Failure Detection Mechanism of Software Defined Satellite Network

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Abstract

In the view of the vulnerability of satellite network nodes, the failure detection mechanism of software defined satellite network nodes (SDSN-FD) is designed. In this paper, the failure detection of the satellite nodes and the fast localization of failure nodes are detected by the combination of periodic detection and active reporting. The simulation results show that the SDSN-FD is superior to the traditional failure detection mechanism in both misjudgment rate and failure detection delay.

Keywords

Failure Detection; Software Defined Network; Satellite Network.

1. Introduction

With the development of satellite network, the function of satellite links and nodes are also keep increasing. When any satellite node fails or encounter some unpredictability factors, it will cause the quality of satellite network services decreased or even become paralyzed. Therefore, real-time detection of satellite nodes failure is crucial to improve the reliability of satellite network and ensure the high quality of satellite network services [1].

Failure detection mechanism is the basic research content of fault tolerant field, and it is also an important guarantee technology to realize high availability of system [2, 3]. Failure detector is the core of failure detection mechanism. Most of the current failure detectors are based on timed heartbeat synchronization detection to determine whether the system is invalid. Therefore, the selection of timeout value plays a decisive role in the accuracy of failure detection. Literature [4] realizes adaptive failure detection by continuously obtaining the maximum heartbeat message delay as the upper limit of the timeout value. Although this method can realize self-adaptive detection, it is difficult to guarantee the efficiency of detection and accuracy of detection; Literature [5] is improved on the basis of literature [4]. It is obtained by calculating round-trip delay α as revised to adjust the timeout value, can achieve the forecast of the heartbeat message arrival time. This method can improve the accuracy of failure detection, but the disadvantage in failure detection delay cannot make up for; Traditional satellite network failure detection is carried out through ground detection station [6]. This approach needs to transmit the situation of the satellite to the ground station, and then the ground station will send the recovery method to the satellite, which not only increases the link overhead, but also increases the delay; Literature [7] proposed a link fault detection scheme based on Bayesian theory, which was applied to satellite network by combining the link fault detection algorithm with dynamic routing strategy.

Software defined network (SDN) is widely used in failure detection and recovery of ground network because of its advantage in real-time. In the literature [9], a local fast re-routing algorithm based on flow aggregation is proposed, which makes SDN controller and switch only need to update a small number of flow table items to complete the failure detection and recovery of the link; Literature [10] proposed a link failure detection and automatic recovery scheme based on SDN. Using LLDP protocol for entire network information and through SDN centralized control and programmable achieve rapid detection and recovery; Literature [11] studies the failure of software defined data center. Using the re-route recovery mechanism based on link real-time load to ensure the network load balance after recovery. However, there are significant differences between satellite network and ground network. How to apply the failure detection mechanism based on SDN to the large-scale satellite network is a hot topic in today's research.

In this paper, based on the failure detection architecture of software defined satellite network, a set of failure detection mechanism of software defined network is designed. The simulation results show that the SDSN-FD is superior to the traditional failure detection mechanism in both misjudgment rate and failure detection delay.

2. SDSN-FD

2.1 SDSN-FD Architecture.

The common software defined network architecture (SDSN) [12] is designed based on the three-layer model of application layer, control layer and data forwarding layer of SDN. Compared with the traditional satellite network architecture, SDSN is evident in scalability and flexibility, however, when the failure of a satellite node leads to network failure, this architecture has obvious shortcomings in the delay and efficiency of failure detection. The SDSN-FD architecture is shown in Fig.1:

