Fusion Application Mode of IoT and Blockchain in the Field of Specialized Air Logistics

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Abstract: Specialized air logistics service is an important field of air logistics, providing important support for the operation of the industrial chain, the development of the economy, society, and people's livelihood. At present, the digitalization level of specialized air logistics needs to be improved, and it is of great significance to study how to apply digital technologies to improve its service level. IoT and blockchain are advanced digital technologies, and the analysis of research status shows that although the application research of advanced technologies in the logistics field is becoming increasingly active, there are few literature analyses on how to integrate IoT and blockchain to improve specialized air logistics service. This study first analyzes the main problems in the digitalization process of specialized air logistics, and then elaborates on the coupling mechanism between the technological advantages of IoT and blockchain and the demand for improving specialized air logistics service. Based on this, special cargo air logistics, emergency air logistics, and cold chain air logistics are selected as representative fields. Taking live animals, emergency medical materials, and vaccines as examples, three typical application modes are constructed applying IoT and blockchain, effectively improving the service level and guarantee capability of specialized air logistics.

Keywords: IoT; Blockchain; Specialized Air Logistics; Fusion Application; Application Mode

1. Introduction

The air logistics industry is a strategic pillar industry, an important component of the transportation system and a crucial support for the modern industrial chain, providing strong guarantee for the development of the economy, society, and people's livelihoods. However, at present, the specialized service of Chinese air logistics is still relatively lagging behind, and the service capabilities of enterprise entities are still not strong enough. The support for specialized service is insufficient, and it cannot fully meet the needs of new business models such as special cargo transportation, emergency logistics, cold chain logistics, and cross-border e-commerce. Among them, the low level of digitalization is one of the key problems. With the modernization of the industrial chain and the accelerated development of emerging industries, as well as the growing demand of the people for high quality aviation service, it is required that air logistics adapt to the requirements of the new situation, improve the service level and guarantee capability of specialized air logistics.

2. Literature Review

In recent years, the Fusion Application of advanced technologies such as IoT, blockchain, big data, and artificial intelligence in the field of modern industrial systems has become a research hotspot in the academic area. Promoting the integrated application of new technologies in various logistics fields, accelerating the construction of logistics informatization, and enhancing the level of logistics intelligence is an important development trend in the research of IoT and blockchain applications.

Salvador Cunat Negueroles, et.al studied the deployment case of digital twins in IoT and the optimization and control of logistics fleet allocation in supply chain management based on open source blockchain, and proposed an environmentally friendly and low-cost solution

that integrated the application of IoT and blockchain [1]. Mohammed Balfaqih, et.al proposed an IoT logistics system based on blockchain for efficient tracking and management of high-value goods. The system utilized blockchain based smart contracts to achieve automatic approval and payment, and employed a zero-knowledge proof to hide the blockchain address, effectively ensuring identity verification [2]. Nanda Saroj Kumar, et.al proposed a new method for integrating IoT with the health supply chain blockchain. This method can solve supply chain related issues between suppliers and end-users. This study aimed to develop an intelligent health supply chain management system by combining blockchain and IoT technologies [3]. Aiming Shen applied blockchain technology to improve the level of logistics and warehousing management, and built an intelligent WMS model based on existing warehouse management technology, designing an IoT service system for logistics engineering. [4] Pele Pierrick, et.al believed that IoT and blockchain technology can help improve the security of the food supply chain, and has designed a food supply chain logistics framework that integrates the application of IoT and blockchain with a focus on the logistics link [5]. Chen Jun, et.al applied IoT and blockchain to optimize the location selection method of intelligent logistics warehouses, improving the tracking ability of product transportation progress in the supply chain, achieving the goals of low computation, high positioning accuracy, and low total cost, and obtaining the best warehouse positioning results [6]. Ramirez Cristina, et.al designed a cold chain inventory management model for small and medium-sized enterprises applying blockchain, IoT, and cloud computing. By installing sensors in portable devices to measure control variables in the cold chain, they developed relevant software and verified the feasibility of the technology during the distribution process in a controlled environment [7]. Juanjuan Yang, et.al proposed a dynamic distributed iterative computing model that is beneficial for improving asset computing efficiency in shared logistics transactions based on blockchain and IoT, while protecting the privacy of shared logistics payment management and improving economic performance [8]. Pal Amitangshu, et.al has researched a blockchain technology that can improve video streaming in IoT, thereby enhancing traceability and tracking functions in integrated food logistics [9]. Nejc Rozman, et.al proposed a method of integrating blockchain and IoT technology into modern supply chains, constructing a distributed logistics platform based on blockchain and IoT applications, and improving the reliability of supply chain services [10]. Veneta Aleksieva, et.al proposed an integrated model of blockchain and IoT for special logistics services, targeting special goods such as dangerous goods, drugs, and products with limited shelf life. It can apply smart contracts on the blockchain to manage cross transfer warehouses and transportation [11].

