**IoT Inventory Management using Blockchain**

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| Joseph Nguyen School of Computer Science The University of Adelaide joseph.nguyen@student.adelaide.edu.au | Nguyen Khoi Tran School of Computer Science The University of Adelaide nguyen.tran@adelaide.edu.au | | Ali Babar School of Computer Science The University of Adelaide ali.babar@adelaide.edu.au |
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1 INTRODUCTION

1.1 Background

The Internet of Things (IoT) is currently one of the top trending technology worldwide with an estimated growth to more than 5.8 billion connected devices in 2020 [1]. In essence, it is a set of devices, or ‘things’, which uses sensors and embedded software to interconnect over a network, the ‘internet’. This system provides the capability for communication, collection and exchange of data between connected devices over the network, which leads to increased efficiency, automation and control [2]. In recent years, IoT technology has seen a rise in integration with another major technology in blockchains.

A blockchain is a decentralized, public ledger that applies peer-to-peer networking to maintain a list of transaction records linked through cryptography. When a transaction is made, the data is sent to all nodes in the network for validation. Once a consensus has been reached, the data is stored in a block with the cryptographic hash of the previous block, hashed and then added onto the end of the chain. Early implementations of blockchains revolved around the exchange of currency, giving rise to cryptocurrencies such as Bitcoin [3]. However, its scope has now expanded to general applications in market and finance, allowing transactions with assets other than currency and introducing the concept of smart contracts and smart property.

Smart property is property encoded onto a blockchain, enabling ownership to be monitored and controlled through the blockchain via its unique private key. Owners can sell their property by transferring the private key to the new owner. Moreover, smart property can be transacted via smart contracts, pre-defined contracts on the blockchain that execute a set of instructions when certain conditions are met. These properties can be tangible like phones, cars and houses, or intangible like shares, stocks and copyrights [4].

1.2 Motivation

Supply chain tracking allows companies to monitor the movement and status of their inventory, which can affect supply chain efficiency, product safety and security, management of risks and cost and delivery performance [5]. Some common technologies used to assist in tracking supply chains include barcodes and tags. However, these methods share a problem in that the data collected is all stored in a single source. This raises the issue of trust as it becomes increasingly difficult to establish a single point of trust in a growing company. Mismanagement or tampering of data by those controlling the data source could be possible without the knowledge of the rest of the company.

This problem could be resolved by having a secure inventory management system to track properties as they move across organizations and people without a trust based system. This paper proposes such solution through the integration of blockchains to implement a trustless inventory management system that can monitor the transfer, deployment and maintenance of properties using sensors.

The decentralized system of blockchains distributes data to every node in the network, minimizing the need for trust between organizations and people and the risk of data tampering. Furthermore, the transparent nature of the system makes all transactions recorded in the blockchain visible on the network, enabling all connected users to monitor the transactions at any time and thus reducing the risk of fraudulent activities.

Whilst the proposed inventory management system aims to resolve trust issues with previous methods of supply chain tracking, it also has potential uses for smaller scale cases, such as smart homes and personal device tracking, and for larger scale cases in smart cities and industry 4.0.

2 LITERATURE REVIEW

Early research and development on property and supply chain tracking often saw the employment of barcodes and tags to aid in monitoring the movement of properties. In a research on agri-food supply chain traceability, Tian [6] demonstrated the applications of Radio Frequency Identification (RFID) tags to support Chinese agri-food markets. These tags were an upgrade over the barcode system as they did not require line-of-sight scanning thus were more flexible for information gathering and real-time tracking [7]. Whilst they were shown to reduce logistics cost and improve the safety and quality of agri-food, the key issue that was presented was the centralized traceability system of RFID tags. Information extraction and sharing across the organization was difficult and trust became an issue. Likewise, Caro et al. [8] described that agri-food supply chains built upon centralized infrastructures leave room for major concerns such as data integrity, tampering and single points of failure.

