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A community-based hybrid blockchain architecture for the organic food supply chain

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***Abstract* - This paper presents a novel blockchain architecture to incorporate community-level trust into the organic food supply chain by hybridizing Proof of Authority (PoA) and Federated Byzantine Agreement (FBA) consensus protocols. Community-level trust is an important aspect in the organic agriculture industry. Organic farming, in most parts of the world, happens in small scale farms where the farmers represent rural and less-privileged communities. Even though third-party certification systems exist for quality assurance in organic farming, due to many socio-economic reasons, participatory guarantee systems (PGS) have become a popular alternative among organic farmers and consumers. However, such participatory guarantee systems are still prone to frauds and have limitations in scalability as well. With the recent rise of blockchain technology, there is an emerging trend to adopt blockchain technology to enhance the credibility of organic food supply chains and mitigate the risk of fraudulent transactions. However, despite the popularity of participatory guarantee systems among organic farmer communities, the blockchain researchers have paid little attention to develop blockchain architectures by adopting the community-level trust into their consensus protocols. The hybrid consensus mechanism presented in this paper addresses that gap in existing blockchain research. Apart from discussing the details of the proposed blockchain architecture and the underlying consensus protocol, this paper also presents a qualitative analysis on the proposed architecture based on expert opinions**.

Keywords - blockchain, community-level trust, Federated Byzantine Agreement, hybrid consensus mechanisms, proof of authority

I. INTRODUCTION

Consumer trust is an important aspect of organic farming. According to [1], consumer trust is a key prerequisite for establishing a market for credence goods, such as "green" products, especially when they are premium priced. Third-party certifications are commonly used to fulfill this need where a trusted organization accredits the quality of farming practices and the products of a particular farm. However, audits for such third-party certifications incur a significant cost for the farm being audited. Due to many reasons including the high cost of audit, third party certification is not a very trustworthy mechanism to ensure the credibility of organic food supply chains [2]. Alternatively, participatory guarantee systems (PGS) have become popular among organic farming communities, especially in rural areas since it helps avoid the entry barriers of third-party certification systems. According to [3], participatory guarantee systems are locally focused assurance systems that verify producers' compliance to certain organic standards. PGS are based on active participation of stakeholders and are built on a foundation of trust, social networks, and knowledge building and exchange [3].

According to [4], PGS are independent and decentralized systems of local communities that involve producers, consumers, students, professors, agronomists, etc. and the certification is based on a peer review conducted by the stakeholders through an annual visit to the farm. The key elements of this system are mentioned as participation, trust, transparency, learning process, horizontality, decentralization, formation of networks, local focus, and food security and sovereignty [4].

However, this community-based certification system has inherent limitations which hinders the market growth for organic products. According to [3], in practice, PGS are often run and administered by NGOs or farmer´s associations, with limited smallholder involvement, which could be seen as a major flaw in terms of trustworthiness. Moreover, whether this community-based certification system could grow beyond the local market while preserving its original characteristics remains doubtful in terms of scalability. As the organic food industry has a potential to grow beyond local markets, the question of how to ensure trust still remains largely unresolved. In other words, it is important to research on the ways and means of incorporating the stakeholder communities to the certification process while addressing the issues of trust and scalability when the market is growing beyond local boundaries.

In the recent past, many researchers have been interested in adopting blockchain technology to resolve the trust issue of food supply chains [5]. Blockchain refers to an emerging disruptive technology that enables the creation of decentralized information systems with immutable and trustworthy records of transactions. Blockchain-based systems in the domain of agriculture help provide a trustworthy link between farms and the external markets by keeping transaction records immutably in decentralized ledgers, thereby enabling the traceability of sequences of transactions pertaining to a particular lot of produce throughout its journey along the supply chain. Research on food supply chains mainly focus on ensuring the trustworthiness of the products, transparency of supply chain activities as well as the technicalities of the blockchain technology such as determining the most suitable architectures and consensus mechanisms which make the system scalable and secure [6]. Various traditional and hybrid consensus mechanisms have been proposed and tested in this context [7]. However, there is no evidence for a research that has attempted to incorporate the community's consensus into the verification and validation protocol (i.e., consensus mechanism or protocol) of a blockchain architecture in the organic food context.

