The Survey on Dynamic Allocation Methods of Edge Computing Resources in Smart Logistics Scenarios

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Abstract. Smart logistics, driven by the Internet of Things (IoT), 5G, and artificial intelligence (AI), depends on real-time data consumption. But, with the need for real-time data processing at the centralized cloud computing layer, centralized cloud computing faces bottlenecks in latency, bandwidth, and privacy. Edge computing supports smart logistics functions by bringing computing close to the edge, but the success of edge computing depends on dynamic allocation of processes to make adjustments for different task loads, devices, and network conditions in logistics scenarios. This review paper will describe the state of research and advances needed for dynamic resource allocation with edge computing research for smart logistics. First, we review the body of work that brings together edge computing and smart logistics, focusing on in-building applications to logistics scenarios such as warehousing, transport, last-mile delivery, emergency logistics scheduling, cold chain logistics monitoring, and, distributed allocation of logistics resources. Next, we discuss key areas of the human-made edge logistics systems to think about a solution for, including resource sensing, prediction, and scheduling. By seeing examples and case studies, we give examples to demonstrate ways of using and improving resource allocations in practice. In addition, we review challenges in coupling heterogeneous edge digital devices and move from low-power sensors through to high-end servers, the urgent need for a few standards or guidelines to allow for seamless interoperable systems. Finally, we discuss the practical challenges of standardization, security, and heterogeneity, and try to highlight opportunities for AI-guided optimization and energy-aware resource allocations are future trends. This review paper will provide a holistic outline to researchers and practitioners with a framework to advance investigations into the management of a dynamic resource allocation system with edge-enabled smart logistics.

Keywords: edge computing, smart logistics, dynamic resource allocation, deep learning.

1. Introduction

1.1 Research Background and Significance

The rapid development of the IoT, 5G, and artificial intelligence has transformed traditional logistics into an intelligent and interconnected ecosystem, making intelligent logistics a core pillar of modern supply chain management. In warehousing, IoT sensors monitor inventory in real-time, RFID tags track goods flow, and AI-driven robots enable automated picking [1]. In transportation, 5G facilitates seamless vehicle-control center communication, while AI optimizes routes via real-time traffic data. For last-mile delivery, smart lockers and edge-computing-equipped drones ensure timely services [2]. These technologies have improved efficiency and reduced costs in mature systems. However, the exponential growth of device-generated data poses key challenges to centralized cloud computing: latency-sensitive tasks suffer from remote transmission delays, large-scale concurrent uploads may cause bandwidth congestion, and transmitting sensitive data exacerbates privacy risks. Edge computing, which processes data locally at the network edge, like warehouse servers or on-board gateways, addresses these issues with three core advantages: ultra-low latency for real-time responses, reduced bandwidth via local filtering, and enhanced privacy through localized sensitive data processing. Yet, the dynamic nature of intelligent logistics fluctuating task loads, diverse edge device performance, and unpredictable networks, creates challenges for edge resource utilization. Efficient dynamic resource allocation thus becomes crucial: it ensures real-time allocation of computing, storage, and network resources, minimizing latency, reducing energy consumption, especially for battery-powered devices like drones, and maintaining reliability [3]. Research on such methods is key to unlocking edge computing's potential and building resilient, efficient, intelligent supply chains.

1.2 Research Content and Methods

This paper focuses on dynamic resource allocation in edge-supported intelligent logistics. It first clarifies the core objective: to fill the gap in existing research that lacks a focused review of intelligent logistics and edge computing integration. It then breaks down the key technologies: resource sensing protocols for real - time edge node status monitoring, machine learning models predicting task loads like delivery volume and robot tasks, and scheduling strategies assigning tasks to edge nodes based on sensing and prediction data. Next, it analyzes practical applications, evaluating performance and real-world challenges to verify allocation method effectiveness. By comparing with existing reviews, this paper sorts out key technologies and applications from literature, identifies research gaps, and proposes future prospects. Its goal is to provide a comprehensive understanding of current practices and clear guidance for researchers and practitioners to promote dynamic resource management in edge-supported intelligent logistics. (Figure 1)

