Research on Complex System Intelligent Maintenance Decision Method

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June 9, 2021

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***Abstract*—With the development of information technology, the goal of complex system maintenance and support is to be scientific prediction and precise logistics. There is an urgent need to build a flexible networked logistics architecture, to utilize the equipment's real-time health information efficiently and to schedule logistics resources successfully in a complex and dynamic logistics environment. In order to establish a precise, dynamic and networked maintenance system, the characteristics of logistics networks are analyzed entirely to improve logistics organization flexibility, a method of state collaborative analysis and intelligent support decision-making is proposed. This method generates test data through offline and online execution of fault test cases; based on online state monitoring and historical data of sensors, the equipment state is estimated and judged, thereby providing intelligent guarantee decision-making services.**

Keywords- Complex system; Condition assessment; Maintenance decision

I. INTRODUCTION

Future maintenance is developing in the direction of systematic, three-dimensional, and distributed operations. In this combat system, all main combat equipment will become a node in the distributed system. Through the command network, combat commanders can monitor and schedule the status of these equipment (nodes) in real time, so as to better and better [1]. Complete various combat missions quickly. At present, the traditional passive equipment support system of our army cannot effectively support the rapid response capabilities required for future wars [2, 3]. Take the aircraft as an example. After the introduction of the active equipment support system, the real-time perception of the status of the aircraft itself and its components can be realized through the processing and fusion of various intelligent sensor information inside the aircraft. According to the real-time status of the aircraft and the real-time situation of the battle, the support system will carry out support deployment in advance, and issue the corresponding orders for the allocation of fuel, ammunition, and spare parts to the supply system. The active support system is based on multiple network support, realizes accurate perception of support resources through multiple sensors, and combines advanced technologies such as cloud computing and big data analysis to schedule various support resources, optimize the support organization structure, and coordinate the operation of the support system [4].

A logistic support system that is stable and reliable and adapts to the dynamic environment of the battlefield is an important task of war logistic support. Many domestic research institutes have also conducted in-depth research in this field [5-8]. For example, the intelligent logistics equipment support system proposed by the National University of Defense Technology builds a logistics support platform based on information integration technology, and combines the Internet of Things and cloud computing technology. Realize the intelligent logistics equipment system; the Armored Force Engineering Institute has studied the use of big data technology to efficiently and quickly process existing data to support the decision-making process of equipment support in accordance with the characteristics of large amount of data and various types. This paper takes the optimization of complex system support time as the goal, proposes collaborative support resource awareness technology, establishes a hierarchical rapid positioning method of support resources through multi-level regional balance division, multiple matching modes that support complex strategies, and a rapid reconstruction method of support resources.

II. UNIFIED INTERCONNECTION OF NETWORK DATA

Active equipment support system emphasizes on network as the center, combining fault diagnosis and intelligent support decision-making technology, through real-time acquisition of equipment maintenance support requirements, dynamic allocation of support resources to improve equipment reliability and reduce support costs and risks [9-12]. The acquisition of equipment support and dynamic configuration of support resources all need to monitor the status of equipment, storage and spare parts. Therefore, a large number of nodes are deployed in the active equipment support system, such as node for status monitoring of weapon and equipment components such as aircraft, node for physical or environmental status monitoring of different positions, node for spare parts identification and positioning, etc. These nodes have great differences in hardware and software, and they have obvious heterogeneous characteristics. Active equipment support system must follow the cloud fog edge end heterogeneous architecture, effectively interconnect these heterogeneous nodes, and interact with storage, supply chain, maintenance transfer, task and other systems.

Heterogeneous nodes lead to different communication protocols, data formats and data semantics, which challenges information exchange and efficient operation, and requires unified network data format. For the aircraft and other weapons, most of the status information is in specific data format, so the node of state monitoring usually uses specific data format for communication. Due to the advantages of XML structure and semantic information, more and more Internet of things systems and logistics information systems begin to use XML format for data transmission and exchange. Even in the environment of limited resources (such as wireless sensor network, RFID, etc.), it also uses various XML varieties or extensions to describe data, such as the ONS standard of RFID (sensor description language), transducer markup language, m2mxml (communication protocol between M2M devices), etc. According to the project requirements, the data format, data semantics and data scale of heterogeneous nodes involved in the active equipment support system are analyzed. The unified data description method of active equipment support system based on XML is designed.

