

Blockchain Application and Industry-Education Deep Integration in Low-altitude Air Logistics from the Perspective of New Quality Productive Forces

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Abstract: Low-altitude economy is a typical representative of new quality productive forces. Low-altitude logistics is one of the core areas of the low-altitude economy, and an important field for enhancing new quality productive forces and cultivating new driving forces for development. Innovation in the application of new technologies such as blockchain is an important path to empower the development of new quality productive forces in low-altitude logistics. The industry-education integration is an organic connection point between the industrial chain, talent chain, innovation chain, and education chain. Promoting the industry-education deep integration is an important support for improving the productive force of low-altitude logistics. Therefore, studying the application of blockchain in low-altitude logistics and the industry-education deep integration is of great significance. This study first applies consortium blockchain to construct a three-dimensional collaborative monitoring system for low-altitude logistics UAV operation. Then, it develops a blockchain-based preservation technical solution for low-altitude logistics UAV operation data, and proposes a blockchain-based authentication method for UAV across logistics areas. Finally, a four-dimensional deep integration mechanism of industry-education and its system of low-altitude logistics talent cultivation are constructed.

Keywords: New Quality Productive Forces; Low-altitude; Air Logistics; Blockchain; Industry-education Deep Integration

1. Introduction: Research Background and

Significance

1.1 Low-altitude Economy Market Maintains High-speed Growth Trend

Low-altitude economy is a typical representative of new quality productive forces and is becoming a new growth point for China's economy. Since 2024, more than 20 provinces across the country have proposed the development of low-altitude economy in their local government work reports. Driven by factors such as policies, demand, and capital, the low-altitude economy market is maintaining a high-speed growth trend and has become an important layout for China to establish a modern industrial system, seize development opportunities, and promote high-quality development.

1.2 Developing Low-altitude Logistics is an Important Way to Enhance New Quality Productive Forces

Low-altitude economy is a comprehensive economic form that relies on low-altitude airspace, with low-altitude flight activities as the driving force and radiation to promote the integration and development of related fields. It has the characteristics of a long industrial chain, complex application scenarios, diverse users, and involves multiple departments and fields. Low-altitude economy related products mainly include unmanned aerial vehicles (UAV), electric vertical takeoff and landing vehicles (eVTOL, Electric Vertical Take-off and Landing), helicopters are widely used in logistics, agriculture, transportation, emergency rescue, cultural tourism and other fields, playing an important role in building a modern industrial system. Among them, low-altitude logistics is one of the core areas of low-altitude economy, which is an important way to enhance new quality

productive forces, cultivate and develop new driving forces, and strengthen emerging industries. It has broad development prospects and rich and diverse application scenarios.

1.3 The Significance of This Study

Blockchain is a new generation of advanced technology, which requires the timely application of advanced technology and the acceleration of the construction of a modern industrial system to develop new quality productive forces. The low-altitude logistics industry is a strategic emerging industry, and researching the technological innovation empowered by blockchain in the field of low-altitude logistics is of great significance. The integration of industry-education is an important path to promote the development of new quality productive forces. Deepening the integration of industry-education can provide strong support for the accelerated formation of new quality productive forces and the high-quality development of low-altitude logistics.

Low-altitude airspace has become a national strategic resource, widely serving important fields such as low-altitude transportation, public safety, and emergency relief. [1] Due to the increasing maturity of technology, the application fields of various types of UAV are constantly expanding, such as military reconnaissance, agricultural and forestry production, and logistics transportation. [2] However, the increasing number of UAV and the diversity of their applications due to their mobility and dynamism [3] have posed significant security risks at multiple levels, including airspace security, spectrum security, and data security. [4] Therefore, studying how to effectively enhance the comprehensive security monitoring of Low-altitude logistics UAV has important practical value.

