the case of GET) raw files from a decentralised external storage system. The obtained unique identifier for each file is then stored on the blockchain using the functionalities provided by (i). On the other hand, RESTful APIs are independent from any specific BCT or decentralised storage system. On top of RESTful APIs, a Web GUI has been developed to enable supply chain actors to save/read lots information (either stored on-chain or off-chain, depending on the business logic implemented within the POST/GET components). Figure 2 shows an example of a bottle traceability data in the consumer's Web GUI.

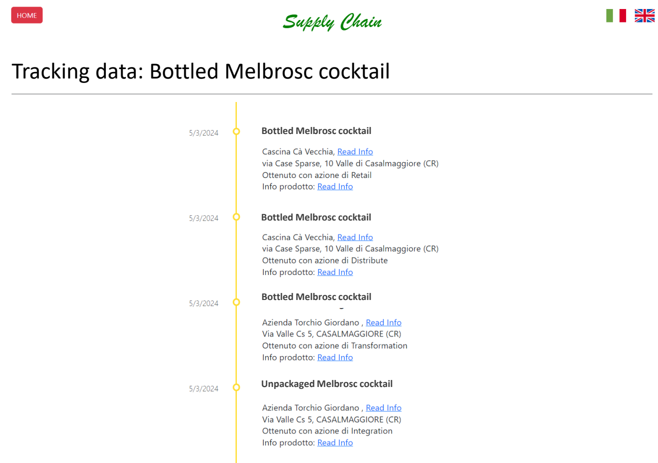

Fig. 2. Example of a bottle traceability data for the consumer.

IV. Conclusion and Future Work

The paper briefly reports on the experience in the application of BCT to traceability of products in local food supply chains. In the research experience, two issues have been addressed: limiting blockchain storage costs and providing non-skilled actors with a simple interface to interact with the blockchain. The adopted solution leverages: (i) a conceptual model to describe supply chain data to be stored on-chain or off-chain; (ii) RESTful Services, exposed through a REST API, to hide the complexities of underlying data persistence. Future research will consider, for example, the adoption of other blockchains, like IOTA, which is designed for IoT-based data and is crucial for Agri-Food 4.0 applications.

References

[1] R. M. Ellahi, L. C. Wood, and A. E.-D. A. Bekhit, "Blockchain-based frameworks for food traceability: A systematic review," *Foods*, vol. 12, no. 16, 2023. [Online]. Available: https://www.mdpi.com/2304-8158/12/16/3026

[2] L. Compagnucci, D. Lepore, F. Spigarelli, E. Frontoni, M. Baldi, and L. Di Berardino, "Uncovering the potential of blockchain in the agri-food supply chain: An interdisciplinary case study," *J. Eng. Technol. Manag.*, vol. 65, p. 101700, 2022.

[3] I. Román-Martínez et al., "Blockchain-based service-oriented architecture for consent management, access control, and auditing," *IEEE Access*, vol. 11, pp. 12 727–12 741, 2023.

[4] G. Falazi *et al.*, "Smart Contract Invocation Protocol (SCIP): A Protocol for the Uniform Integration of Heterogeneous Blockchain Smart Contracts," in *32nd Int. Conf. on Advanced Inf. Systems Engineering (CAiSE 2020)*, 2020, pp. 134–149.