Due to the flexibility of the physical system, the link relationship between nodes that constitute the active equipment support system is usually dynamic. For example, the logistics includes not only the warehouse node, but also the vehicle monitoring node and the changing loading and unloading equipment node. These nodes access information system through wireless network, but their connection status and access network location will continue to change. This project plans to design a multi-source heterogeneous gateway to act as an edge device to realize the dynamic access of heterogeneous nodes. Heterogeneous multi-source gateway supports the access of multiple heterogeneous communication protocols, and can convert other heterogeneous network packets to local protocol or from local protocol format to heterogeneous network protocol format. In addition, the heterogeneous multi-source gateway also supports the transparent transmission mode, which transmits other heterogeneous network packets to the local network through the tunnel. The gateway model is shown in Figure 1.

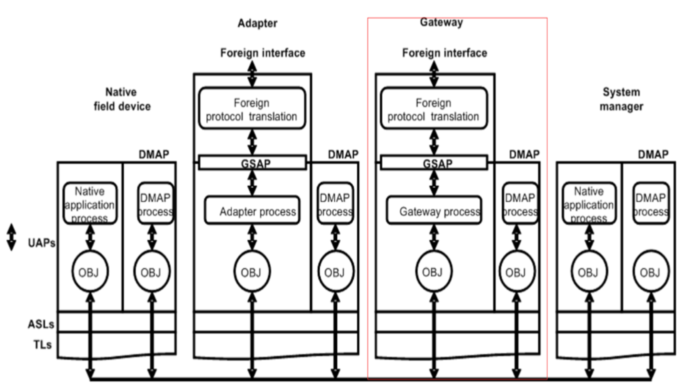

Fig. 1 Multi-source heterogeneous gateway model

In the gateway model of gateway, the gateway provides external network services through the gateway advanced interface, namely gateway service access point (GSAP). The protocol converter uses these service team communication packets provided by the gateway for protocol conversion through GSAP. Gateway process provides high side services for GSAP by using application object obj. The object communicates through the method provided by ASL. After the gateway receives the data sent by the external device, it processes the data according to the protocol type and data request type of the data, and processes the data packets by tunnel or direct conversion.

In the active equipment support system, due to the large number of access nodes and dynamic access, the system must have self-organization and adaptive functions, dynamically manage the access nodes, use software to define the network and network virtualization according to the changes of physical network, establish overlay network among a group of associated nodes, and adapt to the dynamic changes of physical network, As shown in figures 2.

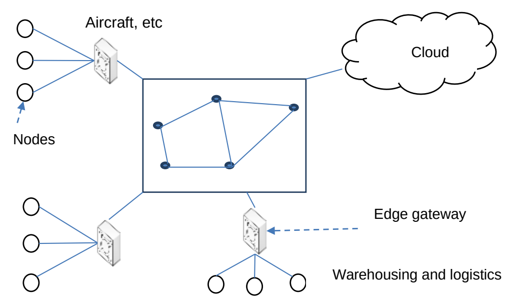

Fig. 2 Active equipment support system network

III. COOPERATIVE GUARANTEE DECISION-MAKING METHOD

The complex system support system can provide equipment health support decisions during the entire life cycle of equipment operations. For example, during the execution of the flight mission of the aircraft from point A to point B, the health protection system needs to be based on the location of the aircraft (such as the distance of resources that can be secured), the time required for protection (such as the time required to refuel or replace parts), Information such as the number of materials required (such as the number of required resources and the number of support personnel) to complete the equipment support task. Therefore, in the process of equipment health protection, resource data presents a collaborative multi-dimensional characteristic. Collaborative guarantee realizes multi-source perception of global resource guarantee resources and efficient resource scheduling decision-making through virtual and real linkage.

The assurance perception index divides the resource space hierarchy into multi-level subspaces, and the resource data can be mapped to a globally configurable multi-dimensional space in the platform, realizing real-time perception, coordinated deployment and effective decision-making of data resources.

Real-time resource perception forms a global multi-dimensional spatial mapping in the platform. Dimensional attributes include temporal and spatial relationships, attribute relationships, and association relationships. In collaborative guarantee, resource perception forms a dynamically reconstructed resource pool to obtain real-time available guarantee resources. The available guarantee resources have the ability of linkage decision-making. Collaborative linkage of guarantee resources is realized through data retrieval containing predicate relations, that is, whether specific guarantee information is within a certain range of guarantee scope, and provide global warehouse and maintenance factory coordinated linkage decision-making. For example, if spare part A exists in the local warehouse but spare part B does not exist, call A to quickly locate spare part B in the local warehouse. When performing resource coordination, guarantee resources realize multi-source compound scheduling and reconstruction through node attribute coordination.