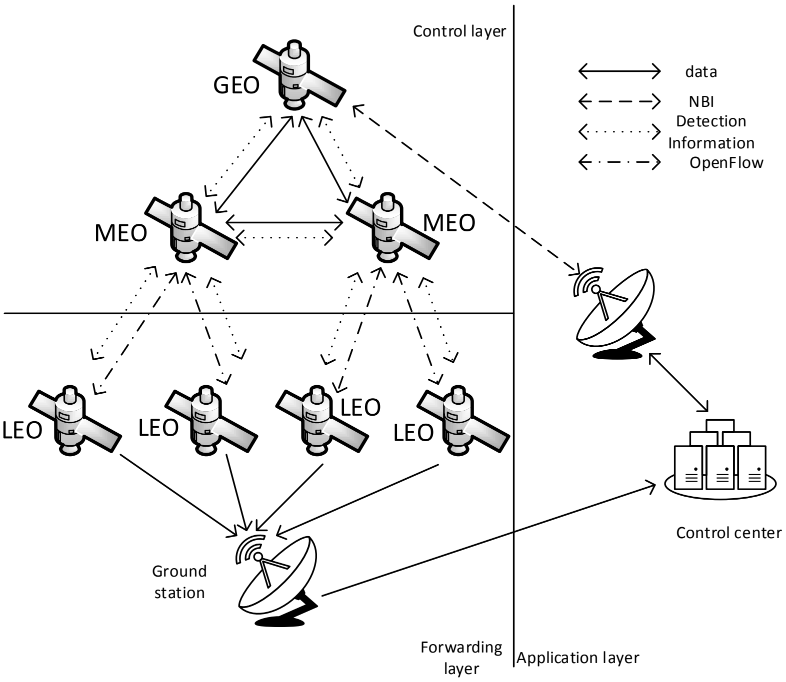

Fig. 1 SDSN-FD architecture

As shown in Fig.1, the SDSN-FD architecture redivides the traditional high, middle and low orbit satellites into three layers: application later, control layer and forwarding layer. The roles of the satellites are: GEO as the main controller, MEO as the general controller and LEO as the switch. Among them, the application layer is composed of the application layer control center; the control layer is composed of GEO and MEO; the forwarding layer is composed of LEO and ground station. GEO communicates with the application layer through the northbound interface protocol, and detects whether MEO fails at the same time. MEO controls LEO through the OpenFlow protocol, and LEO does not have the function of data processing. It only needs to have simple forwarding and storage functions. In addition, GEO needs to maintain a global network status view table, which enables global information to be shared. As shown in Table 1:

Table 1 Global Network Status View Table

Content	Type of Data	Description
Main Controller ID	String	The unique identifier of the main controller.
General Controller ID	String	The unique identifier of the general controller.
Switch ID	String	The unique identifier of the switch.
Suspect Information	String	The controller information which is in suspect.
Feedack	String	The message chich seitch sends to main controller.
Lost Connection Information	String	The faulty general information.

The control layer in this logical set can control the entire physical network, thus obtaining the global network status view and optimizing the network according to the global network state view.

Compared with SDSN, the architecture which proposed in this paper has the following advantages:

(1) The multi-controller architecture can improve the extensibility of satellite network, and the sharing of global information through the main controller can improve the resource utilization.

(2) When a general controller satellite (MEO) fails, we can use the failure detection mechanism to quickly identify the cause of the failure of the satellite node location. Then through the corresponding failure recovery method for failure recovery. Thus ensuring the service quality of the entire satellite network.

2.2 Failure Detection Mechanism of Software Defined Satellite Network.

In the architecture shown in Fig.1, the failure detection of satellite nodes is carried out by means of periodic detection and active reporting. Among them, periodic detection refers to the detection information between GEO and MEO in Fig.1. GEO sends ofpmp_port_describtion message to each MEO node at regular intervals, which is the request type. MEO sends a reply message to GEO after receiving the message, and GEO determines whether the node is failure by looking at the state field in the message. The active report is the detection information between LEO and MEO in Fig.1. When LEO loses data communication with MEO, LEO will actively send feedback to the application layer control center on the ground. Then, the application layer control center will forward the feedback message to GEO. At this point, the global network status view table will store the feedback message. If the MEO fails, the information of this MEO will be added to the table’s lost connection information.