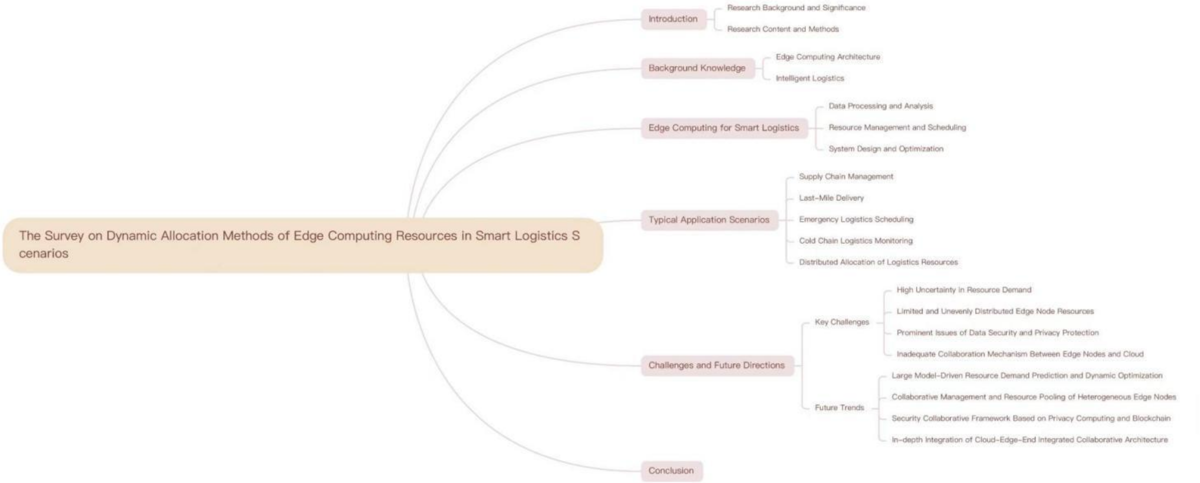

Fig 1. Paper Framework

2. Background Knowledge

2.1 Edge Computing Architecture

Edge computing architecture is a distributed computing paradigm that deploys data processing, storage, and application logic at the edge of the network, namely, close to devices, sensors, or terminals that generate or consume data, rather than relying solely on centralized cloud or data center infrastructure. This proximity-based deployment effectively reduces latency, minimizes bandwidth consumption, and enhances real-time responsiveness, making it one of the key technologies supporting the efficient operation of intelligent logistics [4]. Its core components include edge devices, edge nodes/gateways, and cloud/data centers. Edge devices, as endpoints for data generation or collection, perform basic data filtering or preprocessing to reduce upstream data transmission. Edge nodes/gateways, located between edge devices and the cloud, handle more complex computing tasks, such as integrating data from multiple devices, running lightweight applications, managing device connections, and routing data to the cloud when necessary. The cloud, on the other hand, is responsible for long-term data storage, complex computations, and overall system management. In intelligent logistics scenarios, the localized nature of edge computing precisely meets the real-time requirements of logistics processes: for example, real-time obstacle avoidance and path planning of warehouse robots require millisecond-level responses, dynamic navigation of transport vehicles relies on instant road condition analysis [5], and device collaboration in last-mile delivery needs to quickly process environmental data. All these tasks can be completed locally through edge computing, thereby avoiding the impact of cloud transmission latency on logistics efficiency and providing underlying technical support for the full-process optimization of intelligent logistics.

