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A Satellite Networks Fault Management Method based on Cooperation

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Abstract: Different from terrestrial networks, satellite network topology is time-varying. Moreover, satellite networks communication resources are scare and expensive. So it is important to research on the fault management for satellite networks to insure it work safely and smoothly. However, the traditional fault management method for terrestrial networks is difficult to use for satellite networks. In this paper, the satellite networks topology is studied and the satellite networks management architecture is established. Based on these the three level management mechanism is proposed and put forward a new fault management method for satellite networks. When a satellite agent could respond to the network management instruction received from the management station, the traditional fault management method was used through network management technique. If the satellite could not respond to the network management demand, the intra-domain cooperation or inter-domain cooperation would be activated. The suspected fault satellite could be tested through cooperation among the satellite agents in satellites. The simulation results shows that in the circumstance of the low faulty frequency, the new method could be effectively used in satellite network with short cooperative time and low throughput.

Keywords: Satellite networks; network management; fault management; cooperation

1. Introduction

In terrestrial networks, many links and nodes are needed to reach long distances and cover wide areas. They are organized to achieve economical maintenance and operation of the networks. The nature of satellite networks makes them fundamentally different from terrestrial networks in terms of distances, shared bandwidth resources, transmission technologies, design, development and operation, and costs and needs of users [1].

Functionally, satellite networks can provide direct connections between terrestrial networks [2]. The user terminals provide services and applications to people, which are often independent from satellite networks, i.e. the same terminal can be used to access satellite networks as well as terrestrial networks. The satellite terminals, also called earth stations, and are the earth segment of the satellite networks, providing access points to the satellite networks for user terminals via the user earth station (UES) and for terrestrial networks via the gateway earth station (GES). The satellite is the core of satellite networks and also the centre of the networks in terms of both functions and physical connections [3].

The most important roles of satellite networks are to provide access by user terminals to internetwork with terrestrial networks [4] so that the applications and services provided by terrestrial networks such as telephony, television, broadband access and Internet connections can be extended to places where cable and terrestrial radio cannot economically be installed and maintained. In addition, satellite networks can also bring these services and applications to ships, aircraft, vehicles, space and places beyond the reach of terrestrial networks. Satellites also play important roles in military, meteorology, global positioning systems (GPS), observation of environments, private data and communication services, and future development of new services and applications for immediate global coverage such as broadband network, and new generations of mobile networks and digital broadcast services worldwide.

With the development of satellite networks, they have grown up to be a common user system, and widely adopted in both commercial and governmental use. As is true for many systems, satellite network has transitioned to become IP-centric [5] to be compatible with baseband applications that have become crucial for many missions, and especially for forces deployed to areas having little or no communication infrastructure. This greater reliance on commercial satellite network has benefited the war fighter by allowing rapid infusion of IP-centric efficient systems. The efficiency of this system is a core attribute of the commercial market, which embraces the principles of optimizing total system cost inclusive of capital acquisition and operational cost. In general these systems have been standards-based, but commercial market segmentation has caused these systems to be optimized for the various market segments they served ranging from small to large networks and from hub-spoke to mesh topologies. Satellite network has become a hot topic and the recent research has focused on the satellite network fault diagnosis. In [6], a real-time monitoring and diagnosis technology is used in satellite telemetry data. The satellite fault diagnosis technology is also researched in [7]-[9]. However, in these literatures the satellite is taken as a single isolated entity. The fault diagnosis methods are used to find the faulty of the components. In [10], a mend fault diagnosis algorithm is proposed for satellite networks. The algorithm supposes that when the fault diagnosis is proceeding; the topology of satellite network is unchanged. So satellite networks fault diagnosis must be completed in a little time based on this algorithm. It is difficult to satisfy these conditions in reality.

According to the time-varying geometry characteristics and real-time fault diagnosis requirements an efficient and effective satellite networks management [11]-[14] method based on multi-agents[15, 16] is proposed in this paper in order to deal with the threats from networks [17]-[21]. The experiment [22] results show the method can reduce the resources of satellite communication [23].

In this paper, the first section introduces the development of satellite networks and the necessity to research its management method. In the second section the satellite network architecture is described. The following section establishes satellite networks management architecture, and discussed the mechanism of how to establish management domains and their components. The fourth section details and researches a satellite networks fault management method based on cooperation among the satellite networks management agents. The experiments results and the analysis base on them shows that the method proposed in this paper is effective in the end.