2. Current Research Status of Blockchain Applications in the Field of Low-altitude

In the past two years, research on blockchain applications in the field of low-altitude has gradually increased. Blockchain is applied to monitor real-time information, abnormal dynamics, and important events of UAV operation, and to process and share operational data, providing effective and traceable full process records for low-altitude operation for monitoring subjects. Luo et al. designed a

blockchain consensus based on network coding to achieve efficient and secure communication in UAV networks. [5] Sarenche et al. proposed a decentralized auditable security logging system for UAV ecosystems based on blockchain, which relies on hash chains and Merkle trees to generate proofs for stored log records. [6] Aljumah et al. proposed the UAV data security framework based on heterogeneous blockchain to ensure the security and confidentiality of the data collected by UAVs. [7] Akram et al. utilized blockchain technology for malicious node detection in the Internet of Drone Things of UAV, resolving the issue of distrust between providers and consumers during service delivery in IoDT. [8] Hafeez et al. proposed a set of basic analysis and key requirements to help build a privacy and security model for blockchain assisted UAV communication, and to assist UAV management and support decentralized data storage systems. [9]

Some scholars have also applied blockchain to improve verification methods for UAV operator's identity and enhance authorization management for UAV operation. Subramani et al. proposed a blockchain authentication method for physical security and privacy protection to address privacy, security, and cross domain authentication issues during UAV task execution. [10] Mishra et al. proposed a blockchain-based security authentication key management framework with big data analysis function to solve the privacy and security problems faced by UAV Internet of drone communication. [11] Pan et al. proposed a blockchain-assisted UAV authentication and access control scheme to address the drawbacks of traditional UAV authentication and access control schemes that cannot meet UAV cross domain authentication and monitoring requirements. [12] Lee and Shin proposed a secure UAV leasing mechanism based on blockchain, which provides mutual authentication mechanism and can resist impersonation, modification, replay, and relay attacks. [13]

The above research results have important value, and the proposed blockchain application scheme can help regulatory agencies track and trace UAV low-altitude operation activities. However, most of them focus on the supervision of information on the blockchain and have not broken the data barriers formed

by traditional supervision methods. The application of different types of information on the blockchain in cross domain or cross regional contexts has not yet been realized; Therefore, so far, there are few studies on the overall on-chain and off-chain control of UAV low-altitude operation data, and literature on low-altitude logistics UAV operation data is even rarer.

To address the issues of information fragmentation and lack of data coupling between on-chain and off-chain platform, this study combines data from on-chain platform with information from off-chain scenarios. Firstly, a consortium blockchain is applied to construct a three-dimensional collaborative monitoring system consisting of blockchain, logistics scenarios, and regulatory platform. Then, it develops a blockchain-based proof preservation technical solution for low-altitude logistics UAV operation data, and proposes a blockchain-based authentication method for UAV across logistics areas. Finally, a four-dimensional deep integration mechanism of industry-education and its system of low-altitude logistics talent cultivation are constructed.

3. Three-dimensional Collaborative Monitoring System for Low-Altitude Logistics UAV Based on Consortium Blockchain

In order to meet the high requirements of Low-altitude logistics UAV for security monitoring of low-altitude airspace, operational data, and other aspects, this study explores the application of consortium blockchain to construct a low-altitude logistics UAV three-dimensional collaborative monitoring system for on-chain and off-chain collaborative monitoring.

At the overall framework level, the application of blockchain technologies such as smart contract and encryption is utilized to construct a three-dimensional low-altitude logistics UAV monitoring system consisting of consortium blockchain, logistics scenarios, and monitoring platform. Faced with the problems of wide operating range and difficult control on the low-altitude logistics service monitoring chain, as well as low reliability of off-chain business behavior monitoring, a hierarchical penetration monitoring mechanism based on elliptic curve encryption algorithm is established to integrate

the three monitoring objects (alliance blockchain transaction behavior, off-chain monitoring service process, real-time logistics information), and conduct full process security monitoring in UAV low-altitude logistics process including before-service, during-service and after-service, breaking down the information barriers between different logistics distribution types and achieving effective interaction and sharing of low-altitude logistics business information in the alliance blockchain system, thereby enhancing the support of the monitoring system for the entire process of UAV low-altitude logistics.

