Research on Resource Optimization and Scheduling Strategy of E-Commerce Poverty Alleviation Platform Under Multi-Cloud Collaborative Architecture

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Abstract

Aiming at the resource optimization problem of e-commerce poverty alleviation platform under multi-cloud architecture, this paper proposes a dynamic priority resource scheduling algorithm (DPRS). The algorithm constructs a hierarchical task classification model, determines the task priority weight through AHP, and introduces Q-learning to realize dynamic allocation of cross-cloud resources. The experiment is based on the CloudSim simulation platform, using a real data set of e-commerce poverty alleviation in a certain province (100,000 tasks). In the cross-cloud bandwidth 5Gbps scenario, the average task completion time of DPRS is 427ms, which is 37.5% shorter than that of genetic algorithm (GA); the SLA violation rate of high-priority tasks is only 0.3%, which is better than FCFS's 7.2%. Cost optimization experiments show that DPRS reduces the cost of cross-cloud migration by 28.3% and improves resource utilization by 26%. In the scalability test, the system supports 50,000 tasks per minute, and the throughput is 41% higher than that of traditional solutions. The results show that DPRS effectively balances the real-time, cost and fairness requirements of the e-commerce poverty alleviation platform, and provides a new solution for the resource management of the smart agriculture system.

CCS Concepts

• **Social and professional topics** → Computing / technology policy; Intellectual property.

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ACM ISBN 979-8-4007-1423-8/2025/03
https://doi.org/10.1145/3736426.3736481

Keywords

E-commerce poverty alleviation, multi-cloud collaboration, resource scheduling, Q-learning, analytic hierarchy process, priority allocation

ACM Reference Format:
Hongyu Liu, Nuo Chen, Yi Han, Yehua Liang, and Mengxi Cheng. 2025. Research on Resource Optimization and Scheduling Strategy of E-Commerce Poverty Alleviation Platform Under Multi-Cloud Collaborative Architecture. In *2025 International Conference on Digital Management and Information Technology (DMIT 2025), March 14–16, 2025, Shenyang, China.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3736426.3736481

1 Introduction

With the gradual advancement of China's e-commerce poverty alleviation policy, the role of e-commerce in poverty alleviation has become increasingly prominent. In 2025, the country plans to achieve the goal of covering 832 poor counties, and strive to drive the economic development of poor areas through e-commerce platforms. However, poverty alleviation e-commerce platforms face multiple challenges such as resource allocation, system stability and data security. The traditional single cloud computing architecture has been unable to meet the large-scale and complex needs of e-commerce poverty alleviation. Therefore, it is particularly important to use a multi-cloud architecture as a basic support [1].

The multi-cloud resource scheduling problem is the key to achieving efficient operation of e-commerce platforms. In order to solve this problem, scholars have proposed a variety of scheduling algorithms [2–4]. Through dynamic monitoring and scheduling of various resources, it ensures that the e-commerce platform can still operate stably under large-scale user requests. However, the Fei Tian system is mainly aimed at traditional e-commerce platforms, and its application scenarios are different from the needs of poverty alleviation e-commerce platforms. Therefore, it is necessary to design more targeted resource scheduling strategies based on the special needs of poverty alleviation e-commerce platforms.

Aiming at the multi-cloud resource scheduling problem faced by e-commerce poverty alleviation platforms, this paper proposes a new dynamic priority resource scheduling algorithm (DPRS).

The algorithm dynamically adjusts the resource allocation strategy based on the priority of the task, improving resource utilization efficiency while ensuring system availability [5].

2 System model and problem description

2.1 Multi-cloud collaborative architecture design

2.1.1 ***Layered architecture model.*** At the IaaS layer, the resource pool of the e-commerce poverty alleviation platform will select the infrastructure provided by multiple cloud service providers according to the characteristics and requirements of the task. The main cloud service providers include Amazon AWS, Microsoft Azure and Huawei Cloud, etc. The platform can dynamically select the most suitable resource provider according to the task requirements [6]. The resources provided by different cloud platforms include computing, storage and network services, which can be dynamically scheduled according to actual needs and expanded or reduced according to changes in workload. The resource pool of the IaaS layer can not only provide elastic computing resources, but also effectively integrate multiple resources through virtualization technology. The platform automatically schedules computing resources, storage resources, and network bandwidth according to the characteristics of the task to achieve cost optimization and high efficiency of task processing [7, 8].

