5-15-2019

A BLOCKCHAIN TRACEABILITY INFORMATION SYSTEM FOR TRUST IMPROVEMENT IN AGRICULTURAL SUPPLY CHAIN

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Blockchain and IoT integration for Trust Improvement in Agricultural Supply Chain

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1 Abstract

Across organizations, the integration of business processes and information is crucial for all involved parties. However, the lack of trust is often a roadblock. Researches show that supply chains have incurred challenges in information sharing and trust, while trust widely works in supply chain practices and deeply affects supply chain decisions. On the other hand, Blockchain as an emerging technology for decentralized and transactional data sharing across a network of untrusted participants has appeared to have many applications. The main purpose of this research is trying to increase trust among agricultural supply chain parties to guarantee the food quality, safety and sustainability from a supply chain management perspective, and the key issue is using a decentralized technology which is not dependent on the trust of a central authority or organization for the whole supply chain. Using Design Science Research method, this research is going to develop an artifact to explore the most important trust requirements and priorities at every stage of agricultural supply chain, required to implement a blockchain information system for real-time agricultural food traceability. Special emphasis has been placed on the roles of the incorporation of the IoT in Blockchain-based solutions.

Keywords: Blockchain, Agricultural Supply Chain, IoT, Trust, Design Science Research, Traceability

2 Introduction

Due to the rapid development of world's economy over the recent years, people's living standards have been improved, and it has made changes in the consumers eating habits, so more and more attention has been attracted to the food safety and quality assurance issues. Agricultural supply chain plays a great role in supplying agricultural commodities from farms to the plates of final users. The agricultural system activities are grouped into four stages: producing food, processing and packaging food, distributing food, and retailing food (Ericksen, 2008), and sustainability principles and market requirements associated with quality, consistency and safety are highly significant in each stage of Agricultural Supply Chain (ASC) activities (Borodin, Bourtembourg, Hnaien, & Labadie, 2014; Golini, Moretto, Caniato, Caridi, & Kalchschmidt, 2017). The perishable nature of the products as well as high variations in demand and prices in handling the fresh products are additional challenges in ASC compared to other types of supply chains (Shukla & Jharkharia, 2013). Nowadays due to the environmental concerns and the sustainability development, consumers are more inclined to know if the products they purchase have passed through a sustainable supply chain. Researches show that customers trust in the food production industries was deeply broken as a result of many food crisis and misconducts is safety, to name a few, mad cow disease and genetically altered food, (Aung & Chang, 2014), contaminated milk power, and trench oil (Jing, Ziyu, & Beiwei, 2012), that all occurred over the last two decades. Hence, customers want to receive more transparent information regarding production and delivery situations and want to know exactly about the genuine origin of products, and the way they are managed. The final customers may only rely on vendors virtue when they inquire about the origin of an organic product, and they do not know much about the real roots of the food they are purchasing (Bettín-Díaz, Rojas, & Mejía-Moncayo, 2018). So, many steps have been taken so far to improve the quality and safety control through the transparency of the agricultural food supply chain management (Akkerman, Farahani, & Grunow, 2010), but supply chain transparency is one of the most imperative and difficult areas to achieve in supply chain management (Abeyratne & Monfared, 2016). Supply chains have been put to dispute due to the lack of information transparency and liability which are the results of the complexity of dealing with a huge number of members engaged throughout the supply chain networks (Casey & Wong, 2017).

Enterprise Resource Planning (ERP) systems such as SAP are currently used for information sharing and increasing transparency among members of a supply chain. This technology requires the involvement of intermediaries for storing the shared information (Nakasumi, 2017). However, all of these information systems are centralized systems which might have many flaws. The main weakness is that this kind of centralized system are mainly exclusive, asymmetric and non-transparent information system, which could lead to the trust concerns, such as fraud, corruption, tampering and distorting information. Besides, there are some other problems, such as uncompleted and duplicate information, which can negatively affect the efficiency of the food supply chain management. But thanks to the internet of things and the blockchain technologies, solutions can be proposed for these kinds of challenges (Tian, 2018).

