Scheduling Mechanism of FC-AE-1553 Network Based on Credit Ranking

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***Abstract*—Aiming at the data transmission demand of large space information network, we propose a network bandwidth scheduling mechanism based on credit value sorting for FC-AE-1553 network based on passive optical network technology. The business types of FC-AE-1553 network include cyclical business, strong timeliness business and burst business. In this paper, a multi service FC network simulation platform is constructed, and the scheduling mechanism is analyzed by combining theoretical analysis with simulation development. The results show that, under the typical working condition at the 32 nodes, the network throughput can reach 3.44Gbps, the average time delay of the burst traffic is 58ms, and the average time delay of the strong timeliness burst service is 23us.**

Keywords—FC network ; FC-AE-1553; bandwidth scheduling; thoughput

I. INTROCTION

With the expansion of the application in the aerospace, more payloads are mounted on large aerospace information networks, which have various types, complex control, larger amount of information and higher data rate. All kinds of those new features demand higher real-time performance, more data transmission bandwidth, larger data processing capability and system reliability to the information network[1-5].

FC-AE-1553 protocol could be as a potential solution for future aircraft network with high data rate and reliability, because of its good real-time performance, large bandwidth, high reliability, low energy loss and well compatibility with MIL-STD-1553 protocol. By using the fiber channel technology, the transmission performance of FC-AE-1553 in physical layer and link layer has been greatly improved[6-7]. PON technology based on passive optical network is a kind of optical access network technology, which uses a bus architecture with shared bandwidth, which has the characteristics of supporting dynamic bandwidth allocation, simple fabric and high reliability[8-9].

On the basis of PON technology, this paper proposed a schedule of carrying the FC-AE-1553 protocol on the upper layer of the fiber channel, and the dynamic bandwidth allocation algorithm based on the credit value sorting, fully exerts the high bandwidth transmission advantage of the bus FC-AE-1553 network fiber channel, and can increase the network throughput to 3.44Gbps, ensure the application service and average time delay.

II. FC NETWORK ARCHITECTURE AND BUSINESS TRANSFER TYPE BASED ON PON

A. FC network architecture based on passive optical network technology

The bus based network topology include the network controller (NC), the network terminal (NT) and the physical link (PL). The network architecture is shown in Figure 1.

- The network controller is the node that sends out the command in the network. The main function of NC is to dispatch the resources of the whole network and determine the data transmission in the network. Every data exchange in the network begins with the NC launching of data transmission command. The main parameters of the NC node include the size of the N port cache and the credit value of the N port. In the design of the scheduling scheme, the port cache of the NC node is 2112 bytes and the port credit value is 8;
- The main function of the network terminal is executing the commands issued by NC. NT exchange data with NC or other NT according to the commands of NC. The main parameters of the NT node are the same as those of NC, the port cache is 2112 bytes, and the port credit value is 8.
- The physical link is FC link, and the protocol specifies three standard transmission rates, namely 1.0125Gbps, 2.125Gbps and 4.25Gbps. The physical link rate in this scheduling scheme is 4.25Gbps, and the length of the optical link is 0~300m. The branch ratio of the optical splitter is 1:2~1:32 optional.

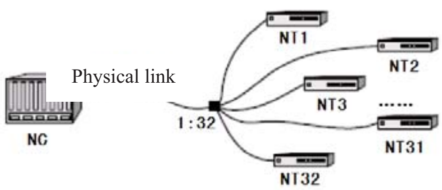

Fig. 1. FC network architecture diagram based on passive optical network technology

B. business type

According to the data transmission characteristics of the multi service platform electronic system, the business type can be divided into the following three categories:

- Cyclical traffic is the data generated periodically during the network operation, and has a strong time transmission rule.
- Strong timeliness of business which sensitive to time delay and highest transmission priority, if the delay is not controllable, will cause serious damage or failure of terminal network paralysis.
- Sudden business is the large data service that emerges in a certain period of time during the operation of the network, which needs a large number of network bandwidth, but is relatively insensitive to time delay.

III. NETWORK TRAFFIC PLANNING PRINCIPLE AND SCHEDULING MECHANISM

A. Data control strategy

The network can be divided into three stages: login stage, data transmission and logoff. Because FC-AE-1553 is a command response protocol based on bus architecture, the data transmission between nodes does not require strict clock synchronization and accurate ranging, so the FC-AE-1553 network scheduling scheme must be able to accommodate the transmission error caused by the range finding.

