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Simulation and Analysis of Civil Aircraft Cabin Core Network Architecture based on Daisy Chain

Han Xiaoqiong [1, a, *], Lu Xi[1, b], Gong Ruiqi[1, c] and Zhu Qing[1, d]

[1]Shanghai Aircraft Design and Institute of COMAC, Shanghai China;

[a,*] hanxiaoqiong@comac.cc; [b] luxi@comac.cc; [c] gongruiqi@comac.cc; [d] zhuqing2@comac.cc;

Abstract. With the rapid development of electronic technology, the application of civil aircraft cabin electronics is becoming more and more advanced. The traditional cabin core network architecture can no longer meet current cabin application requirements. Meanwhile, there are multiple of devices with duplicated functions in cabin of civil aircraft, and the number of each device with duplicated functions is very large. In order to solve the problem of repetitive deployment of a large number of devices with duplicated functions in the cabin system, the civil aircraft cabin core network architecture is proposed to adopt a two-level daisy chain network topology which has many advantages such as high robustness, high scalability and less cables. In the design phase of civil aircraft cabin core network architecture, modeling and simulation of the network architecture through simulation tools is an important means to study, predict, justify and judge the network performance. In this paper, a two-level daisy chain network architecture model with about 67 nodes for civil aircraft cabin core network is developed and the network performance of the model mentioned above is simulated through OPNET simulation tool in order to perform a trade-off analysis and evaluate the cabin core network architecture.

1. Introduction

With the rapid development of electronic technology, the application of civil aircraft cabin electronics is becoming more and more advanced. The new generation cabin system is no longer only serving the cabin system in the traditional sense, but will serve as the control and management center of the cabin electronics application, providing a centralized cabin management and service platform to serve the whole cabin of civil aircraft. The new generation cabin system will serve not only cabin crew and passengers, but also maintenance personnel. By arranging a certain number of electronic devices, sensors and other devices in the cabin, service area, lavatory, passenger seats, crew rest area and other areas, the cabin crew can monitor and manage the status information of each area of the cabin, including but not limited to a series of cabin seats, PSUs, overhead bins, service area facilities, kitchen facilities, lavatory facilities, doors system, water and waste system, cabin temperature, mood lighting system, electronic dimmable windows, etc. The ability to monitor and manage the status information of each area of the cabin can greatly improve the work efficiency and quality of cabin crew and then to serve the whole cabin [1][2][3].

Traditional cabin core network architecture mostly uses discrete lines, analog audio lines and a small amount of low-rate data buses, which are characterized by a large number of cables and low transmission rates, and are suitable for systems with small data volumes and low refresh rates. With the increasing number of electronic applications in the cabin, the disadvantages of the traditional cabin core network have gradually emerged, with poor scalability, large number of cables, and large equipment size plaguing the host manufacturers. Ethernet technology is widely used in industry because of its low price, stability and reliability, high communication rate, rich hardware and software products, and mature supporting technologies. The new generation of cabin system gradually adopts Ethernet data bus-based cabin core network to connect internal cabin system devices, external cabin system interface devices and external other aircraft systems to the cabin core network, thus solving the problems of low transmission rate, low data throughput and large cable weight of traditional cabin core network.

Daisy chain is a bi-directional transmission ring network topology, each network node device is connected by its left and right neighbor network node devices, so that all nodes in the network constitute a ring network [4][5][6][7]. In the daisy chain network based on the RSTP protocol defined by IEEE 802.1w, each network node device has data exchange function, and data messages are transmitted in both directions among the nodes, so when one of the nodes in the network fails, data can be transmitted from the other direction, which will not lead to the whole network paralysis. When the network needs to add or reduce nodes, it does not affect the topology of the network. Therefore, daisy chain network topology has many advantages such as high robustness, high scalability and less cables.

There are multiple of devices with duplicated functions in cabin system of civil aircraft, and the number of each device with duplicated functions is very large. In order to solve the problem of repetitive deployment of a large number of devices with duplicated functions in the cabin system, the civil aircraft cabin core network architecture is proposed to adopt a two-level daisy chain network topology as shown in Figure 1[8]. The primary network is a 1000-Gigabit Ethernet daisy chain data network, consisting of cabin core servers and cabin data distribution units. The secondary network is a 100-Gigabit Ethernet daisy chain data network, consisting of cabin data distribution units and passenger server control units. The network protocol of the two-level daisy chain data network adopts the RSTP standard protocol defined by IEEE 802.1w, which can well solve the problem of broadcast storms that easily occur in the network.

