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A Review on Blockchain Technology in Fish Supply Chain

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ABSTRACT

The implementation of blockchain in fish supply chain has attracted wide interest among researchers recently. A blockchain is a ledger of distributed records in the form of encrypted blocks or a public record of all transactions or digital events conducted and shared between entities involve, which can also be verified at any point in the future. The supply chain would be a massive technological leap with the combination of blockchain technology that will bring major changes to different facets of the fisheries industry, such as record immutability, improved traceability, quality assurance, improved knowledge flows, decentralized power structure, and decreased chances of fraud. However, there are issues with scalability that lead to different problem in the computational power and complexity of mining process in the device. Thus, this paper provides a review on the use of blockchain in the fish supply chain from both a computational and an applicative perspectives. The discovery suggests that blockchain is promising concept to be used in the supply chain that creates transparent, supervisable, safe and convenient blockchain-based fish supply chain but still immature and hard to apply due to its complexity.

1.0 Introduction

A fish supply chain is a network of facilities and distributors comprising producers, manufacturers, distributors and resellers responsible for the procurement of raw materials, the processing of raw materials into intermediate and finished products and the sale to consumers of end product [1]. The primary aim of the supply chain is to optimize the overall value generated. Supply chain management is necessary to ensure the productivity of flow materials and finished products from manufacturers to consumers, the manufacturing facilities and warehouses will be used in the process. Manufacturers, suppliers, transporters, warehouses, retailers, and customer are involved in all stages of manufacturing industries whether directly or indirectly, in order to meet the customer request [1]. The main factor in creating an efficient supply chain is transparency and traceability.

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In the new era of technology, Internet of Thing (IoT) has been adapted into fish supply chain to enhance both traceability and transparency. The IoT improves the competitiveness of the supply chain by tracking content flows more equitably. This increases the capabilities and improves efficiency of crucial schedules and processes. The IoT aims to strengthen the distribution of more detailed and timely information related to development, quality assurance, delivery, and logistics within the multi-exchange party supply chain. In addition, IoT technologies can be used to maximize the productivity of processes that occur in manufacturing plants and, by extension, supply-chain IoT devices can be used to increase efficiency, minimize operating costs and satisfy customers [2]. The threats to data privacy and security breach, however, are arising from the insufficiency of basic security technologies. Due to its decentralized topology and IoT device resource limitations, existing protection and privacy approaches are not applicable to the IoT [2]–[4].

As a decentralised and distributed platform, Blockchain is recommended to ensure the safety of the IoT in the fish supply chain. It is a distributed ledger with blocks that are chained together. It can monitor and organise transactions and store data for billions of IoT users [5], [6]. The most important advantage of blockchain technology is decentralisation, it facilitates peer-to-peer interactions based on mutual credits in distributed networks. It utilises stamping of motion time, distributed consensus, encryption of data, and economic incentives. It reduces costs in centralised organisations, increases efficiency, and provides solutions to the problem of insecure data storage.

The objective of this review is to have an analysis of the scientific studies carried out on the use of blockchain technology in the fish supply chain from both a computational and an application perspective. The paper is organized as follows. Section 2 focuses on the recent blockchain technology and how it integrates with IoT sensor. Section 3 identifies the suggested methods for applying blockchain technology in fish supply chain. Section 4 provides a discussion about benefit and limitation that occur when blockchain-based system is applied in fish supply chain. Section 5 concludes the paper and proposes some related future work based on the finding of this review.

2.0 Blockchain Technology

Blockchain is the best mechanism to strengthen and secure fish supply chain. Due to its ability to ensure decentralization, accountability and immutability, blockchain has a tremendous potential to be implemented in a variety of applications. A ground breaking technology in the Internet age, blockchain adopts an underlying decentralized system of cooperation to build a distributed ledger. Chronologically created blocks attach the data, creating the right data structure suitable for any decentralized trust network [7].