On the basis, spatial distributed monitoring is implemented for low-altitude logistics service systems, monitoring subjects, and user groups, using technologies such as key sharing to perform distributed access control on monitoring objects and monitoring subjects. Based on the linkage and collaboration between on-chain and off-chain, with the goal of data integrity, trustworthiness, authenticity, and tamper resistance, in order to protect the security of private information, confidential data, or sensitive materials, they are stored off-chain through access control and encryption technology. Any user can only access plaintext information or data if they comply with permission control regulations, otherwise they can only access encrypted data. As a result, the application of blockchain technology enables secure data sharing, significantly enhances information confidentiality, and effectively improves the defense and attack capabilities of information systems, thereby improving the low-altitude logistics UAV information management and service guarantee capabilities.

The main shortcomings of traditional regulatory methods are data silos and information fragmentation. On the one hand, the data of different types of services in low-altitude logistics are isolated, and effective information collaborative control has not been formed, which hinders cross business applications due to data silos. On the other hand, traditional blockchain monitoring only focuses on on-chain information, and the information between on-chain systems and off-chain scenarios is fragmented, resulting in the inability to couple data. The Low-altitude logistics UAV monitoring system carries out

technological breakthroughs from a three-dimensional perspective consisting of consortium blockchain, low-altitude logistics scenarios, and monitoring platform, effectively repairing the main deficiencies of traditional

supervision and traditional blockchain monitoring. Low-altitude logistics UAV monitoring system based on consortium blockchain is shown in Figure 1.

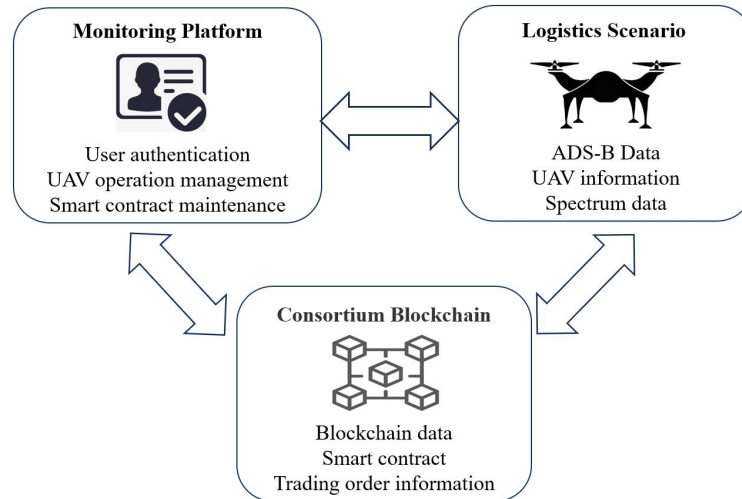


Figure 1. Three-dimensional Collaborative Monitoring System for Low-Altitude Logistics UAV Based on Consortium Blockchain

4. The Blockchain-based Preservation Technical Solution for Low-altitude Logistics UAV Operation Data

4.1 UAV Operation Data is Important Data for Low-Altitude Logistics Activities

In the operation of low-altitude logistics services, UAV operation data is an important data for logistics activities, mainly including logistics activity subjects, activity time, activity location, activity process, activity results, activity accidents and important events, aviation routes and flight trajectories, and other data. This study applies blockchain technology to preserve UAV operational data, aiming to enhance the traceability and effectiveness of UAV operational data, improve data privacy and timeliness, and provide critical basis for tracing, replaying, and analyzing low-altitude logistics and flight activity process.

4.2 The Blockchain-based Technical Solution of Proof Preservation for Low-Altitude Logistics UAV Operation Data: Framework and Technical Path

This study explores the innovative application of blockchain in the field of low-altitude logistics, targeting UAV operation scenarios, and proposes a new technical solution of proof preservation for low-altitude logistics UAV

operation data using blockchain related technologies.

4.2.1 The Technical Framework of Proof Preservation for Low-altitude Logistics UAV Operation Data

Firstly, with computing resources, storage resources, and network resources as the main support, providing infrastructure for blockchain application in low-altitude logistics UAV operation data proof preservation. Secondly, with distributed ledger, consensus mechanism, peer-to-peer transmission, digital signature, and hash algorithm as core technologies, blockchain applications in low-altitude logistics UAV operation data proof preservation are endowed with core functions. Thirdly, with data on-chain, data query, and data verification as the main modules, providing data interface services for blockchain applications in low-altitude logistics UAV operation data proof preservation. Fourthly, providing program support for blockchain applications in low-altitude logistics UAV operation data proof preservation, with access applications, digital model management, proof preservation, certificate issuance, and verification as the core services. Fifth, with application supervision, performance monitoring, data auditing, information security, and operation maintenance as the main functions, providing monitoring and management for blockchain

applications in the operation data proof preservation of low-altitude logistics UAV.