2.2 Intelligent Logistics

Intelligent logistics is an advanced management model that integrates cutting-edge technologies such as the IoT, big data analytics, AI, cloud computing, blockchain, and automation. It optimizes the entire supply chain from procurement and warehousing to transportation, distribution, and customer service, enabling intelligent and efficient operation of logistics systems [6]. With IoT sensors and RFID tags, intelligent logistics can track the location and status of goods in real time, reducing the risk of loss and delays. Big data analytics and AI algorithms can accurately predict market demand, optimize inventory levels, and dynamically adjust delivery routes based on real-time traffic conditions. The core demands of intelligent logistics lie in improving the real-time performance, accuracy, and collaboration of the entire process. These demands are highly aligned with the low-latency and high-responsiveness characteristics of edge computing, making edge computing an important technical support for intelligent logistics to break through traditional bottlenecks and achieve efficient operation [7]. Overall, smart logistics represents a shift from traditional, manual, and reactive logistics management to a more intelligent, data-driven, and proactive ecosystem, driving innovation and competitiveness in the global supply chain.

3. Edge Computing for Smart Logistics

3.1 Data Processing and Analysis

Data processing and analysis for smart logistics refers to a technical framework that leverages edge computing to perform real-time collection, localized preprocessing, feature extraction, and intelligent analysis of multi-source logistics data. Its core lies in utilizing edge nodes' proximity to data sources to minimize transmission latency and enhance the timeliness and relevance of data-driven decision-making.

In recent years, some studies have proposed methods for data processing and analysis in the application of edge computing in smart logistics. A system deploying a semantic context extraction pipeline on edge servers is used to analyze video streams collected by mobile robots. By real-time parsing of key information such as cargo positions and movement trajectories in the robot's visual data, it quickly identifies abnormal events, significantly shortening the time difference between event detection and the generation of response instructions, thus achieving rapid event detection and response acceleration [8]. A logistics packaging defect detection method combining improved morphological technology and support vector machine classifier achieves high-precision identification through edge image processing. The improved morphological technology can enhance the extraction of edge features of packaging surface defects, and the support vector machine classifier runs locally on the edge, reducing reliance on cloud computing power while ensuring the real-time performance and accuracy of defect identification [9]. An architected cloud platform performs streaming analysis on logistics sensor data. Edge nodes preprocess real-time data collected by sensors such as temperature, humidity, and equipment operating parameters, and then upload the cleaned data to the cloud for global trend analysis, facilitating the extraction of real-time insights for end-to-end process optimization [4]. A positioning system using EMVS-MIMO radar and edge computing rapidly parses radar echo data through edge nodes, and corrects positioning deviations by combining multi-source sensor fusion algorithms, realizing efficient processing of radar data and accurate positioning of logistics vehicles [5]. A QR code-based system adopts edge computing to realize multi-level information access for cargo export. Edge nodes store basic information associated with QR codes, such as cargo specifications, and place of departure, and only call deep data from the cloud like customs declaration records when necessary, optimizing the response speed of cross-entity data interaction [10]. A cold chain monitoring platform integrating IoT sensors and edge computing processes temperature, humidity, and vibration data in real-time. It quickly identifies parameter fluctuations beyond safe ranges through an anomaly detection model deployed on the edge, triggering a local early warning mechanism to ensure localized quality supervision [11]. Edge computing is used to analyze supply chain data collected by the IoT, and combined with a cost-benefit model to predict order volume and price fluctuations. Edge nodes perform localized feature extraction on data such as historical orders and inventory levels, which are then input into the XGBoost model for short-term prediction, providing timely support for strategic decision-making [12].

Edge-based localized processing emerges as a pivotal force in intelligent logistics, revolutionizing operations through latency reduction. By conducting data handling at the network edge, it enables near-instant responses for time-critical tasks like cold chain monitoring and vehicle tracking. This not only speeds up decision - making but also bolsters the reliability of real-time systems, as dependence on long-haul data transmission is lessened. The integration of machine learning on edge nodes is a game-changer. Algorithms from support vector machines to gradient-boosted models empower edge nodes to analyze diverse data types, such as package defect images or historical order patterns. This leads to more precise defect detection and anomaly identification, enhancing supply chain efficiency. However, challenges persist. Edge nodes, constrained by computing resources, struggle to deploy complex models like deep learning. Also, data privacy safeguards remain incomplete. Despite these hurdles, edge-based processing is a cornerstone for data-driven logistics. It balances efficiency and innovation, pointing to a future where overcoming resource and privacy issues will unlock even greater potential in intelligent logistics operations.