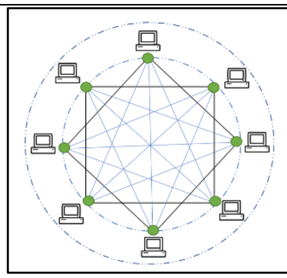
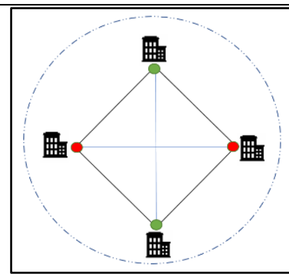
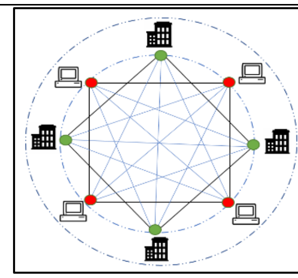
A distributed ledger technology is employed by blockchain, which produces an atmosphere of low confidence that can fully remove dependency on central authority. Via a consensus algorithm on a blockchain network, each node achieves storage data compatibility. Honest nodes control the hash rate more collectively than any associative group of attacking nodes, as long as the system is protected. Even if the attacker comes from an internal system, the data stored on the blockchain cannot be compromised [8], . The blockchain is considered to be the most powerful engineering for preserving the protection of public account books and, in the age of the 4th Industrial Revolution, it holds a high potential according to the United Nations (UN). There are three categories of blockchain as described in Table 1, which are public, private, and consortium.

The first and most commonly used blockchain to be called "fully decentralised" is the public blockchain. A simple view on the structure of public blockchain is shown in Table 1. All documents are open to the public and anyone can engage in the process of consensus, it allow everyone in the blockchain to read and submit transaction [9], [10]. For the verification of transactions, this technology favour the used of “Proof of Work” or “Proof of Stake” consensus algorithms. Since public chain stored record on a large number of participant, it almost impossible for transaction to be tempered [5], [11]. However, the large number of participant effect the time taken to complete the transaction, making it less efficient.

Private blockchains are the category that specifically fabricated to fulfil the actual operational functional needs while maintaining high confidentiality. It greatest concern is security and privacy. There is some knowledge that, in the case of capital markets, must be hidden, such as inside information and corporate secrets. Therefore only one entity or all subsidiary entities within the same community are authorised to read and verify messages in this form of blockchain [9], [10]. It also offer higher level of efficiency due to an entry is granted to only a selection of pre-authorized nodes. So, the nodes should not take up more resources than average in any way.

The consortium categories is a semi-central blockchain type consisting of multi-organization consortiums, enabling preselected nodes to run the nodes for each participating entity. It refers to the blockchain approval process which managed by some pre-selected nodes. These blockchain are known to be "partly decentralised". The right to access blockchain documents is only given to all members or the organisation and is only revealed via the API to particular individuals [12]–[14]. In addition, data between consortium nodes is not necessary homogeneous because some blockchains allow private transactions that lead to fragmentation of information [15].

Table 1: Public, Private and Consortium Blockchain

Type of Blockchain	**Public Blockchain**	**Private Blockchain**	**Consortium Blockchain**
Diagram			
Consensus management	All participant	Manage by central institution	Selected set of participant
Consensus process	Permisionless	Pemissioned	Permissioned
Condition for network participation	Non	Manage by central institution	Non or manage by selected institution
Centralized	No	Yes	Partial
Reading permission	Public	Could be public or restricted	Could be public or restricted
Efficiency	Low	High	High
Immutability	Nearly impossible to temper	Could be tampered	Could be tampered
Identification	Anonymous	Identifiable	Identifiable
Transaction proof	Proof of work/ Proof of stake	Transaction verification conduct by centarl institution	Transaction verification through certification and block
Example	Ethereum, Litecoin and Bitcoin	Enterprise Ethereum, Hyperledger Fabric, Corda, Ripple, and Quorum.	Quorum, Hyperledger, and Corda.