Blockchain technology has been recommended as a solution for networking issues (McConaghy, McMullen, Parry, McConaghy, & Holtzman, 2017), trust concerns (J. Wang, Wu, Wang, & Shou, 2017; Weber et al., 2016), and traceability in the supply chain (O'Marah, 2017). Blockchain remedies allow supply chain parties and stakeholders to track bottlenecks in the flow of products. The system can discover if the products are kept in one place for a long time or placed at a wrong location which is particularly significant for refrigerated goods (Casey & Wong, 2017). Moreover, blockchains provide right and precise information about potential suppliers and customers' liquidity as well as current financial status. In fact, blockchain is a solution for risk reduction and trust enhancement among supply chain partners (Tapscott & Tapscott, 2017). Blockchain remedies with its features capable of traceability and transparency enhancement, are considered an approach for the supply chains monitoring concerns (Casey & Wong, 2017). So potential challenges such as supply chain sustainability can be tackled through applying blockchain solutions. In this way, all company transactions are recorded in the ledger which makes it possible to proof responsibility and company dishonesty in sustainability related issues (Xia & Yongjun, 2017).

In addition, many researchers have proposed the deployment of Internet of Things (IoT) technologies, including RFID (Radio-Frequency Identification), WSN (Wireless Sensor Network), GPS (Global Positioning System) and GIS (Geographic Information System), etc., in supply chain management. The position of products, packages and shipping containers can be traced at each step with IoT, radio-frequency identification (RFID) tags, sensors, barcodes, GPS tags and chips. This allows an enhanced, real-time goods tracing information reliability and security. The combination of blockchain and the IoT is proposed to tackle the aforementioned challenges in addition to preserving consistent data. Offering a reliable sharing service, blockchain can be used to develop the IoT, where information is trustable and observable. Data sources are always detectable and it will stay immutable through enhancing the security. This integration would be a key solution under circumstances where the IoT credential information should be distributed among numerous members in the network. This has been initiated to be known as cited by Malviya (2016), when blockchain technology has been proposed as the solution to privacy, scalability and tractability concerns in the IoT paradigm.

Nevertheless, blockchain is not completely perceived yet and the tendency to its application for supply chain traceability beside IoT is still in preliminary stages due to its immaturity (Francisco & Swanson, 2018). Additionally, even the most innovative and high-level technologies are impractical if they are not properly being adopted by their users in spite of the hype and potentials (Mathieson, 1991). For this reason, in this research, we have tried to apply the blockchain technology in order to address the participants trust requirements in collaborative business processes of agricultural supply chain. In this context, this research pursues the integration between the blockchain technology and IoT in supply chain in the agricultural industry. Our proposed research would be conducted through Design Science Research (DSR) method. Using Design Science Research method, this research is going to design an artifact to explore the most important trust oriented requirements and priorities at every stage of agricultural supply chain for a blockchain information system in order to implement real-time agricultural food traceability, and significantly improve the trust among agricultural supply chain stakeholders. Proposing Q methodology as the research artifact, through the iterative approach of DSR, we are going to explore supply chain participants' subjectivity about the trust requirements and priorities in different stages of agricultural supply chain that can be fulfilled by the blockchain features, and consequently evaluate the blockchain contribution to agricultural supply chain trust improvement.

3 Literature Review

3.1 Blockchain

Blockchain is reckoned a novel innovation within the IS research context and has yet a long way to become a part of the typical IS research (Morisse, 2015). Some scholars consider blockchain as a distributed data structure, database or system (Böhme, Christin, Edelman, & Moore, 2015; Lewenberg, Sompolinsky, & Zohar, 2015; Ølnes, 2016; Zhao, Fan, & Yan, 2016), while others name it a decentralized network (Bonneau et al., 2015; Kosba, Miller, Shi, Wen, & Papamanthou, 2016). Blockchain was initially applied to support the digital currency BitCoin (Nian & Chuen, 2015). Further than its first application, blockchain has also been generalized and investigated in some other contexts. González, Ramos, De Paz, and Corchado (2015) believe that smart contracts are able to make quick and effective transactions between different users through the implementation of blockchain. Abeyratne and Monfared (2016) argued the possible benefits of blockchain technology in manufacturing supply chain. They claimed that the innate features of the blockchain technology increase trust through transparency and traceability within any transaction of data, goods, and financial resources.