4.2.2 The Technical Path of Proof Preservation for Low-altitude Logistics UAV Operation Date

In Phase 1, when using blockchain technology to store the operational data of low-altitude logistics UAVs, following the rules of node authentication, password management, and application access system, and prioritizing the logistics service operator and relevant parties as the main entities of proof preservation.

In Phase 2, prior to data proof preservation, establish technical rules and definitions for data proof preservation, providing technical specifications and requirements for subsequent series of certification activities.

In Phase 3, Completing data generation and processing, data storage on on-chain platform, data publishing and querying, data acquisition and verification. Thus, a low-altitude logistics UAV operation data proof preservation process consisting of four core technical links is formed, as shown in Figure 2.

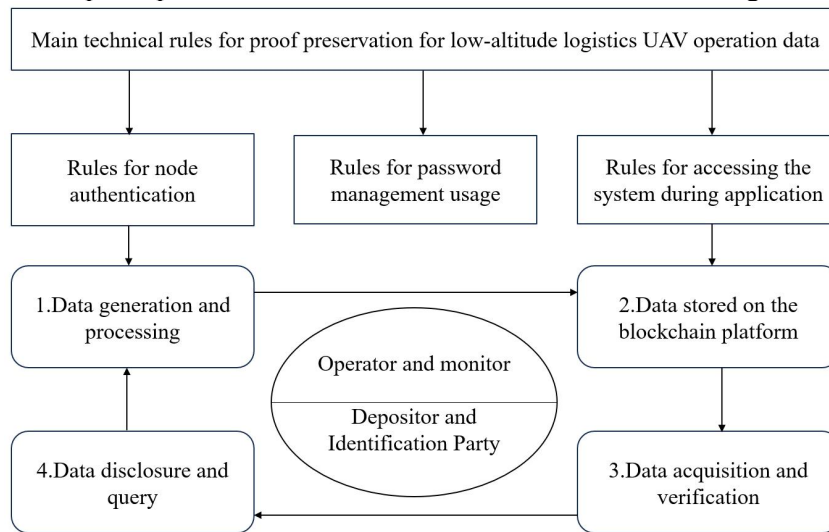


Figure 2. The Blockchain-based Technical Solution of Proof Preservation for Low-altitude Logistics UAV Operation Data

5. The Blockchain-Based Authentication Method for UAV across Logistics Areas

When UAVs cross different trusted logistics areas or network environments, there are deficiencies in UAV identity verification. In the traditional verification method, UAV is authenticated by the central authority, which has problems such as incomplete certificate mechanism and duplicate identity verification. Therefore, this study utilizes the decentralized technology advantages of blockchain distributed ledger to meet the needs of UAV across logistics areas. It proposes an authentication method for UAV using blockchain to cross different logistics areas, aiming to effectively solve the identity verification problem in different regional monitoring center scenarios.

Firstly, replacing the third-party in traditional key distribution methods, utilizing the tamper proof and reliable technical features of blockchain smart contract, and using smart contract as a new key generation center,

effectively enhancing credibility and transparency.

Secondly, the cryptographic data of the application alliance blockchain is utilized to assist in the verification of UAV identity by utilizing attribute information such as UAV product serial number and factory data, combined with real-time information of UAV location (including longitude, latitude, altitude, etc.), thereby achieving secure and reliable UAV identity verification.

Thirdly, utilizing virtual identities to achieve anonymity in UAV signature authentication. By decoupling the real registered identity from the virtual on-chain identity, unauthorized individuals are unable to obtain the true identity of UAV, effectively avoiding the exposure of UAV information, UAV owner, and manufacturer identities, thereby protecting UAV identity privacy and information security. The blockchain-based authentication method for UAV across logistics areas is shown in Figure 3.

