Research on a Management Control System in Space-Terrestrial Integrated Network

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Abstract. In order to improve the efficiency and stability of Space-Terrestrial integrated network resource management and control, a multi-element multi-domain network management protocol (MMMP) is proposed. Based on MMMP, Space-Terrestrial integrated network management and control system (STi-NMCS) is designed. By abstracting network management objects, the efficiency of network management is greatly improved. Experiments are carried by comparing the overhead and the success rate of network management between MMMP, simple network management protocol(SNMP) and common management information protocol (CMIP). The results show that by using MMMP rather than SNMP as well as CMIP, the Space-Terrestrial integrated network management system archives high success rate and low management overhead.

Keywords: Space-Terrestrial integrated network · Network management · Management integration

1 Introduction

Space-Terrestrial integrated network has a series of features such as broad coverage, flexible networking, none geographical restriction and so on. It has received the attention of many countries and institutions. At present, a Chinese satellite network is still in the experimental stage, single satellite telemetry and remote control is still the basic management mode of all satellites and the industry has not yet designed a mature network management and control system for the Space- Terrestrial integrated network. Under the background that satellite networking has become an important development trend [1–3], the research and

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design of management and control system based on Space-Terrestrial integrated network has important application value and engineering significance.

Aiming at the characteristics of Space-Terrestrial integrated network, such as network heterogeneity, multi-information, high dynamic change of topology, complex and diverse management equipment, this manuscript proposes a multi-element multi-domain network management Protocol [4]. Based on this protocol, STi-NMCS is designed, which manages and processes network information from six aspects: platform management, node management, user management, resource management, performance management, security management, greatly improving the management efficiency of the Space-Terrestrial integrated network. The Space-Terrestrial integrated management and control system studied in this manuscript has the following characteristics:

– Referring to the telemetry and remote-control systems of various satellite platforms at home and abroad, a management and control system based on satellite network is designed, which can achieve the management and control objectives of "The whole network visible while anyone satellite visible, the whole network controllable while anyone satellite controllable".
– According to the characteristics of satellite communication environment, a multi-element multi-domain network management protocol is designed, which not only reduces the communication overhead of network management, but also ensures the efficiency and timeliness of management and control.
– Modular design and abstract mode are adopted to manage and control the objects of Space-Terrestrial, realize modular management of platforms, equipment nodes, network users, resources, performance and security, visually display the real-time status and situation of each module and strengthen the control system user friendliness and management effectiveness.
– The Space-Terrestrial network management and control system is designed based on modularization, which has strong expansibility and can add new management and control functions conveniently according to management requirements without increasing system management overhead.

STi-NMCS provides an integrated solution for the management and control of space information network. It provides a reference for solving the problem that China cannot manage and control all on-orbit satellites in real time and effectively because ground stations can't be built around the world casually, which makes certain research significance.

2 Analysis of Research Problems

Due to the extremely harsh conditions of satellite communication and the complexity of networking, the management and control of the Space-Terrestrial integrated network is the key to ensuring the effective operation of the integrated network. The complexity of the Space-Terrestrial integrated network management and control is mainly reflected in some aspects.

The first one is the complexity of the space network environment. Due to the high-speed operation of satellites in space orbit and the long distance between satellites, the channel is easily interfered by the space environment including temperature, radiation and other factors, resulting in excessive data transmission loss and excessive signal attenuation. Satellites and spacecraft orbiting the planets for high-speed rotating cloud motion, and link breaks are likely to occur between network nodes. In summary, the space network has the characteristics of high latency, high bit error rate, dynamic topology changes, and unstable communication links.

Secondly, the complexity of network management technology is an important feature of space networks. With the rapid development of computer networks, the network becomes more and more complex, and the structure level is more and more diversified. The specific performance is that the various protocols put into application in the industry are complex and diverse [5]. Usually, a network management system needs to support different functions, such as communication protocol, alarm monitoring, traffic management, task concurrency, fault detection and analysis, data interaction, etc. At the same time, it also needs to consider the network management technology when the architecture of the space network needs to be changed in the future. So, the complexity of network management technology is more obvious.

The complexity of space network equipment is another major feature. In the early days, each satellite platform was developed for a specific task. Due to the simplification and security considerations of application design, different satellite systems are independently designed and isolated from each other, arising a major problem that the difference in the satellite equipment of different constellations is significant. The real need for the development of space-integrated networks is to build these multi-heterogeneous networks into networks and make full use of space network resources. Therefore, how to manage complex and diverse space devices is a serious problem.

