Blockchain framework for supply network distribution

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Abstract

Blockchain systems are a technology that is still the topic on ongoing research. As a promising technology still in its infancy, there are many applications which may still yet benefit from the key features of blockchain systems [1]. One such application is with managing supply networks for various corporations. Current supply networks experience issues with transparency and the tracking of goods from owner to owner. supply networks rely on networks of suppliers, manufacturers, and distributor in order to fulfil shipping orders. Current approaches to managing supply networks are heavily centralized and with that, more susceptible to tampering. Recently, researchers from academia and industry have begun to explore the potential for leveraging the strengths of blockchain systems. Research has pointed to several possible ways blockchain's distributed ledger technology can be leveraged to increase security, transparency, and trust in supply network environments. This paper proposes an implementation of such a system as well as notable areas to improve upon in subsequent implementations.

1 Introduction

Our society depends on the efficient distribution of goods, foods, and products in order to help ensure food stability and quality of life. Current methods are however, inefficient and lacking in the transparency required to rapidly respond to situations where a product recall may be required. This lack of transparency also means that no participants in a supply network can know for certain that their shipment wasn't altered or tampered with[2, 3, 4, 1] In extreme cases, this can and has lead to cases of extreme illness and loss of life. Blockchains, as a distributed ledger technology, facilitates the development of distributed applications. Blockchains allow for transparency on a distributed ledger such that any member of the blockchain network can view and verify the full history of. The purpose of this paper is to illustrate the benefits offered by adopting blockchains into current approaches to supply network management

2 Supply Networks

Broadly speaking, supply chains refer to transfer of goods and resources through networks in intermediary manufacturers and distributors. They define the logistics and delivery from resources, through the manufacturing process, to the end-user or consumer. The network itself is organized into different layers, or echelons which help distinguish which step of the supply network they manage. These systems are vital to the ongoing wellness of modern society. Food is grown, processed, packaged, and delivered to grocery stores where it's eventually purchased and eaten. This is, unfortunately, a bit of an oversimplification as food or medicine may spoil or be otherwise destroyed during transit. Items may be tampered with or replaced with inferior versions. Current approaches to managing these supply networks have a number of limitations to consider. [2]

The largest and most obvious is that as these supply networks grow the task of monitoring and verifying, as well as inter-party communication becomes increasingly complex. Another issue plaguing supply-line management is the difficulties present in tracking goods as they change ownership and move from party to party. It becomes increasingly difficult to track an Item from it's destination back to it's origin. This poses a problem for consumers as they have no way to verify the origin of an item or which parties the item passed through [3]. The ability to accurately track shipments is critical in the event that a product must be recalled.

Finally, current supply-chain monitoring is often handled by a centralized third party. This leaves the records vulnerable to tampering or falsification. This, of course, poses a problem for the other parties at play within the supply network as they are unable to trust the data being offered. This also contributes to consumer woes, as they are left with no alternative option then to simply trust the integrity of a product[3]. The introduction of these third party, centralized fulfillment services is that

3 Problem Statement

As mentioned in the previous section, current approaches to supply network monitoring falls short of expectations in regards to a number of vital areas. Current approaches tend to be cumbersome prone to error. To address this, the author has chosen to focus on three closely connected issues present in modern supply networks based on current literature [2, 4, 5].

3.1 Lack of Transparency

Mentioned briefly was a lack of transparency. This poses an issue to participants at every level of a supply network as no single party present in the network has a full registry of all previous owners of a given item. It can be difficult, to nearly impossible to track a given item back to it's point of origin[2, 1].

3.2 Lack of Authenticity

The lack transparency also contributes to a lack of authenticity. As contributors of a supply network have little to no means of verifying the authenticity of items in transit, they cannot determine that an item came from the expected origin. As noted by [2, 4] this can manifest at the consumer level as a lack of trust in products, IE; Are vegetable organic, are manufacturing compounds chemically pure, etc. Additional costs may be incurred by various echelons of the supply network, if delivered goods are not help to suitable standards.