In a bus structure, the login process is implicit after the system is turned on, and the data transmission environment between NC and NT or NT and NT is completed by implicit login. After the entire login process is completed, that is, after all the operating environments are built successfully, data can be transmitted between the nodes. Each data transfer process begins with the NC starting command frame.

The protocol adopts deterministic communication under the command and response mode of NC centralized control. The normal operation of the entire network requires NC to send command frames to control. The FC-AE-1553 protocol includes three types of command frame, data frame and status frame. The transmission in the network ensures the normal operation of the network. Among them, the command frame is mainly NC to control the behavior of each NT. The data frame is mainly used for the transmission of data between NC to NT, NT to NT, and the state frame is mainly reported to NC by NT.

There are three kinds of switches in bus architecture, namely NC to NT, NT to NC, and NT to NT. In addition to NT to NT exchange, the other two exchange processes are exactly the same as the exchange process under the exchange structure. In the bus-based structure based on PON technology, it is limited by the one-way transmission of the optical path. There is no direct data transmission between NT and NT. The transmission of NT to NT must be transferred through NC.

In the standard FC-AE-1553 protocol, it is stipulated that the state frame return process of NT to NT exchange is to receive NT sending State frames to send NT, and then send NT to return state frame to NC. In the bus structure, it is adjusted to receive the NT sending status frame, and NC sends it to the sending NT after receiving it, sending NT to receive the status frame and then returning the state frame to NC. The schematic diagram of the NT to NT exchange in the bus structure is shown in Figure 2.

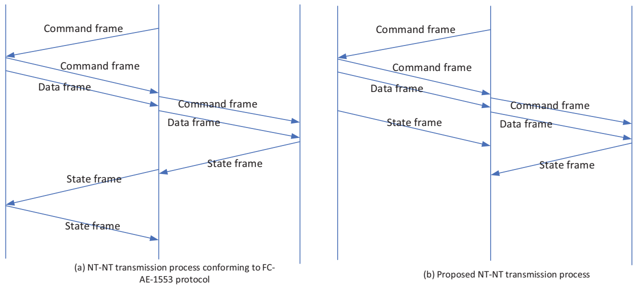

Fig. 2. FC network architecture diagram based on passive optical network technology

In a bus based FC-AE-1553 network, the transmission time between NC and NT can only be estimated by the farthest NT. In order to fully conform to the protocol switching process, the return of the state frame is guaranteed to increase the bandwidth reservation of 1 protected time slots. When data retransmission is carried out, NC sends ABTS boot retransmission: NC detects a switched state frame timeout, selects the ABTS (exception termination sequence) protocol, and the bit0 of the ABTS parameter is set to "0", receiving the NT node of the ABTS to judge that the switch is terminated by the exception. Send NT to send the data exchange bandwidth to the NC request again, wait for NC to redistribute the bandwidth to send the command frame.

B. Design of scheduling scheme

The types of services carried on the network include cyclical business, burst business and strong timeliness burst business. The following three kinds of business scheduling strategies are introduced respectively.

The period of periodic traffic is fixed in the whole dynamic bandwidth scheduling cycle, as shown in figure III.1. During the periodic business time period, the periodic business cycle is fixed and known, so the NC polling NT is not required to obtain the periodic service requests. Each dynamic bandwidth scheduling period assigns fixed bandwidth to the periodic service, and the bandwidth of the periodic service accounts for about 4% of the total bandwidth. The periodic business period is usually placed at the beginning of the dynamic bandwidth scheduling cycle. In a cyclical business period, NC performs periodic downlink business first and then performs uplink periodic business, as shown in figures 3 and 4.