3.2 Resource Management and Scheduling

Resource management and scheduling for smart logistics involves edge computing-enabled dynamic allocation, task offloading, prioritization, and collaborative scheduling of logistics resources (computational, storage, transportation, and task loads). Its primary goal is to maximize resource utilization efficiency and minimize response delays by leveraging the distributed computing capabilities of edge nodes, addressing the limitations of centralized resource management.

Over the years, some researchers have proposed targeted methods for resource management and scheduling in edge computing applications for intelligent logistics. The Distributed Logistics Resource Allocation Network (DLRAChain) integrates edge computing, blockchain, and smart contract technologies. It optimizes the scheduling of warehousing and transportation nodes through the Stackelberg game algorithm, where the game model can balance the resource demands and profit expectations of each node. Smart contracts automatically execute scheduling results to reduce manual intervention, enabling fair and efficient material distribution [3]. The two-layer hybrid scheduling model for logistics cloud robots combines graph neural networks and deep reinforcement learning technologies. Graph neural networks are used to construct robot task association graphs for optimizing path planning, while deep reinforcement learning dynamically adjusts task allocation strategies through real-time feedback, effectively shortening task response time [13]. The ESD-MEC strategy adopts edge computing and agent-based negotiation mechanisms to dynamically schedule emergency vehicle resources. Edge nodes act as negotiation intermediaries to synchronize the position and load status of each vehicle in real time, and solve problems such as inconsistent tracking data and delivery delays through multi-agent collaborative algorithms [14]. The GSA-PSO algorithm realizes joint task offloading and resource allocation in the Internet of Vehicles edge network. It quickly finds the optimal nodes for task offloading through the particle swarm optimization algorithm and balances node loads by combining the gravitational search algorithm, significantly improving the efficiency of emergency logistics [15]. The federal collaborative caching mechanism in the 5G + edge environment schedules distributed storage resources. Edge nodes dynamically adjust cached content according to the access frequency of logistics data, and ensure the coordination of caching strategies among various nodes through the federated learning mechanism, improving the access speed and consistency guarantee of logistics data [16]. The energy-aware strategy (TOSS) for drone delivery systems uses edge computing to optimize task offloading and resource conflict resolution. Edge nodes monitor the remaining battery power and computing load of drones in real time, and offload complex route planning tasks to ground edge nodes through dynamic task allocation algorithms, achieving an optimal balance between maximizing load and reducing energy consumption [17]. The Dynamic Network Slicing and Resource Allocation (DNSRA) algorithm optimizes long-term slice admission and short-term resource allocation through edge computing. The long-term admission mechanism reserves slice resources based on the priority and resource requirements of logistics tasks, while short-term allocation dynamically adjusts subcarrier and power parameters to achieve a dynamic balance between operator revenue and latency [18].

Leveraging the distributed nature of edge nodes, dynamic resource management in intelligent logistics has achieved significant breakthroughs in adaptive performance adjustment. Unlike centralized systems, edge nodes scattered across warehouses, transport vehicles, and delivery hubs enable real-time adjustments to resource allocation based on fluctuating demands. This flexibility not only alleviates the load pressure on centralized servers but also drives tangible improvements in resource utilization. However, these advancements come with notable challenges that hinder optimal performance in practical deployment. First, the robustness of resource rescheduling algorithms is insufficient in highly dynamic scenarios. Sudden order surges during peak seasons or unexpected equipment failures often catch current algorithms off-guard. Struggling to reallocate resources swiftly, they may cause temporary resource shortages, delayed task execution, or even cascading disruptions in the logistics chain. Second, the lack of standardized collaboration frameworks between edge nodes and the cloud creates inefficiencies. Inconsistent protocols for task partitioning ratios, data transmission, and synchronization lead to fragmented operations. Edge nodes might misjudge their optimal task-cloud matching, either overburdening themselves with ill-suited tasks or underutilizing their computing power. Such inefficiencies waste cloud and edge resources, weakening the synergy between the two layers and limiting the overall potential of the integrated system. In summary, while edge-enabled dynamic resource management brings transformative adaptability to intelligent logistics, addressing algorithmic robustness and standardizing cross-layer collaboration are critical. Resolving these issues will be key to fully unlocking the efficiency and responsiveness promised by edge-based intelligent logistics systems, ensuring they can handle real-world complexities and deliver stable, optimized performance across the logistics lifecycle.

