Resource scheduling for smart IOT system quality management method research

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ABSTRACT

The power intelligent IOT system is an important support to guarantee data analysis and intelligent decision making of power system, which realizes power information communication and resource business scheduling through edge-side and cloud master station architecture. With the deployment of massive smart terminal devices leading to problems such as insufficient channel communication resources and delayed middle station service scheduling, this brings obstacles to resource scheduling for the intelligent operation and maintenance of power grid. To address the above problems, this paper proposes a quality management optimization method for the resource scheduling strategy of smart IOT system. The method uses cloud-edge collaboration technology to analyze the existing smart IOT system, constructs a cloud-edge collaborative resource quality management architecture, and studies the collaborative resource interaction method between the cloud and the edge. A multi-dimensional quality optimization model is established based on the edge computing terminal container to realize the optimal management of resource quality. The experimental simulation results prove that the method can efficiently solve complex computing tasks and reduce the data communication frequency delay between the edge side and the cloud center by up to 15%. Its overall improvement of the quality of resource scheduling in the smart IOT system provides a technical method for intelligent assessment of grid quality.

Keywords: Quality management optimization, smart IoT system, edge computing, cloud-side collaboration.

1. INTRODUCTION

With the continuous improvement and development of smart grids, a huge amount of intelligent sensing data exists in the information system of electric power as well as in the whole production process cycle. Due to the large amount of existing multi-source heterogeneous data with inconsistent processing logic, long storage cycle, and high computational frequency[1-3]. Therefore, in order to realize the full awareness of power integrated business status and promote the transformation of automation and digitalization in the power industry, the State Grid has proposed a power IoT architecture consisting of "cloud, management, edge and end". By deploying a large number of multi-physics measurement sensors and terminals with certain storage and computing capabilities as IoT edge sensing, we can realize the collection and transmission of multi-source heterogeneous data [4]. However, these sensors and edge terminals are of more types and have a more complex composition structure, leading to inconsistent physical interfaces of these terminals. There are large differences in the underlying connection protocols. As a result, IOT terminals and access devices exhibit a high level of coupling [5]. Meanwhile, with the heterogeneous access of massive IOT terminals, the field sensor data is uploaded to the cloud master without pre-processing. This can lead to heavy data processing tasks and failure to meet the real-time requirements of the business in the cloud. This leads to the aggravation of system-level data sharing and service delay [6-8]. Therefore, this paper delves into the cloud-side collaboration mechanism under multi-scenario business conditions to improve the processing efficiency of IOT-aware data by improving the quality of resources at the edge side, which provides important methodological support for realizing the data resource management of the smart IOT system [13].

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In the existing intelligent IoT architecture, the cloud is mainly responsible for tasks that require more computing resources such as model construction, algorithm analysis and knowledge mining of data to meet different business requirements. The edge computing terminal is mainly responsible for tasks such as temporary storage, pre-processing and uploading of data to meet the real-time requirements of the business[7, 11]. And with the advancement of digital transformation of power grids, it follows that many new business requirements for different scenarios have emerged in power distribution, power usage, etc., which also put forward higher requirements for the resource allocation problem of the existing IoT architecture. Therefore, for the resource scheduling problem of the cloud-edge collaborative system, related scholars at home and abroad have conducted relevant research [10]. premsanker [8] et al. studied the application of edge computing technology in mobile terminal games, using the computing resources of mobile terminals to handle some real-time data computing tasks such as responding to finger operations in games. This method reduces the communication latency with the cloud server. Although edge computing technology can meet part of the real-time requirements of the IIoT edge, it also alleviates the problem of tight computing resources of the cloud server. However, due to its low power consumption and light weight, the computational power is not powerful and thus cannot replace the cloud, which still needs to take on tasks such as processing and model building for large amounts of historical and real-time data. Therefore, edge computing technology and cloud computing need to work together to meet the demands for computational resources, real-time data processing, communication quality, and device power consumption in IIoT application scenarios. Xia [12] et al. proposed a deep learning model deployment strategy for a collaborative system of cloud-edge resources to balance both computational performance demands and resource consumption. Huang [13] et al. proposed a hybrid cloud- and edge-server-side network architecture to achieve a reasonable allocation of computational resources between the cloud and the edge. Mudassar [14] et al. proposed a collaborative processing framework for data collection and transmission of edge-side sensors under the condition of limited network bandwidth. The approach improves the performance of target identification and the quality of service of end-point sensing. The current related research is based on the cloud-edge collaborative system of IoT, which reduces the pressure of cloud-edge communication by distributing some or all computing tasks from the original cloud to the devices with computing capability at the edge. And improve the real-time of the service, but the computing resources at the edge still cannot meet some of the complex computing tasks. The data communication frequency between the edge side and the cloud center is more frequent, and the growing distribution data also brings more communication pressure on the cloud side, and the computing resources at the edge side cannot meet the quality demand of computing resources.