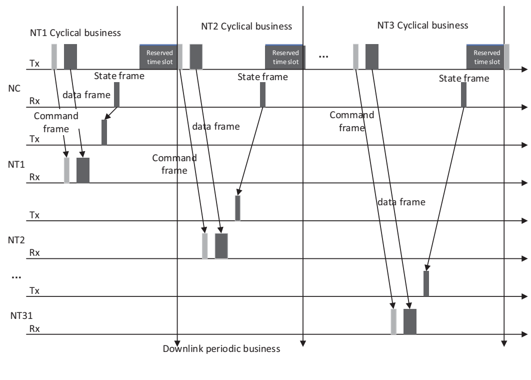

Fig. 3. Cyclical business schematic (downlink)

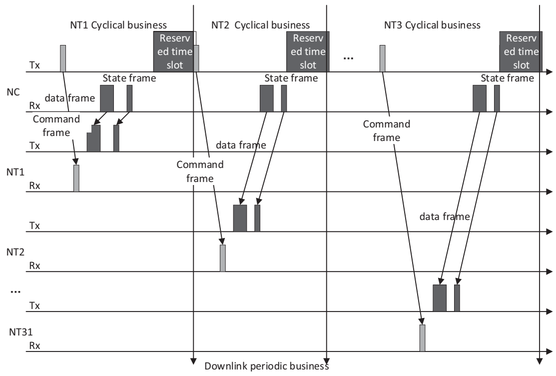

Fig. 4. Cyclical business schematic (uplink)

In the bus structure, periodic business exists only between NC and NT, and there is no cyclical business between NT and NT. For the downlink periodic service, the maximum amount of data for single service is 512Bytes, the command frame length is 60Byte, the sending time of the command frame and the periodic business data is 1.35us, the 600m fiber transmission time is 3us, the NT response time is 5us, and the transmission time of the state frame is 0.1us. Therefore, the maximum execution time of a downlink periodic business exchange is 12.5us.

For the uplink periodic service, the transmission time of the command frame is 0.15us, the 600m fiber transmission time is 3us, the NT response time is 5us, and the periodic service data transmission time is 1.2us. For periodic broadcast services, NT does not need to reply to NC, so the execution time of a periodic broadcast service exchange is 4.35us. Therefore, the maximum execution time of an uplink cyclical traffic is 12.4us.

In summary, any cyclical business switch can be executed in 12.5us, so the time slot allocated for each periodic message is not less than 12.5us. The upside and downlink periodic business exchange is shown in Figure 5.

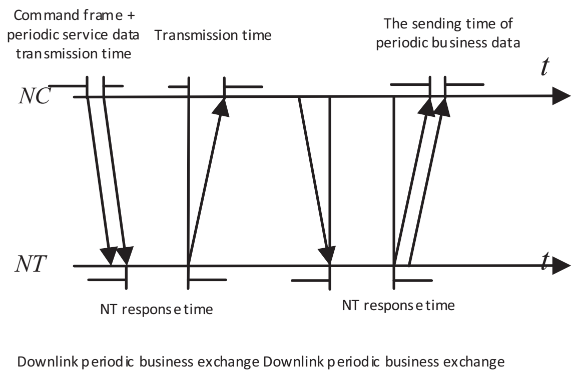

Fig. 5. Up and down periodic business exchange schematic diagram

During the transmission of cyclical traffic, NC nodes may receive strong time demand business. The same method is used to deal with this kind of conflict with the switched network. The scheduling mechanism reserved the processing slots for the strong timeliness burst service between two periodic services to ensure the real-time demand for the time delay sensitive traffic data transmission.

Under the bus sharing architecture based on bandwidth sharing, there will be no transmission conflict between periodic business and bursty traffic through NC task scheduling and orchestration.

The burst traffic under bus architecture also includes bursting traffic from NC to NT, NT to NC, and NT to NT. Among them, the burst traffic from NT to NT is limited by the upstream and downlink wavelengths, and the data needs to be relayed by NC nodes, which restricts the utilization of network bandwidth to a certain extent.

The scheduling of sudden traffic is based on the single time axis of NC, which includes three stages: terminal state polling, bandwidth allocation and dynamic scheduling.