In summary, the application research of advanced technologies such as IoT and blockchain in the logistics field is becoming increasingly active, and the existing achievements have important value. Overall, the application modes and scenarios of new technologies in the logistics field are becoming more diverse, but there are still some shortcomings. Firstly, there is still relatively little research on the application of new technologies such as IoT and blockchain in the field of air logistics. Secondly, due to the late start of research on the application of new technologies in the field of air logistics, existing studies are relatively scattered and fragmented, have not yet formed a complete system, and there is still significant room for research expansion. The systematicity of research results needs to be improved. Thirdly, There are few studies on the integrated application of IoT and blockchain in the field of specialized air logistics, indicating a lack of specificity.

3. IoT and Blockchain Technologies

Narrowly defined, IoT refers to a network that connects objects to achieve intelligent identification and management of objects. In a broad sense, IoT can be seen as the integration of information space and physical space, digitizing and networking everything, achieving efficient information exchange between objects, objects and people, and people and the real environment, and integrating various information technologies into social behavior through new service

models. The basic characteristics of IoT can be summarized as comprehensive perception, reliable transmission, and intelligent processing [12]. The key technologies of IoT can be considered from both hardware and software aspects. Hardware technologies include Radio Frequency Identification (RFID), Wireless Sensor Network (WSNs), Embedded Intelligence, and Nanotechnology. Software technology includes information processing technology, self-organizing management technology, and security technology [13].

In the past two years, blockchain has developed rapidly, and people have begun to try to apply it to fields such as finance, education, healthcare, and logistics. It is generally believed that blockchain is a new distributed computing and storage paradigm that integrates multiple existing technologies. It uses distributed consensus algorithms to generate and update data, and utilizes peer-to-peer networks for data transmission between nodes. A distributed ledger that combines cryptographic principles and timestamp technology ensures the immutability of stored data, and uses automated script code or smart contracts to implement upper layer application logic. The characteristics of blockchain can be summarized as decentralization, tamper-proof, openness and transparency, anonymity, and contract autonomy [14].

The integration of blockchain and IoT is currently an important direction for the development of blockchain. The integration of IoT and blockchain can shorten the data transmission delay through direct communication between devices. Combined with edge computing and other technologies, it can not only solve the problem of waste of idle resources, but also shorten the transmission distance between terminal devices and servers [15].

4. The Coupling Mechanism between the Advantages of IoT & Blockchain and the Demand for Improving Specialized Air Logistics Service

Specialized air logistics service is an important field of air logistics, providing important support for the operation of the industrial chain, the development of the economy, society, and people's livelihood. However, at present, the digitalization level of specialized air logistics in China needs to be improved, and accelerating the application of advanced digital technologies in this field has become an inevitable development trend. Firstly, the level of informatization varies greatly, with some air logistics enterprises, airlines, airfreight stations, airports and other nodes lagging behind in informatization construction and lacking in capacity. Secondly, the information systems of various entities in air logistics are relatively independent, with inconsistent information standards and serious information silos. Thirdly, multiple departments closely related to the development of specialized air logistics have not yet established a data sharing mechanism and achieved data interconnection, which cannot effectively support the operation and supervision of logistics chain.

IoT and blockchain are advanced digital technologies. In order to enhance the specialized air logistics service capabilities and accelerate the construction of informatization, this study integrates IoT and blockchain, selects special cargo air logistics, emergency air logistics, and cold chain air logistics as representative fields, and applies two technologies to construct three typical application modes and scenarios. There is a close coupling mechanism between the technological advantages of IoT and blockchain and the demand for specialized air logistics service.