3.3 Lack of Accountability

The lack of transparency and the lack of Authenticity both contribute to a larger, looming issue with current supply networks. That is, a distinct lack of accountability and a lack of viable corrective options when faced with product recall scenarios. Product recalls have been on the rise in recent years[6]. The World Health Organization estimates that each year, nearly one in ten people will become sick due to food contamination. The annual death toll of those affected amounts to roughly forty-two-thousand deceased people around the world each year[6]. The author mentions these statistics in the hopes of establishing the need for improvement in these areas, as improving these aspects of supply networks could help prevent unnecessary deaths related to contamination.

3.4 Solution: Increased traceability

Each of the mentioned issues present in supply networks can be mitigated or improved upon by increasing the ability of any member of the supply network to trace the history of an item from it's destination to it's point of origin. One such method to facilitate this is with the use of RFID tags which contain information about an item[2]. These tiny transmitters can be scanned, read from, and written to in a contactless manner to avoid contaminating items during validation. These RFIDs can be used in conjunction with distributed ledger technology to allow all parties in a supply network to verify digital signatures of items and the item's history of ownership[2]. A natural technology to consider for the task, are the use of blockchain applications.

4 Blockchains

This section will briefly describe Blockchains as well as their desirable properties. Blockchains a type of distributed ledger which exploded in popularity thanks to Bitcoin[1, 5]. The network consists of a population of servers or nodes, each node is responsible for maintaining the distributed ledger. The ledger itself contains a list of all transactions written to the blockchain. When a new transaction is made on a blockchain network, it is transmitted to all nodes to be verified. When the nodes arrive at a consensus, the transaction is added to the blockchain as a new block[7].

An important quality to note of block chains is their immutability. Once a transaction is verified and written to the block, it cannot be altered or changed. The transaction is also then replicated across the entire network, in case data becomes corrupted. This makes it significantly more difficult to tamper with when compared to the centralized supply network management options.

4.1 Smart Contracts

A key design feature of many blockchain platforms is the implementation of code known as smart contracts. A Smart contract is a program of sorts, which may be deployed on a blockchain network in order to manage some computational task. The execution of these contracts is verified by multiple additional nodes in the network based on the platform's consensus mechanism. That is to say, the method which the nodes use in order to come to a common decision about the validity of a transaction. These smart contracts can be used to automate the execution of transactions between intermediaries, within the context of supply network management. This increases trust in a network where trust isn't typically a viable option[8, 2, 5]. Network participants are able to view the ledger, and by extension, confirm the execution of these contracts as they validate in real time.

4.2 Blockchain qualities

An important distinction between blockchain platforms is their visibility. Broadly, there are public blockchains which can be viewed and joined by anyone. In addition to these public blockchains, there are also private blockchains which may not be accessible to parties without a stake in the network. The visibility of the blockchain's ledger should be an area of consideration for developing the supply network management system [1].

Mentioned briefly was the inherent trait of blockchain technologies that their ledger may be queried by any participant in the network. The transparency enabled by blockchains marks a considerable improvement over traditional supply network management techniques. Offering the ability for any member of the supply network to trace back the full history of an item back to it's origin as well as where the item has ended up also improves manufacturer's ability to efficiently recall items when the situation arises.

Finally, being a distributed ledger means the history of ownership for items is replicated across nodes in the network. In traditional, centralized approaches to supply network management introduce a single point of failure and a multitude of potential errors related to the security of the ledger. It is significantly easier for data to be altered and tampered with in a centralized application. Additionally, if the data becomes corrupted it may be lost. The benefits to introducing blockchain as the distributed ledger responsible to recording ownership is multifaceted, but for the context of this paper, I choose to focus on replication and multiple distributed copies of data to be the primary advantage over centralized approaches.