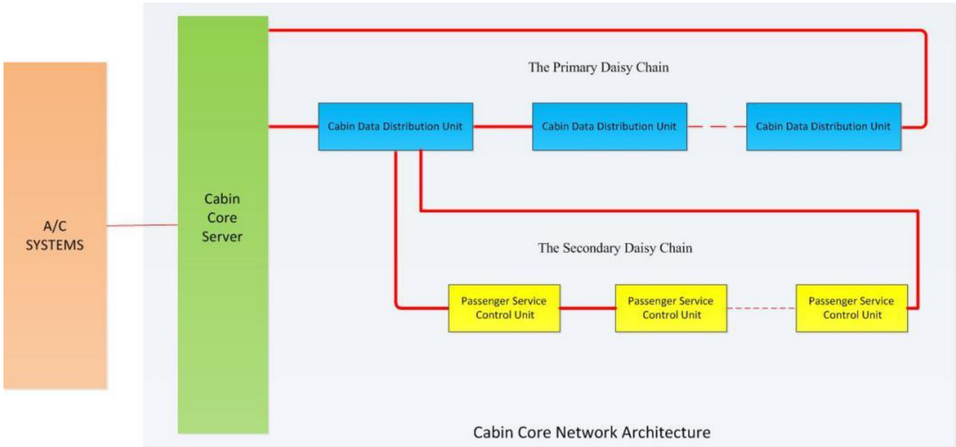

Figure 1. Cabin core network architecture

In the design phase of civil aircraft cabin core network architecture, modeling and simulation of the network architecture through simulation tools is an important means to study, predict, justify and judge the network performance [9]. The initial convergence time, reconvergence time after failure are the important performance parameters in daisy chain network. In this paper, a two-level daisy chain network architecture model with about 67 nodes for civil aircraft cabin core network is established, and then simulate the network performance of the model mentioned above through OPNET simulation tool in order to evaluate the performance of two-level daisy chain network architecture [10].

2. Simulation inputs

2.1. Simulation purpose
The main objectives of the cabin core network architecture simulation analysis are as follow.
- To perform a trade-off analysis of the cabin core network architecture.
- To evaluate the performance of the cabin core network architecture.

2.2. Simulation tools
The simulation tool used for the cabin core network simulation is OPNET software.

2.3. Simulation inputs
The network configuration is as follows.
- The primary daisy chain consists of 7 nodes.
- The secondary daisy chain consists of 60 nodes.
- Both the primary daisy chain and the secondary daisy chain uses the RSTP protocol.
- Both the primary daisy chain and the secondary daisy chain belong to the same VLAN.
- Node_0 in the primary Daisy Chain network is the only node interconnected to the external system with a gateway IP address of 192.168.2.1.
- All other nodes in the network communicate with the external system for data through this gateway IP.

2.4. Simulation outputs
The contents of this simulation test are as follow.
- Output the initial convergence time of the cabin core network.
- Output the reconvergence time after cabin core network architecture node failure.

3. Simulation Process

3.1. Establish the Simulation Model
According to the simulation inputs above, a two-level daisy chain network architecture model with about 67 nodes is developed and shown in Figure 2.
The primary daisy chain consists of node_0 to node_6, and the secondary daisy chain consists of other 60 nodes.

3.2. Network Protocol Configuration
After the simulation model is established, the RSTP protocol needs to be configured for each network node in the simulation model.

The RSTP protocol is configured for all 67 network nodes and the configuration process is as follows:
- Set the RSTP protocol version for each network node to IEEE 802.1w.
- Set the MAC address of each Layer 2 switch, with the default setting of node_0 having the smallest MAC address.
- According to the RSTP protocol, the node with the smallest MAC address is the root node and the other nodes are the leaf nodes, whereby the transmission path of the packets is determined.
- Set the Global Attribute->Simulation Efficiency->Switch Sim Efficiency setting to Disabled in order to make the RSTP protocol enabled.