- Terminal state polling stage, NC obtains the bandwidth request of NT next round cycle scheduling through the state frame returned after each switch is completed. When NT is not reported, it is indicated that there is no state frame return in the last dynamic bandwidth scheduling cycle, and there is no data transmission in the NT. At this time, the bandwidth of the NT in the current dynamic bandwidth scheduling period is NC as the minimum bandwidth allocated to the terminal node to ensure that the NT can transmit data within the current dynamic bandwidth scheduling cycle, and this mechanism is similar to the bandwidth allocation mechanism in the passive optical network.
- Terminal state polling stage, NC obtains the bandwidth request of NT next round cycle scheduling through the state frame returned after each switch is completed. When NT is not reported, it is indicated that there is no state frame return in the last dynamic bandwidth scheduling cycle, and there is no data transmission in the NT. At this time, the bandwidth of the NT in the current dynamic bandwidth scheduling period is NC as the minimum bandwidth allocated to the terminal node to ensure that the NT can transmit data within the current dynamic bandwidth scheduling cycle, and this mechanism is similar to the bandwidth allocation mechanism in the passive optical network.
- According to the result of bandwidth allocation, NC arranges each terminal node to carry out corresponding data transmission operation. All operations are initiated by the NC side.

The network throughput can be improved to a certain extent by judging whether the downlink business exchange can be concurrent or not, when the bandwidth allocation and the switching execution sequence are completed. There are two conditions for concurrent downlink burst traffic to be concurrency.

- In NC downlink burst traffic, NC sends data longer than the maximum protection slot. At this point, the uplink burst traffic exchange can be performed concurrently within the time interval of the NC downlink burst service switching. At this point, the concurrent slot can be allocated to the NT with uplink burst request. To a certain extent, it achieves NC uplink and downlink concurrency and improves network throughput.

- Another kind of concurrency is the data exchange in NT-NT. The current mechanism is that NC receives the NT after sending a complete FC frame to send NT. At this point, the uplink and downlink of NC can be regarded as simultaneous data transmission.

Abrupt traffic is insensitive to delay parameters, so it can be interrupted by the most powerful and time-consuming burst service in the transmission process. In each scheduling period, the scheduling mechanisms used by strong aging services are all static bandwidth allocation, which will reserve transmission slots for strong real time services during this period. Interruption of sudden business, data transmission after the completion of strong timeliness business transmission.

Strong time burst business is generated by NC with the destination address of NT. The duration of the burst timed business is the time required to perform a strong timeliness burst business exchange, as shown in Figure 6.

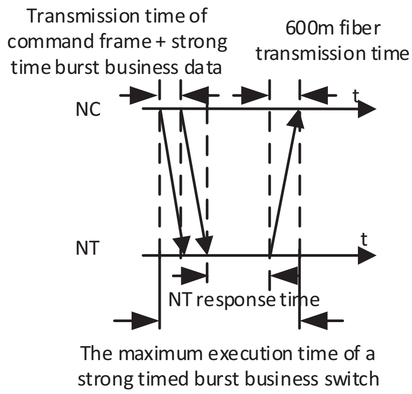

Fig. 6. Strong timeliness burst business exchange schematic diagram

The maximum amount of data in the strong aging burst service is 100Byte, plus the command frame length 60Byte, and the transmission time is 0.4us at the link rate of 4.25Gbps (8b/10b rate). The transmission time of the 600m fiber (both upstream and downlink distances according to 300m) is 2us, the NT response time is 2us, and the sending time of the 44Byte state frame is 0. 1us, therefore, the longest execution time of a strong time burst business exchange is 4.5us. For broadcast hard time bursty traffic, NT does not need to reply to NC status frame, and its execution time is less than that of unicast hard time burst business switching.

In bus network, bandwidth reservation is adopted for strong timeliness business to ensure the timeliness of data transmission. Strong time burst business is usually generated by NC with the destination address of NT. In the scheduling mechanism, the concept of detection period is introduced, and in each detection period, a time slot is reserved for the strong aged burst service. The length of the time slot is determined by the number of requests for strong timeliness burst services that can be produced most within a single detection cycle. The duration of strong time burst business is the time needed to perform a strong time burst business exchange.

C. Design of bandwidth allocation algorithm based on credit ranking

The bus scheduling mechanism adopts a dynamic bandwidth scheduling mechanism based on periodic rotation and credit ranking. The strong timeliness burst service and periodic service adopt static fixed bandwidth allocation mechanism, that is, the bandwidth of strong timeliness burst service and periodic business periodic allocation is fixed within a dynamic bandwidth scheduling cycle. Yes. The dynamic bandwidth allocation based on guaranteed bandwidth is adopted for the burst service. In a dynamic bandwidth scheduling cycle, there are four parts of the dynamic bandwidth scheduling period, which include the strong timeliness burst service time period, the periodic business time section, the sudden business time section and the dynamic bandwidth scheduling time section.