With the rapid development and gradual maturity of research on micro-satellite platforms at home and abroad in recent years, the conflict between management requirements and resource constraints will become more and more intense in the future when the number of satellites increases sharply. Due to Chinese special national conditions, it is currently impossible to establish stations on a global scale. Therefore, the construction of a satellite-based network management and control system has become an important solution. The goal is to achieve "The whole network visible while anyone satellite visible, the whole network controllable while anyone satellite controllable" with real-time and high-efficiency control of the Space-Terrestrial integrated network.

3 Network Management Protocol

3.1 Traditional Network Management Protocol

The satellite Space-Terrestrial integrated network management protocol is an improved model derived from the traditional ground network management protocol [6,7]. Although the satellite network management protocol is more complex

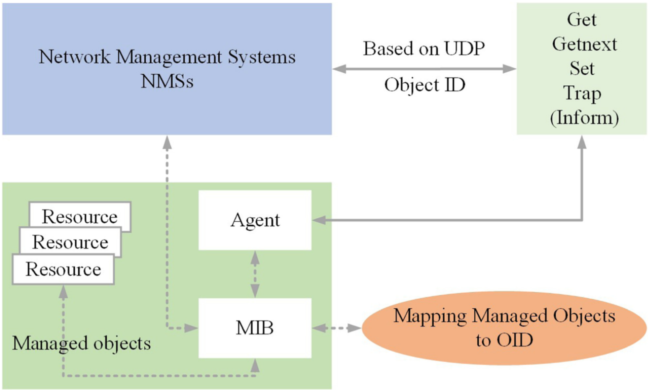

Fig. 1. Structure of simple network management protocol.

due to its specific network characteristics and special communication environment, it can be analyzed by analyzing the traditional terrestrial network management protocol [8,9]. The characteristics, development, application status and respective advantages and disadvantages of network management are more fully understood. In the modern network management system, it mainly includes four parts: Network Management System (NMS), Agent, Management Information Base (MIB) and Network Management Protocol (NMP) (Fig. 1).

Simple Network Management Protocol (SNMP) is proposed by Internet Engineering Task Force (IETF), while Common Management Information Protocol (CMIP) is proposed by International Organization for Standardization (ISO). Besides there are ANMP (Ad Hoc Network Management Protocol) [10], WMI (Windows Management) Instrumentation), CTL (Command-line interface), Netconf and so on. In these protocols, each implementation standard has its own application scenarios and advantages and disadvantages. For example, the SNMP protocol is applicable to TCP/IP networks, while CMIP originally originated from the telecommunication network, and the ANMP protocol is based on the improved SNMP protocol. A protocol for early Ad hoc network management.

SNMP is an application layer protocol based on UDP transmission. The SNMP management program does not need to establish a connection in advance during the interaction process with the agent of the managed device, so the communication overhead for the device system is low. The SNMP management program manages and monitors the managed devices of the entire network by polling, setting keywords, and monitoring pre-set special network events. The structure of the SNMP protocol is divided into Manager and Agent in Fig.Structure.

Another mature network management protocol is the Common Management Information Protocol (CMIP), which is a TCP-based connection-oriented application layer protocol, and is proposed by ISO for the management protocol in the terrestrial typical network framework. Unlike SNMP device management based on polling mechanism, CMIP is based on event reporting management. CMIP includes a Manager, a proxy running on a managed device, a set of protocol description modules, a common information management structure CMIS (Common Management Information Structure) and a series of operational primitives during communication operations. Figure 3 shows the CMIP management structure. Similar to the SNMP, CMIP also has information exchange between the manager and the agent according to the management information base and the respective agreement protocols. The difference is that the management party and the managed agent of the SNMP are one-way and irreversible. In a group of information interaction process of the CMIP, a device can be either a management terminal or a managed device to send device information through a proxy.

CMIP is highly complete and the management information is very complete. The device computing resources occupied by the CMIP are dozens of times that of SNMP. Therefore, the protocol has high performance dependence on the deployed devices and high device management overhead. CMIP runs a large number of processes while running network agents, so the burden of network agents increases dramatically.

3.2 MMMP

MMMP is a connection-oriented network management protocol in the application layer. In order to distinguish the transmission service from the lower layer to the connection, the transmission mode of the lower layer can be determined by the management entity through negotiation during the establishment of the connection. Therefore, the case that management information is blocked or delayed due to connection-oriented services of CMIP can be avoided. What‘s more, the case that management information is not reachable or discarded due to the completely connectionless services supplied by SNMP, which has an obvious impact on the notification of key events and the statistical calculation of indicator parameters.