3.3. Timer parameters configuration
For all 67 network nodes, Timer parameters are configured based on engineering experience, and the configuration process is as follows.
- Set the Maximum Age of each network node to 40s.

- Set the Forward Delay of each network node to 21s.
- Set the Hello Interval of each network node to 1s.

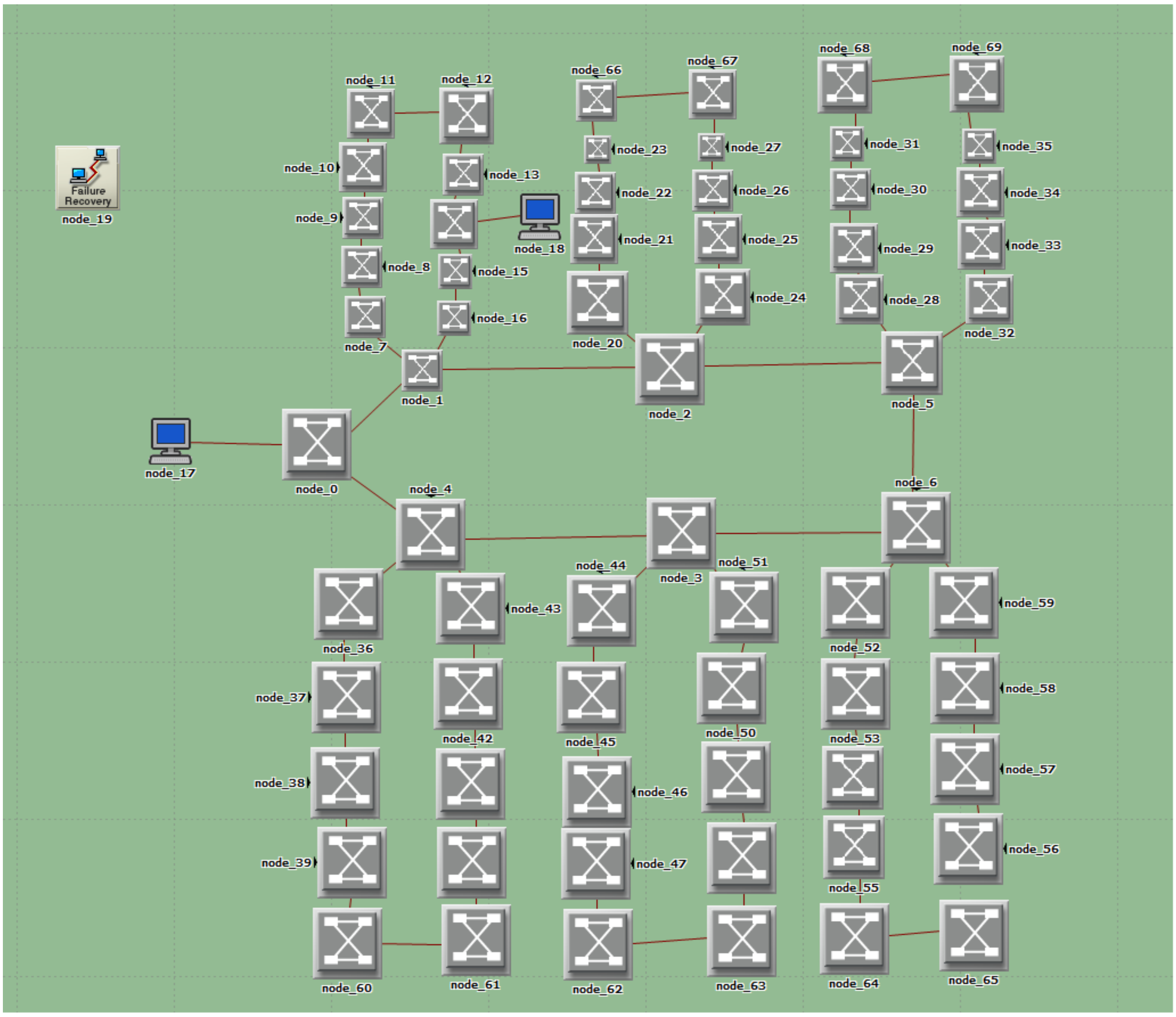

Figure 2. Cabin core network architecture model

4. Simulation Results and analysis

4.1. Initial convergence time

Node_0 is the root node which is mentioned above, and after running the RSTP protocol, the spanning tree routing is shown in Figure 3. The primary daisy chain network where node_1 is located, the spanning tree routing is node_0-> node_1->node_2->node_5->node_6->node_3->node_4 and the data translate routing of node_17 to node_18 is node_0 ->node_1->node_16->node_15->node_14.