3.3 System Design and Optimization

System design and optimization for smart logistics focuses on developing edge computing-integrated architectures tailored to specific scenarios (e.g., last-mile delivery, railway logistics, cold chain) and optimizing processes like data transmission, task collaboration, layout planning to enhance overall system efficiency, reliability, and adaptability. It addresses traditional logistics systems' limitations in intelligence and scenario-specific adaptability through fusion with IoT, blockchain, and other technologies.

In recent years, many scientists have proposed the intelligent logistics system based on edge IoT proposes a design method integrating the flower pollination algorithm and XGBoost. It optimizes the device positioning logic through the flower pollination algorithm to improve positioning accuracy, and combines the XGBoost model to analyze supply chain user behavior data, thereby solving the problems of positioning deviation and lagging demand prediction in traditional systems [1]. MEC-blockchain drone delivery system, which deploys blockchain nodes on edge devices to build a collaborative architecture integrating edge computing and blockchain. Edge nodes are responsible for real-time processing of delivery routes and equipment status data, while blockchain nodes record transactions and task execution information. Verified through an Ethereum prototype, it addresses the multi-party trust issues in the last mile [2]. A cross-cultural trade logistics platform integrating the Internet of Things and edge computing proposes a deep reinforcement learning scheduling model. Edge nodes process multi-source information in real-time during cross-border transportation and dynamically optimize transportation routes and customs clearance procedures through reinforcement learning, solving scheduling delay problems in cross-cultural scenarios [19]. A layout optimization scheme for railway logistics centers based on mobile cloud-edge computing designs a two-layer offloading strategy. The edge layer handles real-time transportation data and cargo loading/unloading scheduling, while the cloud layer deals with long-term planning and global optimization, significantly reducing system latency with better performance than traditional methods [20]. An edge-driven intelligent logistics architecture proposes a data hierarchical processing mechanism, where edge nodes preprocess and isolate sensitive data, and the cloud performs global analysis and system management. It balances local response and global collaboration through task scheduling strategies, ensuring operational security and data integrity [6]. An edge-driven intelligent logistics architecture puts forward a data hierarchical processing mechanism. Edge nodes are responsible for preprocessing and isolating sensitive data, while the cloud leads global analysis and system management. It balances local response and global collaboration through task scheduling, ensuring operational security and data integrity [7]. A cloud-fog-edge integration framework proposes a logistics process classification system and enterprise architecture model. Through the fog layer coordinating the collaboration between edge nodes and the cloud, it enhances the system's adaptability to multi-modal transportation scenarios, improving reliability and transparency [21].

In summary, integrating edge transport with technologies like IoT and blockchain has made notable progress in tackling scenario-specific intelligent logistics challenges. Leveraging edge computing’s low-latency, localized processing, plus IoT’s real-time data capture and blockchain’s tamper-proof records, these architectures better adapt to diverse logistics scenarios, from parcel delivery to cross-border freight. However, technical barriers remain. A lack of unified standards across scenarios hinders cross-scenario resource sharing in railway and cold-chain logistics. High hardware costs for edge devices and software adaptation expenses limit adoption by small-medium enterprises. Moreover, some architectures face technical risks node synchronization delays and high computing power consumption during large-scale deployment may affect system stability. Future research should focus on standardizing architectures, reducing implementation costs, and optimizing technical designs to overcome these hurdles, promoting wider, more reliable application of edge - driven intelligent logistics. (Table 1)

