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Research on Link Aggregation of Ethernet Train Backbone Network based on OPNET

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Abstract

With the development of the network of the train, Ethernet train backbone network becomes the control network of the train. With the rapid growth of train network information in the future, all aspects of network performance will be challenged. In order to solve this problem, In this paper, the dynamic link aggregation LACP protocol of link aggregation technology is used to aggregate the Ethernet train backbone network. The load balancing algorithm is added at the switch port to realize the balance of data traffic. The Ethernet train backbone network and link aggregation technics will be introduced in detail below, and uses OPNET simulation software to simulate it. The simulation results show that the application of link aggregation to the Ethernet train network can solve the problem of loaded data in the train network and improve the performance of the network.

Keywords

Ethernet Train Backbone Network; Link Aggregation; Load balancing; OPNET.

1. INTRODUCTION

Since the promulgation of IEC61375-2-5 protocol in 2010, the world's major train network communication research and development institutions began to invest in the research of Ethernet train backbone network. Ethernet train backbone network introduces the advantages of industrial Ethernet, such as fast speed, high bandwidth and good real-time performance, to adapt to the development direction of train network communication system in the future. Ethernet Train Backbone (ETB) is different from traditional industrial Ethernet in that it is forbidden to use network initialization protocol, spanning tree, fast spanning tree protocol and network topology [1-2]. With the development of intelligent, high-speed and comfortable train network, the data types and quantity of train network are increasing. More and more different kinds of data need to be exchanged through etbn. In the field of train communication, it is urgent to solve the network performance problems such as bandwidth, throughput, delay, etc. Therefore, this paper proposes the link aggregation of train Ethernet backbone network to solve the related problems, improve the stability of train communication network, and ensure the continuity of train network communication.

2. ETHERNET TRAIN BACKBONE (ETB)

The traditional Ethernet uses star, bus, ring and so on. IEC61375-2-5 protocol issued in 2011 combines the characteristics of train Ethernet backbone network and train network, and stipulates that ETB adopts linear topology structure, and the whole train network is connected

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by Ethernet Train Backbone node ETBN. As shown in Figure 1, 6 consist train, 4 motor and 2 trailer.

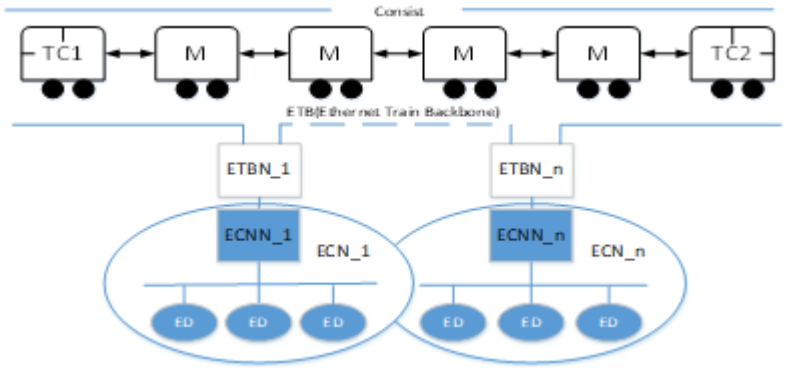

Figure 1. Stratified Topology of Ethernet Train Backbone Network

The ETB topology is a hierarchical structure. Train Backbone network of the upper layer can be dynamically marshalled and the consist network of various equipment inside the lower layer vehicle. The Ethernet Train Backbone Node (ETBN) is connected to the Ethernet Consistent Network (ECN). The communication data between different Ethernet networks can only be transmitted through the Ethernet train backbone network, so that the communication information can be transmitted through the backbone network in the whole train. Each ETBN has two reference directions: direction 1 from Tc2 to Tc1 and direction 2 from Tc1 to Tc2. The physical connection of the vehicle makes the ETBN direction 1 and vehicle direction 1 the same, which ensures that the direction 1 of each node is the same and the train communication direction is the same in the case of multiple nodes. The address of the first node of the train is 01, and the other nodes are numbered in ascending order from 02 according to bus direction 2, and the last named node is the tail node [3].