In order to enable two MMMP management entities, i.e. management requesters and Agents, to communicate with each other, it is necessary to establish a management relationship between them, which involves the linkage mechanism of MMMP. The purpose is to establish management and application services, so as to make management activities more standardized and reliable. In the research on the structure of network management system, this manuscript organizes network management information and elements based on object-oriented method. Besides encapsulated attributes, the agents contain actions, parameters and announcements. Besides creating and revoking instances of agents, the Execute-service also specify some agents to execute corresponding actions.

Network managers keep query function for agents through Get-service, mainly to obtain the attribute values of agents; Set-service implements the modification service to agents which setting the attribute values of managed instances, including setting the attribute values to new ones or restoring default values; Inform-service, as an announcement of management information, can be either

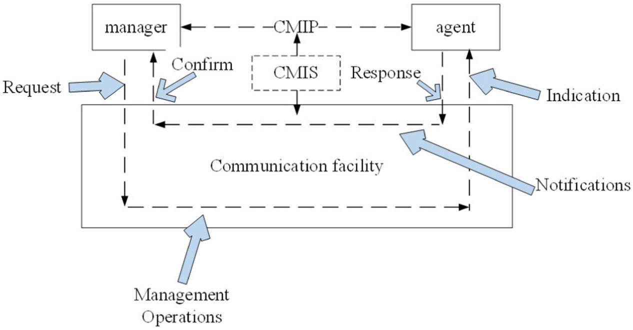

Fig. 2. Structure of common management information protocol.

from the management station to the agents, or vice versa. Cancel-service can be used to cancel a query operation or terminate an ongoing task, or to release the reserved resources; Resources-service and Mission-service can complete the corresponding resource and task management (Fig. 2).

3.3 Design of STi-NMCS

The integrated network management and control system is designed in the space information network. Because satellites are in high-speed orbit from hundreds of kilometers to thousands of kilometers, it is unrealistic to maintain the normal operation of satellites by means of on-the-spot maintenance. It is necessary to manage the status of satellites by remote and select the corresponding solution. Therefore, how to monitor the real-time status and parameters of the network as well as satellites and how to manage users in the space network are of particular importance. This manuscript divided the management and control system into the series modules including platform management, resource management, performance management, user management, node management and security management.

Platform Management: Platform management refers to the intuitive representation of the state of the Space-Terrestrial integrated network, including the whole network topology, the location of whole network equipment, the user list and the application list, analyzing the whole network state from different levels.

Resource Management: Resource management in integrated network includes computing resource management, network resource management and storage resource management, which contains the following aspects such as streaming table of LEO satellite, available bandwidth, real-time bandwidth, bandwidth utilization, packet loss rate, number of forwarding packets, forwarding packet rate and so on. Resource management is a very important part of integrated network management. It serves space tasks directly and provides available resource in physical layer, link layer and network layer for the scheduling of tasks.

Performance Management: Performance management is a vital part of the maintenance of integrated network. With the continuous expansion of network services, the increasing amount of spatial data transmission, the expanding of Multi-heterogeneous spatial network structure and the increasing demand for integration network construction, It is the core topic of integrated network performance management on how to grasp network performance more efficiently and conveniently In addition, as well as on how to enhance the reliability of integrated network and identify potential network risks.

- Define Management Areas. The increase of management domain means the expansion of management scope. The system overhead of network management system will also increase. Therefore, different management domains should be reasonably divided according to the specific functions of different modules.
- Select Performance Indicators. Network performance parameters are indicators to evaluate the performance of integrated network management and control system. These indicators directly reflect the network status and predict the trend of network development to a certain extent. The performance indicators selected in this manuscript include aspects such as satellite node routing information, link current bandwidth, traffic tracking, during of service response, bandwidth utilization, network bottleneck detection and so on.
- Analysis of historical performance data. It is limited to manage the performance of integrated networks by manual or regular means, which can neither accurately analyze, nor meet the needs of the rapid growth of the volume. In this way, analyzing on historical performance data is an extremely important research content. The conclusion can be drawn through the analysis of historical performance data. Computing with the current real-time status and parameters can provide more comprehensive and accurate services for the integrated network management system.
- Visual display. By making full use of real-time state and parameters, visualization technology is used to display the state of spatial network in real time and intuitively, which provides an intuitive reference for network administrators to carry out network analysis and expand new services.

