FOOD TECH BLOCK CHAIN USING PYTHON

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ABSTRACT

Ensuring high quality and safety of food products has become a key factor on one hand to protect and improve consumers health and, on the other one, to gain market share. For this reason, much effort in the last year has been devoted to the development of integrated and innovative Agriculture and Food (Agri-Food) supply chains management systems, which should be responsible, in addition to track and store orders and deliveries, to guarantee transparency and traceability of the food production and transformation process. In this paper, differently from traditional supply chains which are based on centralized systems, we propose a fully distributed approach, based on blockchain technology, to define a supply chain management system able to provide quality, integrity and traceability of the entire supply chain process. The proposed framework is based on the Hyperledger Fabric technology, which is a permissioned blockchain system: a prototype has been developed and, by using some use cases, we show the effectiveness of the approach.

1. INTRODUCTION

The recent attention on food safety and product quality requires more reliable and efficient processes for the management of agri-food supply chains ([15, 21]). Government authorities need to respond more promptly to food scan- dals and accidents to maintain customer confidence in the food industry. To this end, ensuring the traceability of food products allows to provide consumers with a complete view of the different phases of product harvesting, processing and distribution ([5, 10, 20]). Many of the management processes of current supply chains have been automated to reduce operational costs and errors and to improve the monitoring and collection of information related to the various activities within the supply chain. Therefore, by collecting and making accessible the set of traceability information of a product, it is possible for consumers to know about the entire life cycle of that product, its related transactions and chain of owners and its provenance.

However, one of the issues of today's supply chain management systems is that they are often based on centralized systems: supply chain processes and product traceability data are managed by a single authority on which supply chain members rely on to transfer and share their informa tion. These centralized systems are often non-transparent, monopolistic and asymmetric information systems. This can pose a serious threat to the security and reliability of the traceability information and make fraud, corruption and data falsification easier ([23]). Furthermore, another issue with such centralized systems is related with the risk of a single authority to become the weak link and single point of failure. Also operation throughput and scalability are limited.

To deal with such issues, the usage of blockchain technology in this domain has recently been proposed to support the management of supply chain traceability ([2, 12, 27]). Blockchain technology in particular offers cryptographic primitives to store data within a distributed ledger, guaran- teeing their immutability and authenticity. The decentraliza tion that blockchain provides reduces the risk of data loss and corruption. In particular, whenever an actor attempts to change data on the blockchain, network participants would be immediately aware of the tampering upon inspection of the chain. This eliminates the need for supply chain members to trust a single entity to manage their traceability information. Furthermore, being a distributed system, the blockchain can mitigate the problems of limited scalability and single point of failure. If, on the one hand, the use of a blockchain implies an additional overhead with respect to a centralized system, on the other one the higher management costs are compensated by a higher traceability and visibility on supply chain operations.

In this paper, by extending our previous work presented in [17], we propose a complete model of a blockchain based agri-food supply chain traceability system providing a proto- type implementation to show the applicability of blockchain technology in this domain. The main focus of the system is to take advantage of the blockchain features to allow supply chain members to store and manage product-related trace- ability information in a transparent, reliable and tamper- proof way. Using this information final consumers can then reconstruct a complete history of the transactions related to a product during its life cycle. Transactions of the real world, involving transformations and exchanges of physi- cal goods, proceed as usual. Our framework registers and stores information about these transactions, but how this information are generated and retrieved is out of the scope of our work. The main goal of the proposed approach is to make supply chain transactions traceable and verifiable by external users. The business logic of the system is executed by a smart contract that allows to automate some of the management processes related to supply chain activities. The smart contract offers operations that can be invoked by the supply chain members to store and update traceability information. The proposed system also makes it possible to associate rules with supply chain products, allowing the expression of product-specific quality control mechanisms. This functionality has been included considering that in the context of agri-food supply chains the regulatory aspects are of fundamental importance to ensure food safety and qual- ity, also taking into account that these aspects vary from a case to another one and dynamically evolve over time ([8]). The system was implemented using the Hyperledger Fabric1 blockchain, an emerging open-source technology widely used also in other proposed examples of supply chain management systems ([25]). In addition, the components of our system are deployed in a cloud environment within a Kubernetes2 cluster, showing that, although our system is a prototype, it can be easily migrated to a scalable production environment. Finally, to show the behaviour of our system and the effectiveness of the approach, we present two slightly different use cases where the main features of the prototype are demonstrated.