2. Satellite networks architecture

Satellite networking is an expanding field, which has developed significantly since the birth of first telecommunication satellite, from traditional telephony and TV broadcast services to modern broadband and Internet networks and digital satellite broadcasts. Many of the technological advances in networking areas are centered on satellite networking. With increasing bandwidth and mobility demands in the horizon, satellite is a logical option to provide greater bandwidth with global coverage beyond the reach of terrestrial networks, and shows great promise in the future. With the development of networking technologies, satellite networks are becoming more and more integrated into the GNI. Therefore, internetworking with terrestrial networks and protocols is an important part of satellite networking.

The ultimate goal of satellite networking is to provide services and applications. User terminals provide services and applications directly to users. The network provides transportation services to carry information between users for a certain distance. Figure 1 illustrates a typical satellite network configuration consisting of terrestrial networks, satellites with an inter-satellite link (ISL), fixed earth stations, transportable earth stations, portable and handheld terminals, and user terminals connecting to satellite links directly or through terrestrial networks.

Like terrestrial networks, satellite networks are increasingly carrying more and more Internet traffic, which now exceeds telephony traffic. Currently, Internet traffic is mainly due to classical Internet services and applications, such as WWW, FTP and emails. Satellite networks only need to support the classical Internet network applications in order to provide traditional best-effort services.

To support IP over satellites, the satellite networks need to provide a frame structure so that the IP data-

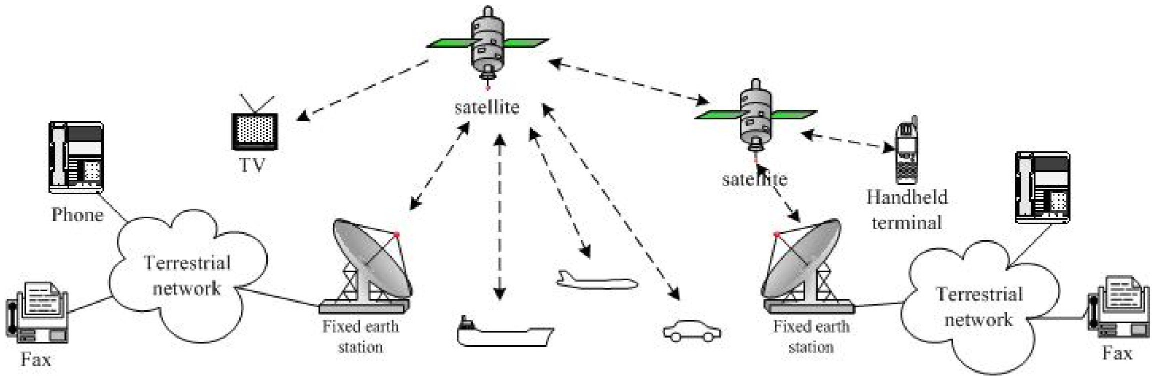

Figure 1 Typical applications and services of satellite networking

gram can be encapsulated into the frame and transported via satellite from one access point to other access points. In a satellite environment, the frame can be based on standard data link layer protocols. Encapsulation of IP is also defined in the existing networks, such as dial-up link, ATM, DVB-S and DVB-RCS, which support Internet protocols or internetwork with the Internet. ATM networks use ATM adaptation layer type 5 (AAL5) to encapsulate IP packets for transmission over the ATM network, and in DVB-S, IP packets including multicast are encapsulated in an Ethernet-style header using a standard called multi-protocol encapsulation (MPE).

It is also possible to encapsulate an IP packet into another IP packet, i.e., to create a tunnel to transport the IP packets of one Internet across another Internet network.

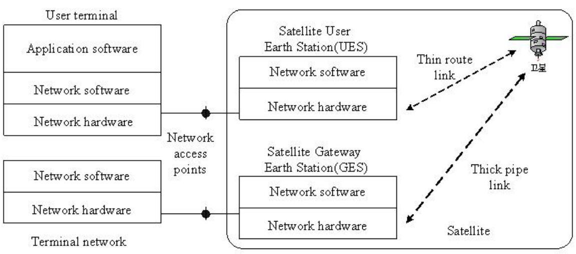

Figure 2 Functional relationships of user terminal, terrestrial network and satellite network