In the FC-AE-1553 network scheduling scheme based on bus structure, the bandwidth of the whole network is abstracted as a single time axis. The single time axis refers to the time axis of the NC node, which includes the NC downlink timeline and the NC uplink time axis.

In the bus architecture, because there is no ranging mechanism, NC can control a switching initiation time and the end time of the exchange completion (the maximum protection time slot is estimated), but it does not control the exact time of the data frames on the NT uplink. Therefore, in order to ensure that the state frame does not conflict with other transmission, the uplink and downlink of NC is related to a certain extent, and is guaranteed by timeout mechanism.

The up and down time axis of the NC is associated to a certain extent. When data is transmitted in any time axis direction in the NC and down, the other time axis can not be transferred in theory. However, not all NC up and down are associated, as shown in Figure 4.7, in a downlink exchange, there is still a fully secure time for uplink switching, and there is no connection between the upstream and downlink of the NC in this period, so that NC can be concurrently on the downlink. The scheduling mechanism designed in this paper is by calculating the time segment of each NC downlink exchange time, and reassigning this part of the secure transmission time to the NC uplink request to realize the concurrency on the NC, thus improving the network throughput.

The resource of network scheduling is the bandwidth of the whole network, and the time axis of scheduling refers to the time axis of the whole network. A scheduling cycle in the dynamic scheduling time axis of network bandwidth is divided into several time periods: strong timeliness burst service time gap, periodic business time section, burst business time period and bandwidth allocation calculation time. Fig. 7 is a diagram showing the distribution of time periods on the periodic bandwidth dynamic allocation time axis.

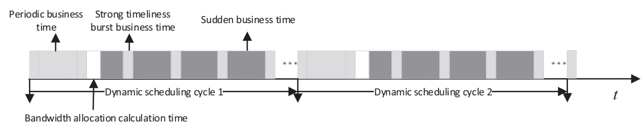

Fig7. Time axis schematic diagram of network dynamic bandwidth scheduling

Because NC's downlink can go to any NT node, NT can only report one request (taking 32 nodes as an example). There are 31 connections in the NC downlink and 31 uplink connections in NT, totaling 62, that is, there are 62 credit values. The data transmission is based on the result of the credit value sorting, and the bandwidth allocation is arranged according to the credit value. Until the bandwidth is allocated, the nodes that do not receive the bandwidth authorization will report the unsent and the newly generated total request. The relationship between the nodes in the network on the timeline is shown in Figure 8.

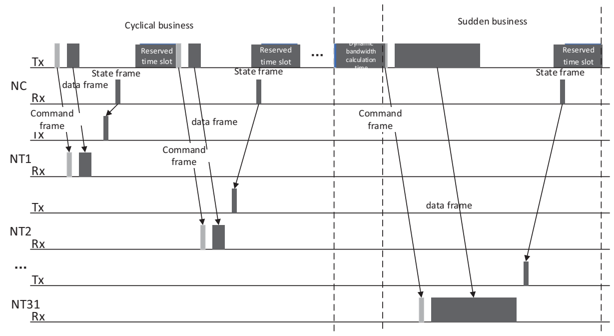

Fig. 7. On the time axis-a

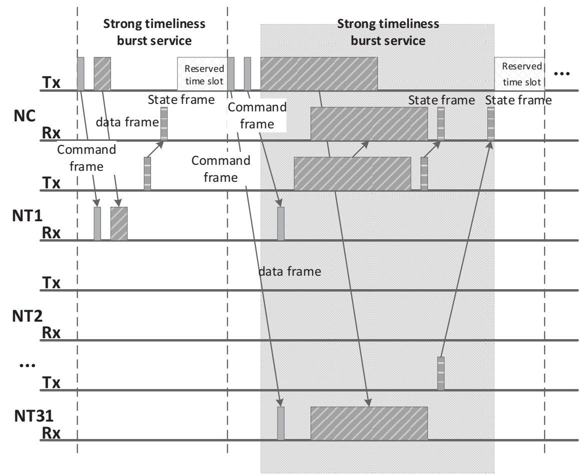

Fig. 8. On the time axis -b

For network login and new node joining, the login process after network initialization is implicit.