Table 1. References by Category

Research category	Data Processing and Analysis	Resource Management and Scheduling	System Design and Optimization
References	[8],[9],[4],[5],[10],[11],[12]	[3],[13],[14],[15],[16],[17],[18]	[1],[2],[19],[20],[6],[7],[21]
Contributions and Advantages of Literatures	[8] Edge-based semantic analysis for rapid logistics event detection. [9] Edge-deployed defect detection with high precision. [4] Edge preprocessing for real-time logistics sensor data insights. [5] Edge-accelerated radar data processing for accurate vehicle positioning. [10] Edge-stored QR code info to optimize cross-entity interaction. [11] Real-time cold chain monitoring and local warning via edge. [12] Edge feature extraction + XGBoost for supply chain prediction.	[3] DLRAChain: Optimized logistics resource scheduling with blockchain and edge. [13]Hybrid model shortens logistics robot task response time. [14] Edge-based multi-agent collaboration for emergency vehicle scheduling. [15] GSA-PSO algorithm improves emergency logistics via joint task offloading. [16]Federated caching enhances logistics data access in 5G+edge. [17] Energy-aware strategy optimizes drone delivery task offloading. [18] DNSRA balances revenue and latency via dynamic slicing.	[1] Integrates flower pollination algorithm and XGBoost to solve traditional system flaws. [2] MEC-blockchain system resolves last-mile trust issues. [19] Edge-based reinforcement learning optimizes cross-cultural logistics scheduling. [20] Two-layer offloading reduces railway logistics center latency. [6][7] Hierarchical data processing balances local response and global collaboration. [21] Cloud-fog-edge framework enhances multi-modal transportation adaptability.
Existing Limitations	Difficulty in deploying complex models like deep learning on resource-constrained edge nodes. Incomplete data privacy protection mechanisms.	Insufficient robustness of resource rescheduling algorithms in highly dynamic scenarios. Lack of standardized collaboration frameworks between edge nodes and the cloud, affecting synergy efficiency.	Absence of unified cross-scenario standards, hindering resource sharing between scenarios. High hardware costs of edge devices and software adaptation expenses, limiting adoption by small and medium-sized enterprises.

4. Typical Application Scenarios

4.1 Supply Chain Management

Intelligent logistics and supply chain management cover the entire process from material production, warehousing to transportation. Real-time logistics data is collected through IoT devices to support supply chain decision-making and logistics tracking. Edge computing nodes are deployed in logistics hubs to achieve localized real-time data processing, including parsing cargo location information, preprocessing user demand information, and synchronizing key results to the cloud. Meanwhile, edge nodes coordinate the task allocation of logistics equipment to ensure smooth process connection. The dynamic resource scheduling mechanism retains high-frequency, real-time key tasks at edge nodes for processing, and only uploads aggregated data to the cloud, which effectively alleviates the pressure on cloud computing and bandwidth consumption, reduces the processing delay of real-time tasks, and improves the response efficiency of the supply chain. The low-latency feature and distributed resource pool of edge computing provide computing support for real-time supply chain decisions, avoiding cumulative delays caused by centralized cloud processing.

4.2 Last-Mile Delivery

Last-mile delivery refers to the final link of goods from the terminal distribution center to the user, involving distribution route planning, equipment collaboration, and dynamic response to user needs. Edge computing nodes are deployed in terminal scenarios such as communities and distribution stations to process environmental data from delivery equipment in real-time, generate dynamic routes, connect with user order information, and flexibly adjust the delivery sequence. Edge computing dynamically allocates computing resources of delivery equipment in real-time, assigning complex route optimization tasks to edge nodes with sufficient computing power to reduce the local computing pressure of the equipment. This mechanism shortens the response time for route adjustment, reduces equipment energy consumption, and improves the overall throughput of the terminal distribution network through on-demand resource allocation. The localized computing power of edge computing supports real-time collaboration of delivery equipment, avoiding command delays caused by long-distance cloud transmission, and has become a core technical support for solving the efficiency bottleneck of the last mile.