2. LITERATURE SURVEY

There is a variety of works that propose the use of blockchain technology to build agri-food supply chain management systems and in some cases implementations of such systems are also proposed. Some of these works are briefly described below.

In Malik et al. [16] a permissioned blockchain system, called Product Chain, is proposed. The system is administered by a consortium of entities participating in a generic food supply chain, including governmental and regulatory entities. It stores product traceability information made accessible to consumers. The authors propose the use of a three-tier sharded architecture that ensures reliability and availability of data for consumers and scalability with respect to transaction execution throughput. They also propose the use of a transaction vocabulary and the implementation of access control mechanisms to manage read and write privileges on the blockchain.

Wang et al. [24] propose a product traceability system based on the Ethereum blockchain and the smart contract primitive. The system stores information related to the products life cycle and also provides for the implementation of eventresponse mechanisms to verify the identities of both parties of all transactions at the time of their sub- mission, so that their validity is guaranteed. All the events are kept in the system permanently so that any disputes can be managed and the responsible for certain actions can be traced.

In Caro et al. [6] the AgriBlockIoT is proposed, a totally distributed and blockchain-based supply chain management system, able to integrate multiple IoT devices that collect and produce digital data along the supply chain. To efficiently evaluate AgriBlockIoT, the authors defined a use case based on the from-farm-to-fork model. This use case was then implemented using two different blockchain systems, namely Ethereum and Hyperledger Sawtooth.

Casino et al. [7] propose a distributed functional model based on blockchain to create distributed and automated traceability mechanisms for a generic agri-food supply chain. To evaluate the feasibility of the proposed model, a use case is presented. The applicability of the model is also illustrated through the development of a fully functional smart contract and a private blockchain.

Tian [11] propose a food supply chain traceability system for real-time food tracing based on HACCP (Hazard Analysis and Critical Control Points), blockchain and the Internet of Things, which provides a platform that ensures openness, transparency, neutrality, reliability and security for trace- ability information. The proposed system uses big chain DB, which combines the key benefits of distributed databases and blockchain.

Biswas et al. [4] propose a blockchain-based system to achieve the traceability of the activities that occur within the supply chain related to wine production. The proposed traceability system uses MultiChain to implement a private blockchain.

Shahid et al. [22] present a complete solution for block- chain-based agri-food supply chains. The proposed solution leverages the key features of blockchain and smart contracts, deployed over Ethereum blockchain network. All transactions are written to the blockchain which ultimately uploads the data to Interplanetary File Storage System (IPFS). The storage system returns a hash of the data which is stored on blockchain and ensures an efficient, secure and reliable solu- tion. Authors provide simulations and evaluation of smart contracts along with the security and vulnerability analyses.

Cocco et al. [9] propose a blockchain-based system for the supply chain management of a particular Italian bread. To realize the system authors relied on the blockchain and the Internet of Things technologies to provide a trustless environment. The system is designed so that along the sup- ply chain, the nodes equipped with several sensors directly communicate their data to Raspberry Pi units that elaborate and transmit them to IPFS and to the Ethereum blockchain. Furthermore, authors designed ad hoc Radio Frequency Identification and Near Field communication tags to shortly supply the proposed system with information about the prod- ucts and batches.

Baralla et al. [3] present a blockchain oriented platform to guarantee the origin and provenance of food items in a Smart Tourism Region context. The proposed solution uses smart contracts in order to guarantee transparency, efficiency and trustworthiness. The system is particularly suitable to man- age cold chain since it interfaces with IoT network devices providing detailed information about data monitoring food such as storage temperature, environment humidity, and GPS data.

Marchesi et al. [18] propose a general-purpose approach for the blockchain-based agri-food supply chain management, proposing a system that can be configured for most agri-food productions. The primary purpose is to provide a methodology to facilitate and make more efficient the devel opment of supply chain management applications that make use of blockchain technology. It is based on general smart contracts and apps interacting with the same smart contracts, which are configured, starting from the description of the specific system to be managed, using JSON files.

Like the aforementioned research works, in our work we propose a complete solution of a blockchain-based agri-food traceability system, providing, in particular, a description of the architectural components, the information model and the business logic of this system. A distinctive contribution of our work, is the capability to allow the specification of cus- tom regulations for supply chain products at runtime and to automate the validation of these regulations. Our framework has addressed this aspect considering the heterogeneity of product regulations among supply chains and the fact that these regulations change over time.