For the rapid decision-making of tasks, support tasks form a variety of feasible execution tasks in the global perception resources, that is, the coordinated decision set J of equipment resources is decomposed into n support tasks J={j_1,j_2,…,j_n}, then for Maintenance job j_i, all of its execution flow constitutes a set. For the maintenance job set J, all feasible decision queues are obtained through real-time perception of historical data and resources, as shown in Figure 3. The cloud system divides the maintenance job set J into several maintenance job subsets to optimize the overall time execution time of each maintenance job subset. After obtaining the calculation queue, the cloud platform forwards the decision result to the intelligent guarantee service for execution.

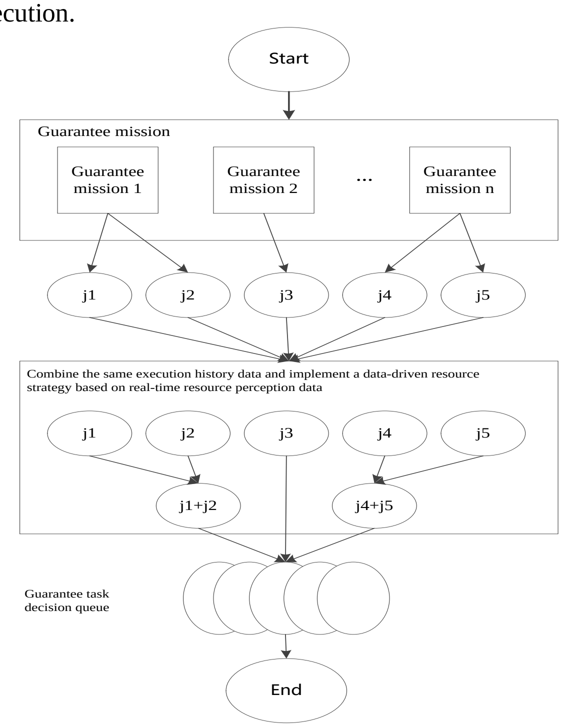

Fig. 3 Decision-making method for multi-operation equipment support based on graph time optimization

IV. INTELLIGENT GUARANTEE SERVICE BASED ON COLLABORATIVE MODEL

Equipment support involves the arrangement of support procedures, the deployment of support personnel and support resources and other services. In order to rationally allocate resources, reduce maintenance costs, and improve support efficiency, this project combines the complexity, distribution, and dynamics of the support operation process, and organically integrates personnel, materials, equipment, tools, time, location, and procedures, etc., and proposes equipment intelligent support service technology based on the collaborative model is developed.

Because the complex process of equipment support operations is distributed, each process node has a certain degree of independence, and at the same time, they are closely connected to form an indispensable part of the support work, and cooperate to complete the support task. The equipment support coordination model is shown in Figure 4.

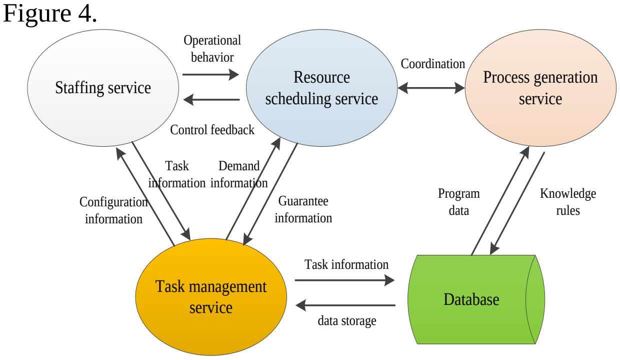

Fig. 4 Equipment support coordination model

The role of the task management service is to manage all the information related to the task, and to assign the guarantee task to the relevant guarantee executor. In the process of collaborative guarantee operations, the assignment of tasks plays a vital role in the smooth progress of follow-up operations. In order to improve the synergy effect in guarantee operations and meet the requirements of switching roles and operating resources in the dynamic environment of collaborative work, a dynamic allocation strategy is adopted to reallocate and adjust tasks at any time.

Personnel deployment service is to manage the personnel information in the operation process, and manage the specific operation authority of the operation personnel.

Resource scheduling service is a unified management platform for guaranteeing materials, equipment and tools, including information such as resource attribute parameters and status. The resource scheduling module is connected to the corresponding resource through the interface, and can also pass the job task request to the resource.

Process generation service is determined by specific guarantee tasks, corresponding to specific processes and managing related data and production scheduling processes. In addition to the interface for interacting with personnel and resources, the process generation module also includes a reasoning knowledge base for analyzing, processing and optimizing operating data.

V. TEST RESULTS AND ANALYSIS

The network fuel supply of active equipment support system is the most basic support operation for military aircraft to perform various tasks. The current airport fuel supply usually starts to dispatch refueling vehicles in place after aircraft landing. This scheduling method will not be able to meet the support demand of fuel supply in the future multi aircraft multi task cooperative combat environment. In addition, there is no real-time interaction and effective cooperation between the fuel filling system of the refueling vehicle and the fuel management system in the aircraft during the refueling process of military aircraft, which cannot achieve accurate and appropriate automatic fuel supply based on task information.

