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Blockchain-based Framework for Supply Chain of Agri-food Sector in Malaysia

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgement has been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

In the advent of blockchain technology, buzzword such as bitcoin, cryptocurrency and blockchain is gaining a lot of hypes around. As the enabler for cryptocurrency, the technology of blockchain is vastly applicable in different field, one of the most promising is supply chain. Recent research shows a lot interest on blockchain applying into supply chain, but most of them is covering the use case using public blockchain like Ethereum. Public blockchain is accessible for all user but feature like this might not be suitable for the use case of supply chain management as it involves unrelated party in the supply chain network. While some studies involve the implementation of blockchain based for supply chain solution, there is a gap on relating blockchain to supply chain transparency and traceability in quantitative approach. Quantitative approach is very meaningful in this study as it provides more clarity compared to qualitative approach in existing research. The first focus of this research is to investigate the differences between public and private blockchain. Secondly, this research proposed a framework to determine the transparency and traceability of each blockchain solution with the use case of supply chain of pepper industry in Malaysia. This study has presented results of traceability and transparency in a quantitative approach for both public blockchain, which is Hyperledger Fabric and Sawtooth. The result shows that Sawtooth able to achieve higher transparency and traceability than Fabric in most cases.

Keywords: Blockchain, supply chain, transparency, traceability

Kerja Berasaskan Blok Rantai untuk Pengurusan Rantaian Bekalan Sektor Agri-Makanan di Malaysia

ABSTRAK

Melalui kemunculan teknologi blok rantai, terma seperti bitcoin, kriptowang dan blok rantai menjadi semakin popular. Selain teknologi kriptowang, teknologi blok rantai terdapat banyak aplikasi dalam bidang yang luas, salah satunya ialah untuk bidang rantaian bekalan. Penyelidikan terkini lebih mengkhusus kepada teknologi blok rantai yang berkait dengan rantaian bekalan, tetapi kebanyakannya meliputi kes penggunaan menggunakan blok rantai awam seperti Ethereum. Blok rantai awam boleh dicapai oleh semua pengguna, tetapi ciri seperti ini mungkin tidak sesuai untuk kes penggunaan pengurusan rantaian bekalan kerana melibatkan pihak yang tidak berkaitan dalam rangkaian rantaian bekalan. Walaupun beberapa kajian berjaya mengimplementasi rantaian bekalan berasaskan blok rantai, kebanyakkannya tidak menjelaskan bagaimana blok rantai membekalkan ketelusan dan kebolehkesanan rantai dalam pendekatan kuantitatif. Pendekatan kuantitatif sangat bermakna dalam kajian ini kerana memberikan lebih kejelasan berbanding dengan pendekatan kualitatif seperti yang disediakan oleh kajian yang ada. Perkara pertama yang ingin ditumpukan kajian ini adalah perbezaan blok rantai awam dan blok rantai swasta. Selain itu, kajian ini menentukan ketelusan dan kebolehkesanan setiap aplikasi rantaian bekalan industri lada di Malaysia. Kajian ini telah membentangkan hasil pengesanan dan ketelusan dalam pendekatan kuantitatif untuk kedua-dua blok rantai umum, iaitu Hyperledger Fabric dan Sawtooth. Hasil kajian menunjukkan Sawtooth dapat mencapai pengesanan dan ketelusan yang lebih tinggi daripada Fabric dalam kebanyakan kes.

Kata kunci: *Blok rantai, rantaian bekalan, ketelusan, kebolehkesanan*

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LIST OF ABBREVIATIONS

1PL	First Party Layer
2PL	Second Party Layer
3G	Third Generation
3PL	Third Party Layer
4G	Fourth Generation
4PL	Forth Party Layer
5G	Fifth Generation
5PL	Fifth Party Layer
BFT	Byzantine Fault Tolerance
CA	Certificate Authority
CFT	Crash Fault Tolerance
dApps	Decentralized Application
DPoS	Delegated Proof of Stake
ERP	Enterprise Resource Management
EVM	Ethereum Virtual Machine
FBA	Federal Byzantine Agreement
GPS	Global Positioning System
IoT	Internet of Things
JAKIM	Jabatan Kemajuan Islam Malaysia
MSP	Membership Service Provider
P2P	Peer to Peer
PBFT	Practical Byzantine Fault Tolerance