This research addresses the issue of developing a highly scalable blockchain architecture for the organic food supply chain with a consensus mechanism that hybridizes the traditional Proof of Authority (PoA) protocol with the Federated Byzantine Agreement (FBA) protocol. The key hypothesis here is that the community, as in the case of PGS, is a powerful component in the process of ensuring the credibility of organic food supply chains and hence, needs to be incorporated into the verification and validation process. However, this needs to be done without bypassing the formal regulatory process of the territory where the supply chain is being operated. It is assumed that by hybridizing the PoA protocol with the FBA protocol it would be possible to create a consensus mechanism, which enables the incorporation of the community dimension into the verification and validation process, while adhering to the formal regulatory procedures imposed by the governing bodies. Hybridizing both these consensus aims to mitigate the scalability issues and enhance trustworthiness. PoA is proposed to empower the authorized persons to propose blocks. While the size of the network increases, FBA resolves the issues of scalability and latency. The hybrid blockchain architecture presented in this paper and its underlying consensus protocol is designed based on this assumption, after a thorough review of literature on existing consensus protocols as well as an interviewing process which involved different stakeholders of the organic food supply chain in Sri Lanka. The key objective of this paper is to present the details of the proposed blockchain architecture and also to have a discussion on the incorporation of community-level trust into the consensus mechanism pertaining to the organic food supply chain.

The rest of this paper is organized as follows. Section II presents a summary of the existing literature on blockchain-based systems in the organic food industry. Section III provides an overview of current consensus mechanisms. Section IV then introduces the proposed blockchain architecture and the hybrid consensus mechanism. Section V carries a concept review on the proposed architecture as a simple qualitative analysis and section VI provides conclusions and directions for future work.

II. Literature Review

Adoption of the blockchain technology in the organic and other agricultural supply chains has been a trending topic since the recent past. Such research pays attention to avoiding a range of issues in agricultural supply chains such as inefficiencies, safety concerns and scandals, using blockchain technology. In [8], a blockchain-based model for rice supply chain management (RSCM) is proposed for the Food Corporation of India, to avoid significant wastage of rice and enhance the operational efficiency. In [9], a framework is proposed to trace out the major issues in traditional rice supply chain management and deploy blockchain technology to resolve these issues. In another notable research, a blockchain-based architecture is proposed for the traceability and visibility in the soybean supply chain [10]. In that research, an Ethereum-based smart contract is implemented and tested to govern and ensure the proper interactions among key stakeholders in the soybean supply chain. To ensure a high level of transparency and traceability, all the transactions are stored in the block chain's immutable ledger with links to a decentralized file system (IPFS). Another traceability intended blockchain-based application is presented in [11], which focuses on the berries supply chain, with evidence of the proof of concept with a pilot study. Moreover, a commercially important blockchain implementation is reported in 2017 where Walmart has successfully tested IBM's blockchain pilots for food provenance: pork in China and mangoes in America [12]. In that study, the challenges of implementing blockchain technology in the food supply chain and the opportunities for deploying blockchain solutions are also highlighted. Besides, an IoT-based blockchain architecture for enhanced transparency and traceability in food supply chains is proposed in [13].

Despite the undeniable benefits of blockchain, technical challenges and barriers to the adoption still remain. A study on the challenges and potential use of blockchain for assuring traceability and authenticity in the food supply chains is reported in [14] whereas another study on the challenges of adopting blockchain in food supply chains as well as a potential future direction by integrating blockchain with IoT is discussed in [15].

A few researches have been done on the adoption of blockchain technology in the organic food supply chains as well. [16] evaluates the application of blockchain technology to improve organic or fair-trade food traceability from "Farm to Fork" in light of European regulations with the intention of shedding light on the challenges in the organic food chain to overcome, the drivers for blockchain technology, and the challenges in current projects. The findings of the research highlights, among a few more, 1. optimizing chain partner collaboration and, 2. the selection of data to capture in the blockchain as key challenges. Furthermore, easy verification of certification data, accountability, improved risk management, insight into trade transactions, simplified data collection and exchange, and improved communication are highlighted as key benefits. Moreover, a prototype implementation of a blockchain-based system addressing the traceability issue in organic food supply chains is presented in [17].