2.1 Integration of Blockchain in IoT

Supply chains have grown into more dynamic value networks in the last year and have become a critical competency. With growth, however, as they move through the network of the value chain, it's become progressively hard to ascertain the source of materials and manage product and merchandise transparency. The implementation of the Internet of Things (IoT) will allow organization within their respective supply chain networks to distinguish, track, and control the goods, operations, and processes. Other IoT applications include inventory control to improve warehousing, production, and transportation operations. IoT involves devices that are connected over a network, for instance sensors, inactive, semi-inactive (or semi-active), and active radio frequency ID tags (RFID). Together, these technologies can execute a variety of functions, including movement, motion or temperature monitoring. Action and collection; Process, store and share data [2], [16].

There are a lot of advantage an IoT have gave to the environment and global. The use of IoT technology can increase the productivity and efficiency of previous systems, and IoT-enabled systems can deal with the rural monitoring and implement a hierarchical model for the rural monitoring. The IoT, combined with advances in artificial intelligence, has an enormous effect on how individuals perform different activities in their daily lives, particularly in terms of making many of these activities much easier to perform. The accessibility and expansion of these IoT devices (approximately 75 billion by 2025) makes computing transparent, in the sense that most people are not familiar with the technology of these devices and what it can do to their world [17]. IoT also offers a streamlined way for data transfer through various workstations, enabling real-life control for quick access to the device.

However, the new IoT systems are unable to adapt to existing security technologies because they can consume large quantities of energy and have significant overhead processing [2]. In addition, issues such as hacking, physical manipulation, data theft and counterfeiting among supply chain exchange partners can lead to confidence issues. Professionals and academicians consider security to be the most critical problem from the perspective of IoT vulnerabilities [4], [18].

Blockchain is a perfect IoT security breach solution. It can adapt flexibly to dynamic and evolving network environments, as a transparent and stable distributed transaction technology. Failure of any nodes has no effect on the system's stable operation. To prevent the network from being entered by malicious nodes the distributed authentication between nodes. Just because a few node numbers are compromised, there will be no messing with the ledger. In a multi-node network, any time a new device is added, the machine ID information must be declared on the blockchain. Every machine's ID, hash of important data, public key, and other information is stored in the blockchain ledger. At the very same time, in the blockchain network, each computer is a node and a consensus mechanism ensures that the same information is processed by each node. Public key encryption will be used for the authentications between IoT devices any time peer-to-peer communication occurs [8].

The unique construction process has enriched the blockchain with such features as decentralized, traceable, trust-free and smart contracts. The decentralized function is shown by the absence of a central node, the equivalent status of all nodes, and the failure of any node does not affect the system's operation. Where, without mutual confidence, inter-nodal communication is possible and the nodes are unable to spoof each other under the blockchain law[19], [20]. The traceable feature means that no information is created without a foundation in the blockchain [5], [21]. A trust-free environment guarantees that all operation of data in the system are transparent and open [22], [23]. The details about the previous block can be accessed by any block, since all blocks are sequentially connected in the blockchain. Smart contract function attests to the notion that the agreement between the transacting parties is automatically executed by pre-written code in a blockchain; execution is resistant to any intervention, making it easier to conclude, more effective and less expensive to execute [7].

3.0 Application of Blockchain Technology in Fish Supply Chain

This section will reported some simulation and project that concerning implementation of blockchain technology in fish supply chain. Probst [5] discuss how to improve trust and transparency in fisheries through advanced data technologies. Blockchain works between two partners that need to be mediated by a third authority as the latest intermediate. The blockchain network is used to verify the transactions, it is self-organized and thus cannot be compromised afterwards. Smart contracts are self-executing blockchain scripts that automate predefined processes, such as crypto-currency trading rules or other properties. There, smart contracts expand the capabilities of blockchain to enable more complex operations than just basic asset transfer. On all participating network nodes, decentralised and synchronised storage makes it invulnerable towards subsequent data manipulation and hacking.