PKI	Public Key Infrastructure
PoA	Proof of Authority
PoET	Proof of Elapsed Time
PoS	Proof of Stake
PoW	Proof of Work
QR Code	Quick Response Code
RFID	Radio Frequency Identification
RPCA	Ripple Protocol Consensus Algorithm
RW	Read Write
SCM	Supply Chain Management
SOLO SBFT	Simplified Byzantine Fault Tolerance
WSN	Wireless Sensor Network

CHAPTER 1

INTRODUCTION

1.1 Research Background

Koo, Othman, Moy and Khor (2017) said that agribusiness, the business of agri-food sector contributed around 8.6 percent of Gross Domestic Product in Malaysia and become one of the key contributors in economy of Malaysia. One of the notable agrifood, pepper, also known as King of Spices, has been exported with a tremendous amount that worth RM490.20 million to Japan, China, Hong Kong, South Korea, Taiwan and Singapore in 2016 (Mah, 2017).

However, there are certain challenges faced by this industry. Fletcher (2017) reported that near the border with the Camar Bulan village at West Kalimantan, up to one hectare of land in the Samunsam Wildlife Sanctuary Sarawak has been turned into pepper farms illegally by the Indonesians who live there. The pepper industry in Malaysia has produced jobs and income for about 67,000 farming families and households. Mah (2017) mentioned that many pepper farmers from Sarawak still depend on crops of pepper as their main source of income. This highlighted the importance of transparency and traceability in supply chain management to ensure that all production of agri-food is from authorized sources for the sake of income of the farmer and economy of the country.

Supply chains are a series of linked suppliers and customers until products reach to customer (Ernest & Handfield, 2002). A strong supply chain management consists of both traceability and transparency. Supply chain transparency is the extent to where all stakeholders have a mutual understanding and access to the information that they request without delay, loss, distortion, and noise (Hofstedel, 2005; Deimel et al., 2008). Aung and Chang (2014) explain traceability in terms of what, where, why and how aspects of a product along the supply chain. An effective food traceability system able to manage food quality, safety risks and developing Food Supply Chain management (Manzini and Accorsi, 2013). Recently, supply chain industry is exploring blockchain technology and some even suggests that it might have positive impact to the transparency and traceability of supply chain management.

Blockchain is a distributed ledger that is used to store transaction record and share across in a business network (Gupta, 2017). Every record is encrypted before stored in a decentralized manner and trackable which meets the requirement of a transaction that is secure and fast. There are some building blocks in a blockchain. First is consensus, stakeholders in the blockchain network must follow an agreed protocol to validate a transaction creation. Second is provenance, the source of information of a transaction in a blockchain network is traceable. Third is immutability, it is not feasible to tamper the information of a transaction once it is validated and stored in the blockchain. Furthermore, blockchain has another feature that act as a digital agreement called smart contract (Surasak et al., 2019).

Bitcoin which is currently one of the most popular cryptocurrencies is running on blockchain (Meng and Yaou, 2018). However, the ability of blockchain is far beyond creation of cryptocurrency and theoretically it can be utilized into supply chain management to tackle certain issues. A systematic review will provide understanding of blockchain technology in depth (Wang et al., 2019). This is where this study came in, to understand on how blockchain will benefit the current supply chain scenario on agri-food in Malaysia.

1.2 Problem Statement

Supply chain of most industries have been operating in centralized model for decades. With the approach of centralized model of recording transactions and tracking assets, every participant on a network keep their own ledgers and records (Gupta, 2017). This is causing issues like lack of information about the origin of the products for the consumer (Casado-Varaa et al., 2018). Therefore, transparency in supply chain management is crucial as information could be altered purposely or accidentally without acknowledging the relevant party in the supply chain network.