In recent years, blockchain has also been called a ''trust-free" technology (Beck, Czepluch, Lollike, & Malone, 2016) and it is projected to be the infrastructure for today's mainly platform-driven sharing economy. Greiner and Wang (2015) introduced the concept of trust-free systems, which uses blockchain capabilities to automatically create an immutable, generally agreed, and visibly available record of past transactions, overseen by the whole system to erase trust concerns in peer-to-peer systems. Rachel Botsman (2016) anticipates that blockchain technology will basically change the way trust is generated among people, through trust distribution. Moreover, a new discussion paper published by IBM argued that blockchains is capable to build a ‘‘sharing economy 2.0” through trust decentralization (Lundy, 2016). Also the majority of the academic literature believe that blockchain technology will succeed in dealing with trust related concerns and eventually will end up in the resolution of one of the basic challenges of peer-to-peer markets and sharing economy activities (Glaser, 2017).

3.2 Internet of things and Food Traceability Management

Many scholars have investigated the application of the IoT technologies, including RFID (Radio-Frequency Identification), WSN (Wireless Sensor Network), GPS (Global Positioning System) and GIS (Geographic Information System), etc., in supply chain management (Tian, 2018). Several researchers tried to apply these traceability tools in food supply chain management in various methods. For example, L. Wang, Kwok, and Ip (2010) developed a rule-based decision support system which serves to oversee real-time agricultural products throughout the distribution process. Manikas and Manos (2009) developed a model to establish food traceability in the supply chain Based on the theory that data must be collected, saved and distributed in each link of the supply chain. Grunow and Piramuthu (2013) developed a new model in which incorporated the RFID technology in a highly perishable food supply chain from the distributor, retailer, and consumer point of view. In their research they concluded that the investment in the application of RFID technology could accrue benefits for the distributor, retailer, and final consumer. Cao, Zheng, Zhu, and Wu (2009) using RFID proposed a traceability framework for the safety of animal food. They used the discovery service and the object name service in their framework to detect dynamic dispersed information servers for dynamic data distribution. Tian (2016) developed a quality and safety control system for agricultural supply chain in China. The research applied blockchain and RFID technology to solve typical centralized system issues and proposed a new decentralized traceability information system for the agricultural supply chain.

4 Research Motivation and Research Questions

Due to the immaturity of blockchain, this technology is not properly understood yet, and the intention towards its application to improve supply chain performance is still unknown (Francisco & Swanson, 2018). Moreover, to the best of researcher’s knowledge, there are still visible gaps in the literature with regard to making sense of the use of blockchain technology and integrating that with IoT for trust improvement in agricultural supply chain communication. So, the main aim of this research is trying to enhance trust in agricultural food supply chain to improve the quality and safety of products at every stage of the chain, and according to the analysis of the literature above, we will achieve this aim from several perspectives. The first key step is that we will try detect trust priorities and requirements to establish a new decentralized information system framework based on the blockchain and IoT technologies. Then, relying on this information system we aiming to solve the issue of information asymmetry and opacity in agricultural food supply chains and contribute to agricultural supply chain trust improvement. In order to achieve our research purpose, we propose the following research questions:

Q1: How do the priorities of members differ between the stages of a blockchain-enabled agricultural supply chain?

Q2: How do the priorities of members affect trust between different stages of a blockchain-enabled agricultural supply chain?

Q3: How does the use of blockchain technology would contribute to agricultural supply chain trust improvement?