Cruz and da Cruz define a smart contract on Ethereum blockchain, in order to implement a traceability platform on fishery value chain [24]. The smart contract should allow registration of product and provide a history of traceability information, from fishing or production until consumption. There are four different user entities; The entity responsible for creating and adding new operator is known as SysAdmin; The entity who work for the operator of the value chain and responsible maintaining information regarding activities performed is known as Worker; The entity who administer within the domain of value chain operator is known as WorkerAdmin; and, final consumer is the last entity, they wereable to read traceability information of any fish. Solidity smart contact was used inside the Ethereum blockchain. It composed the declaration of the data involved (data storage variable and data structs set) and functions set, including a constructor. All objects stored in a blockchain cannot be modified, it is not possible to alter a contract that has already been distributed, except through a new distribute. Tracking function were done outside of smart contract, which is the service software layer that access the contract It requires multiple product batches and can include several operators of the supply chain. Implementation of smart contract increase the transparency of the value chain and it derivation, improves communication and the coordination between the parties involved and improves the integrated process.

The work by Hang et al. suggested a fish farm platform based on blockchain to ensure the integrity of agricultural data [25]. A distributed ledger technology is used to store all record of action that occur on the fish farm and it also link with data that was being recorded by farm sensor. The permissioned blockchain (Hyperledger) network exclusively granted to approve users ability to perform blockchain operations, and subset of user signature must be contain in a block for it to be valid. This approach removes the possibility of data breaches and guarantees that no invalid user is able to enter or interact with a blockchain transaction. Moreover, a change can only be made on smart contract if it receive the consent of all users involved in the transaction. This feature uses a distributed database architecture by implementing Couch DB located on each blockchain pair. It also conceals the details of monitored environmental data and operation chronicle, it also records any manipulation of resource done by any unauthorized user. There are four main phases that are carried out by four modules in the entire fish farm setup operational phase: the sensor interface module, the prediction module, the optimization process module, and the pump controller module.

In the Tilapia supply chain, Rejeb implements traceability that go throughout farmers until the final consumers in Ghana [26]. To revolutionise it and bring benefits to the production of Tilapia from farmers to the final customers, it incorporates blockchain technology into the supply chain. All supply chain participants need to register and match their identities and digital profiles in the back-end database in the peer-to-peer network that maintains a publicly distributed ledger that can be monitored at any time and from any venue. Via an important trace-back feature, blockchain technology ensures Tilapia's authenticity and provenance. Whenever the ID is inserted, all relevant data and information througout the retailers and farmers will be given to the customer in the supply chain. The improvement of the platform is assured by a drive towards accurate product originality assurance that meets the needs of customers.

Provenance is among the first companies that use Ethereum blockchain technology to track movement of product, in 2016 the technology is used in the tuna industry. Mobile (Near Field Communicator (NFC) devices) and smart tags (Radio-Frequency Identification (RFID) tags) were also used to track product and validate attribute from field to time of purchase. The used of peer-to-peer technology to track the movement of tuna fish caught in Maluku, Indonesia until it reach consumer demonstrate how implementation of blockchain technology enable supply chain transparency and traceability. The system collects fishermen's SMS messages, and uses an RFID and QR tag scheme. The NFC on the product packaging are responsible for communication in provenance story [27]–[29].

Fiji tuna blockchain supply chain traceability project were conducted by a few different organization; World Wide Fund for Nature – New Zealand (WWF), ConsenSys, TraSeable Solutions, and Sea Quest Fiji Ltd. The aim of the project was to develop a truly open and traceable supply chain for the fresh and frozen tuna supply chain, using revolutionary blockchain technology. The TraSEAble software-as-a-service (SaaS) blockchain-ready system allows stakeholder collaboration and promotes transparency by enabling regulators with the ability to validate and confirm the end-to-end forward and backward traceability of seafood. Treum (formerly Viant) was projected into the supply chain, and the requisite roles (modeller, tracker, and smart builder) and permissions were set. It established frameworks for data entry and rules to collect data. Trialled Radio Frequency Identification (RFID) and Internet of Things (IoT) sensors are used and fish are monitored in processingfacilities by conversion. The one responsible for communication in the provenance storey is a QR codes on the product labels [27], [28], [30].