Most of the existing supply chain managements practice strong traceability but overlook transparency (Nakamoto, 2008; Lee, 2013; Swan, 2015). This lack of transparency is usually intentional as some participants want to hold their competitive advantages from competitors such as a supplier who delivers quality products on time with significantly lower cost (Bateman & Bonanni, 2019). This could result in delays and defaults during the delivery of goods.

1.3 Objectives

The aim of this research is to design and develop a blockchain based framework that consists of transparency and traceability for supply chain management of agri-food sector in Malaysia.

Other objectives include:

i. To study the list of blockchain technologies (public blockchain such as Ethereum and private blockchain such as Hyperledger) and determine which is most suitable to apply to the solution.

ii. To evaluate the transparency and traceability of the blockchain technologies at (i) using the proposed solution in a quantitative approach.

1.4 Scopes of Study

Blockchain technology remain in infancy stage, however it is gaining momentum within certain fields especially supply chain, where factor of trust is predominant on driving adoption. Blockchain is bringing value to supply chain management in these areas which are transparency, traceability, disintermediation, digitalization, improved data security and smart contracts (Wang et al., 2019). This study will focus on transparency and traceability.

On the other hand, the exploration of permissioned blockchain is also a major purpose for this study. This is due to there are certain differences among public blockchain and private blockchain, for instance both are using different consensus algorithm to approve creation of new transaction. Not only that public and private blockchain behave differently, the distinction among them could affect the transparency and traceability. For the reason of making comparison, this study will adopt two blockchain framework. Although it is possible that adopt more blockchain framework in the study could be giving better insights on comparison, but the whole point of the research is to show that different blockchain could affect transparency and traceability, hence two blockchain frameworks are ample to fulfil the purpose.

In the domain of supply chain of agri-food sector, this study will focus on the supply chain of pepper as the case study. The environment for implementation and analysis of each of the proposed framework will model the supply chain process as much as possible from the information gathered.

1.5 Significance of Research

Contributions of this study can be described as below:

i. The proposed blockchain based supply chain solution implements two different private blockchain technologies with different blockchain component such as consensus algorithm, smart contract technology, database management and peer's management.

ii. The results of proposed solution will be analysed base on a supply chain transparency and traceability framework.

1.6 Outline of the Thesis

Chapter 1 describes the background of the research, problem statement, objectives of the project and scope of the research. Chapter 2 discuss the conventional supply chain process of pepper, the definition of supply chain traceability and transparency, blockchain technology according to sources from the official website, related journal, and articles. Chapter 3 discusses about the exploration of blockchain technology and development of solution for the study. Chapter 4 discusses about the implementation and testing of the proposed solution to determine its traceability and transparency. Chapter 5 provide a summary of the study, it consists of the description of limitations, contributions, and future work of the research.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Supply chain is the management of funds, raw materials, components, and finished products, as it moves from suppliers, to manufacturers, wholesalers, retailers, and consumers. Figure 2.1 illustrates the overview of supply chain management of agri-food (pepper) in Malaysia (Caro et al., 2018). The main phases characterizing a generic agri-food supply chain which consists of 5 participants and how products flow in the supply chain network.

Figure 2.1: Typical supply chain in the retail industry in Malaysia

The role of farmer is farming and harvesting the product and then send it to the processor. Processor could have multiple roles depends on the type of food or product in the supply chain network. For instance, the product of pepper will undergo process of fermentation, washing, drying, and grinding. Before transfer the product to distributor, it will be packaged and certified by JAKIM for halal certification, all these processes might involve one or more than one processor. Distributor mainly in charge of warehousing and storage of all the packaged product to be then distribute to other party such as retailer, wholesaler, or other channel so that product is accessible for consumer.

