Tittle Page

Name of the authors: Isti Surjandari[1], Harman Yusuf[1], Enrico Laoh[1], Rayi Maulida[1]

Tittle: Designing a Permissioned Blockchain Network for the Halal Industry Using Hyperledger Fabric with Multiple Channels and the Raft Consensus Mechanism

Affiliation and address of authors: [1] Industrial Engineering Department, Faculty of Engineering, Universitas Indonesia, Kampus UI, Depok 16424

E-mail address of corresponding author: isti@ie.ui.ac.id

Designing a Permissioned Blockchain Network for the Halal Industry Using Hyperledger Fabric with Multiple Channels and the Raft Consensus Mechanism

Abstract Blockchain is an alternative solution that can improve the performance of the halal supply chain. Blockchain can address all the issues in the halal supply chain, such as the contamination of halal products and the disobedience of halal processes among all parties in the chain, including end customers. The type of technology suitable for this case is permissioned blockchain, in which administrators can determine the rights of each halal supply chain participant category. The determination of these rights must be done by consensus so that no party feels aggrieved. This study uses a blockchain network with three channels and the Raft consensus algorithm to design a web interface and test its capabilities. With regard to the web interface, there were no validity failures during the invoke and query tests. In addition, the web interface was also successful in thwarting the formation of a block in the case of data input errors from the user. Additionally, the server can act as a provider of information and validator of the web interface. The results of simulations conducted on the blockchain network show that the system's transaction speed is fast, and all the transactions are successfully transferred to other peers. Thus, permissioned blockchain is useful for the halal supply chain not just because it can secure transactions while addressing halal issues but also because the transaction speed and rate of transfer data are very effective.

Keywords *Blockchain, Hyperledger Fabric, Multiple Channels, Raft, Halal, Supply Chain*

Introduction

The advent of the Fourth Industrial Revolution promises significant opportunities and challenges in many industries, including the supply chain. Supply

chain industries embrace automation and data exchange and implement new technologies, including blockchain, artificial intelligence, and the Internet of Things (IoT) [1]. These innovations are fundamentally changing supply chain dynamics, including those in the halal industry.

The Islamic economic development report published by the Dubai International Financial Center in 2019 states that the halal industry has increased rapidly compared to some other industrial sectors, with an average growth of 100 billion USD annually, and is expected to reach 3.2 trillion USD in 2024 [2]. This growth is influenced by the increase in Muslim populations around the world. From a report on Muslim growth published by the Pew Research Center in 2011, the Muslim population is estimated to grow by 1.63% over the next 10 years, and Muslims are expected to be 26.4% of the total population worldwide in 2030 [3]. The size and growth in the Muslim population will result in an increase it its purchasing power; hence, the value of the halal industry will increase.

Despite the increase in the halal industry's purchasing power and value, it has not yet achieved its optimal potential, as there are still many sectors that can be improved. For example, although Indonesia is recognized as the Muslim world's most populous country, it lags behind other Muslim-majority countries in creating an ecosystem that supports the halal industry, according to the Global Islamic Economy Indicators (GIEI) 2019. Thus, there are still many areas that can be improved to maximize the halal industry both domestically and globally, such as improving the quality of the halal supply chain [4].

The government's role in improving the halal supply chain is substantial, including enforcing laws that require all business actors to provide halal certificates for food products, medicines, cosmetics, and other genetically engineered products. Halal certificates are proof or guarantee that the products are in accordance with

Islamic law. However, halal certificates cannot improve the halal supply chain on their own. The raw materials used and the process to make a product, as well as the final product, must be halal. One way to improve the halal supply chain is to integrate technology for information exchange during the tracking and tracing process in operating and monitoring performance [5]. Moreover, both vertical and horizontal collaborative relationships in the form of trust, transparency, and information disclosure between supply chain participants are essential in order to maximize the integration of technology and information with the halal supply chain and to increase their mutual effectiveness and efficiency [6].

Blockchain may thus provide solutions to improve the halal supply chain because it can ensure the completion of all supply chain transaction notifications for all parties in the blockchain network, up to end customers. Permissioned blockchain is the most suitable type of blockchain for this industry, where the role of each supply chain participant will be determined by an administrator, affecting what information each participant can see and add. Mainly, supply chain participants such as suppliers, distributors, wholesalers, and retailers focus solely on their respective areas. Thus, regulators must determine the role of each supply chain participant; in determining each role, a consensus must be achieved so that no party feels disadvantaged [7][8].

Supply chain transactions grow with the addition of new sequences of transactions, which are grouped as a block. Each block will be added to the blockchain network in a linear chronological order with a timestamp. Each supply chain participant, known as a peer node on the halal supply chain network, receives a copy of the blockchain data that can be downloaded automatically. Peer nodes have access to all information, including the supply chain participant's address and

supply chain path; hence, even the end product user will know the flow of the manufacturing process of a particular product [9].

This paper aims to propose a blockchain framework for the halal supply chain by using Hyperledger Fabric. It also tests this framework to determine its suitability for the halal supply chain and to identify some key aspects that can improve the halal supply chain, validate the transaction process, and test the transaction speed. The rest of this paper is organized as follows. The "Methodology" section consists of related work on the methods that will be used. The "Results" section consists of the proposed blockchain framework and an overview of the finished interface of the blockchain framework. The "Discussion" section consists of a discussion of the results obtained in this research. The "Conclusion" section includes the research conclusions and some possible suggestions for future research.

Methodology

In this section, we will discuss the theoretical basis of the concepts used in this study. The concepts explained include theories and applications of blockchain, permissioned blockchain, supply chains, the halal supply chain, blockchain and supply chains, blockchain and the halal supply chain, and Hyperledger Fabric.