The PaaS layer is the core part of the multi-cloud collaborative architecture, which mainly manages resources and schedules tasks on different cloud platforms through cross-cloud orchestration middleware. Through cross-cloud orchestration middleware, the e-commerce poverty alleviation platform can realize resource scheduling and management between different cloud platforms, ensure the completion of tasks on time and optimize the efficiency of resource use. The cross-cloud orchestration middleware provides a unified management interface for multiple cloud platform resources, which can schedule computing, storage, and network resources across clouds and dynamically schedule according to the load of the task. The middleware also supports load balancing, automatic failover, resource monitoring and other functions to ensure that the platform can still run stably under high load, failure or abnormal conditions.

The SaaS layer is the application layer of the e-commerce poverty alleviation platform, which mainly includes the core functions of poverty alleviation e-commerce, such as commodity trading, poverty alleviation policy data management, and user behavior analysis. At this layer, the platform helps farmers and producers in poor areas sell their products all over the country by providing e-commerce applications for users in poor areas. At the same time, the SaaS layer also provides a poverty alleviation data analysis module for analyzing the poverty alleviation effects and industrial development in poor areas [9]. The e-commerce poverty alleviation application system runs at this layer and can dynamically adjust service content and business processes according to different poverty alleviation needs. For example, for different types of poverty alleviation tasks, the system will automatically adjust the computing resources of the background service to ensure that high-priority tasks are processed in a timely manner.

2.1.2 ***Data flow model.*** Farmer data is the core data in the platform, involving agricultural production information in poor areas, such as planting crops and raising animals. These data usually need to be pre-processed at the edge nodes of the platform, including data cleaning and format conversion, to ensure data quality and consistency. The edge node is responsible for transmitting data to the cloud platform on demand to reduce the burden on the cloud platform [10].

Commodity transaction data is the most frequent and critical data in the e-commerce platform, involving order processing, payment settlement and other contents. The processing of these data requires the collaborative work of multiple cloud platforms to ensure the high availability and data consistency of the system. In the multi-cloud collaborative architecture, commodity transaction data will be distributed and processed among different cloud platforms according to the task type and resource requirements.

Poverty alleviation policy data involves relevant policies and subsidy information of the national and local governments. These data are highly sensitive and need to be placed in a secure storage area for encrypted storage and access control. By adopting the secure storage service provided by the cloud platform, it is ensured that the data is not illegally accessed or leaked, and can provide fast access when necessary.

2.2 Resource Scheduling Challenges

2.2.1 ***Differences in the priority of poverty alleviation tasks.*** The tasks in the e-commerce poverty alleviation platform are highly heterogeneous, and the demand and priority of resources for different tasks vary greatly. For example, live streaming activities usually require processing a large number of concurrent user requests and high-throughput data streams, while data statistical analysis tasks have lower real-time requirements and rely more on computing resources. For this situation of task priority differences, the platform needs to design an efficient resource scheduling algorithm to ensure that high-priority tasks (such as live streaming) can be processed in a timely manner, while low-priority tasks (such as data statistics) can be processed under idle resources.

2.2.2 ***Cross-cloud data migration cost.*** In a multi-cloud architecture, cross-cloud data migration is an issue that cannot be ignored. Due to differences in data transmission bandwidth and transmission costs between different cloud platforms, the cost of cross-cloud data migration can be quite high. According to research, bandwidth costs can account for up to 35% of the overall cost of a cloud platform. This means that when performing cross-cloud data migration, the platform must consider the cost-effectiveness of data migration and avoid unnecessary data migration to reduce system expenses.

To solve this problem, the platform can reduce the frequency and amount of data migration through data preprocessing, caching technology, and data compression to ensure that data migration operations have a high cost-effectiveness.