In order to solve the above data processing problems in the intelligent IOT system, this paper studies the data and business flow direction in the intelligent IOT system based on the intelligent IOT system architecture of "cloud, management, edge and end". It adopts the idea of cloud-edge collaboration, analyzes the intrinsic demand of cloud-edge collaboration relationship, optimizes the existing IOT system, and proposes a resource quality management architecture with three major cloud-edge collaborations: data, business, and computing resources. And based on the application deployment architecture at the edge, the collaborative resource interaction method between the cloud and the edge computing terminal is studied. A deep learning model is established to solve the collaborative computing problem between device data and cloud resources in the wisdom IOT system, and realize the efficient sharing and intelligent quality management of data resources in the wisdom IOT system.

2. QUALITY MANAGEMENT METHOD OF RESOURCE SCHEDULING

In order to realize the efficient sharing and low latency processing of data resources in the intelligent IOT system, this paper applies the idea of cloud-side collaboration to optimize the data resources of the existing intelligent IOT system structure. A cloud-edge collaborative resource quality management architecture is built to realize the cloud-edge collaboration of data resources. At the same time, this paper proposes a multi-dimensional quality management method for data resources in combination with edge device terminal containers, and achieves optimal management of resource quality in combination with collaborative resource interaction mechanisms of cloud and edge computing terminals.

2.1 Cloud edge collaborative resource quality architecture

2.1.1 Resource quality management cloud edge collaboration

Resource quality edge computing is deployed at the network edge side of IoT, which is a new network architecture and open platform that incorporates various resources such as communication, computation, storage, and application deployment [9]. Resource quality edge computing transforms the traditional centralized cloud computing processing to allocate computing, storage, and other resources to the edge side of the IoT and provides edge intelligence services in a user- and endpoint-oriented form. The figure below shows a diagram of the cloud-edge collaborative data resource quality management framework. In this framework, data from multiple heterogeneous sensing devices at the edge side are uploaded to the quality monitoring terminal through the IoT communication private network and filtered by resources and then clouded, and the user side is the data consumer and also the data producer.

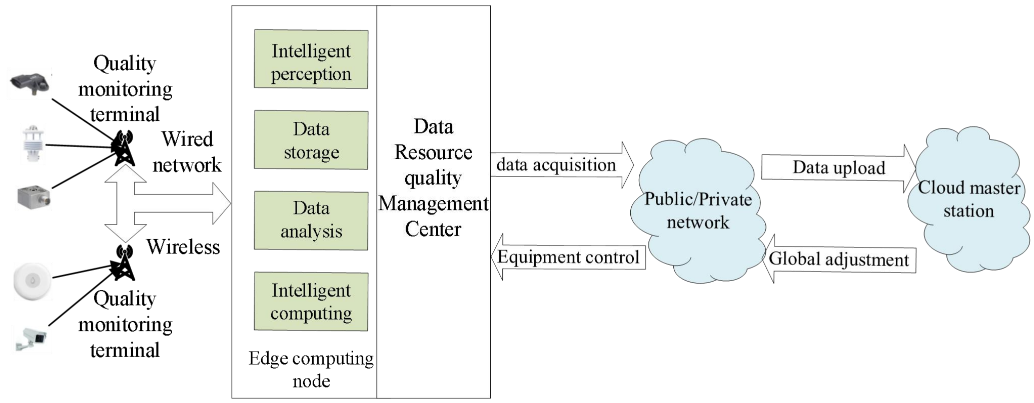

Figure 1. Framework diagram of data resource quality management by cloud edge collaboration

As shown in Figure 1, in the existing intelligent IOT system architecture, the cloud-side collaborative system consists of a cloud center and many edge computing terminals. The IOT devices or hosts at each level communicate with each other through a dedicated network. To achieve quality control of data resources, quality monitoring terminals are added at the edge measurement to batch the uploaded data according to the degree of urgency. After that, both the cloud and the edge are adopted based on container technology as for application deployment architecture, and the core elements of container architecture include data, application container and management container composition. Among them, the management task of cloud-edge collaboration is mainly responsible by the cloud for collaborative management of data, business and computing resources of both. Therefore, the data resource quality management center is added to make secondary adjustments to the business data uploaded to the cloud Zhu station. Business collaborative management is based on microservice architecture, and each business is divided into multiple independently running microservices. According to different business types, they can be divided into immediate business that requires fast response and advanced business that requires large amount of computing resources. Both of them have different requirements for real-time. Obviously, the limited computing resources at the edge cannot meet the needs of advanced services.