Blockchain

Blockchain includes a time-stamped series of data that are managed by all nodes participating in the network. The data are stored as a block and secured and linked to each other using the cryptographic principle (chain), which is immutable. The participants (in decentralized-computer-terminal form) are connected by using a key-access system enabling direct transactions between sellers and buyers without

intermediaries [9]. Many processes can be improved by using blockchain, such as the analysis of big data [10,11]

Permissioned Blockchain

Permissioned blockchain involves an additional blockchain security system, as it includes control over certain identifiable participants' ability to perform certain actions. The intrinsic configuration of blockchain manages transaction nodes and defines the role of these nodes in accessing or making changes to the blockchain, including protecting the identity of each blockchain participant in the blockchain network [7,12].

Supply Chain Management

The supply chain is an interconnected system of organizations, resources, and processes to deliver products or services to end customers, including all facilities, functions, and activities related to manufacturing, production, and distribution from the supplier to the customer [13]. Supply chain management is a process of designing, coordinating, and controlling every aspect of business activities and supply chain activities to provide added value to consumers at a minimum cost to the overall supply chain network while fulfilling the requirements of other stakeholders in the supply chain [14].

Halal Supply Chain Management

Halal supply chain management may be defined as assuring that the entire process of procurement, distribution, handling, and processing materials, spare parts, livestock, work-in-process or finished inventory is well documented and aligned with halal and toyyib standards [6]. The designation of "halal" means that a product is permitted or legally permissible in accordance with the rules in the

Qur'an and the Hadith. The opposite of halal is haram, which means prohibited, illegal or illegal [15].

In addition, the term “toyyib” means healthy and good [15]. The toyyib concept can also be used to enrich society with spiritual, moral and humanitarian values, as well as food safety regulations [16]. However, the gray area (located between halal and haram) causes doubt in the application of the halal concept. Therefore, the opinions of academics, local fatwas (government regulations), and local customs are involved in assessing and determining whether a product is prohibited or allowed to be consumed [17].

Supply Chain and Blockchain

Generally, information systems that are executed in transactions between suppliers, distributors, retailers, and end customers tend to be centralized. This centralized information system causes every supply chain participant to be obligated to maintain the confidentiality of supply chain information. Some distress might arise because the supply chain network became rigid, and every participant has difficulty validating the number of products ordered [8].

Blockchain technology could resolve these problems since it could act as a distributed ledger and entitle all transactions to be completely open, yet confidential and secured. Blockchain provides security by preventing the duplication of data or the distortion of data from outside noise. Some types of blockchains devoted to private transactions have a high real-time speed of transactions [7] [18].

Supply chain transactions will be gathered in a set of blocks when each set of new transactions is successfully added. The block will be added to the blockchain network in a linear chronological order with a timestamp. Each supply chain participant, known as a peer node on the halal supply chain network, receives a

copy of blockchain data that can be downloaded automatically. Peer nodes have access to all information, which includes the supply chain participant's address and supply chain path; hence, even the end product user will know the flow of the manufacturing process of a particular product [19].

Halal Supply Chain and Blockchain

The halal supply chain includes five fundamental issues that are hard to dissociate: traceability (the ability to discover information about the location and origin of the product); regulation of product withdrawal related to halal prerequisites; end-to-end halal supply chain integrity from the producer to the customer; contradictory systems and different interpretations regarding the halal supply chain; and the lack of integration of technology and information in the halal supply chain [20].

The halal supply chain needs transparency so that the authenticity and reliability of halal brands can be ensured. Blockchain enables the combination of distributed ledgers and smart contracts so that the performance of the halal supply chain will increase. The improvement will generate more dependable information and assurance along the halal supply chain; a smooth and effective halal process from the beginning of production to the consumer’s point of purchase; the sustainability of the halal supply chain; consumer trust in halal certification; and global acknowledgement of the halal blockchain [6].

The fundamental principle of the halal blockchain is to combine all mazhab in targeted markets with Islamic schools, religious regulations (fatwas), and local traditions. The halal blockchain must be pertinent for all countries (whether Muslim or non-Muslim). Halal certification prerequisites are vital to the halal blockchain. Halal supply chain participants are automatically given information about process

compliance based on specific product market scenarios. The halal blockchain's authenticity and security are a priority to secure confidential data and minimize the opportunities for cyber attacks [5]

The halal blockchain provides some benefit for producers, distributors, retailers, logistic service providers, and halal certification agencies. Halal certification agencies must adopt the blockchain technology to increase trust in and authenticity of halal certification. They need to support the halal certification of all halal supply chain participants to encourage the obedience to halal standards in transportation and warehousing downstream in the supply chain. Harmonizing the standards of the halal supply chain in various countries will be critical to supporting the halal industry and its global supply chain [5] [20].

Prior research related to blockchain and its impact on the halal supply chain has stated that there are three issues faced by the halal supply chain globally: contamination, disobedience, and perception. In this case, blockchain technology has the potential to resolve the first two problems (i.e., contamination and disobedience). However, the application of blockchain needs to be combined with the halal certification of each supply chain participant to obtain better outcomes [6].

Hyperledger Fabric

Hyperledger Fabric is an open-source distributed ledger technology platform that is widely used for various company-related cases. This platform is very interactive in creating a blockchain framework due to its modular and configurable architecture.

Hyperledger Fabric V.1.x can organize transactions into two types: execution transactions and ordering transactions. Thus, there are 3 steps of the transaction flow, which are execution, ordering, and validation. A transaction can

be executed before consensus from the ordering service is executed, and it can be done by different peers [21].

In the blockchain system, there are some key terms, such as nodes, data structures, transactions, ordering services, and channels [7]. Blockchain networks must consist of several nodes. These nodes are usually defined as virtual entities because they can run on physical hardware. Peers, orderers, and clients are nodes in the blockchain network [22]. Peers make transactions and distribute ledgers. In general, all peers are committers. On the other hand, orderers keep all the orders from the transaction that has been committed, creating new blocks, and searching for consensus.

Clients are a set of nodes that act as the end users on blockchain networks. Clients' main actions are to send a transaction proposal to peers, coordinate the results of the execution, verify whether the transaction is valid and send the transaction that has been verified by peers to the ordering service. Furthermore, the data structure maintains the global status among all associates using key value storage and ledgers (KVS). KVS is used to manage and maintain the most recent system, while the ledger provides a valid and verified history of all state changes.