The ETBN connected to the lower train formation network can adopt redundancy or non redundancy mode. When redundancy mode is adopted, all redundant ETBN will keep running. In a train formation, in case of redundancy, only one ETBN is authorized to undertake data interaction between train backbone network and train formation network. When ETBN fails, its redundant ETBN begins to undertake data interaction. In the case of redundancy, according to IEEE 802.1AX protocol, link aggregation can be performed when multiple links are connected between two ETBNs. In order to achieve link aggregation, IEEE 802.1AX protocol uses LACP protocol to exchange data frames and realize link redundancy. There is only one aggregation group containing redundant Ethernet segments between two ETBNs, and the link aggregation process only defines the relationship between the two ETBNs. Considering the limitation of train network on network load, ETB uses TTDP (Train Topology Discovery Protocol) protocol to send LLDP (Link Layer Discovery Protocol) data frame to manage link state.

3. LINK AGGREGATION RECHNICAL RESEARCH

Link aggregation, also known as trunking, refers to the aggregation of multiple physical ports to form a logical port. After the network data flow arrives at the port, it is dynamically and evenly distributed to each link through the port load balancing algorithm, so as to enhance the bandwidth of the logical link and make the bandwidth of the logical link be the sum of the aggregated physical links. Three advantages of improving the link bandwidth, traffic load balancing and improving the reliability of the network are realized. Link aggregation is responsible for controlling and configuring link aggregation sublayer, which is an optional sublayer between MAC layer and MAC Client. As shown in Figure 2.

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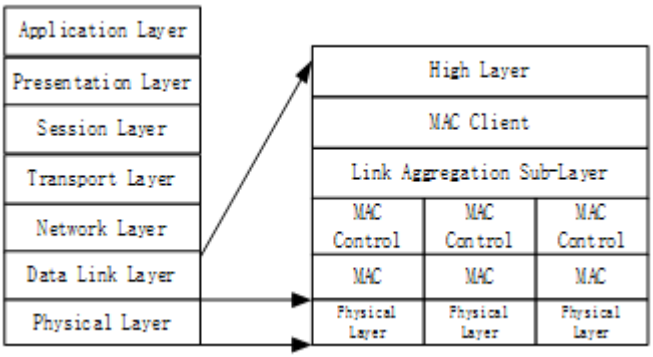

Figure 2. Location of Link Aggregation Sublayer in OSI Reference Model

Link aggregation sublayer is mainly composed of three parts: aggregator, aggregation control module and control parsing multiplexing module. The aggregator is composed of frame sending module, frame receiving module and aggregation analysis multiplexing module. The aggregator will be assigned a unique MAC address. For the MAC Client layer, this MAC address can be either the destination address of the received frame or the source address of the transmitted frame [4].

According to different aggregation methods, link aggregation can be divided into static link aggregation and dynamic link aggregation. LACP provides a standard control method for dynamic link aggregation.

3.1. Lacp Procotol

The main content of IEEE 802.3ad standard is link aggregation control protocol (LACP), which defines the control mode of dynamic link aggregation. LACP protocol stipulates that both sides of aggregation exchange their aggregation information through the protocol, and select appropriate ports to aggregate data together according to the States and relevant parameters of both parties. After the aggregation is established, the port in the dynamic aggregation group sends LACPDU (Link Aggregation Control Protocol Data Unit) periodically to the opposite end to inform the peer of its system LACP protocol priority, port LACP protocol priority, system Mac, port number and operation KEY, so as to realize real-time information exchange. By comparing the real-time information contained in the LACPDU with the information received from other interfaces, both ports can join or exit a dynamic aggregation group together.

When receiving a message, LACP message and non LACP message are distinguished by control analysis multiplexing module. As shown in Figure 3, the control parsing multiplexing module distinguishes the mixed messages, LACP messages are sent to the aggregation control module, and non LACP messages are sent to the aggregation analysis multiplexing module. The LACP message is transmitted to the aggregation control module to control the aggregation port of the link; instead, the LACP message enters the aggregator and the aggregator carries out the next operation. If the message comes from MAC client, it will enter the aggregator directly. The aggregator will transmit it to the corresponding control analysis multiplexing module according to the load balancing algorithm, and then send it to the lower layer.