III. Overview of Consensus Mechanisms

Consensus mechanism or protocol plays a critical role in the implementation of a blockchain-based system. In other words, it can be considered as the backbone of blockchain technology. In literature, there are numerous consensus mechanisms reported, each with their own strengths and weaknesses [18]. As the applications' complexity grows, researchers have proposed hybrid consensus mechanisms where the features of traditional consensus mechanisms like Proof of Work (PoW) and Proof of Stake (PoS) are combined to have more advanced functionality. This section summarizes some existing literature on hybrid consensus protocols and introduces the two consensus protocols hybridized in this particular study to create a community-based blockchain architecture.

An improved hybrid consensus algorithm is proposed in [19], combining advantages of the Practical Byzantine Fault Tolerance (PBFT) algorithm and the POS algorithm. According to them, the proposed algorithm reduces the number of consensus nodes to a constant value by verifiable pseudorandom sortition and performs transaction witness between nodes. The improved algorithm is tested and verified in terms of throughput, scalability, and latency. In [20], for incognito payments like tips, a hybrid consensus mechanism is proposed, which consists of a public and private blockchain. The public blockchain is based on the Federated Byzantine Agreement (FBA) consensus algorithm while BRAVO's private, incognito blockchain is based on an anonymizing Proof-of-Stake algorithm, which gives the end-users control on transaction speed, privacy, and cost. Furthermore, a hybrid consensus model (PSC-Bchain) composed of Proof of Credibility (PoC) and PoS consensus algorithms have been proposed in [21]. The PoS consensus is proposed as a means of saving energy. PoC is used to address the problem of coin collapse found in the PoS consensus method, and for credibility verification with the function of attack deterrence. Moreover, the model has combined a sharing mechanism with the proposed hybrid approach to emphasize security. The study has compared attack execution on both the classical blockchain and proposed hybrid blockchain, and also presented an attack analysis and security analysis. The experiment results have confirmed the enhanced scalability and performance of the blockchain-based e-voting system. Most of the existing studies on hybrid consensus mechanisms have focused on enhancing the security and scalability challenges. Notably, there is very little research in the agriculture domain, if not none, reported to have studied the adoptability of hybrid consensus mechanisms in their blockchain architectures.

Given the nature of the problem being investigated, this study proposes to hybridize the PoA and FBA consensus protocols. The selection of these two protocols is based on a thorough desk review of existing consensus mechanisms [18] pertaining to the problem being investigated.

A. Proof of Authority (PoA)

The concept of Proof of Authority (PoA) was coined in 2015 by Gavin Wood, co-founder of Ethereum and Parity Technologies. Later in 2017, a solution to spam attacks on Ethereum's Ropsten test network using PoA was proposed [22]. Recently, the PoA protocol was adopted by commercial platforms such as Microsoft Azure, Ethereum Express, POA Network and VeChain [23]. PoA is considered a modified mechanism of Proof of Stake (PoS), which leverages the identity as a form of stake instead of a wealth (Ex. crypto tokens). Unlike Proof of Work (PoW), PoA eliminates the need of high computational power to validate a block. The core of this consensus is to empower the pre-authorized persons to create a new block of transactions by considering their individual identity as a stake. In other words, the block creator in PoA protocol puts his or her authority at stake when authorizing a transaction into the block. This acts as the key control mechanism to eliminate fraudulent transactions from the network.

Even though PoA is adopted by some public block chains, it still lacks the full decentralization. The validator should be an identifiable participant and selected among the pre-authorized nodes by the network, thus the potential validator group is often relatively small compared tothe entire network [23]. Hence, it is more scalable while the group of validators are limited. Inherent features of PoA reveals that, though it sacrifices its decentralization, it achieves high throughput and scalability, and it is well suitable for private blockchains [23].

B. Federated Byzantine Agreement (FBA)

Federated Byzantine Agreement is a consensus protocol stemming from the famous Byzantine Generals Problem [24], which explains a situation of avoiding complete failure of a decentralized peer-to-peer system while reaching a common consensus among majority, even though some of them are malicious. Other consensus protocols which belong to the same family includes the famous Proof of Work (Pow) protocol by Satoshi Nakamoto, the founder(s) of Bitcoin system as well as the protocols such as Practical Byzantine Fault Tolerance (PBFT) [25] and Delegated Byzantine Fault Tolerance (DBFT) [26]. PBFT is a promising consensus protocol, which is scalable when the group of nodes is small but becomes inefficient for large scale of networks [27]. DBFT is an advanced version of PBFT, which overcomes the scalability issue. FBA is the latest addition to the family, which ensures a robust decentralized system with the help of a concept called quorum slice [28], [29]. Several commercial blockchain systems such as Ripple and Steller have adopted FBA successfully [30]. FBA is the most preferred protocol among the members of the BFT family because of its high throughput, network scalability, and low transaction costs [31].