The initial convergence times of the directly connected nodes receive data immediately after sending services, while the initial convergence times of the non-directly connected nodes need 3s to converge because the data transmission and reception starts at 3s on the horizontal axis as shown in Figure 4.

4.2. Reconvergence time after failure

Before the test, the link between node_1 to node_1 in the primary daisy chain of the model should be disconnected. After running the RSTP protocol, the spanning tree routing after failure is shown in

Figure 5.According to Figure 5, the spanning tree routing is changed, and the new routing is node_0-> node_4->node_3->node_6->node_5->node_2->node_1 and the data translate routing of node_17 to node_18 is also changed and the new data routing is node_0-> node_4->node_3->node_6->node_5->node_2->node_1->node_16->node_15->node_14.

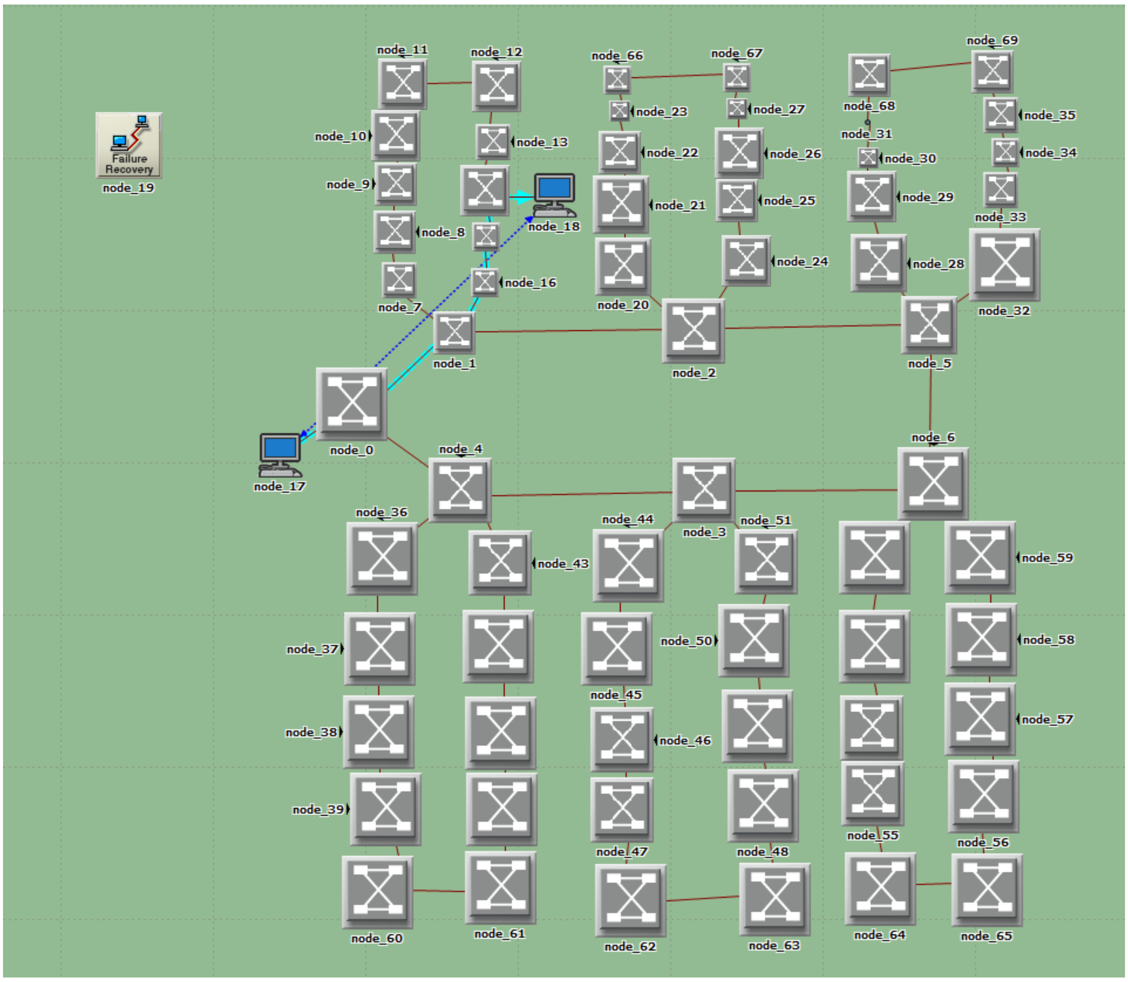

Figure 3. The initial spanning tree routing

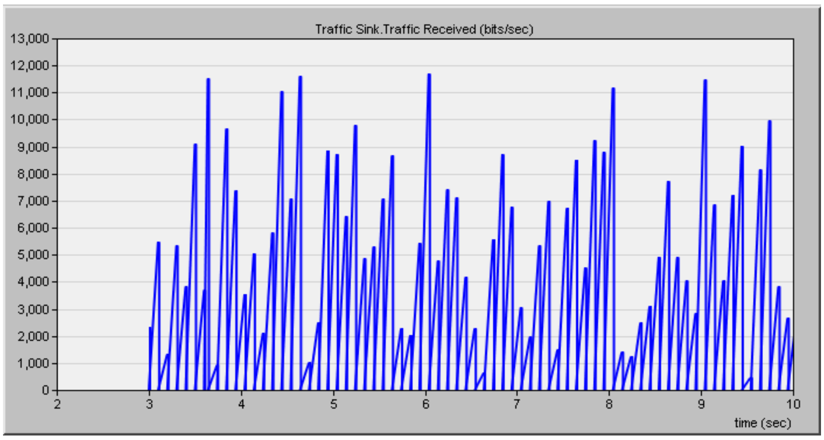