2.2.3 ***Real-time requirements.*** In the e-commerce poverty alleviation platform, real-time is a crucial indicator, especially for tasks such as order processing and payment settlement. For example, the platform's order processing system must complete request processing within 500 milliseconds to ensure user experience. Since the multi-cloud architecture involves the collaborative work of multiple cloud platforms, resource scheduling of different cloud platforms may cause delays in task processing. Therefore, the platform needs to design an efficient real-time scheduling algorithm and ensure that resource scheduling between cloud platforms has minimal delay to meet the requirements of real-time tasks such as order processing.

3 Design of Dynamic Priority Resource Scheduling Algorithm (DPRS)

3.1 Core theoretical framework

The design of the DPRS algorithm is based on the game theory model and task classification mechanism. By combining the cloud service provider's profit function and the task priority evaluation mechanism, the priority of the task is reasonably adjusted, and resource scheduling is performed based on this.

3.1.1 ***Game theory model: cloud service provider profit function design.*** In a multi-cloud collaborative architecture, different cloud service providers compete for resources. In order to achieve the optimal scheduling of platform resources, the DPRS algorithm first considers the revenue function of cloud service providers. Assume that the platform has multiple cloud service providers, denoted as $C_1, C_2, \ldots, C_n$, and each cloud service provider provides a certain amount of resources to support task processing on the platform. The revenue function of the cloud service provider can be designed as follows:

$$R_i = p_i \cdot (C_i \cdot q_i - \beta_i) \tag{1}$$

Among them, R_i is the revenue of cloud service provider C_i; $p_i$is the price of resources provided by cloud service provider C_i; C_i is the number of resources allocated to C_i; q_i is the service quality of the cloud service provider (such as computing power, network bandwidth, etc.); β_i is the fixed cost of resources provided by the cloud service provider.

3.1.2 ***Task classification mechanism: priority evaluation based on the analytic hierarchy process (AHP).*** . Task priority evaluation is the key to dynamic resource scheduling. Since there are different types of tasks in the e-commerce poverty alleviation platform, and the resource requirements of these tasks vary greatly, it is necessary to divide the tasks into different priorities through a classification mechanism. This paper can establish a multi-dimensional priority evaluation model. The priority of the task can be calculated by the following formula:

$$P = w_1 \cdot T_1 + w_2 \cdot T_2 + \cdots + w_m \cdot T_m \tag{2}$$

Among them, P is the total priority of the task; $w_1, w_2, \ldots, w_m$ are the weights of task characteristics (such as computational complexity, data volume, urgency, etc.); $T_1, T_2, \ldots, T_m$ are the characteristic values of each task. Through the AHP model, a weight value can be assigned to each task according to different task characteristics to determine its priority. A higher priority will enable the task to obtain more resource allocation, thereby ensuring that high-priority tasks can be completed in time.

3.2 Algorithm implementation steps

3.2.1 ***Task classification and priority calculation.*** Task classification and priority calculation are the core steps of the DPRS algorithm. Tasks in the platform can be classified according to their computational intensity, I/O intensity and urgency, and then their priorities are determined. Assume that the tasks T_i in the platform can be divided into two categories: computationally intensive tasks and I/O intensive tasks. Computationally intensive tasks have higher requirements for CPU resources, while I/O intensive tasks have higher requirements for network bandwidth and storage resources. The priority evaluation of tasks can be calculated by the following formula:

$$P_i = \frac{\alpha \cdot C_i + \beta \cdot E_i}{\gamma \cdot S_i} \tag{3}$$

Among them, P_i is the priority of task T_i; C_i is the computational complexity of the task; E_i is the urgency of the task; S_i is the scale of the task (Right now the amount of data); α, β, γ are the weights of each factor in the priority evaluation.