As mentioned before, the novelty of FBA is its use of the concept of quorum slice to establish trust [29]. By definition, a quorum is a group of nodes that require to attain common agreement while communicating with each other. A quorum slice is a subset of a quorum, which is a small group of nodes in the system who have reached a consensus. In the FBA protocol, each participant node can choose which other nodes they trust, and their list of trusted nodes forms their quorum slice. Accordingly, it allows open-membership and forms decentralization. Quorum slices can be formed dynamically, thus an individual node can appear on multiple quorum slices called quorum intersection. This overlapping helps to achieve common consensus in a decentralized peer-to-peer network. Through the process of collective decision-making, it can surpass the impact of a faulty node's action.

Despite the promising advantages, the FBA has some shortcomings as well [32]. In this mechanism, each participant node can choose which other nodes they trust, and their list of trusted nodes forms their quorum slice. In such a situation, the nodes usually choose the nodes with a higher reputation. In other words, whether FBA actually reduces centrality is questionable and only a few studies have been done to elaborate on this. In [32] they have proposed a reputation mechanism to incentivize all the peers to be validators in a democratic way in order to be trusted by other peers in the network.

IV. PROPOSED FRAMEWORK

The proposed framework encompasses all the processes of the organic food supply chain, from the farm to the end customer. However, in order to reduce the complexity of the initial model, the processes are limited to those that involve the farmer and supermarket. The important component of transportation has been removed from this version of the framework but will be included in the future frameworks. As depicted by Fig. 1, at each of these supply chain components, there is a set of actions that need to be recorded in the blockchain system. The role of the consensus protocol is to keep those actions securely (immutably) recorded in the system so they could be traced back to recall the history.

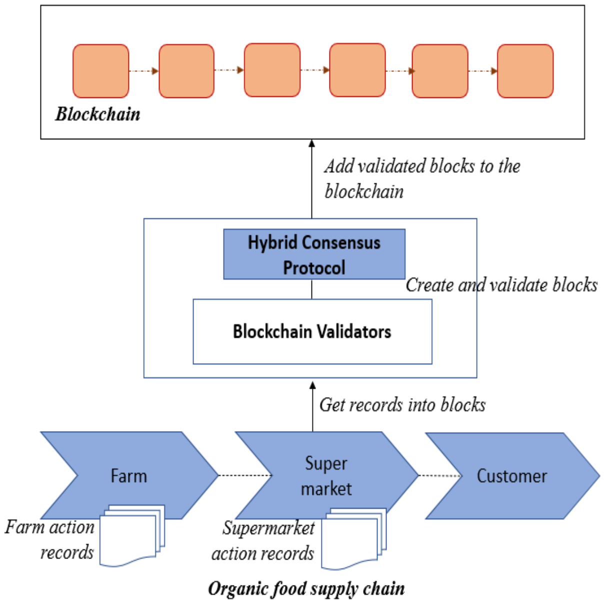

Fig. 1. Overview of the blockchain system

There are two possibilities with regards to a supply chain action. First, the action could be fraudulent. For example, it could be an action, which is not compatible with the concept of organic farming such as a farmer mixing synthetic fertilizers with organic fertilizers. Such actions should not be allowed to be recorded in the system. Second, a particular farmer or supermarket would attempt to alter an action, which is already stored in the system, maliciously. For example, one might attempt to change the recorded figures in a quality test report. Avoiding both of these possibilities is critical to ensure consumer trust on the organic food supply chain.

A blockchain system consists of a consortium of members known as nodes, who actively take part in the process of verification and validation of blocks. In the proposed architecture, there are two groups of members, namely, consortium members and community members. Consortium members are those who have a formal authority vested by the regulatory bodies to oversee, approve, and regulate actions in the organic food supply chain. For example, the agricultural inspector (AI) is a government appointed officer who has the authority to approve/verify some actions of farmers. Community members represent the communities of interest such as consumers, professionals, researchers, religious leaders, social activists, etc. These members do not have a formal authority but their participation in the verification and validation process of a particular action is very much influential to avoid fraudulent actions as well as alterations of records pertaining to past actions. Thus, in the proposed architecture, the involvement of the community members is considered vital in the process of validating a block.