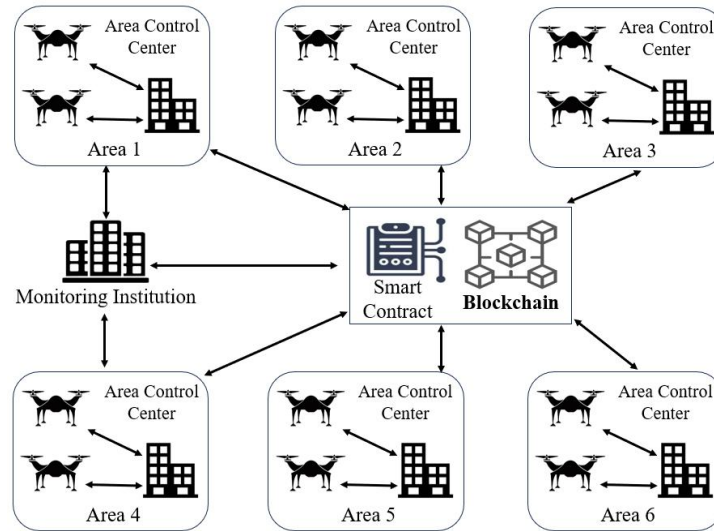


Figure 3. The Blockchain-based Authentication Method for UAV across Logistics Areas

6. Four-Dimensional Deep Integration Mechanism of Industry-education and Its System of Low-altitude Logistics Talent Cultivation

6.1 The Importance of Low-Altitude Logistics Innovation and Industry-Education Integration in the Perspective of New Quality Productive Forces

Blockchain is an advanced technology in the new generation of information technology. Developing new quality productive forces requires timely application of technological innovation achievements and acceleration of the construction of a modern industrial system. Low-altitude logistics is an emerging industry and an important field for enhancing new quality productive forces and cultivating new driving forces for development. Therefore, from the perspective of the development of

new quality productive forces, it is of great significance to study how to apply blockchain technology to empower innovation in low-altitude logistics services. Industry-education integration is an organic connection point between the industrial chain, talent chain, innovation chain, and education chain. It is an important way to develop new quality productive forces. Deepening the integration of industry-education can provide strong supports for the accelerated formation of new quality productive forces and the high-quality development of low-altitude logistics industry, and promote the construction of modern industrial system. Therefore, this study proposes to construct a four-dimensional mechanism for industry-education integration, including subject, object, process and quality, and its talent cultivation system is as shown in Figure 4.

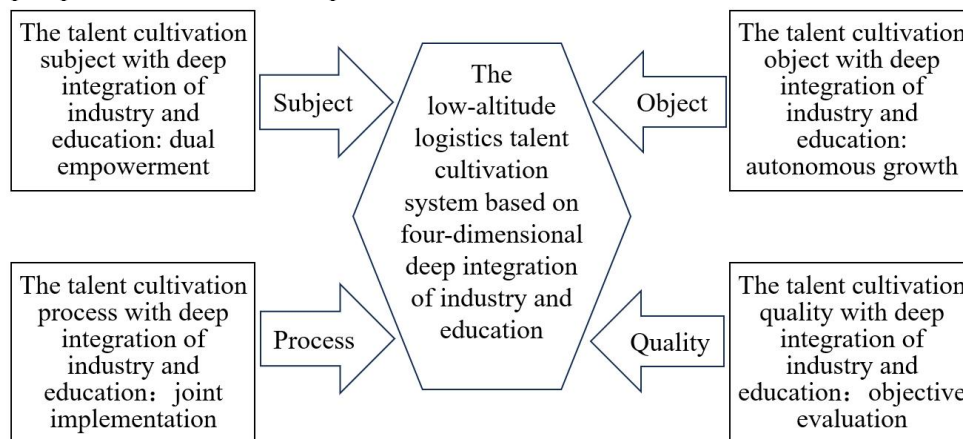


Figure 4. Four-dimensional Deep Integration Mechanism of Industry-Education and Its System of Low-Altitude Logistics Talent Cultivation

6.2 Low-Altitude Logistics Talent Cultivation Subject with Industry-education Deep Integration: Dual Empowerment

Both sides of industry and education jointly improve and implement a collaborative training mechanism that empowers both schools and enterprises, and establish an industry-education integration guidance committee for low-altitude logistics industry composed of experts in education, industry, enterprises, and other fields. Establishing a specialized organization for daily management of the integration of industry-education in the low-altitude logistics industry, as well as a team of on campus and off campus mentors. Both sides focus on the dual mentor system, strengthen the construction of the school enterprise teaching staff for the integration of industry-education, in enhancing the ability and awareness of teachers in the integration of industry-education.