In this paper, the business requirements in each scenario are divided according to the specific business needs based on the computational load, data volume size and real-time requirements of the business. It also specifies the deployment strategy of the business to achieve business cloud-side collaboration and improve the relevance and real-time of the business.

The business and device data in the IOT system has the characteristics of massive heterogeneity. Therefore, after the data is processed at the edge computing terminal, the data needs to be collaborated with the IOT management platform deployed on the cloud. Thus, the security and availability of data are guaranteed. The data collaboration strategy is that the edge IOT agent reports the results of local analysis and the complete data needed in the cloud to the cloud data center through the encrypted transmission module by running container applications or cloud commands. Meanwhile, the cloud center receives the data and sends control commands to the edge after analysis and processing, and responds to the demand from the edge. The whole collaborative strategy is based on message queuing mechanism and MQTT protocol, which can effectively reduce the communication pressure of the cloud-edge system.

2.1.2 Quality management edge IOT agent

The quality management edge IOT agent is the key to the resource scheduling of the intelligent IOT system, which realizes the unified access and control of the local network and remote communication network. And as the edge-side computing center, it undertakes the computing function at the edge, realizing the functions of data storage, computing and resource scheduling.

The quality management edge IoT agent device realizes functions such as protocol conversion of the original terminal and has a simpler structure. It also has certain computing resources and autonomous processing capabilities. Therefore, it can pre-process the sensed data at the edge side, filter invalid and erroneous data, and reduce the pressure on data pre-processing at the cloud. The functional architecture of the quality management edge IoT agent is shown in Figure 2.

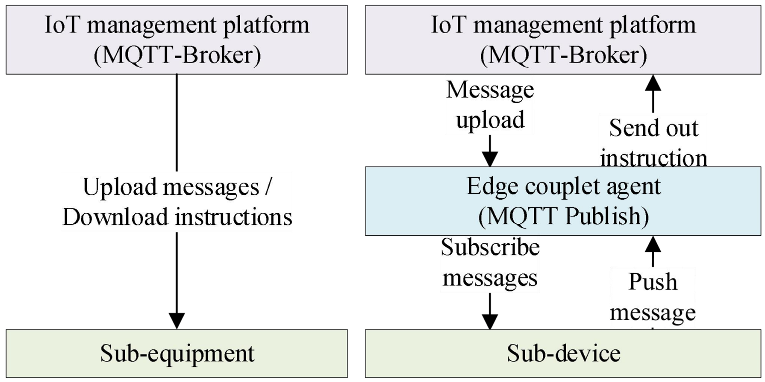

Figure 2. Functional architecture of quality management edge IOT agent

As shown in Figure 2, the quality management edge IOT agent device uses optical fiber to connect to the communication equipment of the plant station, and then connects to the higher level IOT management platform via a dedicated communication network. In terms of protocol, the quality management edge IOT agent device is based on MQTT protocol to achieve communication and data transmission with the IOT management platform. In a certain data collection cycle time, the agent device converts the collected edge-side sensing data into the data format of MQTT protocol. The transmission of multi-source heterogeneous data and the control of edge-side devices are realized.

In the intelligent IOT architecture, the terminal devices have different functional requirements due to their various types. Considering the cost and practicality, according to the different physical forms, this paper designs three different types of quality management edge IoT agents for the smart IoT system to accomplish different edge computing tasks.

- Edge-end separation type: This type of quality management edge IoT agent is a generic edge computing node, designed based on the principle of hardware platformization and software containerization, and complies with the corresponding standards.
- Edge-end convergence type: This type of quality management edge agent is deployed to the control terminal in a modular way to make it computationally capable.
- Edge node type: Such quality management edge IOT agents are deployed in the form of software in a generic server to form an edge computing node, such as a predecessor, system backend, etc., to achieve backward compatibility with the original sensing terminal.