3. Satellite networks management architecture

Current and proposed satellite communications networks use low earth orbit (LEO) constellations as well as geosynchronous (GEO) satellite systems. GEO satellites have a high propagation delay but a few satellites are enough to provide connectivity across the globe. LEO satellites have lower propagation delays due to their lower altitudes, but many satellites are needed to provide global service. While LEO systems have lower propagation delay, they exhibit higher delay variation due to connection handovers and other factors related to orbital dynamics. The effects of the propagation delays are further intensified by the buffering delays that could be of the order of the propagation delays especially for best effort TCP/IP traffic. The large delays in GEOs, and delay variations in LEOs, affect both real time and non-real time applications. Many real time applications are sensitive to the large delay experienced in GEO systems, as well as to the delay variation experienced in LEO systems. In an acknowledgment and timeout based congestion control mechanism (like TCP), performance is inherently related to the delay-bandwidth product of the connection. Moreover, TCP Round Trip Time (RTT) measurements are sensitive to delay variations that may cause false timeouts and retransmissions. Therefore the space environment also affects the communication between the satellites. So satellite network management is faced with a lot of challenges.

As an important establishment which is the access to space systems, ground systems seamless. Satellite network is playing an extremely important role in fields such as the defensive and economic construction of the nation. But in order to make such a highly complex, dynamic heterogeneous network operate effectively and credibly, satellite networks must be effectively and efficiently managed to ensure that the network resources and information can be correctly regulated and configured. It should adapt to changes of the application tasks, oneself and the external condition and deal with complex emergency situations.

According to the time-varying geometry of satellite network, a dynamic hierarchical network management system has been put forward in [4]. Based on this system architecture, the satellite network management system is divided into three levels. The first level is the central management station deployed on the ground, which is responsible for the management of sub-station and in charge of creating the satellite network topology, etc. The second level is consisted of the sub-stations deployed on the ground. These sub-stations are responsible for managing the satellite agents in the management domain and creating the local network topology. The upper level is consisted of satellite agents which are managed by the sub-stations and the central station. The satellite network management level is shown in Figure3.

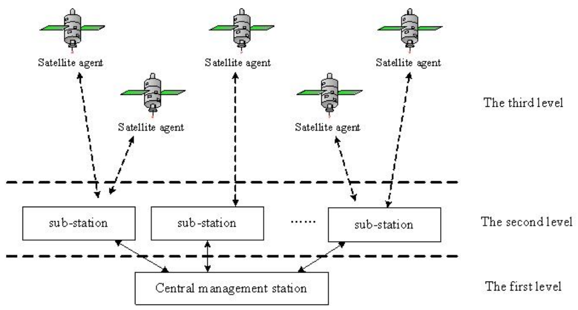

Figure 3 Satellite network management architecture

In the satellite network management architecture [24], the sub-station and the satellites agents composed a management domain. Satellite agents could dynamically registered in and logged out the management domain according to the communication delay between the sub-station and the satellite agents [25]. For the whole satellite network there are multiple management domains existing. A management domain is the aggregate of satellite agents which have registered in the management sub-station on the ground. The aggregate updates dynamically. When a new satellite agent wants to join the management domain, it first registers to the management sub-station. Then the management sub-station justifies the satellite agent. If the satellite agent is accepted, it could be managed by the sub-station. This network management mechanism is suitable to satellite network of the time-varying geometry [26].

As for the network management, a clear division of management domains contributes to enhancing the scalability of the system and avoiding the duplication operations. In the traditional network management, the division of management domains is usually by the geography or structure due to the fact that most of the network device nodes are fixed. That is to say, firstly determine the location of the station manager, and then do topology configuration according to the geographical location of the network nodes and designate a management domain corresponding to the station manager. Once the management domain is identified, the nodes inside the domain can not casually move to another management domain. This management mechanism is able to ensure that the network management applications won't be overlapped, and because of the relatively fixation of network nodes, network topology management is also relatively easy to be implemented. However, this management domain partition method can not be applied into satellite networks [27].

Referring to the satellite network, the mobility of the satellite (or constellation) and frequently dynamic changes of the network topology are due to provisional of the links, so the network management domain must have a clear division of ownership in order to avoid overlapped management operations. At present, researchers have proposed the management domain splitting strategy based on the delay tests and management domain splitting strategy based on delay and hop counts. The basic idea of these strategies is to make the proposed algorithm reduce the negative impact on link delay brought about to the satellite network management. In order to achieve a dynamic division of management domains, the satellite nodes must be able to dynamically register to the management domain and logout from the management domain, this paper proposed the alteration mechanism of satellite network management domains based on login and logout, and designed the communication primitives. It is noted that this paper assumes that the satellite network will use SNMPv3 as its management protocol in the future [28, 29]

In the initial state, all satellite network sub-station managers located on the ground periodically broadcast the login packets to satellites within its ken. Such a broadcast packet provides a chance of validation when the satellite joins the management domain. The role of the broadcast packet is similar to the public access channel of mobile communication systems. The login and logout mechanism provide a good flexibility and scalability for the satellite network nodes to access.