User Management: An important challenge is how to manage users in the integrated network. There is no way to predefine the users and the tasks performed by users except for dynamic management technology. The difference between network management technology and network management users is very obvious that technology and physical information of satellite nodes can be clearly defined, but users in space network are a dynamic and complex concept. The prediction of users in space network is compared with real-time satellite state and space network parameters. Predictions are much more complex. User management generally includes a very important part of the specification of user behavior in integrated network. Users with different priorities have different levels of operation rights and instruction levels. Tasks with different priorities have different scheduling orders and scheduling modes.

Node Management: Node management mainly includes real-time operational data, measurement and control data of each satellite platform. By analyzing the node list, device parameters, node real-time status and network management mode, the operation status of the single satellite platform is visually displayed, which provides administrators with management and operational basis.

Security Management: Security management is mainly oriented to the integration of network management and control under network anomalies or specific situations. In this manuscript, fault management, authority management and regional resistance are included in the scope of security management. Privilege management mainly aims at setting the privileges of system administrators and commanders. STi-NMCS displays the information within the privileges and effectively avoid the leakage of sensitive information. Regional denial refers to a function that denying access of services in a particular region with specific states.

3.4 Modeling of MMMP

Space-Terrestrial integrated network has these characteristics' rapid changes in topology, limited transmission bandwidth, high link error rate, large transmission delay, and vulnerability to external interference. We pay attention to the following evaluation indicators: packet loss rate, delay, throughput. We can evaluate the performance of the protocol by substituting typical parameters of different protocols.

Packet loss rate is defined as the ratio of the number of lost packets to the number of packets transmitted during a certain period of time.

$$R = 1 - \prod_{i=1}^{n} \left(1 - \frac{L_t}{C_t}\right) \tag{1}$$

where R is the packet loss rate, L_t is the number of packets lost in time t, C_t is the number of packets transmitted in time t, n is the number of paths the packet passes.

The delay of end-to-end transmission mainly consists of transmission delay, propagation delay and routing delay. The routing delay is composed of processing delay and queuing delay. The total delay of the link is

$$T = \sum_{i=1}^{n} \left(\frac{L}{B_i} + \frac{D_i}{V} + P_i + Q_i\right) \tag{2}$$

where T is the end-to-end delay, L is the packet length, B_i is the i-th path bandwidth, D_i is the spatial distance of the i-th path, and V is the transmission speed of the signal in space, which can be approximated as the constant C, P_i is the processing delay of the data packet in the i-th router, and Q_i is the queuing delay of the data packet in the i-th router.

Throughput represents the maximum rate of information transfer without losing packets.

$$\rho = \frac{L}{\Delta T} = \frac{L}{\frac{L}{B} + T} = \frac{\sum_{i=1}^{n} L_{pi} \cdot 8}{\sum_{i=1}^{n} L_{pi} \cdot 8/B + T} \tag{3}$$

Where L is the total length of the data packet, L_P is the packet length of a certain protocol, n is the number of data packets, each byte is 8 bits, and ΔT represents the measurement time, which is composed of processing time and inherent delay.

4 Experimental Evaluation

Based on Qualnet simulation platform, this manuscript constructs a Space-Terrestrial integrated network with 100 LEO satellites. On the basis of this simulation platform, the management and control system for integrated network is designed and completed. The efficient control and management of network resources, network performance and network equipment are realized. As shown in Fig. 3.

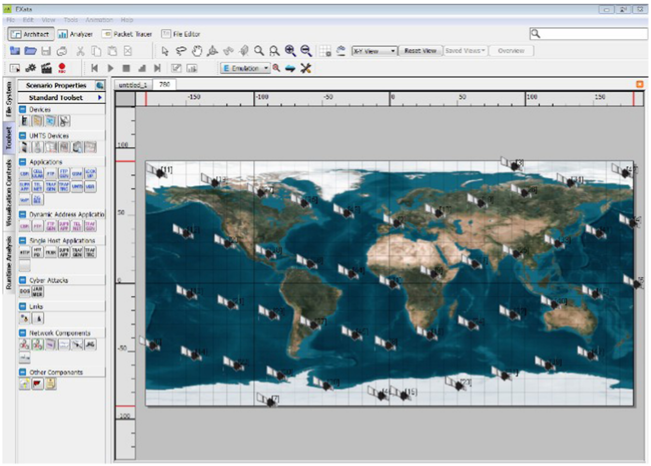

Fig. 3. Real-time topo of the Space-Terrestrial integrated network.