In Hyperledger v1.4.x, there are several types of transactions, such as init (deploy), which is useful for installing and instantiating chaincodes so that transactions can be run; invoke, which is useful for invoking transactions from chaincodes that have been installed and instantiated; and query, which is useful for checking what transactions were successfully carried out in the process [23].

The transaction flow on the v1 fabric follows the following steps:

- The client makes a transaction and sends it to all endorser peers according to the chain

- Each endorser peer authorizes transaction execution and makes endorsement signatures
- Clients collect support signatures from endorser peers through the ordering service
- Ordering services create transaction blocks and maintain orders with a timestamp
- When supporting partners receive a block of transactions, they will assess each transaction against its authorization policy and then determine the validity of the transaction

There are three types of ordering services provided by Hyperledger Fabric currently, namely, Solo (without consensus), Kafka [23] and Raft [24]. Basically, Kafka and Raft are the same type of consensus (crash fault tolerant). However, Raft is easier to use than Kafka, from the configuration to the speed of the process, because the Raft configuration originates directly from the orderer (unlike Kafka, which cannot be configured directly from orderer services and must create a Zookeeper cluster to enable the state machine replication process) [25][26].

All nodes, such as peers, can interact with other peers by using channels or private data. Channels make transactions truly private because only users who are in the same channel can make transactions and see all the data (transparent). Unlike private data, which make transactions truly private in the channel, only peers that are already configured to do so can perform transactions that are very private to specific peers, even though they will eventually be distributed to colleagues when the block is distributed [27].

Results

In this section, we will discuss the blockchain framework that will be designed for the halal supply chain and an overview of the blockchain network server and web interface.

Research Object

For the purpose of this study, an example from the halal meat industry was identified based on the research and will be used in this paper. The reason for choosing the meat industry is that this industry's toyyib compliance involves unique challenges, as meat is perishable and it is exceedingly difficult to control the temperature [28]. These factors create difficulties for the supplier, producer, distributor, wholesaler, and retailer in ensuring that fresh meat is free from contamination, disobedience of halal principles, and perception issues. To handle some of these challenges, blockchain can solve only the first two problems – contamination and disobedience – because of its characteristics, which are explained in the previous section [17].

The supply chain participants in the halal meat industry include suppliers, producers, distributors, and customers. In the halal meat industry, only livestock that meets certain age criteria will be slaughtered. Its meat will be sent to producers to be processed and cooled. The meat will be tested to determine whether it is halal or not. Only halal-certified meat will be sent to the distributor. The distributor will send it to the end customer or refrigerate it [29].

In general, the supply chain participants (suppliers, producers, distributors, and customers) already have halal certification from regulators. However, since customers only see the final product, not the raw material used or the process of

making the product to determine if it is halal, some customers doubt the halal industry supply chain's compliance with halal practices. A diagram of the halal supply chain flow is shown in Figure 1.

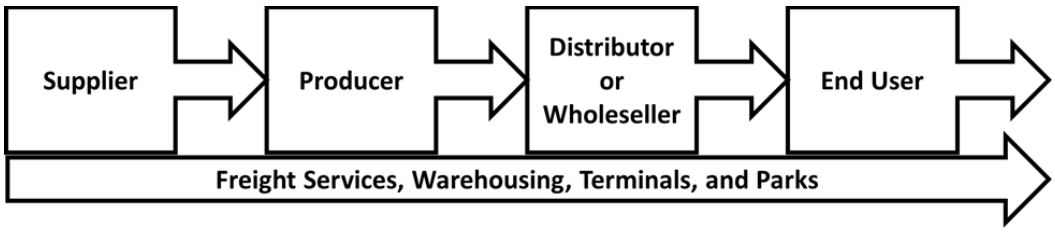

Fig 1. Ordering Service Process from the Halal Supplier to End User [29]

A blockchain network for a meat ordering system was created to resolve traceability problems regarding the final product. Blockchain, as a distributed ledger, is obliged to record transactions in a time sequence. After a transaction is gathered in a set of blocks, the block is irrevocable. The irrevocable nature of blocks can address customers' doubts about the traceability of halal-certified meat.