D. *Design of dynamic bandwidth allocation algorithm*

The dynamic bandwidth allocation algorithm is designed based on the transmission time axis of NC and the receiving time axis of NC. For the downlink burst traffic, the data amount of the single data exchange is 64KBytes, the command frame length is 60Byte, the sending time of the command frame and the burst business data is 150.6us, the 600m fiber transmission time is 3us, the NT response time is 5us, the state frame transmission time is 0.1us, so a downlink periodic service exchange is made. The maximum execution time is 161.7us.

For the uplink burst traffic, the transmission time of the command frame is 0.15us, the 600m fiber transmission time is 3us, the NT response time is 5us, and the burst service data transmission time is 150.6us. For downlink broadcast burst, the execution time is 153.7us. Therefore, the maximum execution time of an uplink burst traffic exchange is 161.75us. Considering the transmission time requirement of data uplink and downlink, the execution time of a 64Kbytes burst service is about 162us.

The flow of dynamic allocation algorithm based on ranking of credit values is shown in Figure 9.

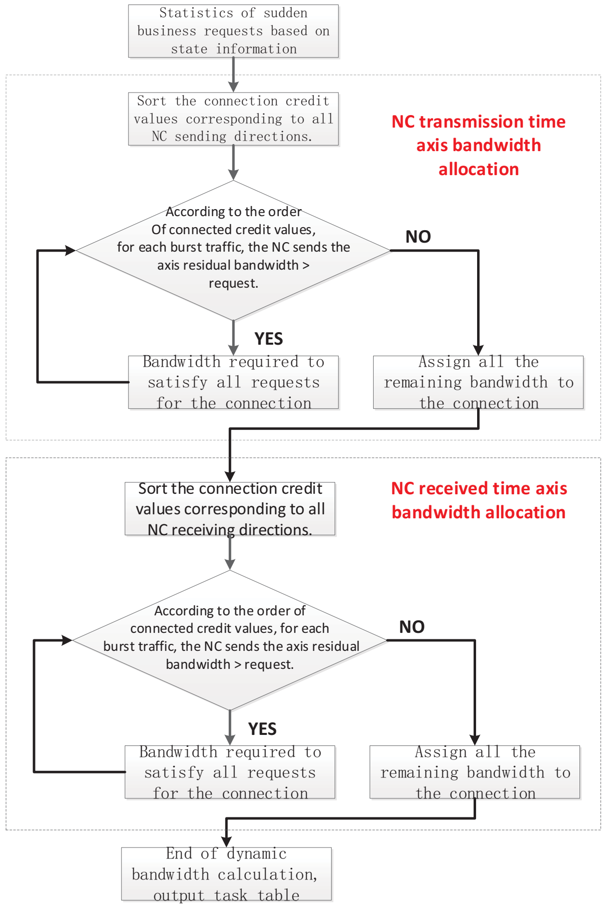

Fig. 9. Flow chart of dynamic allocation algorithm based on ranking of credit values

After the bandwidth allocation is completed, the execution order of the business exchange needs to be determined. The execution sequence of the exchange is based on the information generated by the source address, the destination address and other information in sequence according to the list generated by the bandwidth allocation stage. When an exchange meets a strong timeliness burst business, it will be interrupted. At this point, the amount of data exchanged by the interrupted business will be reduced compared to the amount of data allocated.

IV. NETWORK SIMULATION SYSTEM AND ANALYSIS RESULT

A. *System design*

OPNET Modeler 14.5 is used to build the simulation platform for the bus FC network. The schematic diagram of the simulation topology is shown in Figure 10.

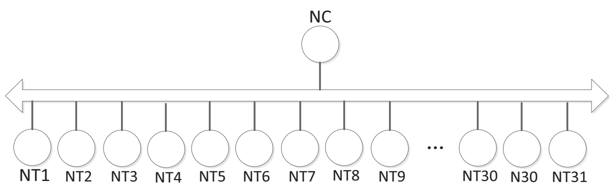

Fig. 10. FC-AE-1553 Primary bus network topology diagram

The simulation verification environment consists of the following four parts:

- NC node×1；
- NT node×31；
- Optical splitter × 1(Implementation of link direct connection and collision detection)；
- 4.25Gbps two-way data communication link

The NC node model consists of four parts: data source module, queue buffer module, protocol processing module and data IO module. The model of the NC node is shown in Figure 11.