Combined with typical equipment support application scenarios of aircraft fuel system intelligent supply, through this scenario, aircraft fuel supply system overall architecture organization, aircraft fuel measurement node, aircraft fuel control node, fuel pump control node fusion modeling and optimization design, and airport refueling The realization of key technologies such as collaborative scheduling of vehicles demonstrates and verifies the effectiveness of the platform architecture, design methods and collaborative strategies proposed by the project. The ground core cloud platform monitors the military aircraft's fuel volume in real time, deploys follow-up missions based on the battlefield situation, and estimates fuel consumption for follow-up missions; aircraft fuel volume information and mission information are instantly transmitted to the airport equipment support management center, and are guaranteed The management system completes the unified deployment of fuel trucks, fuels, and personnel required for the intelligent service of military aircraft fuel supply before the aircraft lands. During the refueling process, the aircraft's fuel measurement node, fuel control node and fuel pump control node of the refueling truck complete accurate and appropriate fuel refueling control through local coordination to achieve efficient intelligent fuel supply guarantee for the aircraft.

The aircraft fuel system intelligent supply demonstration and verification platform consists of two parts, the equipment side and the support side, as shown in Figure 6. The equipment side mainly includes multiple types of sensors (liquid level, attitude, density, etc.), fuel measurement RIU, fuel control RIU, aircraft management computer (VMC), and integrated core processor (ICP). The support side is mainly composed of the core cloud platform, airport equipment support management system, vehicle management system, fuel truck, fuel pump control nodes, and multiple types of sensors (flow, pressure, opening, etc.)

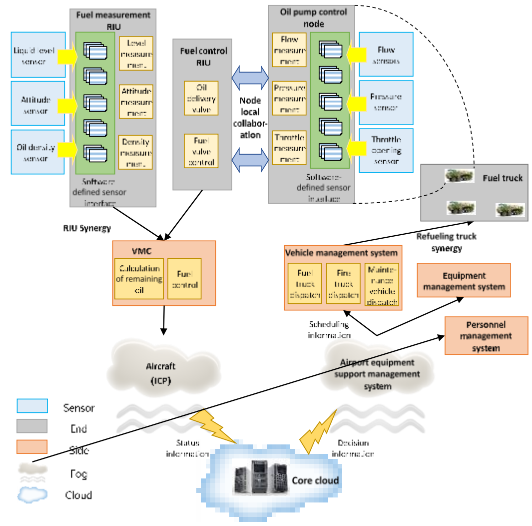

Fig. 6 The aircraft fuel intelligent supply simulation platform

The entire simulation platform will be organized and constructed in accordance with the "cloud-fog-edge-end" heterogeneous inclusive architecture proposed by the project. The platform is equipped with two mainstream liquid level sensors (capacitive and optical), oil density sensors to measure fuel tank liquid level and oil density values, and attitude sensors to measure pitch angle and roll angle information. The software-defined sensor interface is used to connect multiple sensors and RIU to verify the software-defined autonomous organization and adaptation technology; the RIU unit uploads the collected liquid level data, flight attitude data and oil density data to the VMC, and the VMC calculates the remaining fuel tank the fuel quantity is sent to the core cloud platform through ICP. This part of the scene verifies the unit interconnection and edge aggregation technology of unified network data; the core cloud platform receives the status information transmitted by the ICP in real time, and performs the overall situation according to the aircraft status information and subsequent mission requirements Control, and send the decision-making information to the airport equipment support management system; the airport equipment support management system conducts unified scheduling and management of airport logistics support (such as vehicle management, resource management, and personnel management) based on the acquired decision information; this part of the scene will Mainly demonstrate fueling process generation, fueling truck scheduling and personnel deployment, and display it in real-time in the simulation system, verifying the collaborative support decision-making technology based on time efficiency optimization and the intelligent support service based on collaborative models; finally, the fuel refueling process will mainly demonstrate fuel Local coordinated and precise control of the measurement node, the fuel control node and the fuel pump control node of the fuel truck.

VI. CONCLUSION

Aiming at the optimization of equipment support time, the cooperative support resource awareness technology is proposed firstly. The hierarchical fast positioning method of support resources, the multi matching mode supporting complex strategies and the fast reconfiguration method of support resources are established through multi-level regional balance division. Then, a data-driven collaborative support task decomposition and decision-making mechanism is proposed to give full play to the comprehensive efficiency of dynamic and networked maintenance system.

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