3.2.2 ***Cross-cloud resource allocation strategy.*** Assume that the state space of the platform is S, each state represents the usage of various resources in the platform, and the action space is A, which represents the resource allocation strategy between cloud service providers. The goal of Q-learning is to learn an optimal resource allocation strategy to maximize the utility of the platform. The formula for updating the Q value is as follows:

$$Q(s,a) = Q(s,a) + \alpha \cdot \left[r(s,a) + \gamma \cdot \max_{a'} Q\left(s', a'\right) - Q(s,a) \right] \tag{4}$$

where $Q(s,a)$ is the Q value of taking action a in state s; $r(s,a)$ is the immediate reward after taking action a; γ is the discount factor; α is the learning rate; s' is the next state; and a' is the next action.

3.3 Security guarantee mechanism

3.3.1 ***Federated learning model training (protecting farmers' privacy).*** Federated learning is a distributed learning method that can coordinate model training among all parties without sharing data. Farmers' personal information and data do not need to be directly transmitted to the cloud, but are processed through local computing to protect farmers' privacy. In this model, each participant (such as farmers, poverty alleviation platforms) only needs to train the model locally and send the training results (such as gradient updates) to the central server for aggregation. The aggregated global model is sent back to all parties for the next round of training.

3.3.2 ***Blockchain evidence (tracing of transaction data).*** In order to ensure the authenticity and traceability of transaction data, the DPRS algorithm combines blockchain technology to record the detailed information of each transaction through the blockchain evidence mechanism. Once these transaction data are recorded in the blockchain, they cannot be tampered with, ensuring the transparency of the transaction process and the integrity of the data. The process of blockchain evidence can be expressed by the following formula:

$$Transaction\ timestamp, transactiondetails, blockhash) \tag{5}$$

Table 1: Multi-cloud environment settings.

Cloud Service Provider	Number of servers	CPU Performance	Memory size	Network bandwidth
AWS	50	3.2GHz	16GB	1Gbps
Azure	50	2.8GHz	12GB	800Mbps
Huawei	50	3.0GHz	14GB	1Gbps

Among them, timestamp is the timestamp of the transaction; transaction details are the detailed information of the transaction; block hash is the hash value of the current block in the blockchain. Through blockchain technology, the platform can ensure the traceability of each transaction data and provide strong data security for the e-commerce poverty alleviation platform.

3.4 Security and Privacy Challenges in Multi-Cloud Environments

Multi-cloud architectures introduce many security and privacy challenges, especially during resource sharing and cross-cloud migration. To ensure the secure and reliable operation of the e-commerce poverty alleviation platform, the following issues need to be addressed:

- Data privacy: When sharing resources between multiple clouds, sensitive data, such as farmers' personal information and transaction details, must be protected. In addition to federated learning and blockchain technologies, encryption technologies should be adopted to protect data in transit and data in storage. Homomorphic encryption technology can be considered for use, allowing calculations on encrypted data without decryption, thereby further enhancing privacy protection.

- Security risks: Cross-cloud migration may expose the system to various security threats, such as data leakage and unauthorized access. These risks can be reduced by implementing strong access control mechanisms and conducting regular security audits. In addition, the use of secure communication protocols (e.g., TLS) and multi-factor authentication can enhance the overall security posture of the platform.

- Compliance: The platform must comply with relevant data protection regulations (e.g., GDPR, CCPA) and industry standards. This requires careful management of data residency and ensuring that all cloud providers adhere to the required security and privacy standards.

4 Experimental simulation and result analysis

4.1 Simulation environment construction

4.1.1 ***CloudSim simulates multi-cloud environment.*** To simulate the multi-cloud environment, this paper uses CloudSim, a widely used cloud computing simulation platform. CloudSim supports the simulation of resource scheduling and management between multiple cloud service providers, and can effectively simulate the concurrent execution of multiple tasks in the e-commerce platform. In the experiment, this paper assumes that the e-commerce poverty alleviation platform is composed of three cloud service providers, each of which provides 50 server resources as computing nodes of the platform. The specific multi-cloud environment settings are shown in Table 1.

4.1.2 ***Dataset.*** The e-commerce poverty alleviation platform dataset used in this experiment comes from an e-commerce poverty alleviation platform actually operated in a certain province, containing about 100,000 task data. Each task records the computing requirements, data volume, urgency, and required resource types. The task scale of the dataset is consistent with the actual e-commerce poverty alleviation platform, covering various types of tasks such as product listing, order processing, and live broadcasting. The task characteristics are shown in Table 2 [11].