Taking the application field of "live animals air logistics" in Figure 1 as an example. Firstly, analyze the characteristics of IoT technologies (main hardware technologies such as RFID, WSNs, embedded intelligence, nanotechnology, etc., and main software technologies such as information processing, self-organizing management, security technology, etc.), use them to perceive and identify target objects and describe their static characteristics, detect and record the dynamic characteristics of objects in the environment, intelligently process external messages or stimuli, and transmit data, thereby effectively assisting shippers, carriers, and consignees, and improving the ability to monitor the safety and health status of live animals throughout the entire process of air logistics. Then, analyze the characteristics of blockchain related technologies (distributed storage, consensus mechanism, cryptographic technology, smart contracts, etc.), and utilize their advantages of decentralization and transparency, permanent

storage of data and traceability, information authenticity and tamper resistance to enhance the regulatory authority's licensing of live animals transportation. The coupling mechanism between the advantages of two new technologies and the demand for improving specialized air logistics service is shown in Figure 1.

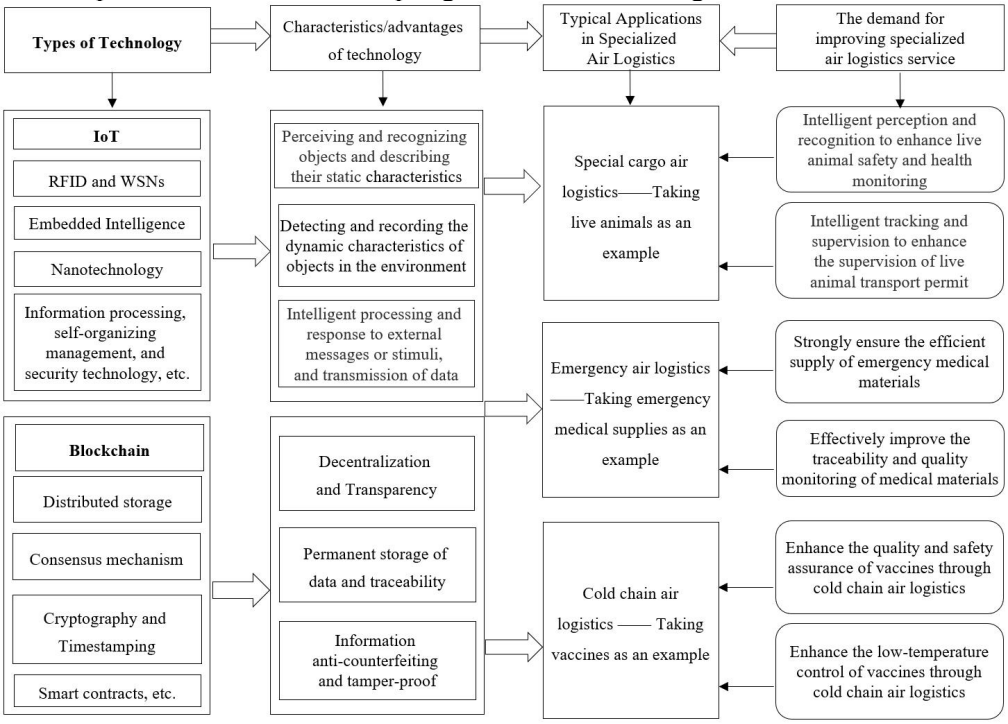

Figure 1. The Coupling Mechanism between the Advantages of Two New Technologies and the Demand for Improving Specialized Air Logistics Service

5. The Fusion Application Mode of IoT and Blockchain in the Field of Special Cargo Air Logistics: Taking Live Animals as an Example

Live animals are one of the most representative special goods in the field of specialized air logistics. In recent years, the demand for specialized air logistics service for such goods has been increasing, and the requirements for service level and safety guarantee capability are also improving. Live animals air logistics service mainly include receiving & checking, temporary storage, containerization, loading, air transportation, unloading, and delivery. At present, the main problems in the above process include two aspects: first, the service quality is not high, and the logistics safety guarantee is insufficient, which is manifested in the difficulty of monitoring the health status of live animals, insufficient care and protection during transportation, insufficient emergency response capabilities after animals escape, and unclear definition of accident responsibilities; Secondly, there are loopholes in the supervision and evidence preservation of the authorities, which are manifested in insufficient basis for the supervision of live animals that are prohibited or restricted from transportation, the need to strengthen the permanent and complete storage of various permit documents, and inadequate security and supervision of live animals transportation involving dangerous goods.