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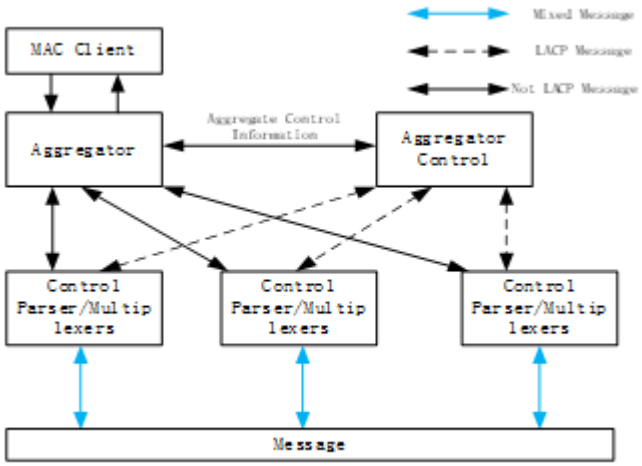

Figure 3. Sub Layer Structure of Link Aggregation in Link Aggregation

In the dynamic aggregation mode, the port selection will refer to the system ID and port ID. When the configuration changes, the link backup information will be automatically adjusted, which is more flexible.

3.2. Load Balancing Algorithm

In link aggregation, the use of load balancing algorithm realizes the feature of link traffic balance. In train network communication, if we want to communicate faster and better, we must solve the problem of network congestion caused by a large number of network services. Load balancing can achieve the advantages of low price, good effect and transparent operation on the basis of the existing network structure. It can expand the bandwidth of network equipment and server, thus increasing the throughput, effectively improving the flexibility and availability of the network, and strengthening the processing capacity of network data. At present, there are many load balancing algorithms, such as polling algorithm, random balancing algorithm and weighted random balancing algorithm.

In this paper, hash algorithm is used to determine the selected link through hash operation, so as to achieve the overall traffic balance distribution. Hash function is a mathematical function that can map long address to short address. There must be a fixed correspondence between the output and the input of a hash function, and the output relative to the input is random. In this algorithm, the MAC address of the request target is used as a hash key to find the corresponding port in the hash table. If the port is available, the message will be sent to the port for forwarding. Otherwise, it will return null. When an aggregation group is created in the switch, the bottom layer will also create a hash table corresponding to the aggregation group. Therefore, the elements in the hash table are one-to-one corresponding to the aggregation port. The hash table can be used to realize the distribution of different traffic. Hash table is a data structure that can be directly accessed based on the key value. It can associate the Key value with the position in the table to speed up the search [5].

The Hash algorithm calculates the key value, performs XOR operation on the extracted MAC address for many times, and finally obtains the key value, which is used to find the corresponding forwarding port in the hash table. The process is divided into four steps:

Firstly, the MAC address is extracted from the message, then XOR operation is performed between MAC address and 0, and the obtained value is stored in H_ Mac [] array:

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```
for (int i = 0; i < 48; i++)
{
    H_MAC[i] = H_MAC[i] ^ 0;
}
```

Then, XOR is performed on the upper 24 bits and the lower 24 bits of the XOR value:

```
for (int i = 0; i < 24; i++)
{
    H_MAC_XOR[i] = H_MAC[i] ^ H_MAC[i + 24];
}
```

At this time, the MAC address is calculated as 24 bit data, and the 23rd ~ 16th bit and 15th ~ 8th bit XOR of the 24 bit data are used, and then the obtained 8bits are replaced by 15bit-8bit to obtain an array of 16 bit data:

