UAV-deployed Secure Data Management System in Industry 4.0 using Blockchain

Md Masuduzzaman, Syed Muhammad Raza and *Soo Young Shin
Department of IT Convergence Engineering,
Kumoh National Institute of Technology (KIT), Gumi, South Korea
Email: {masud.prince, syedraza98, *wdragon}@kumoh.ac.kr

Abstract

Effective and secure data management in Industry 4.0 is crucial to increase efficiency, agility, and innovation. It empowers organizations to harness the potential of data as a strategic asset in transforming industrial operations. There are several challenges to overcome when implementing data management in Industry 4.0, from organizational and ethical concerns to technical difficulties. Therefore, this paper presents a unique idea of unmanned aerial vehicle (UAV)-based secure data management system in Industry 4.0 to convey benefits, enhancing efficiency, safety, and overall operational effectiveness. However, due to the limited memory storage of the UAV, multi-access edge computing server-based efficient data storage technique is exploited. Furthermore, blockchain-based secure data storage technique in MEC server is utilized to provide data integrity throughout the network. Lastly, a sample network is established, and the throughput of the network is analyzed to demonstrate the effectiveness of the proposed system.

Ⅰ. Introduction

In Industry 4.0, data management refers to the systematic processing, scheduling, and implementation of data in the framework of the fourth industrial revolution, integrating digital technology, networking, and smart systems. The foundation of Industry 4.0 is the massive gathering of data from several sources, such as sensors, machinery, and manufacturing systems [1]. Real-time monitoring and continuous data collection in Industry 4.0 are crucial to fully capture the dynamic character of industrial processes [2]. Automating various operations using unmanned aerial vehicle (UAV) may boost productivity and reduce operating costs by increasing efficiency in areas like inventory management [3]. However, due to the low memory storage of the UAV devices, it is challenging to store all the inventory data of a production house. Therefore, the large amount of inventory data can be processed and stored securely in a multi-access edge computing (MEC) server that is located on the same network as the UxV devices [4]. Moreover, additional robust safety precautions must be implemented to prevent critical industrial data leaks from unwanted access, cyber threats, and possible breaches [5]. Among the existing studies, Gilsoo et al. [6] proposed a UAV-based data optimization technique using fog computing. However, the authors did not consider the security issue of providing data integrity in the smart factory and only simulated their idea. By leveraging blockchain in Industry 4.0, organizations can address various security, transparency, and efficiency challenges, leading to a more robust and streamlined industrial ecosystem [7]. Therefore, this paper presents a UAV-based effective and secure data management in Industry 4.0 using MEC and blockchain technology.

Ⅱ. Proposed Methodology

Fig. 1 displays the overall system model of the proposed technique. First, the inventory data management UAV is deployed in the production storage to avoid human interaction and provide automation in an Industry 4.0 environment. The item order is placed in the MEC server first to keep track of all items. For the smart data calculation, each product item in the production storage is attached with a radio frequency identification (RFID) tag. The UAV is also attached with an RFID tag to count down the items in the production storage. Whenever the order is initially placed on the MEC server, the server sends the data securely to the UAV. Whenever the item is moved from the production storage due to the previous order placement on the MEC server, the UAV counts the rest of the items using the RFID technique and sends the remaining item amount securely to the MEC server. To ensure data confidentiality between the MEC server and UAV, the symmetric cryptographic technique is applied, where both of them use one key to encrypt and decrypt the confidential message. Once the MEC collects the existing item amount from the UAV, it stores it in the blockchain to provide data integrity in the proposed network. As the product information is stored in the blockchain, there is no chance of miscalculation or intentionally removing any item from the production storage without informing the MEC server.