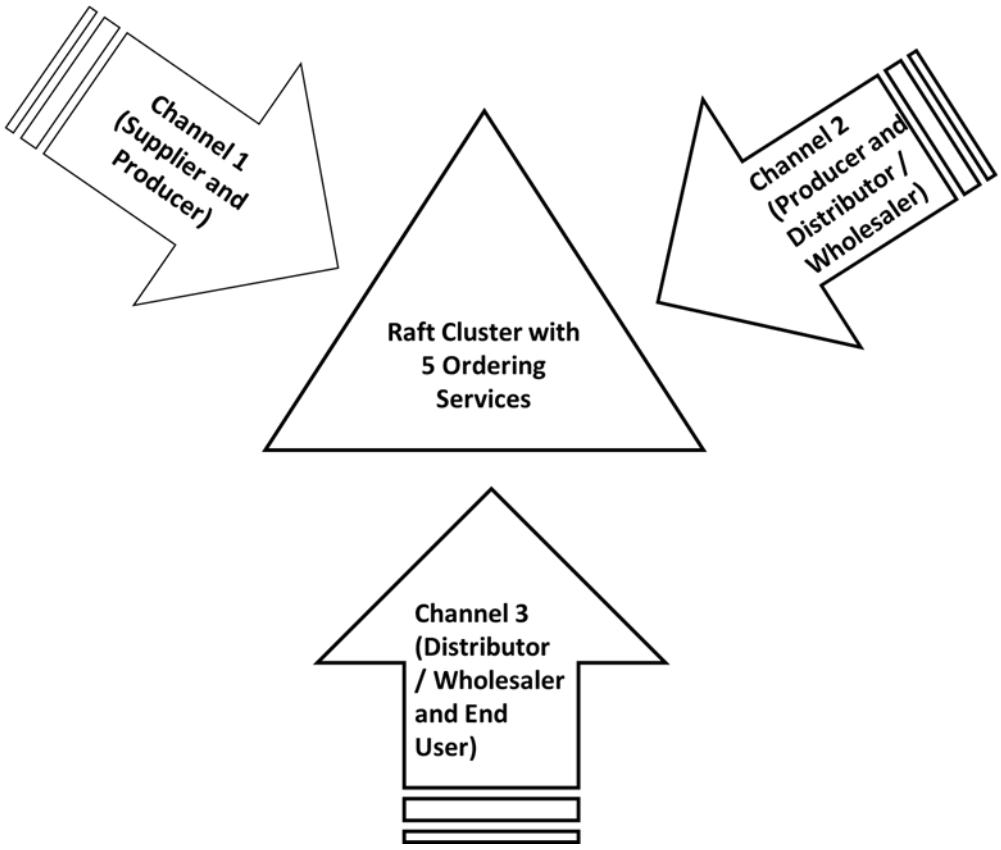

Fig 2. Blockchain Framework for the Halal Supply Chain

The blockchain network in this study consists of three channels, with each channel consisting of two organizations, and each organization consisting of one client and two peers. The first channel connects suppliers and producers, the second channel connects producers and distributors, and the third channel connects distributors and end users. Three separate channels are created because each participant may have a different price agreement; thus, their privacy is protected. The blockchain network also consists of five orderer nodes that have been configured with the Raft consensus mechanism. A channel configuration diagram is given in Figure 2.

For simplicity, this research will explain the process of configuring the first channel, which is the supplier and producer channel (because all the processes in creating the three channels are very similar). The steps for configuring the blockchain network are as follows [30]:

- Creating the blockchain network for all halal supply chain entities and creating network administrators (which needs to be done once in the process because all the channels must be included in the same network to allow some peers to have the ability to interact in multiple channels).
- Defining the consortium of the entities (for example, the supplier will be bound with the producer in the consortium because they will conduct the transaction process).
- Creating the first channel for the consortium process of the supplier and producer.
- Inserting peers of the supplier and producer into the channel (to interact with other peers and save proof of the transaction on the ledger).
- Installing and instantiating the chaincode to each peer (the supplier is needed once in the process but the producer is needed twice because the

producer will be added to the other channels). Although smart contracts in this design are similar, the real-world process is actually different because contracts in the real world should be more complicated.

The result of the blockchain configuration process is shown in Figure 3.

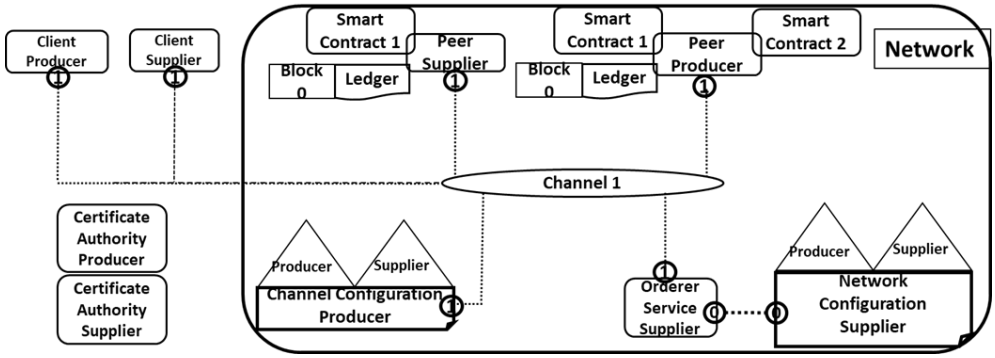

Fig 3. The Results of the Blockchain Channel for Suppliers and Producers in the First Channel of the Blockchain Network [30]

Overview of the Blockchain Network Server and Interface

There are four processes of the blockchain prototype used for the halal supply chain (basically this blockchain is developed with Fabcar, and its chaincode is modified according to the halal supply chain), namely, querying a single item's ID (checking one item in the blockchain), querying all items (checking all items in the blockchain), transferring an item ID (transferring one or more items to another company), and creating an item ID (creating one or more items in the blockchain). The main change from the chaincode is the Create an Item ID process. The layout of the web interface can be seen in Figure 4.

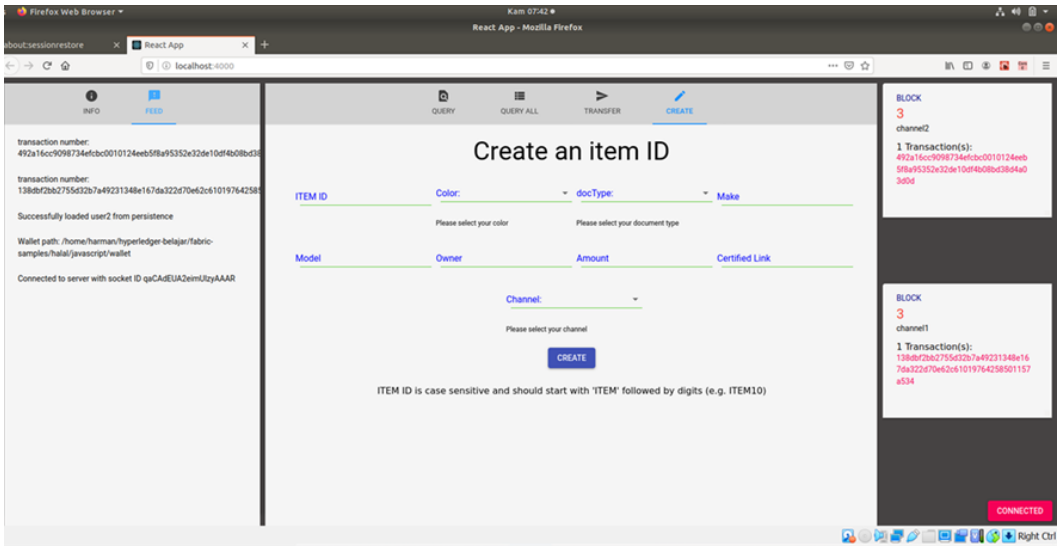

Fig 4. Display of the Blockchain Network's Web Interface

In the process of entering transaction data into the blockchain (invoke), there are two types of processes, called Create an Item ID and Transfer an Item ID. Create an Item ID involves several special attributes consisting of an item's ID, color, doctype (the type of item to be sent), make (item name), model (specification/type of item), owner (owner), amount (amount goods to be transferred), and certification link (proof of halal certification). Then, some companies have special attributes for making transactions on different channels. Some of the attributes that were changed or added from the Fabcar chaincode for the creation of an item ID are color, doctype, amount, certification link, and channel.