The high-level representation of the supply chain management from Figure 2.1 look simple however there is a comprehensive of logistic take place behind the scenes when a product flow from one party to another. To bring trust into the system it requires third party authorities (Alkhodre et al., 2019). In real world scenario, when farmer transfers harvested crops to a processor, the whole process usually involving another entity (a middleman) in the supply chain network known as trusted third-party logistic provider as shown in Figure 2.2.

Figure 2.2: Third Party Logistic (3PL)

According to Chetak Logistic (2015) first party logistic (1PL) is referring to a firm that makes certain shipment from location A to location B by the firm itself, the firm itself has the control of all the logistic process. Second party logistic (2PL) refers to a firm that rents the transportation service from a service provider to get the shipment done, while the firm still has control of all the logistic process. Third party logistic (3PL) is a firm that outsources part or all the logistic work to a service provider. One of the roles of 3PL that distinguish itself from 2PL and 1PL is to facilitate trust in the supply chain process such as certifying raw materials, components, or finished products, as they travel through the supply chain. The reason of a 3PL is involved in the supply chain network is due to systems operating in a centralized model, where all transactions are executed through a trust-based system making all participants dependent on the third party (Nakamoto, 2008; Lee, 2013;

Swan, 2015). The implication of the modern systems operating in a centralized model is that the execution of transactions is dependent on a third party i.e. both the supplier and consumer rely on the third party for the exchange of goods or services.

Laney (2018) point out that current supply chain management consists of certain weak points. These weak points happen when there are multiple enterprise resource planning (ERP) systems in use across different organisations as data does not flow well via interface points between systems or individual ledgers during transference of ownership or change in status between two parties. Thus, data transparency is limited at the hand-off points of raw materials, components, funds, and finished products.

Le et al. (2019) mentioned that every types of business can participate in the blockchain network and use the features of the blockchain system to ensure transparency of participants. Le et al. (2019) also believed that blockchains is able to solve the weak points of current supply chain management by eliminating the need for a 3PL to account for transactions and good among other data or at least reduce its role to 2PL or 1PL because all participants have access of untampered past transactions in the blockchain network .

2.2 Supply Chain Transparency and Traceability

Traceability and transparency are often used as interchangeable terms during discussion of supply chain management. In order to develop a useful solution for supply chain management, it is important to find out differences between these terms as both are different indicators of a good supply chain management system.

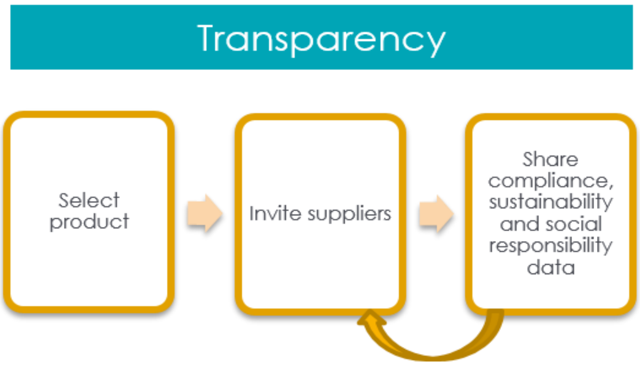

Figure 2.3: Supply Chain Transparency (Tsai, 2018)

Transparency has been defined as the disclosure of information (Egels-Zandén et al., 2015; Doorey, 2011; Mol, 2014) that enables fair competition (Akerlof, 1970), profitable business ventures (Tapscott et al., 2003), and company fulfilment regarding sustainability efforts (Kaptein et al., 2003; Kaynak et al., 2012). According to Tsai (2018), supply chain transparency captures high-level information about a supply chain a product such as product components, names of suppliers, locations, associated certifications, etc. In other word, transparency decide the breadth of the information or disclosure of information that can be exposed to a certain party. Base on Figure 2.3, supply chain transparency enables participants identify all the suppliers for all the components in a product, down to the provenance. Supply chain transparency also enables participants in the supply chain network to identify and collect previously unknown product information and/or communicate and establish specific requirements. Thus, all the participants can gain better visibility of their global supply chains and ensure compliance with safety, sustainability, and social responsibility requirements.