To address the aforementioned problems, this study proposes an integrated application mode of IoT and blockchain in the field of live animals air logistics. Firstly, the construction of an air logistics IoT is mainly composed of WSNs subsystems, RFID subsystems, network subsystems, positioning subsystem, and other components. Sensor collars are worn on the necks of live animals, and RFID tags are embedded in animal containers. IoT covers various links such as receiving and checking, temporary storage, containerization, loading, air transportation, unloading, and delivery to the greatest extent possible. This enables shippers, consignees, carriers, and other parties to query the status of live animals at any time throughout the logistics process, achieving the goals of monitoring health status, monitoring

care service during transportation, tracking animals in case of escape, effective emergency response, and clear division of accident responsibilities. As a result, the quality and safety guarantee capabilities of air logistics service for live animals are significantly improved.

Then, blockchain technology is applied to enhance the informatization level of air logistics, and a logistics information system based on blockchain application is constructed. The qualification certificate of animal health quarantine, transport permit for national key protected wildlife, import and export transport license for endangered wildlife, consignment proof of live animals, notification to captain and cargo airwaybill are stored on the blockchain to achieve the goals of permanent storage, information anti-counterfeiting, data tampering prevention, effective traceability, and accident accountability. This helps the authorities strictly regulate and restrict the transportation of live animals, and provides strong support for the safety guarantee of live animal transportation involving dangerous goods.

In this mode, the application function of IoT is mainly focused on monitoring the status of live animals themselves, while the application function of blockchain is mainly focused on regulating the transportation license of live animals. Through the Fusion Application of two cutting-edge information technologies, the service level and security guarantee capability of special cargo air logistics are improved. The Fusion Application mode of IoT and blockchain in the field of live animals air logistics is shown in Figure 2.

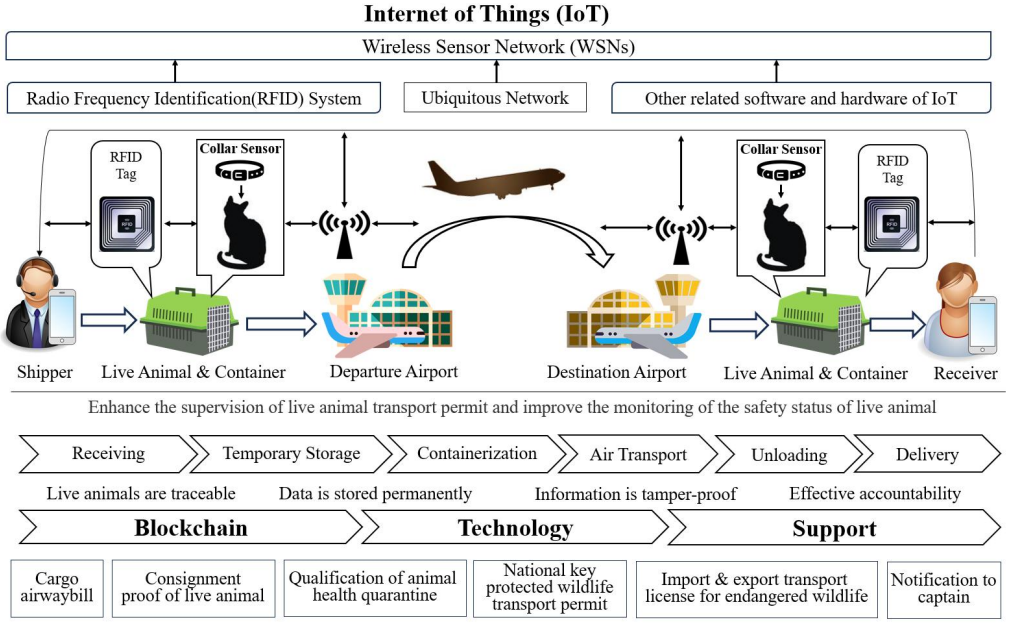

Figure 2. The Fusion Application Mode of IoT and Blockchain in the Field of Live Animals Air Logistics