3. PROPOSED WORK

Blockchain Technology and Hyperledger Fabric Blockchain technology represents a particular class of dis- tributed systems and as such was born with the aim of over- coming some of the problems related to centralized systems ([13, 14]). The application area in which the blockchain was initially introduced is that of transactional systems, in particular electronic payment systems. That is the case, for example, of the Bitcoin blockchain ([19]). However, today blockchain technology is increasingly being adopted in a lot of different application domains.

In general, operations within a blockchain are carried out by nodes connected to each other through a peer-to-peer network. In public blockchains, like Bitcoin, every node can participate in network operations and can decide to exit at any time. Each node participating in the blockchain maintains a local copy of a distributed ledger which contains a set of append-only logs that encode the status information of the blockchain. More specifically, an ordered sequence of blocks is stored inside the ledger. Each block consists of a header and a body that contains an ordered list of transactions which are validated and executed by the peers of the network. To guarantee the immutability and reliability of the data in the ledger, each block of the sequence contains a cryptographic hash of the previous block within a header field. In this way a malicious attempt to change the content of a block would require to correspondingly modify the header of all the fol- lowing blocks in the sequence, which is a computationally expensive task thanks to the non-invertibility property of hash functions. Peer nodes of a blockchain coordinates with each other throughout a consensus protocol. Public block- chains typically use secure but computational expensive consensus protocols, like for example the proof of work protocol. This is motivated by the fact that any node can join a public blockchain and this makes this type of block- chains an untrusted environment. The use of a computational expensive consensus protocol poses some scalability issues and transaction throughput limitations.

Permissioned blockchains are another category of block- chains. In a permissioned blockchain, only authorized peers can participate in blockchain operations. Permissioned blockchains often set aside proof of work consensus protocol because of its nondeterminism and the computational burden it imposes on peer nodes. Instead, they adopt weaker but more performant consensus mechanisms based on traditional protocols from distributed computing, such as Paxos, Raft and Byzantine fault-tolerant algorithms. This is possible because in a permissioned blockchain membership is limited only to a well-known set of entities and this involves less security risks. Agri-food supply chains fit well in the context of permissioned blockchains ([26]). In an agri-food supply chain scenario a limited set of organizations, whose identities are known, are supposed to actively participate in supply chain operations. Organizations typically don’t trust each other, but they need read and write access to a trusted shared data repository. While the presence of an always- online trusted third-party authority that manages all supply chain operations allows to avoid the use of a blockchain, this is not always a realistic scenario. In some situations it is not possible to have a single authority trusted by all parties and delegating all the write operations to a centralized entity can cause it to become a single point of failure. Although the use of a blockchain can limit transaction throughput, the decentralized nature of the blockchain technology allows to obtain better scalability and to solve the single point of failure issue.

Hyperledger Fabric is an open-source blockchain platform, which falls within the category of permissioned block- chains ([1]). Hyperledger Fabric is a distributed operating system that runs applications written in general-purpose programming languages, such as Go, Java, JavaScript, and Python. It introduces the execute-order-validate blockchain model for transaction processing unlike other traditional blockchain systems that use the order-execute model. In the order-execute model a protocol for consensus first orders the transactions and propagates them to all peers that execute the transactions sequentially. This model requires that all trans- actions must be performed sequentially by each peer, and this implies several performance limitations. Furthermore, transactions must be deterministic, which is not always easy to ensure. On the other hand, the execute-order-validate model separates the transaction flow into three steps: the execution of the transaction and check of its correctness, the transaction ordering through a consensus protocol and the transaction validation. In this model, each transaction is executed and checked only by a subset of the peers, which allows for parallel execution and addresses potential non-determinism. This allows to overcome the limitations of the execute-order model mentioned above.

Like some other blockchains, Hyperledger Fabric offers the smart contract primitive. A smart contract is a combination of data and code that encodes a set of transformations on that data. It exposes a set of operations that can be invoked by the users of the blockchain with the aim of changing the state of the distributed ledger. The concept of smart contract, therefore, makes this kind of blockchain a distributed execution environment of general-purpose programmable logic.

Thanks to the aforementioned properties, blockchain technology is a good candidate to address some of the actual problems related to traditional centralized agri-food supply chain traceability systems. In particular, it can guarantee the transparency, verifiability and immutability of traceability data, simplifying the information sharing between the sup- ply chain entities often belonging to distinct administrative organization. In this way the traceability of the supply chain products can be guaranteed, allowing the consumer to recon- struct the entire product’s life cycle within the supply chain and to verify its origin and authenticity. Finally, smart con- tracts can be used to automate the supply chain management and product quality control operations. Although the use of the blockchain technology implies additional overhead than in the case of a centralized system managed by a single authority, this overhead is covered by the interest of supply chain members to produce certified and traceable products to increase consumer trust. In the same way, final consumers would pay more for validated products.