Pacifical-Atato would be the first massive blockchain project in the year 2018 to track purse-seine-caught skipjack tuna for canning. Pacifical is a PNAO (Parties to the Nauru Agreement Office) tuna business creation firm, while Atato is a blockchain services provider based in Thailand. The technology allows traceability via the Ethereum blockchain under Raimond Freres brand of Gustav Gerig's Marine Stewardship Council (MSC) certified canned and pouched Rose tuna range. This project uses the PNAO and processing companies' good information systems of an already recorded KDEs for tuna from capture to process. The KDEs are distributed and written on the blockchain via application programming interfaces using Atato's notary service. [27], [28], [31].

In early 2019, OpenSC revealed its blockchain project for the traceability of Patagonian toothfish in collaboration with WWF-Australia and BCG Digital Ventures. The tagging of toothfish with RFID tags was needed for this project to acquire and collect information on fish movement through the supply chain. In addition, the project discusses the combination of machine learning with GPS data in order to further assess if fish have been captured in a legal area. The platform facilitates the responsible procurement of goods. To track the origin of fish and other goods and their journey through the supply chain, consumers may scan a QR code. At each step in the supply chain, additional information, including storage temperature in transit, is also reported [27], [28], [32].

In March 2019, another blockchain-based supply chain was launched for fish. Bumble Bee Foods confirmed its use of blockchain services from SAP to track "Fair Trade" on an Indonesian Anova yellowfin tuna product. In order to communicate the provenance narrative of the fish, Bumble Bee Foods uses QR codes on the tuna product labels, similarly to several other campaigns. Details on the fish-to-market pathway, such as the scale of the fish, the point of capture and the area where it was captured, as well as useful information to ensure authenticity, freshness, fair trade fishing certificate, sustainability and security. The SAP Cloud Platform Blockchain helps clients, collaborators and developers to use this distributed ledger technology securely. It preserves information and provides a tamper-proof history of the supply chain that can be exchanged and viewed by every member [27], [28], [33].

FishCoin identifies itself as a "blockchain-based data ecosystem" funded by a secure coin token and promoting the collection across the supply chain of data on seafood items. Eachmile use Stellar as blockchain in the FishCoin, it has been developed as a peer-to-peer network that enables decentralized industry stakeholders to use a common protocol to take advantage of the benefits of blockchain so that information can be trusted, transparent and protected. Fisherman capture fishes and gather their capture information. They will probably trade their FishCoin token with any local mobile network operator that is an ecosystem participant for advertise. Fishers sell their capture to the first recipient and they obtain FishCoin tokens in exchange for the capture information. Each participant in possession of the fish brings more information to the ecosystem at any point in the supply chain. Individual who purchase the seafood product swap FishCoin tokens for the capture information with the prior individual before it hits the vendor who sells it to the customer [27], [28], [34].

In May 2019, the Sustainable Shrimp Partnership (SSP) entered the IBM Food Trust blockchain network to support traceability and transparency for its Ecuadorian farmed shrimp, suggesting the increases in food fraud and the distribution of low quality products. According to the SSP, shrimp manufacturers in Ecuador will capture data on the blockchain about how the shrimp is processed, which will then be available to stores worldwide that can monitor each level of the manufacturing process. The SSP aims to include a consumer interface to permit consumers access to the provenance data. Every shrimp has a blockchain-leveraged identification. The entire journey of shrimp life can be observed by everyone across the supply chain [27], [28], [35]. IBM's Food Trust is among the best performing traceability initiatives and it has features with brands such as Nestle, Sustainable Shrimp Partnership, Carrefour, Walmart, and Unilever. There are several other fish provenance project choose to used Food Trust fabric and Hyperledger blockchain is the type of blockchain used.