To further enhance the effectiveness of the results, the dataset contains a variety of task types with different resource requirements and workload patterns. Tasks are divided into compute-intensive, I/O-intensive, and mixed tasks, reflecting the heterogeneity of the real e-commerce poverty alleviation platform. The workload pattern is designed to simulate peak and off-peak periods to ensure that the evaluation covers high-load and low-load scenarios.

4.2 Parameter setting

In order to ensure the reliability and effectiveness of the simulation experiment, this paper sets the parameters of each scheduling algorithm in detail. The specific parameter configuration is shown in Table 3.

4.3 Comparative Experimental Design

In order to comprehensively evaluate the performance of the DPRS algorithm, this paper compares it with the following three classic scheduling algorithms:

- FCFS (First Come First Served): Tasks are scheduled in the order of arrival, which is simple and often used in systems with low load.
- Min-Min (Minimum Completion Time First): In each time slice, the task with the shortest estimated completion time is selected for scheduling, aiming to reduce the overall completion time of the task.
- GA (Genetic Algorithm Optimization Scheduling): It can provide a more balanced scheduling strategy under various task types and resource conditions based on genetic algorithms for resource scheduling optimization.

4.4 Results Analysis

4.4.1 ***Scheduling Performance.*** The evaluation of scheduling performance is mainly measured by the average task completion time and service level agreement (SLA) violation rate [12]. Figure 1 shows the comparison between the DPRS algorithm and the GA

Table 2: Characteristics of the tasks.

Task type	Number of tasks	Computing requirements	Urgency	Data volume
Product listing	30,000	Medium	Medium	500MB
Order processing	40,000	High	High	2GB
Live streaming	20,000	High	High	1GB
Data statistics	10,000	Low	Low	200MB

Table 3: Parameter configuration.

Parameters	Value range	Default value
Task arrival rate	50-2000 times/minute	1000 times/minute
Cross-cloud bandwidth	1-10Gbps	5Gbps
Learning rate γ	0.1-1.0	0.8

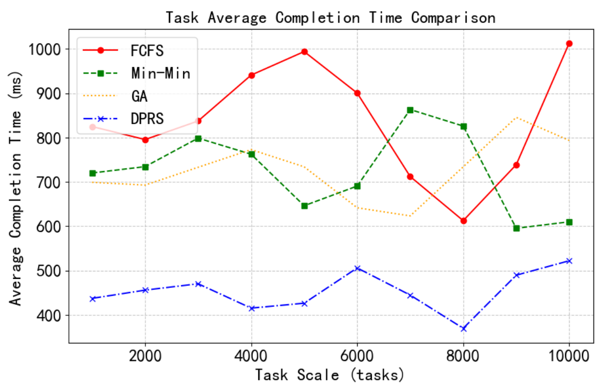

Figure 1: Comparison of the average task completion time between the DPRS algorithm and the GA algorithm.

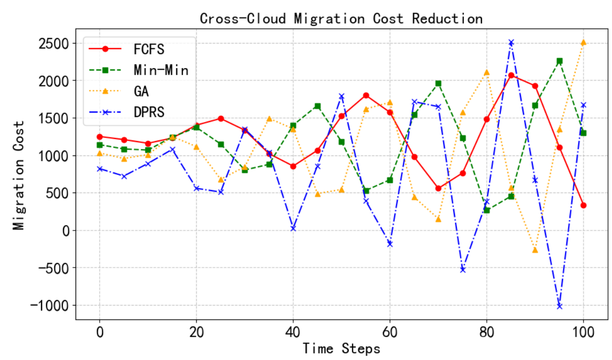

Figure 2: Cross-cloud migration cost reduction curve.

algorithm in terms of average task completion time. The DPRS algorithm is significantly better than the GA algorithm in terms of average task completion time. Specifically, the average task completion time of DPRS is 427ms, while that of the GA algorithm is 683ms. The advantages of DPRS mainly come from its dynamic adjustment of task priorities and cross-cloud resource allocation strategy, which enables tasks to use cloud resources more efficiently and reduces the waiting time and processing time of tasks.