Figure 4. Initial convergence times of the non-directly connected nodes

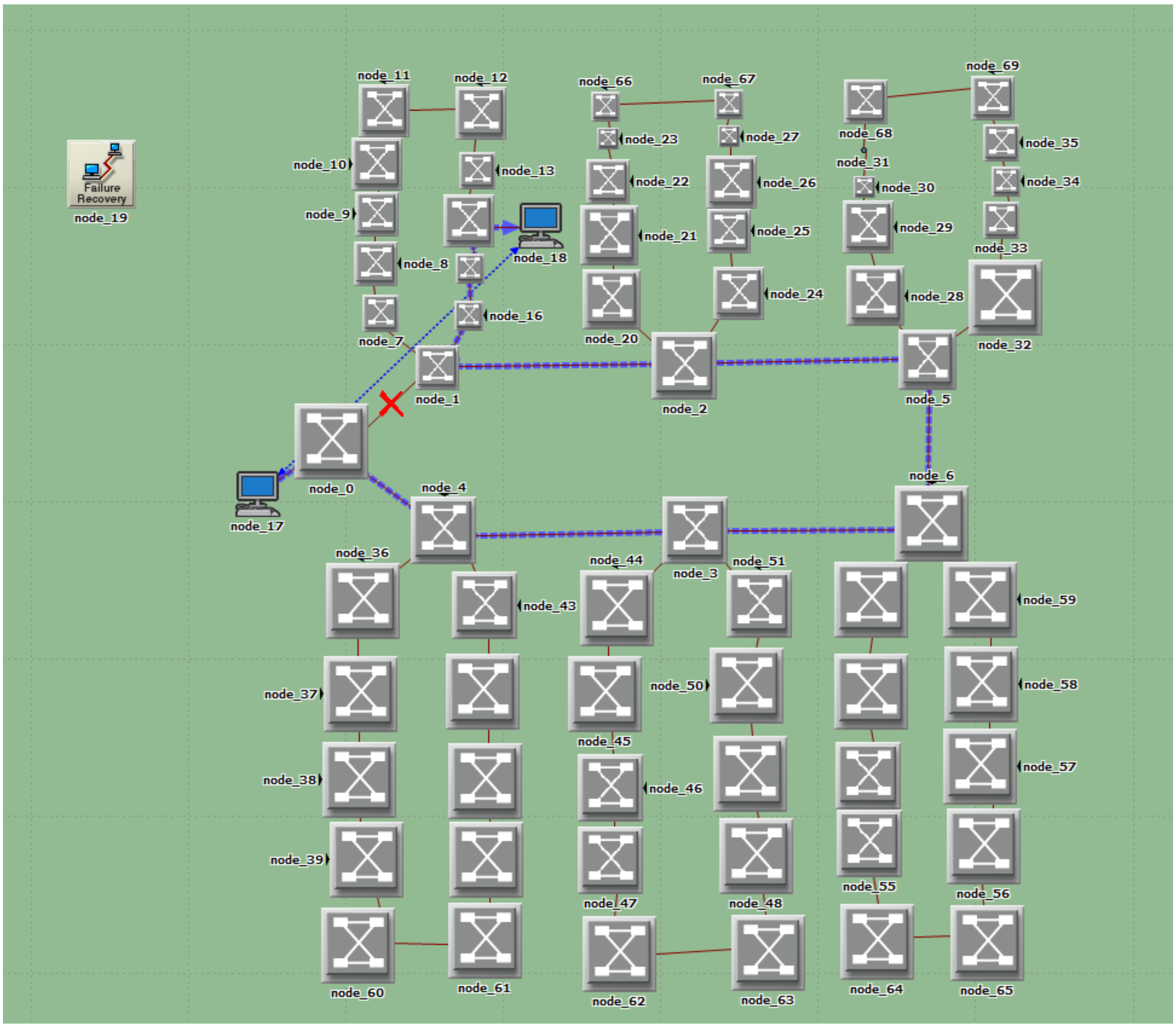

Figure 5. The spanning tree of model after failure

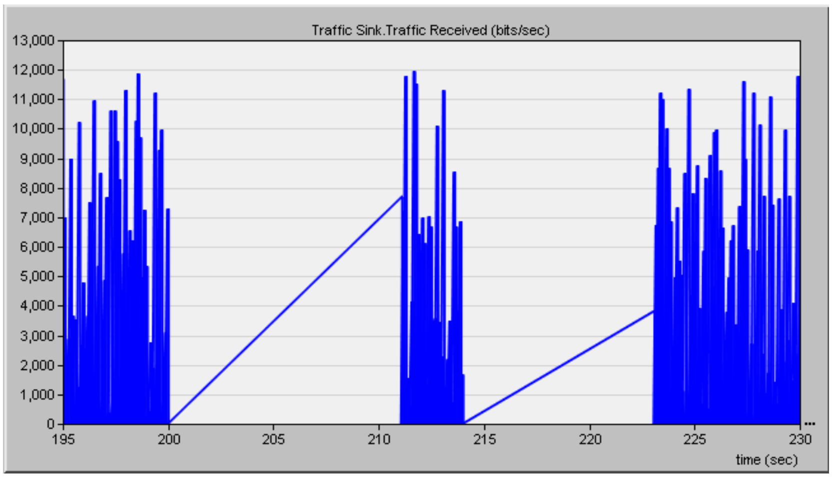

Figure 6. Reconvergence times of the network after failure

The fault directly connected nodes need 4s to detect the fault (hello interval is set to 1s), and the non-directly connected nodes need 10s to detect the fault. The reconvergence time of the network is completed in two phases, the first phase lasts 11s because the data transmission and reception stops between 200s and 211s on the horizontal axis as shown in Figure 6, and the second phase lasts 9s because the data transmission and reception stops between 214s and 223s on the horizontal axis as shown in Figure 6. Finally, the network is not affected by the failure link and can receive data after sending services.

5. Conclusion

In this paper, a two-level daisy chain network architecture model with about 67 nodes for civil aircraft cabin core network is developed and the network performance is simulated through OPNET simulation tool. Two key network performance indicators named the initial convergence times and the reconvergence time of the network are obtained through the OPNET simulation tool and the simulation results is acceptable base on the engineering experience. At this stage, the two-level daisy chain network architecture is feasible based on the simulation results. But the simulation results of the cabin core network architecture can be made more accurate by optimizing the timer parameters configuration and the protocol configuration. In the next stage, the communication of the whole cabin core network will be simulated in order to confirm whether it will be affected when a network storm is generated in the network through OPNET simulation tool by optimizing the timer parameters configuration and the protocol configuration.

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