A. *Block creation*

Block creation in the proposed architecture is done by the members of the first group (i.e., the group of members with authority). In the proposed architecture, block creation happens according to the PoA protocol. The member with the relevant authority pertaining to a particular action is given the chance to create a block and insert the record of the respective action into that block. However, the validation of the block (i.e., permitting the block to be added to the existing chain of blocks) is done based on a quantity defined as the stake of the member. The stake of a particular member is determined by the following formula.

$$S_i = A_i + R_i + T_i \qquad (1)$$

Here, S_i is the stake of the ith member of the system and A_i, R_i and T_i are the authority level, reputation and the duration served of that member. Authority is coming from the position the respective member holds and the duration served is computed using the period in service. Reputation is a value attributed to the block creator by the community (i.e., the second group of members). The reputation is computed by the following formula.

$$R_i = C_i + Q_i + P_i' + P_i'' \qquad (2)$$

Here,
C_i: Number of social connections of the ith member
Q_i: Number of intersecting quorum slices of the ith member
P_i': The probability of creating a block
P_i'': Probability of success in validation

B. *Community-level trust*

Notably, the reputation (R) is a quantity related to the social recognition of the respective member. In other words, the community-level trust is incorporated into the system through this quantity of reputation (R). Thus, according to the equation (ii), the reputation is computed by involving the FBA protocol. To achieve a consensus, master node (i.e., node i) has to convince its own quorum slice rather than convincing a lot of nodes to trust. Accordingly, by the quorum intersection structure, the majority of the network nodes would be convinced, since each node trusts every other node on the network. Thus, by communicating with each other, if only the system-wide consensus is reached, that block is approved as a valid block and is appended to the existing chain of blocks.

C. *Regulatory governance procedure – rewards and penalties*

Participants' honesty and engagement can make the system stable or unstable. The system needs to have control mechanisms put in place to encourage transparent and legitimate actions while penalizing fraudulent actions. Thus, a reward and penalty mechanism is a necessity for the system. In the proposed system, this reward and penalty mechanism is driven by a quantity called trust index (I), which is defined by the following formula.

$$I_i = P_i' + P_i'' \qquad (3)$$

Here,

P_i': The probability of creating a block

P_i'': Probability of success in validation

The block creating node gets a reward for each successful validated block and the validating nodes in the block also get rewarded accordingly for the contribution to validate the block. This mechanism ensures the continuous engagement of the validators and helps sustain the blockchain system in the long run. There is also a penalty mechanism to remove a block creator from the consortium for any fraudulent activity after setting its trust index to zero.

D. *System overview*

The proposed blockchain system works as follows. The actors involved with the organic food supply chain do actions and transactions. When an action or a transaction is initiated, a member from the consortium members will become the master node, which is the member who has the highest stake to initiate a block. As mentioned earlier, the master node is a consortium member who has a formal authority to oversee, authorize and regulate actions and transactions of supply chain actors. As represented by equation (i), authority is a component of the stake of the consortium member. Thus, this part comes from the PoA component of the architecture.

Once a block is initialized, the master node attempts to reach a consensus in its own quorum slice. If a consensus is reached within that quorum slice, the members of that quorum slice communicate it to the other quorum slices they are involved in, through the quorum intersection structure. If a substantial percentage of the network reaches a consensus, the block is said to bevalidated and is added to the existing blockchain. This part of the consensus mechanism comes from the FBA component of the architecture.

As an example, if a farmer needs to record a seed certificate he just obtained in the blockchain, the agricultural officer is the formally authorized person to initiate the block when he signs the certificate. For the agricultural officer to initiate this block, he must have the required stake set by the system. In other words, the reputation of the agricultural inspector as well as the duration in the system will also affect the ability to initiate the block. After initiating the block, the agricultural inspector must convince the members of his quorum slice, who could also represent communities of interest such as the local head of police, the religious priests, other neighbouring farmers, professionals, etc. If a consensus was reached within the slice, the individual members can propagate the details of the block to their other quorum slices through quorum interactions. Through this mechanism, it is expected to reach deeper into communities of interest. If and only if a significant percentage (say 67%) of the network reaches consensus, the respective block carrying the record of the seed certificate would be added to the blockchain. The idea of quorum slices is depicted by Fig. 2.