In this paper, the reason for the detection is that the satellite network is different from the ground network. The satellite network is highly dynamic and the satellite links switch frequently. When one of the detection methods is used to detect the failure of the satellite node, it may be due to the switching of the satellite links. So we put the satellite node in suspect. In this paper, the state of satellite node is divided into three types: normal, suspect and failure. We use “P0” to indicate that the failure is detected by periodic detection. Instead use “P1”. In the same way, “A0” and “A1” are respectively indicate that failure and undetected failure are detected by active reporting. The state transition diagram of the failure detection mechanism is shown in Fig.2:

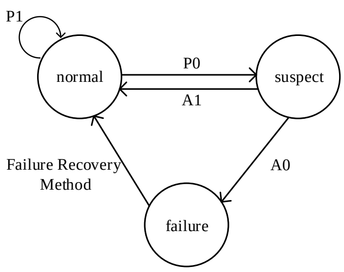

Fig. 2 State transition diagram of SDSN-FD

3. Adaptive SDSN-FD Model and Alogrithm

3.1 Adaptive SDSN-FD Model.

The adaptive SDSN-FD model is shown in Fig.3:

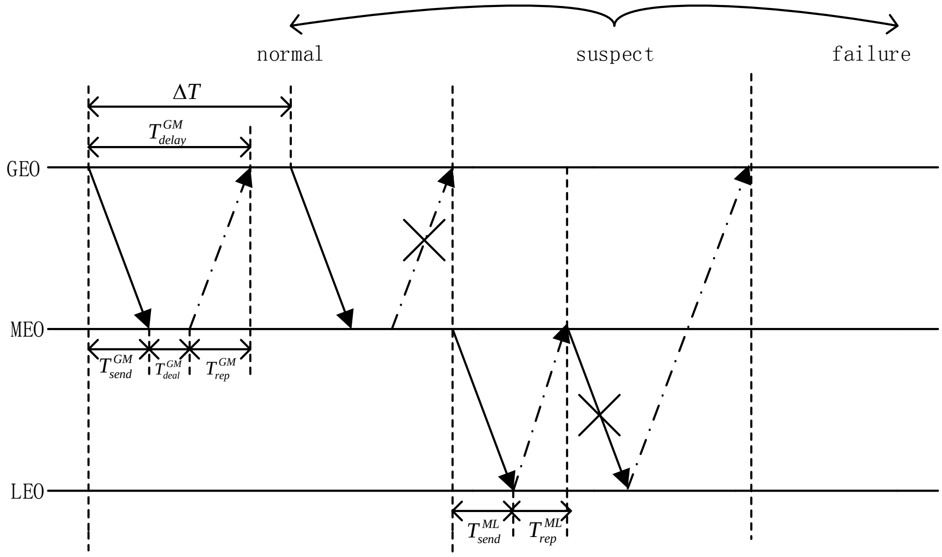

Fig. 3 Adaptive SDSN-FD model

In Fig.3, ΔT is the period when GEO sends ofpmp_port_describtion message to MEO in a normal state. It can be expressed as:

$$\Delta T(n) = (\alpha - \beta) \cdot C^n + \beta . \tag{1}$$

In the formula, n means the number of MEO satellites; C is a constant from 0 to 1; α and β represent maximum value and minimum value of the detection cycle respectively.

$$\begin{cases} \alpha = \Delta T_{\max} \\ \beta = \Delta T_{\min} \end{cases} . \tag{2}$$

T_{delay}^{GM} is the round-trip delay between GEO and MEO. It consists of three parts: send delay T_{send}^{GM}, deal delay of MEO T_{deal}^{GM} and response delay T_{rep}^{GM}. T_{delay}^{GM} should be less than ΔT in normal, otherwise, the detected satellite will enter into suspect. In the same way, if LEO has not received the message of the LLDP protocol sent by MEO in suspect during T_{delay}^{ML}, the MEO is determined to be failed. Otherwise, it is normal.

3.2 Steps of SDSN-FD Algorithm.

The steps of the failure detection algorithm described in this paper are as follows:

Step1: The initialization of the satellite nodes and setting the given parameters.

Initializes the entire network topology and initializes the global network view table maintain by GEO. Its stroage format is shown in Fig.4:

Satellite node set	link set	The node ID that sends the feedback message	The node ID of the suspect state	The node ID of the failure state

Fig. 4. Storage format of global network view table

At the same time, set the value of α, n, β and C.

Step2: Periodic failure detection.