6.3 Low-Altitude Logistics Talent Cultivation Object with Industry-education Deep Integration: Autonomous Growth

Exploring the diversified and profound value of education, focusing on people-oriented, empowering through multiple dimensions, and driving through multiple factors, to enhance students' autonomous experience in the process of cultivating low-altitude logistics talents, and to pay attention to the continuous improvement of students' comprehensive qualities such as self-learning and development ability, independent exploration and innovation spirit, independent practice and experimental ability during their growth process. Adhering closely to the construction of digital education, exploring the cultivation paradigm of interdisciplinary integration and personalized development of students. Integrating sufficient learning resources into an online open course platform that can be synchronized and shared with mobile devices, forming a ubiquitous learning ecosystem where students can learn everywhere and at all times, effectively promoting independent course selection, independent learning, and self-growth.

6.4 Low-altitude Logistics Talent Cultivation Process with

Industry-Education Deep Integration: Joint Implementation

In the integration of industry-education for the low-altitude logistics industry, schools and enterprises jointly optimize the disciplinary and professional settings and talent supply structure, improve the talent supply structure adjustment mechanism guided by industrial demand, and jointly optimize the disciplinary categories and dynamically adjust the professional structure. Both sides jointly adjust the professional layout, optimize the structure of talent supply, promote the active adaptation of talent supply to industrial changes, and enhance the effectiveness of industry education integration and collaborative education.

6.5 Low-altitude Logistics Talent Cultivation Quality with Industry-Education Deep Integration: Objective Evaluation

Both sides introduce low-altitude logistics industry organizations, leading enterprises, professional evaluation institutions and other entities to meet the new requirements of deep integration of industry-education, and integrate the diverse requirements of various entities for the training of technical talents into the process of formulating, implementing and evaluating low-altitude logistics talent cultivation plans. And both sides actively introduce third-party authoritative evaluation institutions to independently evaluate the quality and process of low-altitude logistics talent cultivation.

7. Research Conclusion

In recent years, the low-altitude economy market has grown rapidly, and the low-altitude logistics industry has shown a good development trend. Blockchain, artificial intelligence, big data, and the Internet of Things are the new generation of advanced information technologies. Enhancing innovation in the application of new technologies such as blockchain is an important path to empower the development of new quality productive forces in low-altitude logistics. Although the research results on the application of blockchain in low-altitude fields are gradually increasing, there are few literature studies on using blockchain to solve the problem of on-chain and off-chain data

barriers in low-altitude fields, and the application of different types of blockchain information across areas has not yet been realized.

The research indicates that firstly, applying blockchain to build a three-dimensional collaborative monitoring system for low-altitude logistics UAV operation can solve the problems of information fragmentation and data coupling between on-chain and off-chain, and achieve synchronous coupling between on-chain data and off-chain information; Secondly, applying related technologies of blockchain can provide effective supports for the proof preservation of operation data in low-altitude logistics and its UAV authentication. Thirdly, industry-education integration is an organic connection point between the industrial chain, talent chain, innovation chain, and education chain. Building a four-dimensional deep integration mechanism of industry-education and its low-altitude logistics talent cultivation system can help improve the new quality productive forces of low-altitude logistics and promote the high-quality development of the low-altitude logistics industry system.

Acknowledgments

This research was supported by the following research projects: The scientific research project of Guangdong Province Ordinary University in 2023 “Research on the innovation of specialized air logistics services empowered by blockchain technology in the new development stage” (No.2023WTSCX188); The higher education special project of Guangdong Province education science plan in 2024 “Research on the industry-education deep integration model and implementation path of higher vocational education serving for the development of new quality productive forces” (No.2024GXJK1099). The philosophy and social science planning project of Qingyuan in 2024 “Research on Qingyuan manufacturing industry digitalization transformation and supply chain collaborative innovation” (No.QYSK2024035).

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