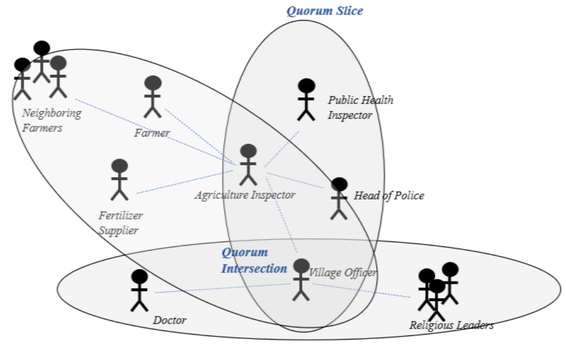

Fig. 2. An example of quorum slices having key officials in the intersections

V. CONCEPT REVIEW OF THE PROPOSED ARCHITECTURE

As the proposed framework is yet to be implemented and tested, as a first phase of validation, a concept level validation of the architecture was done with the involvement of experts in blockchain technology. A series of open-ended interviews were conducted with two academics with a sound track record in blockchain research as well as a practitioner from a leading software development company in Sri Lanka. The interviews were basically conductedfocusing on the novelty and potential validity of the idea of adopting the community-level trust into a blockchain consensus protocol. According to the feedback of the experts, incorporation of community-level trust into the consensus protocol is a novel and a desired idea. Moreover, according to the experts' 1) incorporating the stakeholder communities to the certification process will strengthen the trust over the product 2) hybridizing the consensus protocol will mitigate the lapse of each and enhance the security and scalability of the system 3) a good incentive mechanism is required for the system to sustain 4) a solid reward mechanism and meticulous penalty mechanism should be defined to make the participants behave honestly. The experts' feedback further included some key limitations such as the difficulty of maintaining the credibility of the system while confronting the cultural barriers and social norms.

VI. CONCLUSION AND FUTURE WORK

The architecture presented in this paper is novel mainly due to the hybridization of two existing consensus protocols, namely, the Proof of Authority (PoA) and Federated Byzantine Agreement (FBA). Through this hybridization it is expected to obtain better consumer trust due to the incorporation of community-level trust into the consensus protocol as well as due to the enhanced transparency and scalability resulting from that. Besides, this is one of the very few hybrid blockchain architectures proposed aiming at the organic food supply chain. This paper explains the conceptual design of the proposed blockchain architecture in detail, giving insights into the basic components of the hybrid consensus mechanism. Furthermore, it presents a concept-level validation of the idea of incorporating community-level trust into the consensus protocol of the blockchain architecture, with the involvement of a few active researchers and practitioners.

However, this conceptual design needs to be tested to see its dynamic properties such as sustainability and scalability. After all, there is a highly significant social component due to the involvement of communities of interest in the block validation process. As this might bring lots of human-behaviour related dynamics into the actual behaviour of this blockchain system, the scalability and sustainability of this architecture is very much unpredictable. Hence, the testing of this system is thought to be done best in a simulation environment rather than in a real environment. There, the agent-based social simulation (ABSS) is looked at as a candidate approach in the testing process. As ABSS is acknowledged as the third way of doing science [33], mainly due to its ability to study emergent properties of complex social systems, it seems to be well suited to the testing of a complex system like this. Thus, future work of this research would be conducting experiments on the dynamic properties of the proposed blockchain architecture using the ABSS approach. Such experiments would reveal the potential limitations of the design and allow necessary corrective actions to be taken.

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REFERENCES

[1]. K. Nuttavuthisit and J. Thøgersen, "The Importance of Consumer Trust for the Emergence of a Market for Green Products: The Case of Organic Food," Journal of Business Ethics, vol. 140, no. 2, pp. 323–337, May 2015, doi: 10.1007/s10551-015-2690-5.

[2]. A. Zezza, F. Demaria, T. Laureti, and L. Secondi, "Supervising third-party control bodies for certification: the case of organic farming in Italy," Agricultural and Food Economics, vol. 8, no. 1, Nov. 2020, doi: 10.1186/s40100-020-00171-3.