6. The Fusion Application Mode of IoT and Blockchain in the Field of Emergency Air Logistics: Taking Emergency Medical Materials as an Example

Emergency logistics refers to special logistics activities aimed at providing emergency materials for sudden natural disasters, public health emergencies, and other emergencies, with the goal of maximizing time efficiency and minimizing disaster losses [16]. Medical materials are usually one of the most important types of emergency materials, with the highest requirements for transportation speed and safety. In situations where the distance is long, the transportation of emergency medical materials requires strong support from emergency air logistics. But at the same time, the quality assurance of medical materials is crucial. For a long time, ensuring the quality and logistics safety of medical materials to the greatest extent possible has been the biggest challenge for emergency air logistics. To address this challenge, this study adopts blockchain technologies such as distributed storage, cryptographic technology, smart contracts, consensus mechanisms to improve the quality monitoring of medical materials.

Detailed data of medical materials is registered in the blockchain. Once this step is completed, the data cannot be tampered with or deleted, and even the act of modifying or deleting data can also be permanently recorded by the distributed ledger of blockchain. On the other hand, medical materials with quality problems can be closely tracked, accurately traced, and held accountable in a timely manner, thereby enhancing strict monitoring of the quality of medical materials in all aspects.

On this basis, the integration of IoT and blockchain are applied to innovate emergency air logistics model, in order to achieve effective traceability and quality monitoring, and provide strong support for ensuring efficient supply of medical materials. Specifically, by integrating blockchain and IoT technologies, a medical material quality monitoring system is constructed, consisting of four subsystems: information collection, data management, smart contracts, and business operations.

Firstly, at the information collection layer, RFID, Wireless Sensor Network (WSNs), M2M system framework, and other related software and hardware technologies are used to build IoT and cover the entire supply and logistics process of emergency medical materials (including core links such as production and quality inspection, inventory management, logistics and distribution).

Secondly, in the management data layer, blockchain technologies such as distributed ledgers, hash operations, consensus algorithms, and timestamps are integrated and applied. All parties involved in the medical materials supply chain (authentication groups on the blockchain) jointly account for production quality inspection, inventory management, procurement and sales, logistics and distribution, etc. The data is stored in a distributed manner in the blockchain system, making it tamper proof and not removable. Once there are quality problems with medical materials, accurate traceability and effective accountability can be achieved.

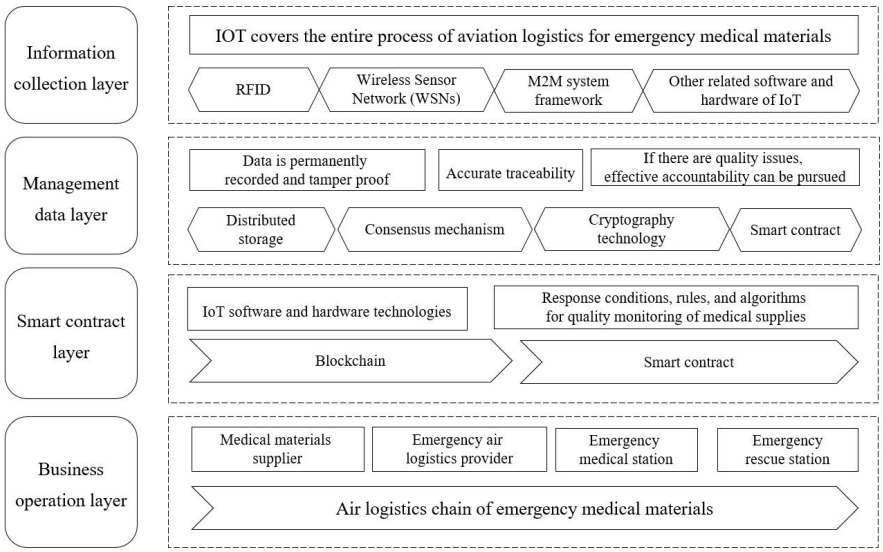

Figure 3. The Fusion Application Mode of IoT and Blockchain in the Traceability and Quality Monitoring of Emergency Medical Materials