Since the introduction of Bitcoin and its underlying blockchain technology by Nakamoto [3], blockchains have been garnering attention as the new and innovative approach to solving these issues. Research by Tian [9] also looked into integrating blockchain and IoT technology to further improve supply chain traceability. The decentralized, distributed system for storing and sharing data would not only increase the credibility of the data but also minimize the risk of fraud. Abeyratne and Monfared [10] explored blockchains in a similar research to discuss the potential benefits of such technology in manufacturing supply chains. They highlighted durability, transparency, immutability and process integrity as key advantages that blockchains provide and proposed a system in which products are given unique identifiers linking them to virtual identities on the network that can be exchanged via smart contracts.

Blockchain technology has also been a trending topic of research in other areas of IoT. Kostal et al. [11] introduced a monitoring and management architecture for IoT devices based on blockchains, utilizing the decentralized and distributive properties to improve network security and storage. Research by Liu et al. [12] explored methods to improve data integrity verification for cloud-based IoT. They capitalized on the peer-to-peer networking of blockchain technology to implement a more reliable data integrity verification system without relying on a third party auditor. Similarly, research on a blockchain platform for industrial IoT by Bahga and Madisetti [13] resulted in enhanced cloud-based manufacturing functionalities from the removal of the intermediary party during transactions.

The proposed inventory management system will be similar to the proposed system by Abeyratne and Monfared. By registering properties onto the blockchain as smart property, they can be transacted with via smart contracts that control information such as their ownership, location and status.

3 GOALS AND CHALLENGES

The project consists of two key components. The first major component is the design and implementation of the blockchain technology behind the inventory management system. The decentralized blockchain system will be able to record information about a physical property, such as its owner, location and status, and store the information as a digital asset on the blockchain network. The property will then be able to participate in transactions defined by smart contracts that will be developed and deployed in the network. This will ultimately enable secure and reliable tracking of smart property ownership as they transfer between organization and people, location as they are deployed and status as they undergo maintenance. The blockchain system will be implemented using Ethereum [14], a global, open-source, programmable blockchain platform for decentralized applications and the smart contracts will be written using the Solidity programming language. The system will then be deployed onto the network where it will become available for interaction through web3.js, the Ethereum JavaScript API.

The second key component of the project is the development of a basic web portal that will be used to display the transaction history of the blockchain based inventory management system. The web portal will gather and organize transaction data extracted from the blockchain network and present the information on a webpage in a clear and simplified manner. The data will be filtered to show relevant information such as the addresses of the parties involved in the transaction, the time at which the transaction took place and the amount of resources exchanged in the transaction if any. This will provide a cleaner and more intuitive user interface for monitoring smart property transactions. The webpage of the web portal will be built using HTML and transaction data on the blockchain network will be accessed with web3.js.

A significant challenge in this project is my limited knowledge in the areas of IoT and blockchains. Before taking on the project, I had never even heard of the terms IoT or blockchains thus had no initial understanding of these topics. Consequently, I spent the first few weeks learning these technologies from the very basics. Furthermore, I had no experience with any of the software and programming languages that will be used for the project thus I also learnt and practiced tasks such as writing smart contracts in Solidity and deploying a local private blockchain on my device. Fortunately, I was able to pick up Solidity and web3.js quickly as they closely resemble C++ and JavaScript respectively, which I have some experience in. However, my skills in these languages are still basic which may increase the difficulty of the design and implementation process for the inventory management system.

Another key challenge in reaching these goals is time. As mentioned above, I had to spend a significant amount of time to learn about IoT and blockchains and gain the required knowledge and skills to be able to design and implement the inventory management system. Moreover, I will need to set aside some time towards the end of the semester to create the poster and write up the final project paper. Hence, the amount of time I have to work on the design and implementation of the system is very limited. A resource that I have to help manage my time is a study plan that organizes the project into two-week sprints. This will help me to distribute my time between different parts of the project and acts as a guideline to ensure that I am on the right track and on time with my work.

4 TIMELINE

The project is divided into two-week sprints over 12 weeks. The first four weeks is to learn about the project requirements and the background about blockchains in order to start writing up the design document. Weeks 5 and 6 will be to research relevant papers for the literature review in order to complete the design document for submission and start designing and prototyping the system. Weeks 7 and 8 will be to implement the proof-of-concept of the system. Weeks 9 and 10 will be to deploy and evaluate the proof-of-concept of the system. Weeks 11 and 12 will be to create the poster and write up the final paper for submission.

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