The satellite registers to internal initialization sub-station manager after entering the orbit. When the satellite goes through another sub-station manager and receives the registered packets, it records the information of the sub-station manager and sends the delay test information. Then it compares the communication delays to different station managers according to the delay test results and determines whether to move to another management domain. The delay test process can reduce the impact of the communication delay on network management. The login and logout mechanism can improve the effectiveness and accuracy of the network management.

The management domains of the sub-station manager are a collection of all the registered satellite nodes, which is dynamically updated and can be flexible to accept new satellites. When a new satellite node joins the network, it does not need to know the distribution of the station managers in the network. With its own orbit operation and doing a certain degree of security authentication, it can register to the sub-station manager flexibility. This login and logout mechanism of the satellite network ensures that the satellite nodes do not depend on a specific management of the sub-station manager. Especially when a few of the sub-station manager are paralyzed due to the failure, it is still able to effectively manage the satellite nodes. But the temporary satellite launched for the specific tasks does not have to notice all of the station managers before the launch.

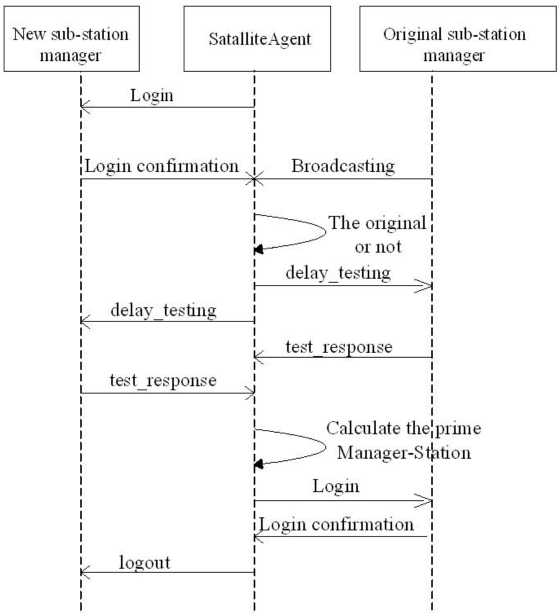

Figure 4 Timing sequence diagram of the login & logout mechanism

Having the synchronization data between the sub-station managers and the central managers, network managers can be kept informed of launching a new satellite into orbit because of an emergency situation. At the same time, this login mechanism can be easily expanded. Because it is a long course to establish and operate the satellite network, the size of the initial network construction will be limited. The dynamic division of the management domains and the way the network elements (including satellite and the station manager) join the network will not impact the whole network management systems and can maintain stability of the system to some extent. The timing diagram of the login and logout mechanism is shown in Figure 4.

4. Fault detection method

An efficient fault detection method could efficiently and effectively support the satellite network. So the satellite network fault detection is a hot topic. In order to establish the satellite network fault detection method and give prominence to the main problems for the fault detection, we supposed with simplicity. Firstly in this satellite network the network management protocol was SNMP, the central management station and the sub-station run the satellite network management system. Each satellite runs the SNMP agent (called satellite agent, SA). Secondly the fault of communication link is not considered in this paper. So the communication link could provide satisfactory services. Thirdly, the management domain which satellite agents belong to remains the same during the management sub-station polling all the satellites agents in this domain. In order to define the fault of satellite network, this paper defined the fault as three types: node fault, agent fault, interface fault. In satellite networks, if satellite node can not be managed normally in network, namely, the satellite has no response to the network management instructions (SNMP instructions), and each satellite interface can not be connected, we define this kind of fault as node fault. In satellite network, if the satellite network node could be managed normally, but at least one interface can not be used to communicate, we define this type of fault as agent fault. In satellite network, if the state of one port in nodes-switcher of satellite is failure, or the port can not communicate with others, we define the satellite which is corresponding to the port as agent interface fault.

4.1 Fault detection based on SNMP protocol

By polling the MIB information in the network node, the management sub-station can judge whether the work condition of each interface in the satellite is proper. The decision can be made according to the value of the ifOperStatus. If the value of the ifOperStatus is zero, it shows the interface is faulty, otherwise the interface works properly. On the other hand, the congestion and link failure of each interface in the satellite can also be detected by analyzing the data of the interfaces. Each management sub-station manages the satellite within its management domain and reports the state information data of all the interfaces in each satellite on management center after the polling is finished. The management center could establish the whole network topology according to the MIB information.