Thirdly, at the smart contract layer, IoT technologies are integrated to pre-set quality monitoring response conditions, rules, algorithms, and other elements. The system automatically checks the quality status of emergency medical materials at various stages of the supply chain, and automatically checks whether the materials meet the quality conditions such as temperature, humidity, and timeliness specified in the contract. If they meet the contract requirements, the system automatically confirms and continues to operate until the final delivery is completed.

Fourthly, at the business operation layer, the medical supplies supply chain based on blockchain applications can achieve dynamic and transparent supervision throughout the entire process, breaking down information barriers between suppliers, logistics providers, medical stations or rescue stations, improving the collaboration and credit of participants, and reducing the risk of medical supplies supply chain breakage. The Fusion Application mode of IoT and blockchain in the

traceability and quality monitoring of emergency medical materials is shown in Figure 3.

7. The Fusion Application Mode of IoT and Blockchain in the Field of Cold Chain Air Logistics: Taking Vaccines as an Example

Vaccination is widely regarded as one of the most effective means of preventing and controlling pandemics. This study first analyzes the special requirements of vaccines for cold chain air logistics. Based on this, two technologies are applied to construct a cold chain air logistics blockchain information platform and IoT system, providing strong support for the quality, safety, and temperature control of vaccine supply.

7.1 Special Requirements of Vaccines for Cold Chain Air Logistics

As temperature sensitive medical supplies, vaccines should mostly be kept in a constant temperature environment of 2-8 ℃ during transportation and storage.[17] The quality and safety of vaccines are crucial, and research on vaccine transportation quality and safety at home and abroad mainly focuses on transportation stability. [18] The primary guarantee for stability is the temperature stability during the logistics process, thereby ensuring the effectiveness of the vaccine. As a special kind of medicine, vaccines are distinguished from pharmaceutical cold chain transportation, and the requirements for vaccine cold chain are higher than those for pharmaceutical cold chain. [19] On the other hand, time control is the key to vaccine logistics. In situations where transportation distance ais long, air freight is the fastest way to deliver vaccines. Therefore, to ensure the timeliness and stability of vaccines, cold chain air logistics is usually used. In summary, exploring how to integrate the application of IoT and blockchain to ensure the smooth operation of vaccine cold chain air logistics has important research significance and practical value.

7.2 The Fusion Application Mode of IoT and Blockchain in the Field of Vaccine Cold Chain Air Logistics

On the one hand, applying blockchain related technologies to build blockchain information platform for the cold chain air logistics. How to ensure the quality and safety of vaccines to the greatest extent possible is a major challenge for cold chain air logistics. To address this challenge, this study adopts blockchain related technologies to improve the quality monitoring of vaccines. Detailed information, complete certificates, and files related to vaccine manufacturers, production licenses, and vaccine products are registered on the blockchain information platform. As long as these operations are completed, the data cannot be tampered with or deleted. Once there are quality problems with vaccines, precise traceability and effective accountability can be carried out, thereby achieving strict monitoring of vaccine quality. On the other hand, the entire logistics data related to vaccine packaging, storage, ground and air transportation, distribution, and delivery are also permanently recorded on blockchain, allowing shippers, consignees, and carriers to check the logistics status of vaccines at any time, achieving the goals of monitoring the transportation process, effective emergency response, and clear division of logistics accident responsibilities, thereby significantly improving the quality and guarantee capabilities of cold chain air logistics service.