In the color attribute, the user can choose a color to add to the attribute without having to write the type of color the item has again. This step will make it easier for the user because some data attributes that input text will cause the user to type the input from the beginning again. In the doctype attribute, items created or transferred on the blockchain are not only in the form of food; drinks or other items in general can also be included in the blockchain. Then, regarding the amount attribute, the company that wants to create an item can specify how many items will be sent so that no repetition is needed when entering data if the items sent are in

large quantities. For created or transferred items to be considered halal, the company sending the item must send a link to halal certification documents so that it can be proven. With the certification link function, trust between companies about items sent in the halal category will increase.

Furthermore, all companies that enter two channels (such as producers who interact with suppliers and distributors or distributors who interact with producers or customers) have a special attribute on the interface, namely, a channel. There are two advantages of this channel attribute: (1) items that the company wants to create or transfer to another company will be sent correctly and (2) the interface of a company that has two channels is not necessarily separated into two interfaces so that it is easier and more interactive to conduct transactions with the company.

To prove that the system can be made, two key areas must be considered: the web interface (whether block data can be created directly from the web interface (client)) and the integrity between the web interface and server of the terminal (whether the data are truly properly stored on the server so that no data are lost).

Discussion

In this section, we will discuss the validity test of the web interface and test the integrity of the web interface and server to determine whether the interface can be used. We also test a blockchain network transaction simulation to determine how many transactions can be received by the blockchain network.

Validity of the Web Interface

When the web interface is successfully initiated in the web browser, the block and transaction ID data for the block will appear on the right. This function shows that data transactions in the blockchain have been carried out. In the previous

image, we can see that the third block of the blockchain was formed before the web interface was used. This occurred because the process of installing and instantiating the chaincode was done previously to initiate the web interface. Then, when all data attributes are successfully entered according to their respective attributes, the latest block (in this case, block 4) and the transaction ID will automatically appear on the right side of the web interface. Moreover, the left side of the web interface will notify the user that data for the item from the user's company is successfully entered.

The process of making a block can only be done using Create an Item ID and Transfer an Item ID. This is because the process of writing and reading data (the process of writing data so that new data appears or changing old data) occurs in both parts. The process of writing new item data can be done using Create an Item ID, and the process of changing item ownership can be done using Transfer an Item ID. Both processes must be separated even though they have the same goal of entering data into the blockchain. Create an item ID can be done only if the item to be entered in the form has an ID that is still not registered in the company's blockchain database. Meanwhile, an item ID can be transferred only if the item is already registered in the blockchain database. This is because the main purpose of transferring an item is to change the database as well (the most recently viewed data), thus creating a new block. Old blocks of data on the IDs of items whose ownership has not been changed will remain the same to maintain the blockchain's tamper-proof nature.

Meanwhile, from querying an item ID and querying all item IDs, the two parts of the web interface have the function of reading data (to check the items in the blockchain and their data attributes). When both parts of the web interface are executed, the new block on the right will not be formed because its main purpose is to check the block and transaction IDs. However, on the left side of the web

interface, database information (the most updated information) about the item and its attributes will appear on demand. The difference between the two parts is that Query an Item ID will search only for a specific item ID that matches the channel that connects the information, while Query All Items looks for all information about the item ID corresponding to the channel for this information.

There are several reasons why a block could be filled with incorrect data and cause the Blockchain to be invalid, such as the incomplete or incorrect entry of data attributes. To prevent this, interfaces and servers are created using prevention methods such as pop-ups or error messages so that invalid data will not be stored in a company's blockchain database server. For example, in the creation of an item ID section, the first requirement is that all data must be entered. If at least some of the data attributes are not entered, then the item’s data cannot be entered into the blockchain channel.

In addition, in the Item ID section, filling in the data form can be done only if the first four letters are "ITEM" in capital letters, followed by a number (for example: "ITEM4"). Then, the item ID must be different from the item ID that exists on the blockchain so that there is no duplication in blockchain item data. If all the requirements above are not met, an error will appear on the interface. Unlike when creating an item ID, transferring an item allows only data on items with existing IDs to be stored. If the item ID of a transferred item is not in the blockchain, an error will appear, reminding the user that the data are not in the blockchain, so the item transfer process cannot be performed.

Integrity of the Web Interface and Server

The server performs other functions in addition to storing transaction data from the web interface. The terminal server also sends notifications to the company

even though the web interface is still not turned on. When the company wants to check information about any item already in the blockchain through the web interface, that information will also appear on the terminal server. Then, when the company sends data or changes data about the item in the blockchain through the web interface, the terminal server will notify the company that sent the notification that the information sent was successfully saved to the blockchain and send information about the number of blocks that have been created in the blockchain. The terminal server also sends notifications to companies that are on the same channel as companies that send data about an item or data changes within the blockchain and send information about the number of blocks that have been created in the blockchain. Finally, if there is an error in inputting data, the terminal server will raise an error that one of the data attributes sent is not in the correct format.