[3]. R. Home, H. Bouagnimbeck, R. Ugas, M. Arbenz, and M. Stolze, "Participatory guarantee systems: organic certification to empower farmers and strengthen communities," Agroecology and Sustainable Food Systems, vol. 41, no. 5, pp. 526–545, Jan. 2017, doi: 10.1080/21683565.2017.1279702.

[4]. E. Nelson, L. Gómez Tovar, R. Schwentesius Rindermann, and M. Á. Gómez Cruz, "Participatory organic certification in Mexico: an alternative approach to maintaining the integrity of the organic label," Agriculture and Human Values, vol. 27, no. 2, pp. 227–237, Mar. 2009, doi: 10.1007/s10460-009-9205-x.

[5]. J. Duan, C. Zhang, Y. Gong, S. Brown, and Z. Li, "A Content-Analysis Based Literature Review in Blockchain Adoption within Food Supply Chain," International Journal of Environmental Research and Public Health, vol. 17, no. 5, p. 1784, Mar. 2020, doi: 10.3390/ijerph17051784.

[6]. S. Saurabh and K. Dey, "Blockchain technology adoption, architecture, and sustainable agri-food supply chains," Journal of Cleaner Production, p. 124731, Oct. 2020, doi: 10.1016/j.jclepro.2020.124731.

[7]. G.-T. Nguyen and K. Kim, "A Survey about Consensus Algorithms Used in Blockchain," Journal of Information Processing Systems, vol. 14, no. 1, pp. 101–128, Feb. 2018.

[8]. A. Kakkar and Ruchi, "A Blockchain Technology Solution to Enhance Operational Efficiency of Rice Supply Chain for Food Corporation of India," in Lecture Notes on Data Engineering and Communications Technologies.

[9]. M.V. Kumar and N. C. S. Iyengar, "A Framework for Blockchain Technology in Rice Supply Chain Management," in Advanced Science and Technology Letters, 2017, vol. 146, pp. 125–130.

[10]. K. Salah, N. Nizamuddin, R. Jayaraman, and M. Omar, "Blockchain-Based Soybean Traceability in Agricultural Supply Chain," IEEE Access, vol. 7, pp. 73295–73305, 2019, doi: 10.1109/access.2019.2918000.

[11]. J. D. Borrero, "Agri-food supply chain traceability for fruit and vegetable cooperatives using blockchain technology.," Revista de Economía Pública, Social y Cooperativa, vol. 95, no. 0213-8093, pp. 71–94, doi: 10.7203/CIRIEC-E.95.13123.

[12]. R. Kamath, "Food Traceability on Blockchain: Walmart's Pork and Mango Pilots with IBM," The Journal of the British Blockchain Association, vol. 1, no. 1, pp. 1–12, Jul. 2018, doi: 10.31585/jbba-1-1-(10)2018.

[13]. S. Madumidha, P. S. Ranjani, S. S. Varsinee and P. S. Sundari, "Transparency and Traceability: In Food Supply Chain System using Blockchain Technology with Internet of Things," 2019 3rd International Conference on Trends in Electronics and Informatics (ICOEI), 2019, pp. 983-987, doi: 10.1109/ICOEI.2019.8862726.

[14]. J. F. Galvez, J. C. Mejuto, and J. Simal-Gandara, "Future challenges on the use of blockchain for food traceability analysis," TrAC Trends in Analytical Chemistry, vol. 107, pp. 222–232, Oct. 2018, doi: 10.1016/j.trac.2018.08.011.

[15]. H. F. Atlam, A. Alenezi, M. O. Alassafi, and G. B. Wills, "Blockchain with Internet of Things: Benefits, Challenges, and Future Directions," International Journal of Intelligent Systems and Applications, vol. 10, no. 6, pp. 40–48, Jun. 2018, doi: 10.5815/ijisa.2018.06.05.

[16]. M. van Hilten, G. Ongena, and P. Ravesteijn, "Blockchain for Organic Food Traceability: Case Studies on Drivers and Challenges," Frontiers in Blockchain, vol. 3, Sep. 2020, doi: 10.3389/fbloc.2020.567175.

[17]. B. M. A. L. Basnayake and C. Rajapakse, "A Blockchain-based decentralized system to ensure the transparency of organic food supply chain," 2019 International Research Conference on Smart Computing and Systems Engineering (SCSE), 2019, pp. 103-107, doi: 10.23919/SCSE.2019.8842690.