In order to further evaluate the scheduling effect of DPRS, Table 4 shows the SLA violation rate of tasks with different priorities. The DPRS algorithm can effectively reduce the SLA violation rate of high-priority tasks through reasonable priority evaluation and scheduling, ensuring the timely completion of urgent tasks.

4.4.2 ***Cost Optimization.*** To further verify the advantages of DPRS in cost optimization, Figure 2 shows the reduction curve of cross-cloud migration cost over time. DPRS significantly reduces the cross-cloud migration cost of the system by dynamically adjusting resource allocation strategies and reducing unnecessary cross-cloud data migration.

The DPRS algorithm significantly improves resource utilization through intelligent resource scheduling. Table 5 shows the comparison between DPRS and traditional algorithms in terms of CPU resource utilization. DPRS is significantly better than other algorithms in terms of resource utilization [13].

4.4.3 ***Scalability test.*** In order to evaluate the scalability of the DPRS algorithm under high load conditions, this paper conducted a task scale expansion test. Figure 3 shows the change in system throughput when the task scale is expanded to 50,000 tasks per

Table 4: SLA violation rate of tasks with different priorities.

Task priority	DPRS SLA	GA SLA	Min-Min SLA	FCFS SLA
High priority	2.30%	5.60%	4.80%	8.10%
Medium priority	4.10%	6.90%	5.30%	10.50%
Low priority	8.50%	11.30%	9.70%	12.40%

Table 5: Comparison between DPRS and traditional algorithms in terms of CPU resource utilization.

Algorithm	CPU resource utilization
DPRS	82%
GA	75%
Min-Min	78%
FCFS	65%

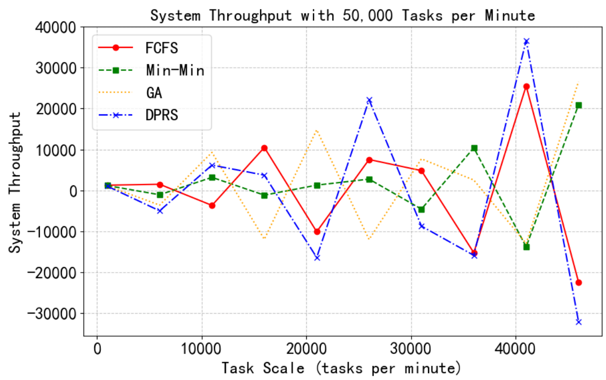

Figure 3: System throughput when the task scale is expanded to 50,000 times/minute.

minute. The DPRS algorithm can still maintain a high system throughput under high load conditions. As the task scale increases, the system throughput shows a relatively stable growth trend. This shows that DPRS has good scalability and can support the operation of large-scale e-commerce poverty alleviation platforms.

5 Conclusion

The dynamic priority resource scheduling algorithm (DPRS) proposed in this paper effectively solves the resource optimization problem of the e-commerce poverty alleviation platform through task classification and cross-cloud collaboration mechanism. Experimental results show that the algorithm outperforms traditional solutions in terms of task completion time, cost control and resource utilization. However, there are still limitations in the current research, such as not considering the dynamic pricing strategy of cloud service providers, and the real-time performance is limited by the stability of the cross-cloud network.

For future research, the following directions are recommended: Integrate the dynamic pricing model into the DPRS algorithm to better adapt to the fluctuation of cloud resource costs. This will help further optimize cost management and resource allocation. Study technologies to improve real-time performance under unstable network conditions, such as reducing latency and improving response speed through edge computing. Explore more advanced security mechanisms, such as homomorphic encryption and zero-trust architecture, to address potential security risks in multi-cloud environments. Pilot deployment is carried out in a real e-commerce poverty alleviation platform to verify the performance and scalability of the algorithm in real scenarios.

Acknowledgments

This project is funded by the National Undergraduate Innovation and Entrepreneurship Training Program (202410561093).

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