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Blockchain-Based IoT-Enabled System for Secure and Efficient Logistics Management in the Era of Industry 4.0

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ABSTRACT: Fulfilling the "seven rights"—delivering the right goods, in the right quantity and condition, at the right location, at the right time, to the right client, and at the right cost—is the goal of modern logistics. However, significant issues have emerged as logistics operations become more digital and complex, particularly with the advent of Industry 4.0 technologies like cloud computing, big data analytics, and the Internet of Things (IoT). These issues include inefficiencies, a lack of transparency, security flaws, and eroded confidence among logistical parties. Traditional operations have been transformed into smart logistics by the widespread usage of IoT devices in logistics, such as RFID tags, GPS trackers, and

I. INTRODUCTION

In an increasingly globalized and digitized world, logistics has become a crucial component of supply chain management, serving as the strategic process that facilitates the efficient transfer of goods, services, and relevant information from their source to the consumption point. Logistics ensures that the right products are delivered in the correct quantity and condition, at the appropriate time and place, to the designated customer, and at a suitable cost—a principle commonly referred to as the "seven rights" of logistics. As industries expand their operations across international borders and the demand for superior service quality escalates, logistics systems are under considerable pressure to improve their responsiveness and transparency. The involvement of numerous agents or parties in the logistics cycle results in a lack of comprehensive visibility of information, which complicates the process and creates challenges for timely and accurate decision-making (Kamble et al., 21). Nevertheless, there has been limited research specifically targeting the paint industry, a sector characterized by unique challenges such as hazardous raw materials, intricate logistics, and fluctuating market demand automated warehouse systems.

II. LITERATURE REVIEW

The IoT based on Blockchain is an essential component in the Fourth Industrial Revolution (IR4), primarily due to its transparency and security features. The advancements in technology within IR4 have propelled blockchain to become more secure and beneficial for all stakeholders involved in the logistics cycle, whether it pertains to one-way or two-way logistics. Numerous authors have contributed to refining the blockchain to enhance its precision and transparency. For instance, Zhang et al. (2018) proposed a framework that integrates cloud storage with IoT-based systems to improve energy efficiency and responsiveness in logistics. By distributing computational tasks and storage across cloud infrastructures, their model addressed issues of energy waste and reduced waiting times in the integration of manufacturing and logistics.

III. DATA COLLECTION AND ANALYSIS

A survey was sent via email to ten executives at Hindustan Unilever who are engaged in sustainability, logistics, and procurement. They were requested to evaluate the challenges based on their relative importance using descriptive terms (e.g., very high, high, medium, low). The respondents are identified as DM1, DM2, ..., DM10. - Step 1: Experts assigned significance ratings (π_i) for each recognized challenge.

- Step 2: Average scores were calculated to obtain aggregated significance, which was then utilized in the SWARA methodology to determine relative weights and rankings.

IV. DISCUSSION

The findings indicate that Data Security & Privacy represents the most significant challenge, possessing the highest normalized weight of 0.239, which underscores the escalating concerns regarding secure data management within blockchain-IoT systems. Following this, Scalability at 0.176 and Real-Time Processing at 0.133 emerge as critical issues, highlighting the necessity for resilient and responsive systems that can accommodate growing data volumes and operational efficiency. Complex Integration, with a weight of 0.133, and Interoperability at 0.094 are categorized as moderate challenges, suggesting that the technical synchronization between IoT devices and blockchain platforms continues to present difficulties. Lastly, Lack of Standardization at 0.068 and High Energy Consumption at 0.048 are viewed as lower priority concerns, yet they still hold significance for the sustainable and cohesive implementation of these technologies.

V. CONCLUSION

This study investigated the major technical challenges that hinder the implementation of Blockchain-IoT (B-IoT) systems in warehouse logistics. By conducting a thorough review of current literature and engaging with specialists, seven key issues were identified: Data Security & Privacy, Scalability, Real-Time Processing, Complex Integration of IoT and Blockchain, Interoperability, Lack of Standardization, and High Energy Consumption. These obstacles present significant barriers to the successful adoption of B-IoT in warehouse environments, where operational efficiency, data accuracy, and system responsiveness are essential.

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