Transaction Simulation Test

Simulation Configuration

The blockchain is tested for four rounds and three iterations for each channel (a total of 36 rounds). Each channel is tested for two rounds for the invoke process (Create an Item ID and Transfer an Item ID) and two rounds for the query process (Query an Item ID and Query All Items). Because the simulation process is intended to test the maximum ability of the blockchain network to receive transactions, each test uses "fixed-backlog" to determine the maximum tps (transactions per second) and the maximum transactions that experience a backlog of 5 transactions. Each iteration has a different transaction duration – 10, 30, and 30 seconds. The reason for choosing a simulation based on transaction duration rather than the number of transactions is the same as the reason for using the "fixed-backlog" type.

The blockchain network’s capability was tested based on previous research cases using three channels and Raft crash tests with Ubuntu 18.04 LTS 64-bit with 18 GB RAM and a 250 GB hard disk installed with Hyperledger Caliper and Hyperledger Fabric.

Simulation Results

Based on Figures 5, 6, and 7, all iterations have the same results and patterns. The are no failures in the capability tests. From the results on all queries (Query an Item ID and Query All Items), it can be seen that in the first iteration (Figure 5), the value of the transaction send rate and query throughput for an item is the highest (74.8 TPS in the first iteration of channel 1), but in the second and third iterations (Figures 6 and 7), both processes have almost the same send rate and throughput (40.0-57.1 TPS). From these results, it can be said that the faster the duration of the transaction is, the faster the query process. In addition to the second and third iterations producing almost the same results, all query result patterns are also almost the same (in terms of throughput and send rate results).

On the other hand, the results of all invoke transactions are almost the same in all iterations. It can be seen that the result for the send rate is approximately 43.5 - 47.2 TPS. However, the "Create an Item ID" throughput rate decreases every iteration (the first iteration is approximately 30-31 TPS, and the second and third iterations are approximately 19-26 TPS), although the "Transfer an Item ID" throughput rate is still almost the same for all iterations of each channel (16-21 TPS). This pattern is also different from the query pattern, which shows that the results for the query throughput rate are approximately twice the invoke throughput rate. From all the results obtained, it can be said that the faster the send rate is, the slower the throughput because the invoke process is more difficult than the query

process. The likely reason why the send rate is slower is the power of the computer running the computing process.