2.2 Container-based multidimensional quality management approach

2.2.1 Quality edge terminal lightweight container

To support the solution to the problem of limited computing resources at the edge end of the IOT system, this paper is based on lightweight container technology to achieve quality control of data resources of the IOT platform. Since container technology has the characteristics of lightweight, it can be used to greater advantage under the condition of limited hardware resources. In addition, container technology has the same design idea as virtual machine, but the latter needs hardware platform as support, while container is built on the operating system level. Therefore, containers can be seen as a lightweight implementation of virtual machines. In addition, containers are easy and convenient to deploy, take up fewer resources, and are more efficient. Through the self-contained service sharing and isolation mechanism, the data in each container can be shared while existing independently. Therefore, this paper uses it as the carrier of data resource processing at the side end, and its architecture is shown in Figure 3.

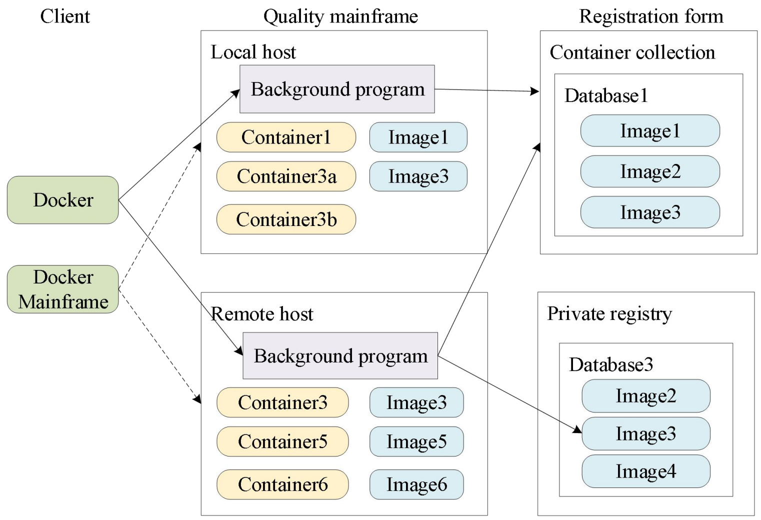

Figure 3. Lightweight container quality management at the edge end

As shown in Figure 3, this paper uses Docker to schedule and process the data resource quality model of the edge end of the IOT system, which is a widely used container engine implementation with a C/S architecture. the Docker daemon acts as the server side to process requests from clients. The client and server side can either be deployed on the same host or communicate through sockets and other means. In container technology, business applications are stored in the form of images and can be started and stopped at any time when they need to be invoked. Therefore, it can greatly improve the efficiency of using resources such as computing and memory on the edge side. Based on Docker container engine technology, applications, runtime environments, and related data of multiple businesses can be packaged into a lightweight and portable container, enabling rapid release and elastic expansion of applications.

2.2.2 Multi-dimensional resource quality management method

In order to realize the quality management of data resources at the edge of the intelligent IOT system, this paper designs a multi-dimensional resource quality management method. Two sets of multidimensional constraints are established according to the computing carrying capacity of the cloud center, and the data resources are scheduled by the quality management edge IOT agent. Finally, the quality improvement of edge data resources is achieved by feedback adjustment through the fitness function.

Step1: First, the computing capacity of each edge computing node is noted as s , the edge cluster node is denoted by S_i , and the cloud computing center is S_v , and the quality management edge agent assigns the task T to each cluster based on certain principles, while this assignment scheme satisfies the requirements of load ws , economic spend c and time consumption t .

Step2: Second, the task as a whole is divided into n subtasks $T=\{T_1,T_2,\cdots,T_n\}$, each subtask is assigned to an edge node for processing, and there can be multiple computational hotspots $S_i=\{S_{i1},S_{i2},\cdots,S_{im}\}$ in each edge cluster node.Since all three metrics are negative metrics, i.e., the smaller the metric value is, denoting node attributes by P , then each computational node can be denoted as $P(S_{im})=\{p_{ws},p_c,p_t,\}$. Then the attributes of each edge cluster node are $P(S_i)=\{P_{ws},P_c,P_t,\}$, denoting each computational total number of nodes, and n denotes the number of subtasks to be computed.