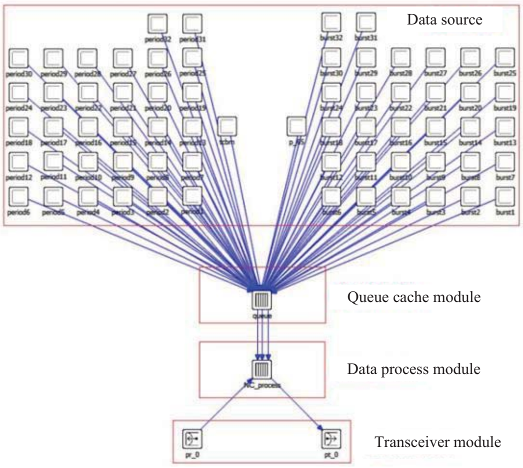

Fig. 11. NC Node model

The node model of NT consists of four parts: data source module, queue buffer module, protocol processing module and data IO module. The main function of the data source module is to generate various types of services. The function of the queue module is to store the service frames generated by the data source and wait for the transmission. At the same time, according to the control information of the protocol processing module, the service request size in each queue is counted.

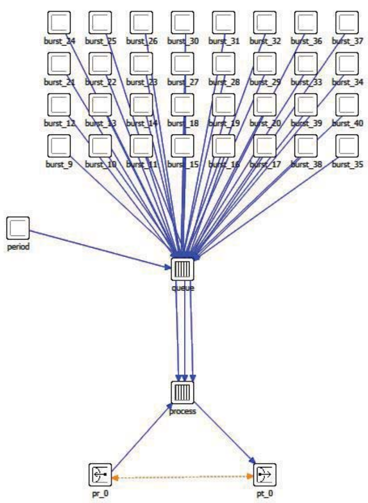

Fig. 12. NT Node model

B. *Comparison and analysis of traditional scheduling strategy*

FC-AE-1553 bus based network scheduling scheme based on credit value ranking adopts command response based scheduling. In the case of no distance between nodes, the static fixed bandwidth allocation method is adopted for the strong aged burst service and the periodic service, and the dynamic bandwidth allocation mechanism based on the request and authorization is adopted for the burst service. In a dynamic bandwidth scheduling cycle, NC gets the bandwidth request of NT through the exchange state frame and receives bandwidth requests from all nodes. The bandwidth allocation of this cycle is carried out according to the dynamic bandwidth scheduling algorithm based on credit value.

The traditional "big cycle and small cycle" scheduling scheme is also based on command response scheduling. In the case of no distance between nodes, the traditional scheme uses static fixed bandwidth allocation for both strong and periodic services, and the small cycle and large cycle are determined in accordance with the business cycle from small P_{min} to large P_{max}. In a large cycle, every time the traffic is completed, the returned state frame will carry the business request of the node, and NC will arrange every unexpected service after the request is received. （L_i as Business length，V as transmission speed）In each small cycle P_{min} Sending time 。The sending time for each service is $L_i/v.(P_i/P_{min})$，will be divided into P_i/P_{min} times to sending, so that can cover the maximum time delay requirement for burst traffic。

From the three aspects of throughput, delay and complexity, the bus based FC-AE-1553 scheduling scheme based on credit value sorting is compared with the traditional FC-AE-1553 scheduling scheme based on "large cycle and small cycle".

The essence of the "large cycle, small cycle" scheduling scheme is to send multiple messages serialized and not to implement concurrent execution of multiple tasks; while periodic concurrent scheduling uses the concurrency of NC up and down, so it supports the concurrency of NC and downlink services. Assuming that the number of NC downlink exchanges accounts for the 1/3 of all exchange numbers in the network, from a concurrency point of view, the concurrency scheme based on the credit ranking will increase the network throughput by about 30% more than the "large cycle, small cycle" scheme.

For the "large cycle, small cycle" scheduling scheme, NC distributes the business to a number of small cycles within the cycle of the business. If the service of the P is assigned to n small cycles and the small cycle is Pmin, the maximum time delay of the service is equal to the cycle Pmin of the business and the average delay is Pmin/2. Therefore, the maximum delay of strong time-consuming burst traffic is 50uS, the average delay is 25us, the maximum delay of burst traffic is less than 500ms, and the average delay is less than 100ms.