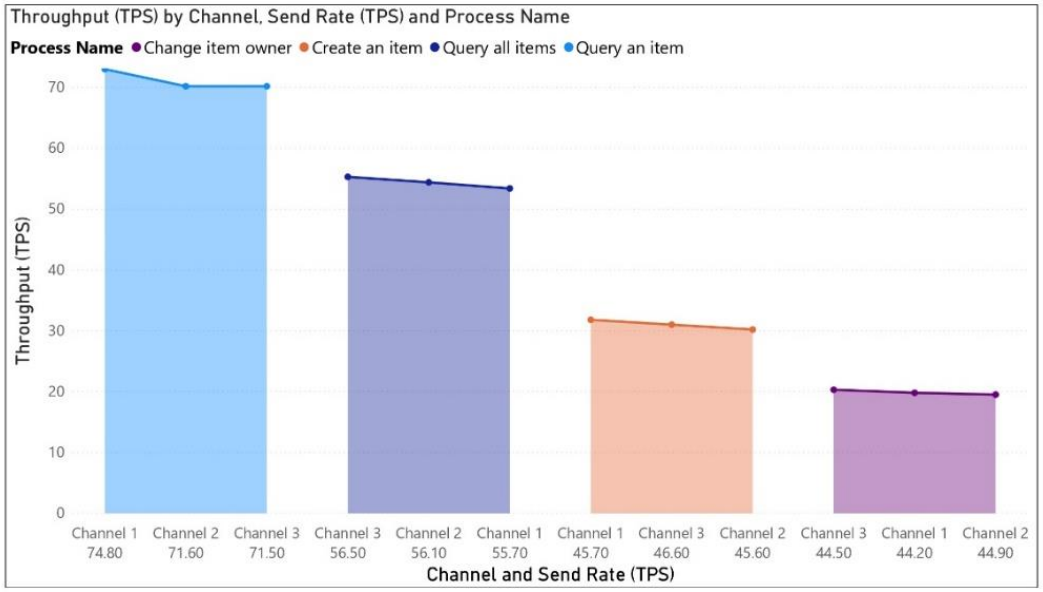

Fig 5. Simulation Results, First Iteration

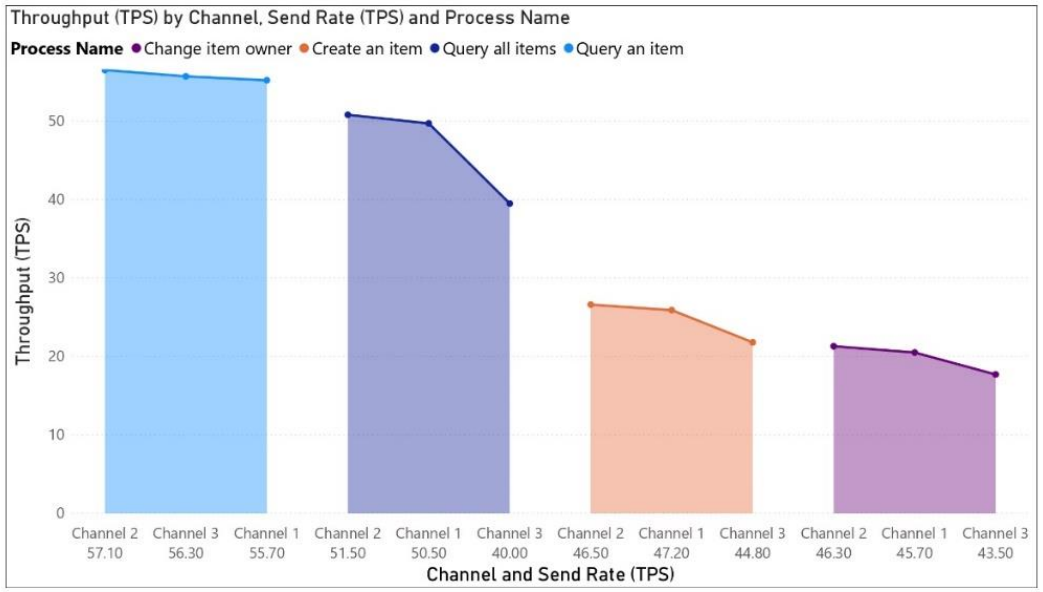

Fig 6. Simulation Results, Second Iteration

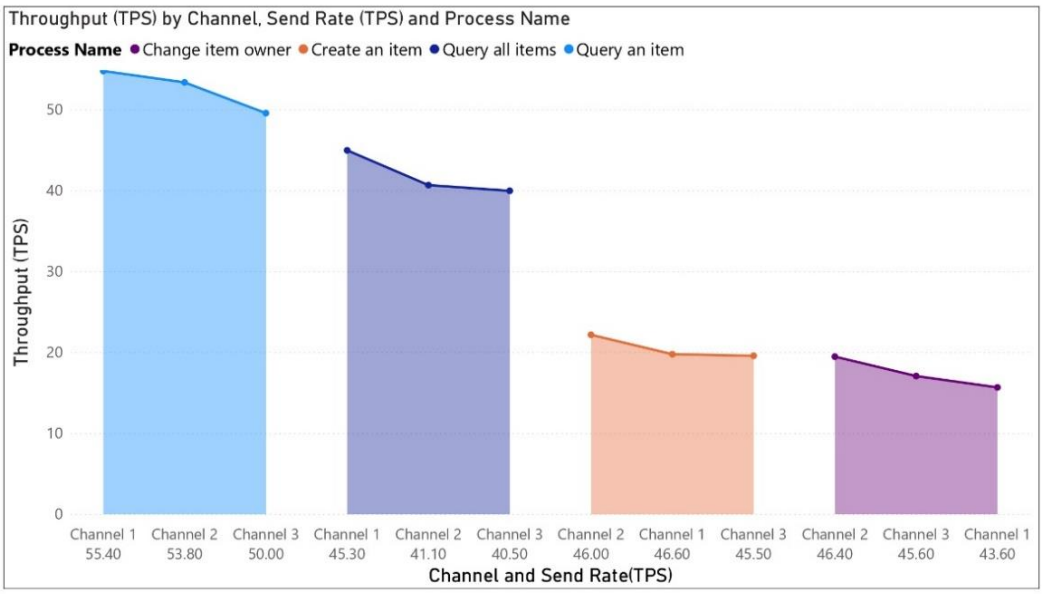

Fig 7. Simulation Results, Third Iteration

Conclusion

Permissioned blockchain is one of the newest technologies to be compatible with the halal supply chain, where administrators can determine the rights of each category of halal supply chain participant, including what information is visible and what information can be added to the blockchain. Usually, halal supply chain participants such as suppliers, distributors, wholesalers, and retailers focus only on their respective areas. Thus, regulators are also needed to determine the rights that exist (so that a contract on the blockchain can be formed in accordance with the case). Of course, the determination of these rights must also be done by consensus so that no party feels disadvantaged.

The web interface created passed the validity test for the invoke function using the Create an Item ID and Transfer an Item ID processes and the query function using the Query an Item ID and Query All Items processes. In addition, the web interface was also successfully tested to thwart the formation of a block in the case of data input errors from the user. In the integration of the web interface

with the server, the server can serve as a provider of information and a validator of the web interface when the invoke or query processes on the web interface are running or an input error occurs on the web interface that causes the failure of blocks to be created on the blockchain.

Finally, from the results of simulations performed on the blockchain network created, we can see that blockchain can secure transaction data because not all transaction processes fail. Therefore, it is especially useful for securing transaction data about halal products, such as food or drinks, on the blockchain. This "tamper-proof" ability also creates transparency for end users who want to examine the halal supply chain process.

In the future, this research can be expanded by using other blockchain consensus methods, such as Practical Byzantine Fault Tolerance and Zero Knowledge Proof. Other consensus methods can be simulated into the blockchain network system to determine which method’s performance is best. Some developments can also be made to the blockchain network web interfaces, such as creating special programs to improve the interface for smartphones or developing user login systems through interfaces to validate blockchain network users. The interface of the blockchain network can also be synchronized with a barcode system to allow users to trace goods (Track and Trace). Furthermore, artificial intelligence can also be integrated into the blockchain network to smooth data input or data processing.

Author Contributions

IS, HY, and EL designed the idea and drafted the paper, IS and HY conducted the programming and analyzed the results, and EL and RM conducted the literature review and prepared the manuscript. All the authors checked and approved the final manuscript.

Acknowledgments

The authors would like to express appreciation and gratitude to Universitas Indonesia for funding this study through PUTI Q2 Research Grants Universitas Indonesia No: NKB-1702/UN2.RST/HKP.05.00/2020.

Availability of Data and Materials

All available data sources are described in this article.

Competing Interests

All the authors declare that they do not have any particular competing interests.

Funding

This research is funded by the Directorate of Research and Development Universitas Indonesia.

References

1. Kehoe L, O'Connell N, Andrzejewski D, Gindner K, Dalal D. Introduction. In: When two chains combine: Supply chain meets blockchain. Deloitte. 2017. https://www2.deloitte.com/content/dam/Deloitte/pt/Documents/blockchainsupplychain/IE_C_TL_Supplychain_meets_blockchain_.pdf. Accessed 20 Aug 2019
2. Dinar Standard. Global Islamic Economy Key Drivers. In: State of the Global Islamic Economy Report 2019/20. Dubai International Financial Centre. 2019. https://salaamgateway.com/reports/report-state-of-the-global-islamic-economy-201920. Accessed 22 Aug 2019
3. Grim BJ, Karim MS. Executive Summary. In: The future of the global Muslim population: Projections for 2010-2030. Pew Research Centre. 2011. http://assets.pewresearch.org/wp-content/uploads/sites/11/2011/01/FutureGlobalMuslimPopulation-WebPDF-Feb10.pdf. Accessed: 26 Aug 2019
4. Ngah AH, Zainuddin Y, Thurasamy R. Barriers and enablers in adopting of Halal warehousing. J Islam Mark. 2015;6(3):354–76. doi:10.1108/JIMA-03-2014-0027