On the other hand, applying IoT technology to build an IoT system for cold chain air logistics. The system architecture consists of active temperature-controlled air containers, Wireless Sensor Network (WSNs), electronic temperature recorders, RFID systems, positioning systems, and interconnected networks, etc. The system network covers various participants such as shippers, consignees, vaccine manufacturers, air logistics companies, airlines, airport freight station, service providers of temperature-controlled container, and providers of electronic temperature recording instrument, etc. The main functions of IoT system include: firstly, 24-hour accurate temperature monitoring of the entire vaccine logistics process; The second is to provide end-to-end effective guarantee for the maintenance and adjustment of vaccine low temperature; The third is to provide strong support for timely emergency response when the vaccine temperature is out of control. The Fusion Application mode of IoT and blockchain in the field of vaccine cold chain air logistics is shown in Figure 4.

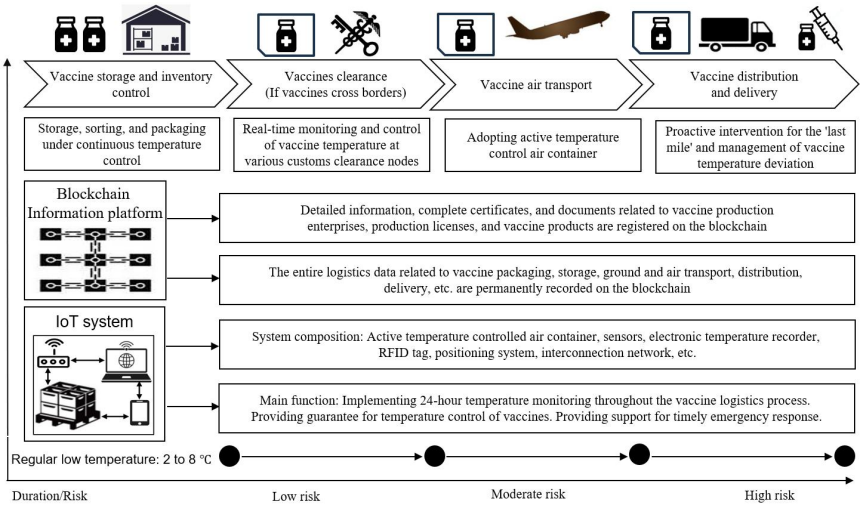

Figure 4. The Fusion Application Mode of IoT and Blockchain in the Field of Vaccine Cold Chain Air Logistics

8. Research Conclusion and Prospect

Air logistics is an important support for the operation of the industrial chain, economic and social development, and people's livelihood, and specialized air logistics is an important service area. This study explores the multi scenario Fusion Application of IoT and blockchain, aiming to promote the informatization construction, intelligence level, and service capability improvement of specialized air logistics. There is a coupling relationship between the technological advantages of IoT and blockchain and the demand for improving specialized air logistics service. Special cargo air logistics, emergency air logistics, and cold chain air logistics are representative service fields of specialized air logistics. The Fusion Application of these two technologies can start from these three fields and construct three typical application modes. Firstly, taking live animals as an example, the application of IoT can enhance the monitoring capability of live animals status, and the application of blockchain can strengthen the supervision of live animals transport permit, thereby improving the level of special cargo air logistics service and security capabilities. Then, taking emergency medical supplies as an example, these two technologies are applied to innovate the emergency air logistics mode, providing strong guarantees for efficient supply of medical materials in case of emergencies, and effectively improving material traceability and quality monitoring. Finally, building a logistics blockchain information platform and IoT system can enhance the safety guarantee and low-temperature control of vaccine quality in cold chain air logistics.

Although specific application modes and related paths have been proposed, this study still focuses on theoretical exploration. Subsequent research can focus on practical cases and empirical analysis of the successful application of IoT and blockchain in the field of specialized air logistics. At the same time, in order to continuously improve the level of specialized air logistics service, further expansion can be made in the types of technologies applied. Based on the advantages of IoT and blockchain technology, in-depth research can be carried out by combining the application of artificial intelligence, big data, 5G and other technologies to promote the intelligent development of specialized air logistics.