SYSTEM ARCHITECTURE

This section provides a high-level description of our block- chain-based system for agri-food supply chain traceability, the goals that guided its design and its general architecture. The proposed system is designed to manage the trace- ability information of products and activities related to one or more agri-food supply chains. The main objective is to allow to reconstruct the entire flow of activities and transactions related to a product from its origin to the end consumer. The system has to automate all those operations related to product quality control and regulatory compliance. It has to be able to dynamically adapt to changes in laws and regulations. It should also be scalable, able to handle an ever-increasing amount of information. Finally, the system has to guarantee reliability and availability, especially when dealing with environments characterized by continuous flows of transactions.

The fundamental part of the framework consists of a permissioned blockchain, implemented through the Hyperledger Fabric framework ([1]). In this blockchain, the core of the system's business logic is executed in the form of a smart contract. The smart contract offers several operations that allow users of the system to add and modify information in the blockchain in a secure and traceable way. Users of the system are the supply chain members and the regulatory departments. The former add and modify information related to their products, while the latter deal with the management and regulation aspects of supply chains. More specifically, the entities participating in the system operations are user organizations, where each user is identified by a certificate issued by a certification authority associated with the organization to which the user belongs. Since the blockchain is permissioned, only a well-defined set of organizations can participate in the system operations. In Hyperledger Fabric the set of organizations participating in blockchain operations is predetermined. Hyperledger Fabric allows to add a new organization or remove an existing one at run-time by sub- mitting a series of transactions to the blockchain that must be approved by a majority of the participating organizations. In this work, we have not considered the ability to add or remove dynamically organizations to the blockchain and this is something that can be evaluated and included in our system in a future work.

The interaction between users and the blockchain takes place through a client application that runs within an application server and the interaction with the latter takes place through a frontend application that is typically hosted by a web server. Each organization has its own application server and web server.

Each organization has its own role that defines its inter- actions with the system and the operations it can perform. According to common models of agri-food supply chain described in [11, 24] we consider the following roles:

- Producer: organization that requires the registration of one or more primary products (i.e. products whose batches do not derive from any other batch). If a registration request is accepted, this organization can register batches associated with the registered product or products in the system.

- Manufacturer: organization that requires the registration of one or more derived products (i.e. products whose batches derive from batches of other primary or derived products). If a registration request is accepted this organization can register batches associated with the registered product or products in the system, specifying a list of batches from which the registered batch derives.

- Deliverer: organization that buys batches from organizations and resells them to other organizations.

- Retailer: organization that sells products to consumers.

- Regulatory Department: organization that manages and monitors the activities within the various supply chains. More specifically, an organization with the role of Regulatory Department adds product types to the system, associating them with rules and assigning roles to the various organizations.

4. CONCLUSIONS

A complete model of a blockchain-based agri-food supply chain traceability system has been proposed in this work, also showing a prototype implementation. The system is based on the Hyperledger Fabric permissioned blockchain, a category of blockchain where participation is limited to a well-defined set of members. This type of blockchain fits well in the context of agri-food supply chains because typically only a limited set of organizations can participate in supply chain operations. By using blockchain technology, supply chain traceability data can be stored in a more trans- parent and reliable way with respect to using a centralized entity. Furthermore, as a fully distributed system, blockchain mitigates the problems of limited scalability and single point of failure. The proposed system allows to automate supply chain management operations with the use of the smart con- tract primitive and maintain traceability information in a transparent, secure and immutable way. Moreover, the system gives the possibility to add and modify rules at runtime and this allows to implement product-specific quality control mechanisms. Finally, the system provides a complete view of the different phases of harvesting, processing and distribution to which batches of product are subject allowing to reconstruct the entire life cycle of each batch, also obtaining provenance information.

5. REFERENCES

1. Androulaki E, Barger A, Bortnikov V, et al. Hyperledger fabric: A distributed operating system for permissioned blockchains. In: Proceedings of the Thirteenth EuroSys Conference, EuroSys ’18, 2018; https://doi.org/10.1145/3190508.3190538

2. Antonucci F, Figorilli S, Costa C, et al. A review on block- chain applications in the agri-food sector. J Sci Food Agricult. 2019;99(14):6129–38. https://doi.org/10.1002/jsfa.9912.