4.2 Fault detection based on the cooperation

When the node is fault, the management sub-station cannot differentiate the satellite node fault or the interface fault, for the fault node could not respond to the polling from the management sub-station. Namely there is no response after the management sub-station sending the network management instructions. Only when all satellite interfaces are justified by fault, the satellite node fault could be deduced. But how to deduce all satellite interfaces fault is difficult. In this paper a lightweight and efficient fault detection method is put forward. This method is based on the cooperation among the satellite agents. The cooperation algorithm is described as follows.

1) When the SNMP command from the ground management sub-station could be responded by the satellite agent, the satellite node then checks up the node as suspected fault node, and initializes a new cooperation.

2) The management sub-station decomposes and synchronizes the tasks, and separates the task to a series of MetaAction.

3) Moreover, the sub-station manager synchronizes tasks and determines the execution sequence of each MetaAction.

4) After the upper three steps, the sub-station manager establishes the theoretical topology and actual topology of management domain in which the suspected fault node is belonged to. Based on these topologies and the location, the communication distance and relative motion of each node with the suspected fault satellite node, the best satellite is chosen to correspond to the interface of the suspected fault satellite node. If there is no satellite node that could be cooperated with in management domain, return to (5).

5) Under this situation the sub-station manager sends cooperation tasks to each cooperation agents. Each agent executes the cooperation task and tries to communication to the suspected fault satellite node and reported the cooperation result to sub-station manager, turn to step (8).

6) If the satellite node corresponding with the specific interface of suspected fault satellite in the management domain could be found, the sub-station manager sends a cooperation requests to network central manager and sends the task decomposition and synchronization information to central manager.

7) Network central manager generates theoretical topology of global satellite network and actual global topology, and selects an optimal coordination satellite corresponding with one interface of suspected fault satellite. If the choice is successful, turn to step (8).

8) If the choice is lost, wait for a random time ($< 200ms$), turn to step (6).

9) Network central manager sends coordination tasks to the best cooperation node. Collaboration nodes report the results to the central manager after finishing coordination; the network central manager will transmit the results to sub-station manager after receiving and confirming the fault type.

10) Cooperation ended.

This cooperation method is efficient and lightweight; for it has no more resourceful requests for each satellite agents. Furthermore it can run efficiently. By analyzing this method, we can find that the algorithm chooses satellites as cooperation node in management domain preferentially in the process of cooperation; it can greatly reduce the communication cost which the real-time fault detection and cooperation bring in. It will trigger the cooperation between the management domains when there is no cooperation node in management domain, the network central manager selects the cooperation node according to specific algorithm. This also can reduce the overhead of communication cooperation and improve the real-time fault detection effectively.

5. Simulation and analyzation

In order to test the effectiveness of the method, we have established the experiment as shown in figure 5.

The simulation is based on the half-entity ground test environment of HLA/RTI, the satellite networks make up of the orbiting satellites node. Each function part of simulation joins the federation as federal member. The functional simulation parts include those satellite members, link members and members of the route.

Satellite network simulation constitutes of two parts, the main part is a set of satellite federal member, each member simulates a group of satellite node entity, it constitutes of space-borne agency module, space borne platform equipment simulation module, space-borne task modules and communications load simulation modules. The other part is network management substations and management center that are composed of a

Table 1 Synchronous semantic description of task decomposition

synchronous rules	**semantic description**
$MetaAction_i \parallel MetaActioin_j$	$MetaAction_i$ or $MetaActioin_j$ should be finished.
$MetaAction_i$ && $MetaActioin_j$	Both $MetaAction_i$ and $MetaActioin_j$ must be finished. However, they can be finished in parallel
$MetaAction_i \uparrow MetaActioin_j$	$MetaAction_i$ must be finished before $MetaActioin_j$, furthermore, The result must be used to implement $MetaAction_i$

series of simulate members.

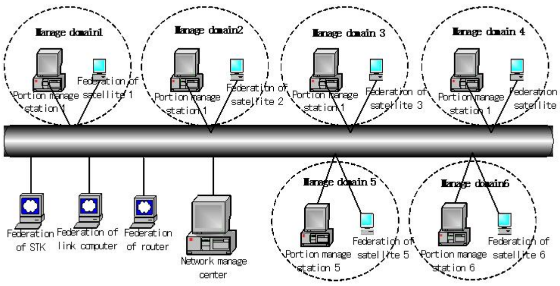

Figure 5 Simulation topology

In order to reduce the complexity of the simulation system, using the command of ping to test the communication between satellite agencies. System sets five ports for each space-borne agent to simulate the satellite interface.