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References

[1] Salvador Cunat Negueroles, Raul Reinosa Simon, Matilde Julian, Andreu Belsa, Ignacio Lacalle, Raul S Julian & Carlos E. Palau. A Blockchain-based Digital Twin for IoT deployments in logistics and transportation. Future Generation

Computer Systems, 2024, 158:73-88.
[2] Mohammed Balfaqih, Zain Balfagih, Miltiadis D. Lytras, Khaled Mofawiz Alfawaz, Abdulrahman A. Alshdadi & Eesa Alsolami. A Blockchain-Enabled IoT Logistics System for Efficient Tracking and Management of High-Price Shipments: A Resilient, Scalable and Sustainable Approach to Smart Cities. Sustainability, 2023, 15:1-18.
[3] Nanda Saroj Kumar, Panda Sandeep Kumar & Dash Madhabananda. Medical supply chain integrated with blockchain and IoT to track the logistics of medical products. Multimedia tools and applications, 2023, 82(21):32917-32939.
[4] Aiming Shen. Design of internet of things service system for logistics engineering by using the blockchain technology. International Journal of Grid and Utility Computing, 2023, 14(2-3):182-190.
[5] Pele Pierrick, Schulze Julia, Piramuthu Selwyn & Zhou Wei. IoT and Blockchain Based Framework for Logistics in Food Supply Chains. Information Systems Frontiers, 2022, 25(5):1743-1756.
[6] Chen Jun, Xu Shiyan, Liu Kaikai, Yao Shuqi, Luo Xiao & Wu Huan. Intelligent Transportation Logistics Optimal Warehouse Location Method Based on Internet of Things and Blockchain Technology. Sensors, 2022, 22(4):1-14.
[7] Ramirez Cristina, Rojas Alix E. & Garcia Alexander. A Cold Chain Logistics with IoT and Blockchain Scalable Project for SMEs: First Phase. IFAC PapersOnLine, 2022, 55(10):2336-2341.
[8] Juanjuan Yang, C. B. Sivaparthipan & Bala Anand Muthu. Dynamic distributed iterative computational model for payment information management in shared logistics using blockchain-assisted Internet of Things approach. Soft Computing, 2021, 25(18):1-13.
[9] Pal Amitangshu & Kant Krishna. Using Blockchain for Provenance and Traceability in Internet of Things-Integrated Food Logistics. Computer, 2019, 52(12):94-98.
[10] Nejc Rozman, Rok Vrabic, Marko Corn, Tomaz Pozrl & Janez Diaci. Distributed logistics platform based on Blockchain and IoT. Procedia CIRP, 2019, 81:826-831.
[11] Veneta Aleksieva, Hristo Valchanov, Aydan Haka & Diyan Dinev. Logistics Model Based on Smart Contracts on Blockchain and IoT. Engineering Proceedings, 2023, 41(1): 8-17.
[12] Sun Qibo, Liu Jie, Li Shan, Fan Chunxiao，Sun Juanjuan. Internet of Things: Summarize on Concepts Architecture and Key Technology Problem. Journal of Beijing University of Posts and Telecommunications, 2010, 33(03)1-9.
[13] Qian Zhihong, Wang Yijun. IoT Technology and Application. Acta Electronica Sinica, 2012, 40(05)1023-1029.
[14] Zeng Shiqin, Huo Ru, Huang Tao, Liu Jiang, Wang Shuo, Feng Wei. Survey of blockchain: principle, progress and application. Journal on Communications, 2020, 41(01):134-151.
[15] Guo Shangtong, Wang Ruijin, Zhang Fengli. Summary of Principle and Applications of Blockchain. Computer Science, 2021, 48 (02): 271-281.
[16] Xie Ruhe, Qiu Zhuqiang. Discussion on the Construction and Operation Management of Emergency Logistics. Logistics technology, 2005(10):78-80.
[17] World Health Organization. Temperature sensitivity of vaccines. Geneva: WHO Press, 2006.
[18] Chun Zheng Ng, Yen Loong Lean, Siang Fei Yeoh, Qi Ying Lean, Kah Seng Lee, Amal Khalil Suleiman, Kai Bin Liew, Yaman Walid Kassab, Yaser Mohammed Al-Worafi, Long Chiau Ming. Cold chain time- and temperature-controlled transport of vaccines: a simulated experimental study. Clinical and Experimental Vaccine Research, 2020, 9(1): 8-14.
[19] John Lloyd, James Cheyne. The origins of the vaccine cold chain and a glimpse of the future. Vaccine, 2017, 35(17):2115-2120.