5 Research Methodology

The research methodology used in this research, is the Design Science Research (DSR) approach in Information System (IS). Design encompasses a process (activities) and a product (artifact); in another words, a verb and a noun (Walls, Widmeyer, & El Sawy, 1992). It portrays the world as acted upon (processes) and the world as sensed (artifacts). This interpretation of design develops a problem solving paradigm which for the same complex problem constantly changes outlook between design processes and designed artifacts. Therefore, a design-science research artifact "includes any designed object with an embedded solution to an understood research problem" (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007). The design process includes a set of professional activities that generates a novel product (i.e., the design artifact). In order to improve both the quality of the product and the design process, the artifact evaluation then offers feedbacks as well as a more clear perception of the problem. This build-and-evaluate loop is technically repeated a few times in order to produce the final design artifact (Markus, Majchrzak, & Gasser, 2002). We refer in our work to the guidelines introduced by (Hevner & Chatterjee, 2010; Von Alan, March, Park, & Ram, 2004). They claimed in their research that the important nature of DSR in information systems is in the detection of new IT capabilities, which are the results of the information systems expansion into new domains. Therefore, the product of our research would be an artifact that addresses the trust related concerns in agricultural food supply chain those applying blockchain and IoT in their value chain.

5.1 The Research Artifact

The outcome of DSR in information systems is a targeted IT artifact produced to resolve an important organizational problem (Henver, 2004). The Artifact created in design research can get several forms such ads constructs, models, methods, and instantiations (March & Smith, 1995). Artifacts created in DSR are hardly ever complete information systems that have been implemented practically, instead, they are innovations that explain the thoughts, measures, technical potentials, and products than can effectively and efficiently contribute to accomplishment of analysis, design, execution, and information systems application (Denning, 1997; Weiser, Brown, Denning, & Metcalfe, 1998).

The core artifact of this research is a purposeful Q methodology design for eliciting key trust requirement viewpoints prevalent among agricultural supply chain members; in fact the requirements that can be satisfied by a decentralized information system based on IoT and the blockchain technology. The Q-sort technique was first designed by William Stephenson in 1935 as a research technique to analyse first-person perceptions about a given subject (Stephenson, 1953). The main principle of Q methodology is enabling researchers to discover and learn about the assortment of human subjectivity (Dennis, 1986). In a Q study, each factor demonstrates a key perspective that exists within the group of study participants. Q methodology enables the analysis of these viewpoints holistically, employing a deep quantitative and qualitative investigation (Brown, 1980; Watts & Stenner, 2005). Q methodology introduces a combination of quantitative and qualitative approaches, which explores subjective perspectives or beliefs and evaluates them with the factor analysis statistical lens (Eden, Donaldson, & Walker, 2005). This procedure is implemented by a tool called the Q sort.

In our research implementation, we will collect a list of subjective statements called the Q set. The statements will be selected from books, previous surveys, and research reports as well as interviews in order to best display the diversification of viewpoints about trust requirements and priorities in ASM. Then we will ask the participants to sort the statements from all of the available opinions about the topic of study, based on a forced-choice frequency distribution board. Our Q sorting participants includes members from all the stages of agricultural supply chain, including suppliers, producers, manufacturers, distributors, retailers, consumers. The possible ways to order the sort the Q statements is immense (Watts and Stenner 2012), and a forced choice board allows comparisons to be made between entire completed Q sorts. We will record the completed Q sorts along with field notes from sorters during the sorting process. Next, they are later examined by statistical analysis software in order to conduct by-person factor analysis. In order to identify patterns, the Q sorts are compared across participants, with Q sorts displaying statistically analogous viewpoints that bundle together. As a result, we can identify a number of primary outlooks about the trust issues in agricultural supply chain, clarifying the subjective viewpoints of the participants and revealing commonalities and divergences in beliefs.

6 Conclusion

A blockchain based information system integrated with IoT removes the need for a trusted centralized organization and introduces a new approach in establishing trust among members. Relying on this system we can implement tracking and traceability management throughout the whole agricultural food supply chain. The outcomes of this research which are the participants' highlighted perspectives about trust requirements and priorities elicited by our research artifact (Q Method), would contribute to achieve a better cognition of trust concerns throughout agricultural supply chain. This can be considered in the development of agricultural supply chain information systems based on the integration between the blockchain technology and IoT in order to improve the safety, security and quality of food products and at the same time diminish the possibility of misconducts such as fraud, corruption, tampering and distorting information.

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