Figure 4 shows the control interface of the management and control system designed and implemented in this manuscript, which can query and respond to network status according to different network management objectives, and can manage and monitor typical network dynamic indicators and real-time parameters in real time.

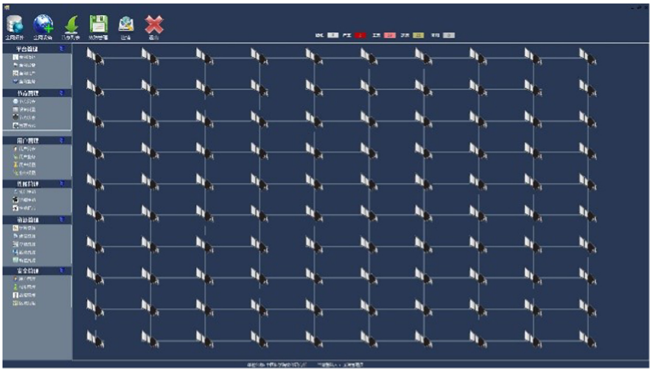

Fig. 4. The control panel of management control system in the Space-Terrestrial integrated network.

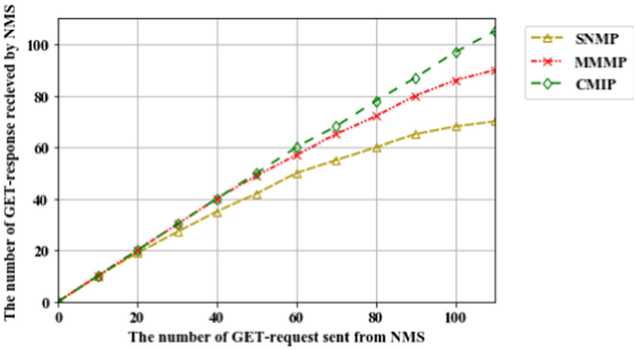

Fig. 5. The number of responses received varies the number requests sent by NMS.

Figure 5 shows the relationship between the number of GET data responses received by SNMP, MMMP and CMIP network management system (NMS) and the number of GET operation instructions sent by NMS. From the analysis, it can be seen that the CMIP protocol represented by the green line has less packet loss and can fully respond to the basic management operations of the management side. Obvious packet loss, because SNMP is for connectionless data transmission; red line represents the MMMP protocol also has packet loss, but not obvious, basically able to respond to the management operation of the management side.

Figure 6 shows the relationship between the number of response data sent by agent of SNMP, MMMP and CMIP protocol and the number of GET instructions received. The agent of CMIP protocol frequently carries out data retransmit operation, which is more obvious when the overhead of management is large. SNMP protocol does not carry out data retransmissions, because it's based on UDP data transmission without reliability of data transmission. MMMP protocol

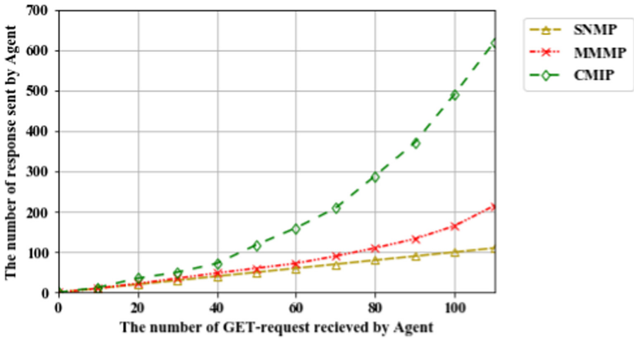

Fig. 6. The number of responses sent varies the number requests received by Agent.

has a certain number of retransmissions when the network management overhead is large, but does not affect normal network management operations.

5 Conclusion

In view of the difficulties, complexity and resource constraints of future space integration network management and control, this manuscript designs a multi-domain network management protocol, which can effectively manage the equipment in each management domain of the whole network without increasing network management redundancy, reducing network overhead and ensuring real-time performance. On this basis, an integrated network management and control system is designed and implemented, which is designed and summarized from six aspects: platform management, user management, performance management, security management, node management, business management and so on. The simulation results show that the Space-earth integrated management and control system designed in this manuscript has good comprehensive performance and efficiency, which has important support significance for the construction of the Space-earth integrated network, especially for the Space-earth integrated management and control.

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