To reduce the complexity of simulation system, in the simulation system, we use ping command for testing among the satellite agencies. To simulate interface of satellite, the simulation system sets five ports for each star-carried agent.

On condition that network management of satellite network nodes is normal, takes the response that satellite nodes give to Getrequest message for example, the relationship between response time and the attribution number of nodes acquired is shown in figure 6.

As shown in figure 6, on condition that network management of satellite network nodes is viable, the response time increases as the number of network attributes rises, response time of network management instructions is in millisecond grade, which meets the time demand of satellite network management.

The relationship between the collaboration flow and the failure rate is shown in Figure 7. In this paper, collaboration flow refers to the network traffic generated through collaboration during the fault detection of suspected fault stars in the satellite nodes, and it is calculated by the number of packets interacted among the management sub-station, network management center and satellite nodes in the collaboration period.

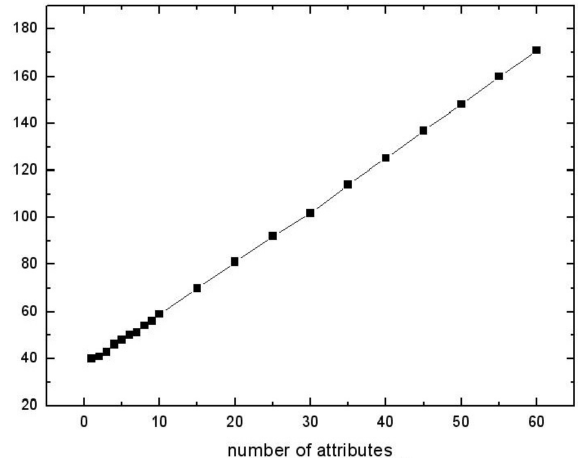

Figure 6 Relationship between attributes number and response time

Provided that the percentage of the suspected faulty satellites (cannot be managed by SNMP) is p, the percentage of the fully diagnosis is D. The relationship between them is as shown in figure 7.

From the figure 7, it is easy to know that with the increasing of the percentage p, the percentage of the successful fault diagnosis is lower. When the percentage of fault is more than percent 35, the percentage of the successful fault diagnosis lowers obviously. That is because that with the increasing of the percentage of the fault, the sub-station and the central station in the satellite networks cannot find the proper satellite node to cooperate. The percentage of the fully diagnosis declines for no cooperation can be applied to diagnosis.

The relationship between the percentage of fault and the cooperation time is as shown in figure 6. From the figure it can be known that with the increasing of the percentage of satellite fault, the cooperation time grows exponentially. Under the circumstance the percentage of satellite fault is lower, the cooperation time is short. This is because that the sub-stations and the central station can control the certain satellite nodes to apply cooperation. The time costs in task decomposition, cooperation nodes search, task assignment

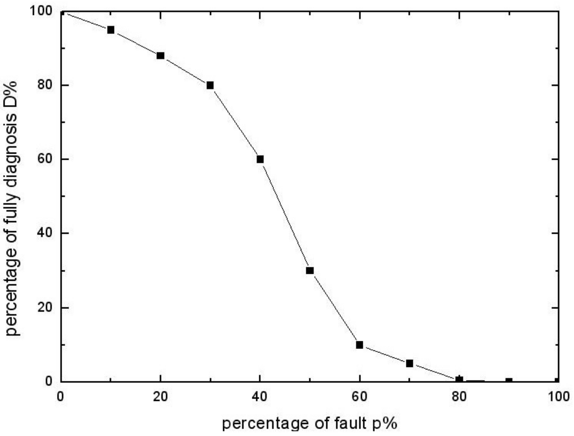

Figure 7 Relationship between the percentage of fault and the fully diagnosis

and executing the tasks and returning the cooperation results. On the other hand, when the percentage of satellite fault is high, it is difficult for the sub-stations and the central station to find the proper cooperation nodes, the cooperation time becomes longer.