5 Implementation

In previous sections, I have outlined many of the benefits that blockchain adoption would have for the manageability of supply networks. Notably in the areas of consumer trust, data trust, and increased traceability of products and goods. In the next section, I will outline the implementation of our application for such a system on the Ethereum blockchain using the solidity language and smart contracts. The implementation outlined below corresponds to the project implementation requirement as part of the expected deliverable.

The following implementation takes inspiration from [4] and was initiated early in the research process in order to complete the deliverable in a timely manner. However as research and development continued, it became apparent that the implementation was undertaken perhaps, a bit naively. The original implementation consists of a single smart contract, which when deployed to the network, acts as both a market place and ledger for transactions processed on the network. The marketplace allows for posting of produced merchandise as well as the purchase of said merchandise by other network participants. As part of the goal to increase product visibility and tractability, the smart contract also handles the details of each transaction by recording it to a distributed ledger associated with the deployed contract.

As part of Ethereum's smart contract platform, smart contracts are validated by other network validators prior to being written to the ledger.

Additionally, in an effort to mitigate the effects of double spending attacks, a waiting period is also implemented so that all funds entering or leaving the supply network blockchain application (Refereed to as "SNBA" hereon for conciseness) must be confirmed and validated prior to the releasing of the funds to the user's etherium address. (Eth address for withdraw transactions, or SNBA address on deposits)

This technique was inspired by current approaches to implementing payment channels via blockchain, as the over-arching concepts hold true for both applications.

The data written to the smart contract holds information about the item in question. This information is recorded as an address to the original item's posted entry, that is, a reference to the seller's item posting. Additionally, the contract records the quantity of the item which was purchased as well as the cost per item and total value sent. After asserting that the seller has sufficient stock and the buyer has offered value greater than or equal to the total transaction value, the transaction as well as the mentioned information may then be grouped together as a waybill [4] before being written to the ledger.

This implementation is perhaps a bit of an oversimplification for reasons that will be described in next section. However for the primary task of increasing traceability, the implementation does still manage to leverage many of the promising attributes of blockchains to allow all network participants to query the network and retrieve the history of their item to the origin a key factor in increasing trust and confidence in supply networks[4].

6 Evaluation

In the following section will discuss and evaluate some of the drawbacks of the previously described implementation. Additionally, to the author's best knowledge, there seems to be a general lack of bench marking or evaluation methods available in the context of supply network management beyond stakeholder trust and access to information. As blockchains and their respective applications are still relatively new in there development, this lack of evaluation tools is to be expected. It is however, a hindrance to the quantitative evaluation of any such application. For this reason qualitative evaluation will be the primary method for the majority of the paper.

As mentioned in the previous section, the design of the implementation was decided considerably early in the project's overall development and decisions made early on had rippling effects later on. It's additionally noted in literature, that one of the main barriers to implementing these applications is a lack of technical understanding on the subject [4]. Unfortunately, it seems the paper which had originally inspired the project's implementation direction had inconsistencies in the information specifically related to blockchains. These inconsistencies, while impacting the development of the application, are evidence that this lack of technical understanding does pose a barrier to the adoption of the technology. For this reason, it's crucial that review of these application should include experts in blockchain technologies in order to ensure that accurate information is offered to all researchers interested in adopting, or researching the potential in adopting blockchains as part of their application.

Additionally, there are a number of case studies which point to the increased traceability mentioned in previous sections. In existing literature, these case studies have formed the foundation of researcher's ability to evaluate blockchain's applications in supply networks[2, 3].

In particular,[8] outlines step-by-step how each member in the network might interact with the system under the hypothetical scenario of manufacturing cardboard boxes. The interactions between each intermediary in the network functions identically as outlined in [8] so or the sake of our discussion, we will use the hypothetical scenario of ice-cream manufacturing.