4.3 Emergency Logistics Scheduling

Emergency logistics scheduling is a rapid deployment plan to ensure the transportation efficiency and route smoothness of emergency resources in emergency situations such as natural disasters and public health events. Edge computing nodes are deployed in mobile scenarios such as emergency command centers and transport vehicles to collect real-time information on regional material supply and demand, use localized algorithms to quickly generate scheduling plans, and coordinate the task allocation of various transport tools to avoid resource conflicts. Edge computing allocates computing and communication resources to key tasks through a resource priority mechanism, and dynamically offloads non-urgent tasks to idle nodes, which significantly shortens the response time of emergency resource scheduling, alleviates resource competition in multi-party collaboration, and avoids scheduling interruptions caused by single-node overload through load balancing. This reflects the advantages of edge computing's distributed resource architecture and real-time processing capability, which is in line with the characteristics of emergency logistics of strong timeliness and dynamic changes, ensuring that scheduling commands can be implemented quickly and accurately.

4.4 Cold Chain Logistics Monitoring

Cold chain logistics monitoring refers to the real-time monitoring of parameters such as temperature, humidity, and vibration during transportation to ensure the quality and safety of environment-sensitive materials. Edge computing nodes are deployed in places such as refrigerated trucks and cold storage to realize real-time collection and analysis of sensor data, trigger local early warnings, and synchronize key data to the cloud for long-term trend analysis. The computing resources of edge nodes are used for local data cleaning and anomaly detection, and storage resources are used for short-term data caching, with only abnormal information and aggregated results transmitted to the cloud. This design reduces unnecessary data interaction, lowers transmission energy consumption and bandwidth occupation, improves the response speed to abnormal situations, and ensures the continuity of cold chain data through the collaboration of local storage and computing. The localized processing capability of edge computing makes up for the quality risks that may be caused by cloud transmission delays, and its resource optimization strategy directly supports the full-process controllability of cold chain logistics.

4.5 Distributed Allocation of Logistics Resources

Distributed logistics resource allocation involves multi-party supply and demand matching of logistics resources such as warehousing space and transportation capacity, requiring fair negotiation and efficient allocation. Edge computing nodes act as intermediaries to process multi-party resource supply and demand information in real-time, run negotiation algorithms to generate resource allocation plans, and solidify the results through smart contracts to achieve multi-party synchronization. Edge nodes dynamically allocate computing resources according to the number of participants and the complexity of negotiations, and avoid single-node overload through load balancing, which improves the response speed and fairness of resource allocation, reduces information asymmetry in centralized allocation, and lowers the impact of single-node failures on overall resource allocation through distributed resource scheduling. This indicates that the distributed architecture and real-time computing power of edge computing provide reliable and efficient resource allocation support for multi-party collaboration, and its resource optimization capability directly determines the feasibility and efficiency of distributed resource allocation.

5. Challenges and Future Directions

5.1 Key Challenges

5.1.1 High Uncertainty in Resource Demand

The complexity and diversity of intelligent logistics scenarios lead to significant fluctuations in resource demand. In warehouse management, a large number of intelligent robots require instantaneous processing of massive data for image recognition and path planning, resulting in extremely high demand for computing resources. In contrast, transportation scheduling mainly involves analyzing vehicle positions and road conditions, with relatively stable resource demand. Such differences in demand between different links, coupled with load fluctuations in the same link during different time periods, make it difficult for dynamic resource allocation to achieve precise matching, easily causing resource waste or shortages and directly affecting the operational efficiency of logistics systems.

5.1.2 Limited and Unevenly Distributed Edge Node Resources

Edge nodes in intelligent logistics are distributed across multiple scenarios such as warehouses, transport vehicles, and distribution stations, with significant heterogeneity in computing power, storage capacity, and energy supply: ranging from high-performance local servers to low-power sensors and small embedded devices. This uneven distribution of resources makes it difficult to achieve globally optimal resource allocation. Meanwhile, some edge nodes are limited by energy supply, and balancing resource allocation and energy consumption control while ensuring task completion has become an urgent issue.