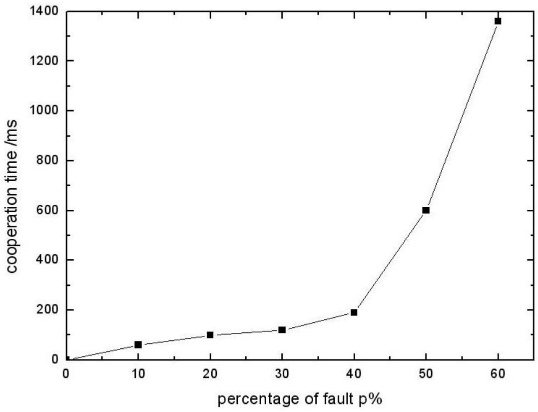

Figure 8 Relationship between the percentage of fault diagnosis and the cooperation time

Through the analysis of Figure 8 , we can see that collaboration flow rises as the failure rate increases, once the failure rate is more than 40 percent , the increase of network traffic that collaboration generated is not distinct, this is because that the algorithm chooses collaboration nodes by comparing the theoretical and practical topology in the management sub-station or network management center ,and it will cause the waste of network traffic instead of the frequent interaction between management sub-station and network management center interact with the satellite nodes .

Comprehensive simulation results show that, on condition that network management of satellite network nodes is viable, we can do nearly real-time detection of the interface faults of the nodes. Otherwise, the fault detection can be completed by the collaboration among nodes. In the case of low node failure rate, the completeness rate of the fault diagnosis is high, cooperate time is short and flow is low. However, in the case of high failure rate, the completeness rate of the diagnosis decreases significantly, collaboration time is significantly longer, and is unable to meet the needs of fault detection. It can be seen that this model is applicable to satellite network of low failure rate, and it meets the demands of satellite networks for the fault detection.

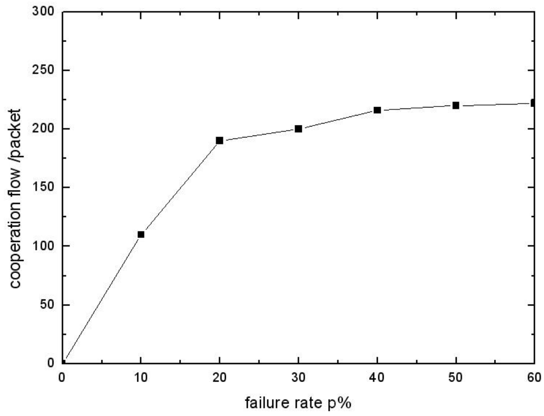

Figure 9 Relationship between failure rate and collaboration flow

6. Conclusion

Satellite network is characterized by its time-varying topology and long communication delay. But this network is very important and its resources are very scare and costly, the fault detection for the network is an important topic. In this paper efficient and lightweight fault detection was put forward and simulated. The simulation results show that the faulty frequency is lower, the cooperative time is shorter. Furthermore, the lower throughput is with higher the efficiency.

7. Acknowledgments

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References

[1] Y. Hu and V.O.K. Li, "Satellite-based Internet: A tutorial", *IEEE Communications Magazine*, 3: 154-162, 2001.

[2] L. Wood, A. Clerget, I. Andrikopoulos, G. Pavlou and W. Dabbous, "IP routing issues in satellite constellation networks", *International Journal of Satellite Communications 2001*: 69-92.

[3] He Yong-jun, Dai Jin-hai, Li Lian-jun. "Design and Implementation of the Integrated Modeling and Simulation Environment for Multi-Satellite Systems" [J]. *Computer simulation*. 21(5):28-31, 2004.

[4] Wen Yingyou, Feng Yongxin, Wang Guangxing. "Algorithm of Cluster Generation and Management Domain Decision in Integrated Satellite Information Networ", *Mini-micro Systems* [J]. 25 (10): 1742-1745, 2004.

[5] Samaraweera, N., and Fairhurst, G., "High Speed Internet Access Using Satellite-Based DVB Networks", *proceedings of Intenational Network Confernence'98*, 23-28, 1998.

[6] Long Bing, Jiang Xing-wei, Song Zheng ji. "Realtime monitoring and diagnosis technology for satellite telemetry data based on multi-agent" [J]. *ACTA AER0NAU TICA ET ASTR0NAUTICA SINICA*, 26(6):726-732, 2005.

[7] Fan X F, Jiang X W"Research of Multi-Agent based satellite fault diagnosis and fusion technology" [J]. *Chinese Space Science and Technology*, 23(2): 39-44, 2003.

[8] Chen H B, Song Z J, Jiang X W, "The application of fuzzy inference based on component in the satellite fault diagnosis", *Chinese Space Science and Technology*, 1: 56-60, 2004.

[9] Yao Min, Zhao Min," Multi-grade faulty diagnosis design of small satellite", *Chinese space science and technology*, February 47-51, 2007.