The edge computing nodes need to satisfy the following conditions, as shown in Equation (1).

$$\begin{cases} P_{ws} = \sum_{i=1}^{n} p_{ws}(S_{ij}), 1 \le j \le m; \\ P_c = \sum_{i=1}^{n} p_c(S_{ij}), 1 \le j \le m; \\ P_t = \sum_{i=1}^{n} p_t(S_{ij}), 1 \le j \le m; \end{cases} \tag{1}$$

Step3: Based on the principle of optimal location of cloud-side collaboration, the data uploading to the edge-side agent device is given priority. Each subtask is deployed on the edge-side agent device and satisfies less than the resource and time consumption of scheduling to the cloud. The following conditions need to be satisfied, as shown in equation (2).

$$\begin{cases} P_{ws} = \sum_{i=1}^{n} p_{ws}(S_{ij}) \le \sum_{i=1}^{n} p_{ws}(S_{vj}), 1 \le j \le m; \\ P_c = \sum_{i=1}^{n} p_c(S_{ij}) \le \sum_{i=1}^{n} p_c(S_{vj}), 1 \le j \le m; \\ P_t = \sum_{i=1}^{n} p_t(S_{ij}) \le \sum_{i=1}^{n} p_t(S_{vj}), 1 \le j \le m; \end{cases} \tag{2}$$

Step4:The cloud computing center has strong computing power to complete the computing tasks, but at this time, the evaluation metrics are all relatively large and not suitable for selection. When assigning a task to an edge-side agent device, the task may fail due to insufficient computing resources. Therefore, equation (3) is designed as an adaptation function.

$$f_i t_i = \begin{cases} \dfrac{1}{1 + (P_i - P_{i_{\min}})}, P_i \ge P_{i_{\min}} \\ 1, else \end{cases} \tag{3}$$

3. EXPERIMENTAL SIMULATION

The experimental simulation part combines the three types of quality management edge IoT agents proposed in this paper for comparison experiments. Since the number of terminals connected within each station area is different, in order to verify the validity of the experiment, the data transmission and processing performance logs of a southern power grid company in the same distribution network station area are selected for comparison in this paper. The results of the comparison experiment are shown in Figure 4.

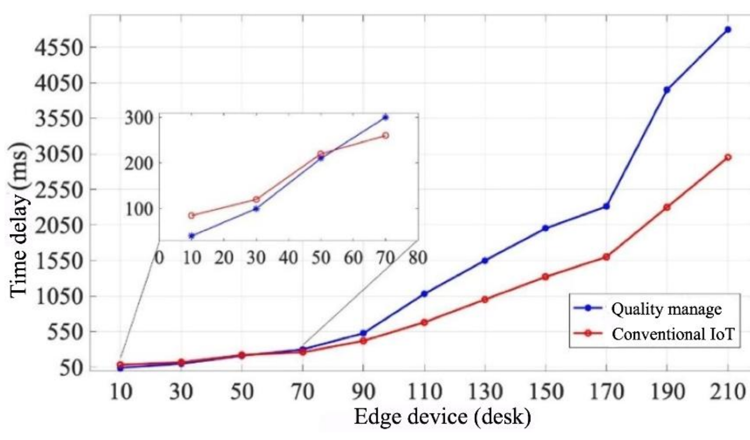

Figure 4. Comparison of the effect of resource quality management in the station area

As shown in Figure 4, the experiment divides the edge devices within the same station area into six groups, each with a different number of devices. The red line represents the data processing after adopting the resource quality management method. The blue color is the comparison test group within the same station area that did not use the method before.

From the experimental results, it can be concluded that when the number of edge devices is less than 50, the improvement effect on the processing of data resources is not obvious. Even transmission and processing delays are generated due to the addition of quality management edge IoT agents. However, as the number of edge devices increases, the performance improvement effect of data processing becomes better. It can effectively improve the quality of key data resources uploaded to the intelligent IOT system in the face of massive data.

4. SUMMARY

In this paper, we proposed a quality management method for resource scheduling of the intelligent IOT system for the communication pressure and business requirements caused by the quality of data resources in the intelligent IOT system architecture. It also proposes a resource quality management architecture based on the cloud-edge collaborative system. Meanwhile, based on the container architecture of edge computing terminal, a multi-dimensional quality management model is established to solve the collaborative computing problem between device data and cloud resources in the smart IOT system. The experimental results show that the method can effectively improve the quality of data resources, reduce the frequency of data communication between the edge side and the cloud center, increase the security and reliability of the system, protect the data privacy of the edge side, and realize the efficient processing of data resources and the maximum use of edge devices in the smart IOT system.

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