4.0 Discussion

Blockchain is one of the fastest growing and evolving technologies that is decisively aimed at providing complete transparency within a given supply chain to allow the process of traceability (tracking and tracing) to be convenient and protected. For the fisheries business, this is a certain added value. The used of blockchain platform on fish supply chain is an ongoing research that were perform to bring the best result for its growth, 2016 has been the year researcher started to develop a few project related to it [28], [36]. The unique formation process has blessed the blockchain [37], which has qualities such as decentralisation, trust-free, traceability, and smart contracts.

The lack of a central node in the network, the equivalent status of all nodes, and the failure of any node having no effect on the system's operation demonstrate the decentralised function. Inter-nodal communication is possible without mutual trust, and nodes are unable to impersonate each other under the blockchain law. The traceable feature ensures that no data is created without a blockchain base. All data operations in the system are transparent and open in a trust-free environment. Because all blocks in the blockchain are chronologically related, every block can access information from the prior block. The intelligent contract function attests to the idea that pre-written code in a blockchain automatically executes the agreement between the transacting parties; execution is resistant to any intervention, making it easier to conclude and more successful and less costly to execute [7]. The Internet of Things (IoT) aids in the connection of devices and sensors, and the combination of IoT and blockchain, which generates a large quantity of data as well, shows to be a cost-effective and time-saving option.

Permissionless blockchain is commonly used in all the project related to supply chain, this is because permissionless blockchain is a highly secure blockchain that provide immutability of records and a fully decentralized power structure [38]. Ethereum mainly chosen for its ability to secure the blockchain platform with smart contract, it's a set of code (its functions) and data (its state) which resides on the Ethereum blockchain at a particular address [39].

As the global demand and consumption of fish has increased, it is important for government or companies to priorities it fish supply chain as it provide information such as the division of labour practices and increase in competition, the global market entry which allows for sustainable income growth, and also how to get the benefits of globalization [1], [40]. In general, all of the above scientific works, presented as current supply chain models for fisheries industries, are defined by a linear model from suppliers and imports to retailers and food service providers. In the meantime, blockchain architecture provide a decentralized infrastructure in the supply chain, where each participant could write their transactions on their own. Each layer sends information from its transactions to the blockchain that interacts with each other with a useful smart contract for the sales transaction.

However, further research is required to disseminate these applications and encourage their potential implementation within the fisheries industries and to explore possible changes to enhance their effectiveness. The main obstacle of using blockchain-based fish supply chain is scalability aspect. Compared to traditional centralized databases, blockchain implementations often require a high degree of computerization, primarily due to the obvious scalability implications of their consensus frameworks and performance issues. It also leads to higher latency and lower transaction throughput. As the scale of the supply chain increases, the mining algorithm's complexity also increases. When mobile or IoT devices are low-battery with limited power, they are often not able to complete the extensive computing and data sharing required by blockchains. Therefore, one of the important problems is the creation of energy-efficient blockchain protocols and algorithms. By overcoming these obstacles, the functionality and effectiveness of blockchain technology will be improved.

5.0 Conclusion

This paper has identified available research and application of blockchain technology in the supply chain, focusing on fish supply chain. With the development of blockchain technology, integrating it into fisheries industries is an interest that started back in the year 2016 and has grown since. Multiple applications have been popping out through the year; however, there are still a few challenges that need to be overcome in order for it to be fully implemented in real life such as the life span of an IoT device due to power consume while performing complex process in blockchain and the cost effectiveness of implementing the technology. There are also secondary factor that need to be consider when implementing the blockchain technology in fish supply chain, such as maintaining the privacy of data in supply chain, connecting all the partner involve in fish-supply-chain, and the possibility of fraudulent activity due to human and machine interaction in the physical layer. In order to create a more stable blockchain infrastructure and strengthen the themes already discussed in this study, there are still aspects that should be deepened in the fisheries industry. Finally, because of their sophistication, these technologies seem very promising and rich in great potential, showing strong versatility for applications in many industries, but still immature and difficult to implement.

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References

[1] S. B. Islam and M. Habib, "Supply Chain Management in Fishing Industry : A Case Study," no. October, 2018.