[10] Hou xia, Yang Hongpo, Fan Zhihua, "A Mend Fault Diagnosis Algorithm of the Satellite Network," *Transaction of System simulation*, November 2006: 3172-3175.

[11] Zhao Wei, Shao Jun-li. "Policy-based Network Management", *Journal of PLA University of Science and Technology(Natural Science)* [J], 6 (2) : 61-66, 2001.

[12] Vivero J, Serrat J. Manbop: "Management of Active Networks Based on Policies" [J]. *IEEE Communications Magazine*, 2002, 32 (7) :135-139.

[13] Zhang Shao jun, Li Jian hua, Zheng Minglei. "Policy-based Network Management", *Computer Engineering* [J]. 29 (9) :127-129, 2003.

[14] Zhang Bin, Sun Gang, Zhang Chuang, Guo Jun. "A New Active Network Management System Based on Policy", *Application Research of Computers* [J]. 21 (3): 174 -177, 2004.

[15] Gorodet sky V, Karsaev O, Samoilov V, et al. "Asynchronous Alert Correlation in Multi-agent Intrusion Detection Systems". In :*MMM2ACNS*, 366-379, 2005.

[16] Liu Hung-Hao, Soo Von-Wun. Intrusion Detection Using Alert Correlation Methods Based on Multiagent Systems. TAAI, 2004.

[17] Shajari M, Ghorbani A A." Application of Belief-Desire-Intentionagent s in intrusion detection and response". In :*Proceedings of Privac, Securit, Trust (ST04) Conference, Fredericto*, New Brunswick, October, 181-191, 2004.

[18] Tseng C Y, Balasubramanyam P, Ko C, et al. "A specification based intrusion detection system for AODV". In: *Proc. of t he 2003 ACM Workshop on Security of Ad Hoc and Sensor Networks (SASN'03)*. Fairfax Virginia, 125-134, 2003.

[19] Shajari M, Ghorbani A A. "Application of Belief-Desire-Intention agents in intrusion detection and response". In :*Proceedings of Privac, Securit, Trust (ST04) Conference*, Fredericto, New Brunswick, October, 181-191, 2004.

[20] Tseng C Y, Balasubramanyam P, Ko C, et al. "A specification based intrusion detection system for AODV". In: *Proc. of the 2003 ACM Workshop on Security of Ad Hoc and Sensor Networks (SASN'03)*. Fairfax Virginia, 125-134, 2003.

[21] Gavrilis, D, Dermatas, E. , "Real-Time Detection of Distributed Denial of Service Attack Using RBF Network and Statistical Feature", *International Journal of Computer Network*, 48:235-245, 2005.

[22] Wu Ming-qiao, Zhong Hai-rong. "Development of Federation Prototype of Satellite Network Based on HLA/RTI"[J]. *JOURNAL OF SYSTEM SIMULATION*. 16(6): 1292-1295, 2004.

[23] Verikoukis, C., Alonso, L., Giamalis, T. "Cross-layer optimization for wireless systems: a european research key challenge", *IEEE Communications Magazine*, 43(7): 1-3, 2004.

[24] A. Alessandri, "Fault diagnosis for nonlinear systems using a bank of neural estimators", *Computers in Industry*, 52: 271-289, 2003.

[25] Aw Jackson, et al. "Active Network Monitoring and Control: The SENCOMM Architecture and Implementation" [C].*Proceedings of the DARPA Active Networks Conference and Exposition*, San Francisco, California, IEEE Computer Society, 118-132, 2002.

[26] Liu, et al., "A Fully Collusion Resistant Public Key Trace and Revoke Scheme with Dynamic Registration and Revocation"[J]. *Electronics Journal*, 18(2): 347-354, 2009.

[27] W. Lee and S. J. Stolfo, "A Framework for Constructing Feature and Model for Intrusion Detection Systems", In: *Proceeding ACM Transactions on Information and System Security*, 3(4):275-281, 2004.

[28] Choi H, Kim N, Cha H. “6LoWPAN-SNMP: Simple Network Management Protocol for 6LoWPAN”. IEEE, ed. *Proceedings of the 11th IEEE International Conference on High Performance Computing and Communications*. New York: IEEE, 305-313, 2009.

[29] Mukhatar H, Kang-Myo K, Chaudhry S, Akbar A, Ki-Hyung K, Yoo S. “LNMP-Management Architecture for IPv6 Based Low-power Wireless Personal Area Networks (6LoWPAN)”. IEEE, ed. *Proceedings of the IEEE Network Operations and Management Symposium*. New York: IEEE, 417-424, 2008.