```
for (int i = 7; i < 16; i++)
{
        H_MAC_XOR_bit[i] = H_MAC_XOR[i] ^ H_MAC_XOR[i + 8];
}
for (int i = 0; i < 8; i++)
{
        H_MAC_XOR[i + 7] = H_MAC_XOR_bit[i];
}
```

Finally, the high 8-bit data and the low-8-bit data are XOR operation, the value obtained is matched with the ID of the aggregation port in the hash table, and the port is selected to send the message. Because the MAC address of the device is different, the selected port is also different. Hash load balancing algorithm is a deterministic algorithm. If the same address and session information are used, the same port will be selected to transmit messages every time to avoid the disorderly sending of packets. Based on the above reasons, this paper selects hash algorithm as the reason.

4. SIMULATION MODELING AND RESULT ANALYSIS BASED ON OPNET

OPNET Modeler is a platform for network simulation development and application. The three-layer modeling mechanism is used to build the simulation platform through network modeling, node modeling and process modeling. It can accurately analyze the performance and behavior of complex networks. Standard or user specified probes can be inserted at any position in the network model to collect data and conduct statistics. In this paper, OPNET simulation software is used to build the Ethernet train backbone network model for link aggregation, run simulation and analyze the results to evaluate the improvement of network performance of Ethernet train backbone network by link aggregation.

The network layer model of ETB Ethernet train backbone network link aggregation is shown in Figure 4. There are six 5-port train level switches with port rate of 100Mbps. There are links l1, l2, l3, l4, l5, l6 and l7 from left to right. One switch represents a car. The ETBN on both sides simulates that the head car and the etbn of the adjacent carriage are connected by two links. The link l1 and l2, and the link l6 and l7 are respectively linked together. Each ETBN is linked to an Ethernet Station. It is assumed that the packets generated by the Ethernet Station are messages from the ECN network, including real-time periodic data, real-time aperiodic data and

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non real-time data. Operation simulation results show that the advantages of link aggregation to train network.

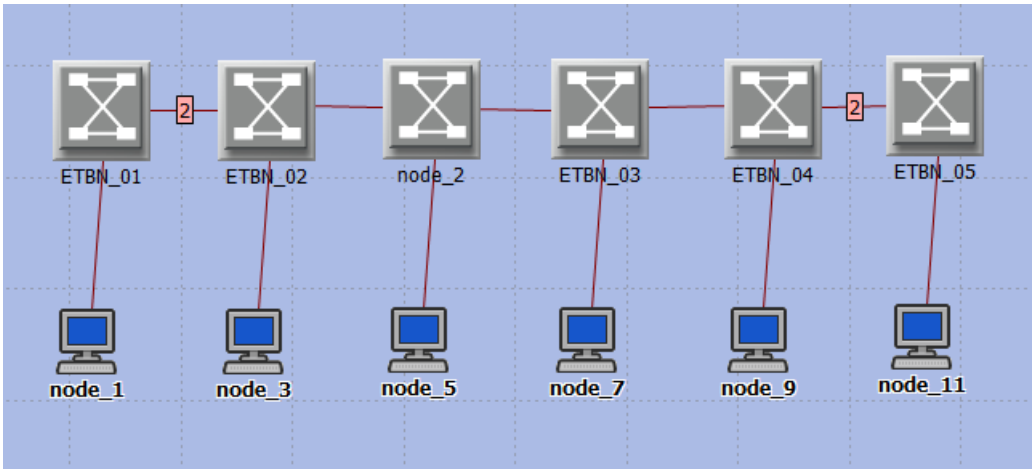

Figure 4. Ethernet Train Backbone Network Model

ETB link aggregation configuration:

1) Configure the properties of the switch Port Group Configuration, The port aggregation group name is JH1.

2) Configure the port properties of the Switch Port Configuration→Port Grouping Parameters, Set the port group to JH1, Enable port aggregation protocol LACP, The port mode adopts Active mode. The hash load balancing algorithm is called at the aggregation port to share the traffic load. In this simulation, two ports are selected as aggregation ports, and two physical links are aggregated into a logical link for simulation.

Before and after the link aggregation, as shown in Figure 5. Because the simulation results of link aggregation are the same, the simulation results show that link l1 and link l2 are aggregated and compared before and after. From top to bottom, green line is link l1 throughput before link aggregation, blue line and red line are link l1 and link l2 link throughput after aggregation, and blue line is link l2 throughput before aggregation.