GEO sends ofpmp_port_describtion message to MEO at the beginning of each detect cycle, the delay of receiving MEO reply is T_{delay}^{GM}. Compare T_{delay}^{GM} with α and β, then update. If T_{delay}^{GM} is less than ΔT, the output satellite node is in a normal state. Exit the program. On the contrary, the satellite node is in suspect state and goes to Step3 to check whether it is failure.

Step3: Active report detection.

If LEO receives the message of the LLDP protocol sent by MEO within T_{delay}^{ML}, the output satellite node is in a normal state and the program is finished. On the contrary, the satellite node is in suspect state and goes to Step4.

Step4: The judgment of failure.

LEO sends feedback message to GEO, including the ID of MEO which is in suspect state. At this point, GEO will looks at the suspect information field of the global network view table. If the MEO is in suspect state, then output the satellite node is in failure state and exit the program. Otherwise, go to Step2.

3.3 Pseudocode of SDSN-FD Algorithm.

Pseudocode of SDSN-FD algorithm is shown in Table 2:

Table 2 Pseudocode of SDSN-FD Algorithm

Input: α, β, C, T_{delay}^{ML}, n, T_{delay}^{GM}
Output:the status of the satellite node to be detected
float $\Delta T(n) = (\alpha - \beta)\cdot C^n + \beta$
int flag = 0;
if($T_{delay}^{GM} < \Delta T$) then
flag = 1;
else
flag = 0;
if(flag == 0) then
if(LEO receives messages from MEO within T_{delay}^{ML}) then
flag = 1;
else flag = -1;
switch(flag)
case -1: return failure;
case 0: return suspect;
case 1: return normal;

4. Simulation

4.1 Simulation Environment Description.

The simulation of this paper is carried out in the mininet environment. Firstly, build the network topology as shown in Fig.5:

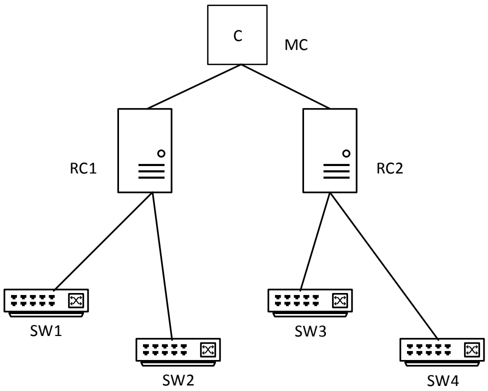

Fig. 5 Simulation Topology

As can be seen in Fig.5, the simulation topology consists of a main controller, two general controllers and four switches. Among them, SW1 and SW2 are connected with RC1, SW3and SW4are connected with RC2. The main controller MC is connected with all the nodes.

4.2 Satellite Link Parameter Setting.

The satellite link parameters involved in this paper are shown in Table 3:

Table 3. Satellite Link Simulation Parameters

Parameters	Attribute
Uplink Bandwidth	10M/s
Downlink Bandwidth	2.5M/s
Link State GEO Orbit Altitude GEO Orbit Altitude GEO Orbit Altitude	Non-permanent Link 35786km 23222km 1500km

4.3 Algorithm Simulation Contrast.

In order to simulate the characteristics of space-time information network space-time scale, it is necessary to assign corresponding propagation delay to each link in the simulation topology. The propagation delay of GEO and MEO, LEO is 41.9ms and 114.3ms respectively, and the propagation delay between MEO and LEO is 72.5ms. In order to simulate the failure of satellite network nodes, it is necessary to manually set the link to be disconnected. In this context, the SDSN-FD described in this paper is compared with the classical algorithm $\lambda - FD$[13], $\Phi - FD$[14] and $Chen - FD$[15]. The results are shown in Fig.6:

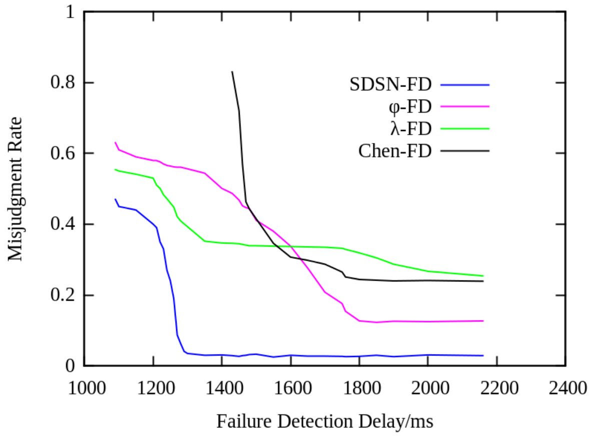

Fig. 6 Simulation of Algorithm

As can be seen from Fig.6, under the same condition of failure detection delay, the misjudgment rate of SDSN-FD proposed in this paper is less than the other algorithms. And the failure detection delay of SDSN-FD is optimal under the same condition of misjudgment rate.

4.4 Multi-controller Failure Detection Delay Simulation.

When a controller fails, the switch in its jurisdiction re-elects the controller and migrates into the new controller's jurisdiction. This will cause the controller traffic and the number of packets suddenly increased, as shown in Fig.7:

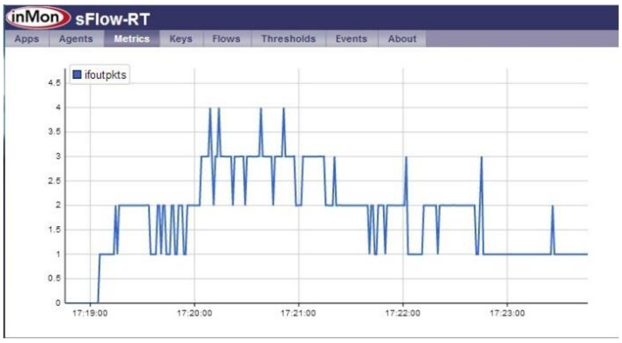

Fig. 7 Change of Packets Which Controller Sends

When the simulation time is 17:20:01, a switch is moved to this controller, resulting in a sudden increase in the number of packets sent by the controller. At 17:21:40, there is a switch to move out of this controller, so the number of packets sent to reduce. Fig.8 shows the effect of the number of controllers on the failure detection delay.

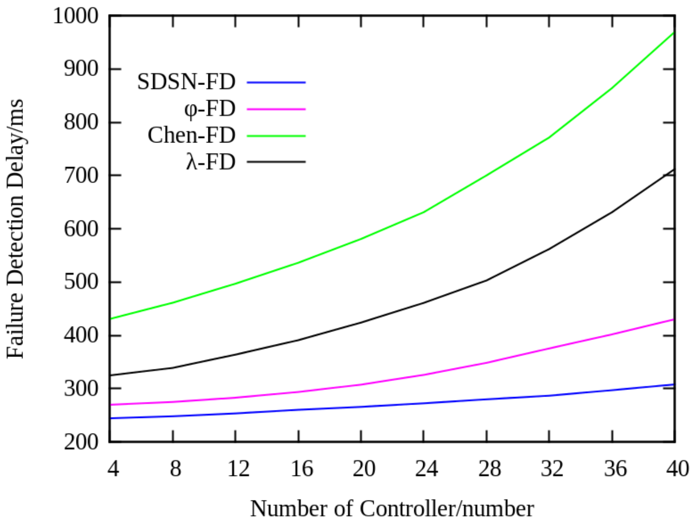

Fig. 8 Failure Detection Delay Simulation

As can be clearly seen from the figure, with the increase in the number of controllers, the four mechanisms of the failure detection delay have increased. Compared with the other three mechanisms, the SDSN-FD has a small increase in the failure detection delay, which greatly improves the service quality of the network.

5. Conclusion

Based on the failure of satellites nodes in satellite network, this paper puts forward the failure detection mechanism of software defined satellite network. Compared with the traditional controller failure detection mechanism, the SDSN-FD proposed in this paper enhances the scalability of satellite network, reduces the complexity of the network and improves the service quality of satellite network. More importantly, SDSN-FD has a significant improvement in misjudgment rate and failure detection delay. In the next step, we will design the recovery plan after failure detection to enhance the anti-destroying ability of satellite network.

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