[2] A. Rejeb, J. G. Keogh, and H. Treiblmaier, "Leveraging the Internet of Things and Blockchain Technology in Supply Chain Management," pp. 1–22, 2019.

[3] A. M. A. Abuagoub, "IoT Security Evolution: Challenges and Countermeasures Review," vol. 11, no. 3, p. 2019, 2019.

[4] A. Vangala, A. K. Das, S. Member, N. Kumar, and S. Member, "Smart Secure Sensing for IoT-Based Agriculture: Blockchain Perspective," vol. 1748, no. c, pp. 1–17, 2020.

[5] W. N. Probst, "How emerging data technologies can increase trust and transparency in fisheries," 2019.

[6] P. J. Taylor, T. Dargahi, A. Dehghantanha, R. M. Parizi, and K. R. Choo, "A systematic literature review of blockchain cyber security," Digit. Commun. Networks, no. January, 2019.

[7] W. E. I. Hu, Y. Hu, W. Yao, and H. Li, "A Blockchain-Based Byzantine Consensus Algorithm for Information Authentication of the Internet of Vehicles," IEEE Access, vol. PP, p. 1, 2019.

[8] D. Li, "A Blockchain-Based Authentication and Security Mechanism for IoT," 2018.

[9] S. Mahendra Kumar and Y. Thomas, "The Distruptive Blockchain: Types, Platform and Applications," Texila Int. J. Acad. Res., no. December 2018, pp. 20–26, 2018.

[10] Z. Zheng, S. Xie, H. Dai, X. Chen, and H. Wang, "An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends," Proc. - 2017 IEEE 6th Int. Congr. Big Data, BigData Congr. 2017, no. October, pp. 557–564, 2017.

[11] A. E. Guerrero-sanchez, E. A. Rivas-araiza, J. L. Gonzalez-cordoba, M. Toledano-ayala, and A. Takacs, "Blockchain Mechanism and Symmetric Encryption in A Wireless Sensor Network," 2020.

[12] S. Kim, U. Kim, and J. Huh, "A Study on Improvement of Blockchain Application to Overcome Vulnerability of IoT Multiplatform Security," 2019.

[13] Z. Cui, F. Xue, S. Zhang, X. Cai, Y. Cao, and W. Zhang, "A Hybrid BlockChain-Based Identity Authentication Scheme for Multi-WSN," IEEE Trans. Serv. Comput., vol. PP, no. c, p. 1, 2020.

[14] N. Elisa, "AIS Electronic Library (AISeL) Consortium Blockchain for Security and Privacy-Preserving in E- government Systems," 2019.

[15] O. Dib, K. Brousmiche, A. Durand, E. Thea, and B. Hamida, "Consortium Blockchains: Overview, Applications and Challenges," Int. J. Adv. Telecommun., vol. 11, no. 1&2, pp. 51–64, 2018.

[16] S. Moin, A. Karim, Z. Safdar, K. Safdar, E. Ahmed, and M. Imran, "Securing IoTs in distributed blockchain : Analysis , requirements and open issues," Futur. Gener. Comput. Syst., vol. 100, pp. 325–343, 2019.

[17] X. Rodriguez, J. Ericsson, S. J. Lee, and A. J. Perez, "A Cost Analysis of Internet of Things Sensor Data Storage on Blockchain via Smart Contracts," 2020.

[18] P. W. Khan, Y. C. Byun, and N. Park, "IoT-Blockchain Enabled Optimized Provenance System for Food Industry 4.0 Using Advanced Deep Learning," pp. 1–24, 2020.

[19] H. Zhang, J. Wang, and Y. Ding, "Blockchain-based decentralized and secure keyless signature scheme for smart grid," Energy, vol. 180, pp. 955–967, 2019.

[20] S. S. Sabry, N. M. Kaittan, and I. M. Ali, "The road to the blockchain technology: Concept and types," Period. Eng. Nat. Sci., vol. 7, no. 4, pp. 1821–1832, 2019.