The abscissa represents the simulation time (in minutes), and the ordinate represents the node load (in bits/s). It can be seen from the figure that when LACP protocol is not configured, there are two data transmission links between switches. Therefore, a port of the switch will be blocked according to STP protocol, so that one of the link data transmission links can not transmit data, so as to avoid broadcast storm. However, the transmission bandwidth is wasted. It can be seen from the figure that the link utilization of link l2 before aggregation is 0. However, after the LACP protocol is configured and the load balancing algorithm is added, the links between the two switches can be used to transmit data, and the throughput of the two links is between 800000bits/ s-1200000bits/s, that is, 0.8m/s-1.2m/s. The link utilization ratio of the two is close to 1:1, and the throughput is half of that before aggregation. The load balancing algorithm realizes the advantage of traffic balance in link aggregation, which makes data traffic evenly distributed between two links, avoids excessive link throughput on a single link, and improves the bandwidth of the link.

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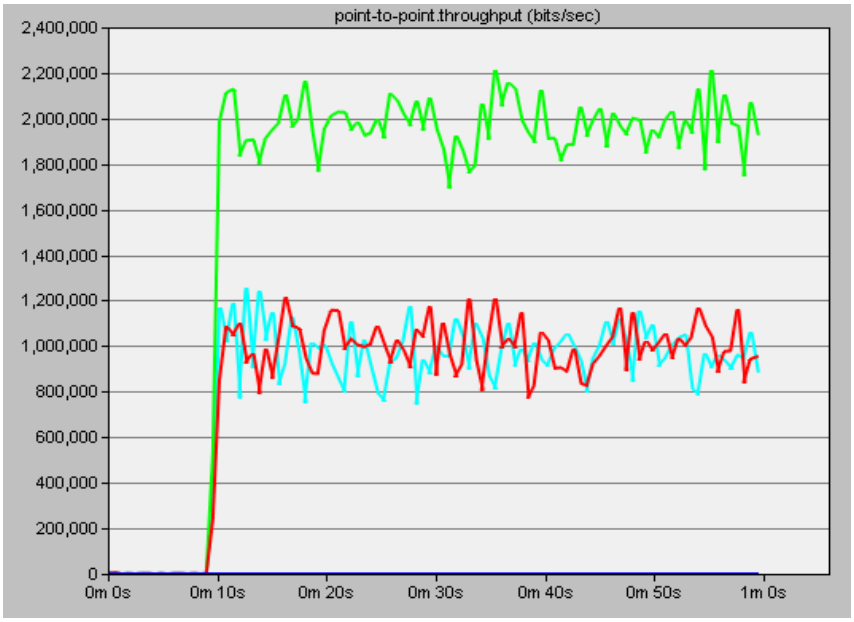

Figure 5. The Throughput of The Link Between ETBN_01 and ETBN_02

As shown in Fig. 6, there is a fault in the middle of link l2. The yellow line is link l1 and the red line is link l2. When the simulation is set for 15s and 0 ~ 5s, the two links are configured with LACP. After the link aggregation, the link l2 will work normally. The figure shows that when the fault occurs, the data will not be interrupted or lost, but will be superimposed on link l1. Due to the automatic backup of dynamic link aggregation LACP protocol, the network reliability is improved. When the fault of l2 of the 10s link recovers, the data of the two links are redistributed evenly and continue to work normally. The advantage of LACP configuration is verified, which improves the reliability of train network.

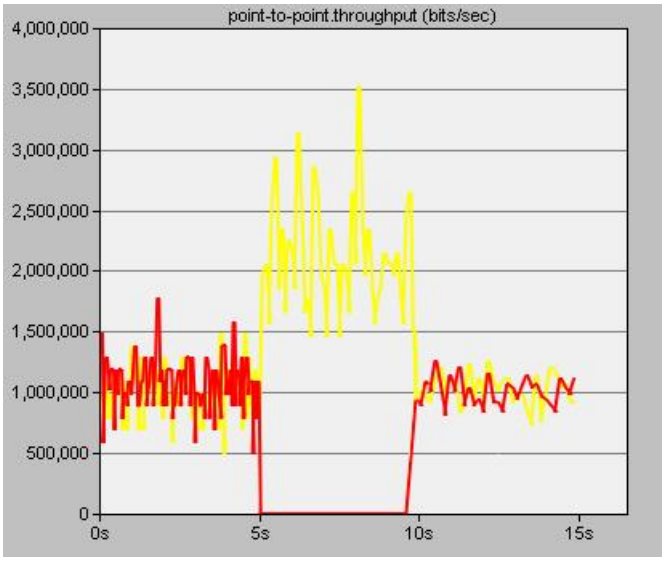

Figure 6. Link Throughput Change

5. CONCLUSION

This paper mainly focuses on the simulation of Ethernet train backbone network link aggregation, introduces the structure of Ethernet train backbone network, introduces the dynamic aggregation LACP protocol in link aggregation, and studies the application process of hash algorithm to realize load balancing. Finally, OPNET simulation software is used to build

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the Ethernet train backbone network platform. Through the analysis of the results, it is verified that link aggregation in the backbone network can reflect its advantages and improve the reliability of train network communication. With the development of train network, the traffic is bound to increase sharply. It will be a key development trend to adopt Ethernet train backbone network with link aggregation as train communication network.

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