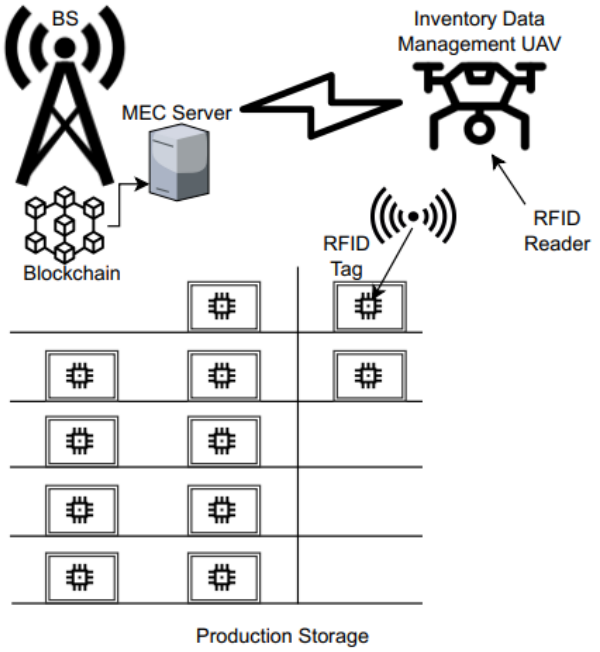

Fig. 1. System Model.

III. Result Analysis

This experiment uses one Parrot Bebop 2 drone as a UAV and one Intel(R) Core(TM) i5-4590 @ 3.30GHz PC as an MEC server to demonstrate the overall performance of the proposed system. On raspberry pi 4 model B as an IoT device and one RFID sensor is attached with the drone to transfer the collected data from the UAV to the MEC server. Then, different sizes of inventory management data packets are transferred from the UAV to the MEC server. To securely transfer the data, the Advanced Encryption Standard (AES-128 bits) symmetric cryptographic technique is utilized, and the overall throughput is measured using a python code.

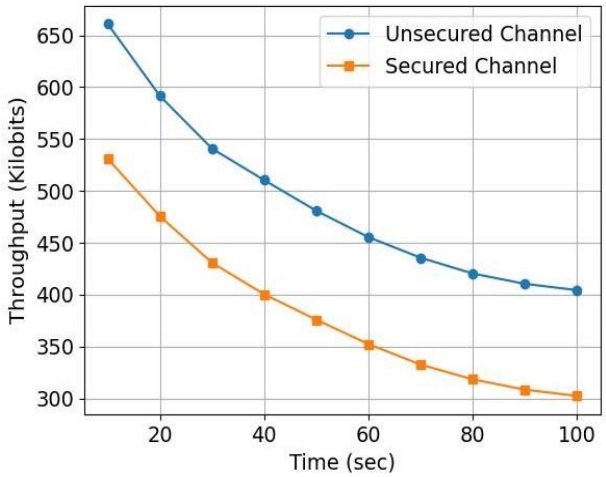

Fig. 2. Throughput Comparison.

Fig. 2 shows the overall throughput analysis of the experiment where the x-axis represents the time in sec and the y-axis represents the throughput in kilobits. Throughput in the secured channel and the unsecured channel is calculated where the AES cryptographic technique is utilized in the secured channel during the transfer of the data from the UAV to the MEC server. It can be shown that the throughput is higher in the unsecured channel as no cryptographic technique is applied here. However, it is recommended to trade off a small amount of throughput as the secured channel can provide data confidentiality.

IV. Conclusion and Future Work

This paper proposes an unmanned aerial vehicle (UAV) deployed secure data management system in Industry 4.0 using blockchain technology. First, the order items in Industry 4.0 are placed in the multi-access edge computing (MEC) server to dispatch these from the production storage. Then, the information is transferred to the UAV using the Advanced Encryption Standard (AES-128 bits) symmetric cryptographic technique. After sending those items, the UAV uses its radio frequency identification (RFID) sensor to calculate the remaining items in the production storage. The UAV then sends the data securely again to the MEC server to store it. The MEC server stores the information in the blockchain to provide data integrity. The result analysis is analyzed based on the throughput performance of the proposed network. Though the throughput is lower in the secured channel, it is recommended because it provides data confidentiality in this proposed network. The analysis of the proposed blockchain network and Quality of Service for using the MEC server can be considered as future work.

ACKNOWLEDGMENT

MERIT (Medical, Electronic, Robotic, IT) Convergence Innovative Talents Training Group for Smart Manufacturing Innovation.

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