3. Baralla G, Pinna A, Tonelli R, et al. Ensuring transparency and traceability of food local products: A blockchain application to a smart tourism region. Concurrency and Computation: Practice and Experience, 2021;33(1). https://doi.org/10.1002/cpe.5857

4. Biswas K, Muthukkumarasamy V, Lum W. Blockchain based wine supply chain traceability system. In: Future Technologies Conference (FTC 2017), 2017; 56–62

5. Bosona T, Gebresenbet G. Food traceability as an integral part of logistics management in food and agricultural supply chain. Food Control. 2013;33(1):32–48. https://doi.org/10.1016/j. foodcont.2013.02.004.

6. Caro MP, Ali MS, Vecchio M, et al. Blockchain-based trace- ability in agri-food supply chain management: a practical imple- mentation. In: 2018 IoT Vertical and Topical Summit on Agri- culture - Tuscany (IOT Tuscany), 2018; 1–4 https://doi.org/10. 1109/IOT-TUSCANY.2018.8373021

7. Casino F, Kanakaris V, Dasaklis T, et al. Modeling food sup- ply chain traceability based on blockchain technology. IFAC- PapersOnLine. 2019;52:2728–33. https://doi.org/10.1016/j. ifacol.2019.11.620.

8. Chen K, xin WANG X, ying SONG H,. Food safety regula- tory systems in europe and china: A study of how co-regulation can improve regulatory effectiveness. J Integrative Agricult. 2015;14(11):2203–17. https://doi.org/10.1016/S2095-3119(15)

61113-3.

9. Cocco L, Mannaro K, Tonelli R, et al. A blockchain-based traceability system in agri-food sme: case study of a traditional bakery. IEEE Access, 2021;9:62,899–62,915. https://doi.org/ 10.1109/ACCESS.2021.3074874

10. Dabbene F, Gay P, Tortia C. Traceability issues in food supply chain management: a review. Biosyst Eng. 2014;120:65–80. https://doi.org/10.1016/j.biosystemseng.2013.09.006.

11. Feng Tian. A supply chain traceability system for food safety based on haccp, blockchain internet of things. In: 2017 interna- tional conference on service systems and service management, 2017;1–6. https://doi.org/10.1109/ICSSSM.2017.7996119

12. Galvez JF, Mejuto J, Simal-Gandara J. Future challenges on the use of blockchain for food traceability analysis. TrAC Trends Anal Chem. 2018;107:222–32. https://doi.org/10.1016/j.trac. 2018.08.011.

13. Gamage HTM, Weerasinghe HD, Dias NGJ. A survey on blockchain technology concepts, applications, and issues. SN Comput Sci. 2020;1(2):114. https://doi.org/10.1007/ s42979-020-00123-0.

14. Kolb J, AbdelBaky M, Katz RH, et al. Core concepts, challenges, and future directions in blockchain: A centralized tutorial. ACM Comput Surv, 2020;53(1). https://doi.org/10.1145/3366370

15. Li D, Wang X, Chan HK, et al. Sustainable food supply chain management. Int J Prod Econ. 2014;152:1–8. https://doi.org/10. 1016/j.ijpe.2014.04.003.

16. Malik S, Kanhere SS, Jurdak R. ProductChain: Scalable block- chain framework to support provenance in supply chains. In: NCA 2018 - 2018 IEEE 17th international symposium on network com- puting and applications, 2018; https://doi.org/10.1109/NCA.2018. 8548322

17. Marchese A, Tomarchio O. An agri-food supply chain traceability management system based on hyperledger fabric blockchain. In: Proceedings of the 23rd international conference on enterprise information systems - Volume 2: ICEIS,, INSTICC. SciTePress, 2021; 648–658 https://doi.org/10.5220/0010447606480658

18. Marchesi L, Mannaro K, Porcu R. Automatic generation of block- chain agri-food traceability systems. In: 2021 IEEE/ACM 4th international workshop on emerging trends in software engineer- ing for Blockchain (WETSEB), 2021;41–48. https://doi.org/10. 1109/WETSEB52558.2021.00013

19. Nakamoto S. Bitcoin: A Peer-to-Peer Electronic Cash System. 2008; https://bitcoin.org/bitcoin.pdf

20. Olsen P, Borit M. The components of a food traceability system. Trends Food Sci Technol. 2018;77:143–9. https://doi.org/10. 1016/j.tifs.2018.05.004.

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