6.1 Dairy farmer

This farmer runs a small family farm and primarily produces milk. This farmer knows his cows well and can produce milk reliably at a approximately 1000 L of milk per week. The farmer posts this as an item listing to the smart contract. The farmer receives a notification that the ownership of the milk can been purchased by an interested individual and sends the item on it's way.

6.2 Ice Cream Manufacturer

This ice cream manufacturer produces ice cream for a large, well known ice cream brand. This manufacturer produces ice cream at such an extreme scale that there are no suppliers available capable of delivering the milk needed in such large volumes. Instead the ice cream manufacturer must order from multiple sources. Using the smart contract the ice cream manufacturer orders milk from a wide range of suppliers to ensure they consistently have the required milk volume. Once the manufacturer receives the milk from the suppliers, they then use it to produce the necessary ice cream, "butterscotch" flavor for the sake of this example before sending it to Ice cream Brand®'s cold storage center.

6.3 Cold Storage Center

As a leading brand of frozen milk treats, Ice cream Brand® operates a number of cold storage centers across the country. These cold storage centers maintain appropriate temperatures for the long term storage ice cream. The ice cream is kept here, while various convenience stores and ice cream trucks use the smart contract to submit orders as part of their inventory management.

6.4 Convenience Store

The manager at the local Convenience Store notices while taking inventory that they are nearly out of Ice cream Brand® "butterscotch" ice cream. Since this has been a popular item given the record heatwave affecting the area, the manager decides to order additional unit. Using the smart contract, the manager is able to submit the order for the ice cream, which is then sent out from the corresponding Cold Storage Center.

6.5 Remarks

While purely hypothetical, the above scenario serves to illustrate the simplicity which the platform can offer. Additionally, as will be discussed in the next section additional tracking capabilities could be implemented to increase the transparency of the handling of the products. Bar codes, and RFIDs among other options allow for additional information to be safely and automatically recorded to the ledger.

7 Future Improvements

This section will outline various ways that the provided implementation could be improved upon, as well considerations for future supply network management implementations. In regards to the implementation provided above, improvements are possible in a number of areas. Firstly, improvements could be made to the transaction handling. Currently the implementation only handles writing transaction history in a "Bill" format. This bill design decision was originally inspired by the previously mentioned article by [4]. The implementation of way-bill in this project lead to a limiting the data which could be collected on the item, and by extension limited the monitoring capabilities for improved traceability. Secondly, there exists an issue of security in the presented implementation. Sweeping improvements could be made to data security by implementing some form of encryption to confirm identities, however as the primary goal of this project was simply to increase transparency in these systems, such security protocols were not implemented.

More generally, blockchain based supply network management solutions should consider adopting some form of item verification at each step of the logistics network. [2] outlines a number of ways RFID tags can contactlessly encode and write information about the product, such as holding temperature, humidity, or physical condition to the distributed ledger where it can then be viewed by other inquiring parties in the blockchain network. Also noted in the same article, bar codes may also be employed as a cheaper alternative where items may not require as strict storage conditions.

8 Conclusion

Current approaches to managing supply networks quickly become cumbersome and inefficient. These approaches additionally offer very little in regards to transparency and the monitoring systems present in current approaches are largely centralized third parties. The trust of these supply networks, as well as their ability to effectively respond to product recalls is heavily reliant on the transparency of these networks.

Blockchains pose a viable method to increase the transparency and data security of these systems and by extension the trust any stakeholder in the network has that the products being delivered are of proper quality. This transparency can be increased further with the introduction of additional information related to storage and transport of products via RFID tags or barcodes to verify shipment's environmental conditions. This would be of major benefit to the food industry as a large portion of food illness cases are related to contamination at some point during it's journey trough traditional supply network channels.

And finally, the author wishes to close on the following note. The proposal and adoption of a quantifiable metric to evaluate supply-chain performance would be of considerable value to more accurately determining the viability of existing supply systems as well as those proposed in the literature utilizing blockchain.

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