[21] Z. Liu and Z. Li, "A blockchain-based framework of cross-border e-commerce supply chain," Int. J. Inf. Manage., no. December, p. 102059, 2019.

[22] A. Moinet, B. Darties, and J. Baril, "Blockchain based trust & authentication for decentralized sensor networks," pp. 1–6, 2017.

[23] S. Guo, X. Hu, S. Guo, S. Member, X. Qiu, and F. Qi, "Blockchain Meets Edge Computing : A Distributed and Trusted Authentication System," IEEE Trans. Ind. Informatics, vol. PP, no. c, p. 1, 2019.

[24] E. F. Cruz and A. M. R. da Cruz, "Using blockchain to implement traceability on fishery value chain," ICSOFT 2020 - Proc. 15th Int. Conf. Softw. Technol., no. July, pp. 501–508, 2020.

[25] L. Hang, I. Ullah, and D. Kim, "A secure fish farm platform based on blockchain for agriculture data integrity," Comput. Electron. Agric., vol. 170, no. December 2019, p. 105251, 2020.

[26] A. Rejeb, "Blockchain Potential in Tilapia Supply Chain in Ghana," Acta Tech. Jaurinensis, vol. 11, no. 2, pp. 104–118, 2018.

[27] B. Francisco and K. Kenneth, Blockchain application in seafood value chains, vol. 1207. 2020.

[28] P. Howson, "Building trust and equity in marine conservation and fisheries supply chain management with blockchain," Mar. Policy, vol. 115, no. September 2019, p. 103873, 2020.

[29] Provenance, "From shore to plate: Tracking tuna on the blockchain | Provenance," 2016. [Online]. Available: https://www.provenance.org/tracking-tuna-on-the-blockchain#overview. [Accessed: 05-Feb-2021].

[30] B. Cook, "Blockchain : Transforming The Seafood Supply Chain," pp. 1–41, 2018.

[31] Pacifical, "Pacifical MSC Sustainable Tuna Now Traceable via Ethereum Blockchain – PACIFICAL," 2018. [Online]. Available: https://www.pacifical.com/pacifical-msc-sustainable-tuna-now-traceable-via-ethereum-blockchain/ [Accessed: 05-Feb-2021].

[32] "WWF-Australia and OpenSC - WWF-Australia - WWF-Australia," WWF-Australia 2018, 2018. [Online]. Available: https://www.wwf.org.au/get-involved/panda-labs/opensc#gs.sd725z [Accessed: 05-Feb-2021].

[33] S. News, "Bumble Bee Foods and SAP Create Blockchain to Track Fresh Fish from Ocean to Table," 2019. [Online]. Available: https://news.sap.com/2019/03/bumble-bee-foods-sap-create-blockchain-track-fish/ [Accessed: 05-Feb-2021].

[34] "Fishcoin: Blockchain Based Seafood Traceability & Data Ecosystem," 2018. [Online]. Available: https://fishcoin.co/. [Accessed: 05-Feb-2021].

[35] J. Jablonska, "sustainable shrimp for a sustainable future," 2019.

[36] F. Antonucci, S. Figorilli, C. Costa, F. Pallottino, and P. Menesatti, "A review on blockchain applications in the agri-food sector," no. June, 2019.

[37] Q. Wang, X. Zhu, Y. Ni, L. Gu, and H. Zhu, "Blockchain for the IoT and industrial IoT : A review," no. xxxx, 2019.

[38] M. K. Lim, Y. Li, C. Wang, and M. L. Tseng, "A literature review of blockchain technology applications in supply chains: A comprehensive analysis of themes, methodologies and industries," Comput. Ind. Eng., vol. 154, no. January, p. 107133, 2021.

[39] L. Hang and D. Kim, "Design and Implementation of an Integrated IoT Blockchain Platform for Sensing Data Integrity," 2019.

[40] C. Pedroza-gutiérrez and J. M. Hernández, "Social Networks and Supply Chain Management in Fish Trade," 2020.