[18]. T. Thanujan, C. Rajapakse, and D. Wickramaarachchi, "A Review of Blockchain Consensus Mechanisms: State of the Art and Performance Measures," in 13th International research conference holistic approach to national growth and security, pp. 315–326.

[19]. Y. Wu, P. Song, and F. Wang, "Hybrid Consensus Algorithm Optimization: A Mathematical Method Based on POS and PBFT and Its Application in Blockchain," Mathematical Problems in Engineering, vol. 2020, pp. 1–13, Apr. 2020, doi: 10.1155/2020/7270624.

[20]. "Analysis between Dash, Zcash, Ripple (XRP) and BRAVO Pay," Medium, Oct. 08, 2018. [Online]. Available: https://medium.com/@BRAVOPay/analysis-between-dash-zcash-ripple-xrp-and-bravo-pay-134dc925edf0. [Accessed: 18-Jan- 2021].

[21]. Y. Abuidris, R. Kumar, T. Yang, and J. Onginjo, "Secure large-scale E-voting system based on blockchain contract using a hybrid consensus model combined with sharding," ETRI Journal, Nov. 2020, doi: 10.4218/etrij.2019-0362.

[22]. "poanetwork/wiki", GitHub, 2019. [Online]. Available: https://github.com/poanetwork/wiki/wiki/POA-Network-Whitepaper. [Accessed:10- May- 2021].

[23]. J. MAGAS, "Proof-of-Authority Algorithm Use Cases Grow: From Pharma to Games," cointelegraph, Nov. 16, 2019. [Online]. Available: https://cointelegraph.com/news/proof-of-authority-algorithm-use-cases-grow-from-pharma-to-games. [Accessed: 12- Apr- 2021]

[24]. L. Lamport, R. Shostak, and M. Pease, "The Byzantine Generals Problem," ACM Transactions on Programming Languages and Systems, vol. 4, no. 3, pp. 382–401, Jul. 1982, doi: 10.1145/357172.357176.

[25]. M. Castro, Practical byzantine fault tolerance. Cambridge, Mass.: Institute Of Techonology, 2001.

[26]. G. CHRISTOFI, "Study of consensus protocols and improvement of the Delegated Byzantine Fault Tolerance (DBFT) algorithm.," Master thesis, Faculty of the Escola Tcnica d'Enginyeria de Telecomunicaci de Barcelona Universitat Politcnica de Catalunya by.

[27]. X. Zheng and W. Feng, "Research on Practical Byzantine Fault Tolerant Consensus Algorithm Based on Blockchain," Journal of Physics: Conference Series, vol. 1802, no. 3, p. 032022, Mar. 2021, doi: 10.1088/1742-6596/1802/3/032022.

[28]. D. Mazières, "The Stellar Consensus Protocol: A Federated Model for Internet-level Consensus," Jul. 2017, [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.696.93&=&rep=rep1&=&type=pdf.

[29]. M. Kim, Y. Kwon and Y. Kim, "Is Stellar As Secure As You Think?", 2019 IEEE European Symposium on Security and

Privacy Workshops (EuroS&PW), 2019, pp. 377-385, doi: 10.1109/EuroSPW.2019.00048.

[30]. J. Innerbichler and V. Damjanovic-Behrendt, "Federated Byzantine Agreement to Ensure Trustworthiness of Digital Manufacturing Platforms," in MobiSys '18: The 16th Annual International Conference on Mobile Systems, Applications, and Services, Jun. 2018, [Online]. Available: https://dl.acm.org/doi/abs/10.1145/3211933.3211953.

[31]. "Consensus Protocols That Meet Different Business Demands," Intellectsoft Blockchain Lab, Mar. 26, 2018. [Online]. Available: https://blockchain.intellectsoft.net/blog/consensus-protocols-that-meet-different-business-demands. [Accessed: 18- Jun-2021).

[32]. A. Zoi, "Study of consensus protocols and improvement of the Federated Byzantine Agreement (FBA) algorithm," Master thesis, Faculty of the Escola T`ecnica d'Enginyeria de Telecomunicaci´o de Barcelona Universitat Polit`ecnica de Catalunya by.

[33]. R. Axelrod, "Chapter 33 Agent-based Modeling as a Bridge Between Disciplines," in Handbook of Computational Economics, pp. 1565–1584.