5.1.3 Prominent Issues of Data Security and Privacy Protection

Intelligent logistics involves a large amount of sensitive data, including cargo information, customer privacy, and trade secrets. During dynamic resource allocation, data needs to be transmitted and shared between different edge nodes, which increases the risk of data leakage and attacks. Additionally, edge nodes may belong to different institutions, and the ambiguous definition of data ownership and usage rights further hinders efficient collaborative resource allocation.

5.1.4 Inadequate Collaboration Mechanism Between Edge Nodes and Cloud

Although edge computing focuses on local processing, complex tasks still rely on cloud support. However, interactions between edge nodes and the cloud are often restricted by network bandwidth and latency, leading to collaboration delays: edge nodes struggle to upload key data or receive cloud instructions in real time, and the cloud cannot promptly respond to resource requests from edge nodes. Such poor collaboration directly affects the timeliness and accuracy of dynamic resource allocation, potentially causing task delays or resource scheduling failures.

5.2 Future Trends

5.2.1 Large Model-Driven Resource Demand Prediction and Dynamic Optimization

Leveraging the in-depth analysis capabilities of large models, historical logistics data and real-time scenario parameters can be integrated to build high-precision resource demand prediction models. For example, through multi-dimensional learning of warehouse robot task loads and distribution vehicle scheduling needs via large models, resource gaps in different time periods and scenarios can be predicted in advance to achieve proactive resource allocation. Meanwhile, large models can real-time optimize resource scheduling strategies, dynamically adjust task allocation based on the real-time status of edge nodes, and improve resource utilization efficiency and system response speed.

5.2.2 Collaborative Management and Resource Pooling of Heterogeneous Edge Nodes

To address the issue of limited and unevenly distributed edge node resources, future efforts will integrate computing, storage, and network resources of heterogeneous nodes through resource pooling technology, forming a logically unified resource pool. Combined with the global optimization capabilities of large models, cross-node dynamic resource scheduling can be realized: high-performance nodes handle complex tasks, low-power devices focus on data collection and lightweight processing, and energy-aware algorithms allocate adaptive tasks to energy-constrained nodes to balance performance and energy consumption.

5.2.3 Security Collaborative Framework Based on Privacy Computing and Blockchain

To solve problems of data security and privacy protection, privacy computing, such as homomorphic encryption and federated learning, will be integrated with blockchain technology in the future. Through privacy computing, data between edge nodes can be made available without being visible, enabling collaborative computing required for resource allocation without leaking original data. By leveraging the decentralized and tamper-proof nature of blockchain, a transparent and trustworthy resource allocation record and permission management mechanism will be established to clarify data ownership and usage rights, ensuring secure collaboration among multiple institutions.

5.2.4 In-depth Integration of Cloud-Edge-End Integrated Collaborative Architecture

A closer cloud-edge-end collaboration mechanism will be built: the cloud relies on large models to complete global resource planning and long-term strategy formulation, edge nodes are responsible for local real-time task processing and dynamic adjustment, and end devices focus on data collection and instruction execution. By optimizing data transmission protocols and collaborative interfaces, interaction latency between the edge and the cloud will be reduced, realizing closed-loop management of "cloud global decision-making - edge local execution - end real-time feedback" and improving the timeliness and accuracy of dynamic resource allocation.

6. Conclusion

Dynamic resource allocation is crucial for unlocking the full potential of edge computing in smart logistics. This paper reviews the latest progress in dynamic resource allocation of edge computing in smart logistics, covering the integration of edge computing with smart logistics, the analysis of key technologies such as resource sensing, prediction and scheduling, and the discussion of typical application scenarios, challenges and future trends. It is concluded that dynamic resource allocation effectively addresses the bottlenecks of centralized cloud computing in latency, bandwidth and privacy, and provides strong support for the efficiency, reliability and intelligence of smart logistics. This review offers a comprehensive framework for researchers and practitioners, contributing to the advancement of edge-enabled smart logistics and promoting the development of more adaptive, responsive and interconnected global supply chains.

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