5. Tieman M, Darun, MR. Leveraging Blockchain Technology for Halal Supply Chains. Islam Civ Renew. 2017;8(4): 547–50. doi:10.12816/0045700
6. Tieman M, Darun MR, Fernando Y, Ngah AB. Utilizing Blockchain Technology to Enhance Halal Integrity: The Perspectives of Halal Certification Bodies. In: Xia Y, Zhang LJ, editors, Services – SERVICES 2019. CA: Academic; 2019. p 119-128.
7. Gupta M. Blockchain for Dummies. 2nd ed. John Wiley & Sons, Inc; 2018
8. Yusuf H, Surjandari I, Rus AMM. Multiple Channel with Crash Fault Tolerant Consensus Blockchain Network: A Case Study of Vegetables Supplier Supply Chain. Proceeding of the 2019 16th International Conference on Service Systems and Service Management (ICSSSM); 2019 July 13-15; Shenzhen, China; 2019.
9. Letourneau KB, Whelan ST. Blockchain: Staying Ahead of Tomorrow. J Equip Lease Fin. 2017;35(2):1–6
10. Magista M, Dorra BL, Pean TY. A review of the applicability of gamification and game-based learning to improve household-level waste management practices among schoolchildren. Int J Tech. 2018;9(7):1439-49. doi: 10.14716/ijtech.v9i7.2644
11. Mavragani A, Tsagarakis KP. Predicting Referendum Results in the Big Data Era. J Big Data. 2019;6(3). doi: 10.1186/s40537-018-0166-z
12. Yusuf H, Surjandari I. Comparison of performance between kafka and raft as ordering service nodes implementation in hyperledger fabric. Int J Adv Sci Tech. 2020;29(7S):3549-54.
13. Russell RS, Taylor BW. Operations management: Creating value along the supply chain. John Wiley & Sons,.Inc; 2009
14. van der Vorst, JGAJ. Supply Chain Management: theory and practices. In Camps T, Diederen PJM, Hofstede GJ, Vos B, editors. The Emerging World of Chains and Networks: Bridging Theory and Practice. s'Gravenhage: Academic; 2004. p. 105-128.
15. Tieman M. The application of Halal in supply chain management: In-depth interviews. J Islam Mark. 2011;2(2):186–95. doi:10.1108/17590831111139893
16. Khan S, Khan MI, Haleem A, Jami AR. Prioritising the risks in Halal food supply chain: an MCDM approach. J Islam Mark. 2019. doi:10.1108/JIMA-10-2018-0206
17. Tieman M, van der Vorst, JGAJ, Ghazali MC. Principles in halal supply chain management. Journal of Islamic Marketing. 2012;3(3):217–43. doi:10.1108/17590831211259727

18. Kshetri N. Blockchain's roles in meeting key supply chain management objectives. Int J Info Man. 2018;39:80–9. doi:10.1016/j.ijinfomgt.2017.12.005
19. Hyperledger. Smart Contracts and Chaincode. Hyperledger Fabric. 2019. https://Hyperledger-Fabric.readthedocs.io/en/release-1.4/SmartContract/SmartContract.html. Accessed 20 Sep 2019.
20. Ab Talib MS, Hamid ABA, Zulfakar MH. Halal supply chain critical success factors: a literature review. J Islam Mark. 2015;6(1): 44–71. doi:10.1108/JIMA-07-2013-0049
21. Sukhwani H. Hyperledger Fabric V1. In: Performance Modeling & Analysis of Hyperledger Fabric (Permissioned Blockchain Network). Duke University. 2018. https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/18268/Sukhwani_duke_0066D_14907.pdf?isAllowed=y&sequence=1
22. Androulaki E et al (2018) Hyperledger fabric: A distributed operating system for permissioned blockchains. Proceedings of the 13th ACM SIGOPS European Conference on Computer Systems; 2018 April 23-26; Porto, Portugal; 2018.
23. Christidis K. A Kafka-based Ordering Service for Fabric. Google Docs. 2016. https://docs.google.com/document/d/19JihmW-8blTzN99lAubOfseLUZqdrB6sBR0HsRgCAnY/edit. Accessed 26 Aug 2019
24. Hyperledger. The Ordering Service. Hyperledger Fabric. https://hyperledger-fabric.readthedocs.io/en/latest/orderer/ordering_service.html. Accessed 2 Sept 2019.
25. Christidis K. Fabric Proposal: A Raft-Based Ordering Service. Google Docs. 2018. https://docs.google.com/document/d/138Brlx2BiYJm5bzFk_B0csuEUKYdXXr7Za9V7C76dwo/edit#. Accessed 15 Sept 2019.
26. Ongaro D, Ousterhout J (2014) In Search of an Understandable Consensus Algorithm (Extended Version). Proceeding of USENIX Annual Technical Conference, USENIX ATC 2014; June 19-20; Philadelphia, United States; 2014. p. 305-319.
27. Nguyen B et al. Multichannel Consensus. Google Docs. 2016. https://docs.google.com/document/d/1eRNxxQ0P8yp4Wh__Vi6ddaN_vhN2RQHP-IruHNUwyhc/edit. Accessed 15 Aug 2019
28. OECD-FAO. Meat. In: OECD-FAO agricultural outlook 2019-2028. OECD Publishing, Paris/Food and Agriculture Organization of the United Nations. 1999. http://www.fao.org/3/ca4076en/ca4076en.pdf. Accessed 30 October 2019

615 29. Simatupang T M. Sistem Logistik Halal. Sistem Logistik Halal. 2016.
616 http://supplychainindonesia.com. Accessed: 20 Sept, 2019.
617 30. Hyperledger. Blockchain Network. Hyperledger Fabric. https://hyperledger-
618 fabric.readthedocs.io/en/release-1.4/network/network.html. Accessed 3 Sept 2019.