Based on the concurrency scheme of credit ranking, the maximum time delay is 50uS, the average time delay is 25us, the maximum delay of the burst traffic is less than 500ms, and the average delay is less than 60ms.

The maximum time delay of the two schemes is basically the same, while the average delay of the concurrency scheme based on the credit ranking is better than the "large cycle, small cycle" scheduling scheme.

The burst traffic in the "big cycle" and "small cycle" scheduling is evenly allocated to multiple small cycles, each scheduling need to calculate $\frac{L_i}{\left\lceil \frac{P_{max}}{P_i} \right\rceil}$, L_i is the Data size of sudden business, P_i is the cycle of sudden business。Therefore, the complexity of the "big cycle and small cycle" scheduling method is 11 division, which is equivalent to 66 addition operations. In the concurrency scheme based on credit value sorting, the complexity of the dynamic bandwidth allocation algorithm for 14 burst services includes the comparison operation of the rated bandwidth 14 times, the 32 comparison operation of the credit value and the 32 addition of the credit value updating when the remaining bandwidth allocation is allocated, and the complexity of the concurrency is 14 comparison operations. The complexity of one comparison operation is the same as the complexity of addition, so the total complexity of concurrency schemes based on credit value ranking is 92 addition operations.

The complexity of concurrent schemes based on credit value ranking is 1.4 times that of the "big cycle" and "small cycle" schemes.

C. Simulation results under optimal operating conditions

The network performance of the 32 node network under different load is simulated under the uniform network condition (the data between the terminal nodes are sent evenly). The simulation parameters are set as follows:

- Connection type: uniform connection;
- Number of nodes and simulation time: 32 nodes, simulation time 20s;
- Node buffer: NC, NT node buffer is 150Mbits;
- Strong time burst business: the time interval is exponentially distributed and the average time interval is 1ms.
- Cyclical business: cycle size 1ms, data volume 512Bytes, accounting for 4% of the proportion of bandwidth resources;
- Burst traffic: NC, NT load, node load separately: 0.002, 0.006, 0.01, 0.012 (The maximum load without losing);
- Dynamic bandwidth scheduling cycle: 4ms.

The network performance of 32 node network under different loads is shown in Table 1, and the trend of change is shown in Figure 13.

Table I Network performance with different network load at 32 nodes under optimal operating conditions

Network load	Strong aging service /us		Cyclical business /us		Sudden business/ms				throughput /Gbps	
	Maximum delay time	*average delay*	*NC-NT1*	*NC-NT2*	*Maximum delay time*		*average delay*			
					mean value	*Vari-ance*	*mean value*	*Vari-ance*	*mean value*	*Vari-ance*
0.064	48	24	2	12	37	2	6	0	0.549	0.053
0.192	48	24	2	12	133	19	38	0	1.444	0.036
0.320	48	24	2	12	404	108	65	3	2.373	0.072
0.384	48	24	2	12	899	161	77	4	2.742	0.035

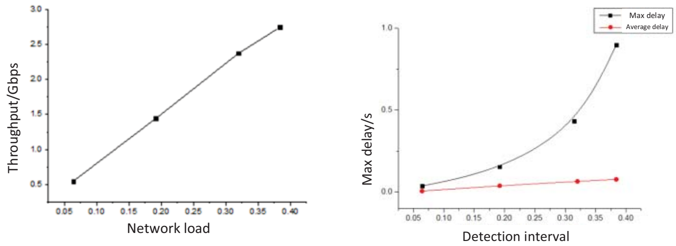

Fig. 13. When the number of nodes is 32, throughput and burst traffic delay vary with network load.

Network throughput increases with the increase of network load, and the trend of increase is basically linear. The maximum throughput of network is 2.74Gbps.

Strong time-consuming burst traffic delay: as shown in Table 1, the time delay of strong time burst business stays within 50us, meeting the requirements.

Burst traffic: as shown in Figure 13, the maximum delay of burst traffic increases with the increase of network load, and the average delay is basically unchanged. When the network load is small, the maximum delay growth of burst traffic is slow. With the increase of load, the maximum delay of burst traffic grows faster. When the network load is greater than 0.3, the delay of bursty traffic increases rapidly with the increase of network load. Therefore, under the condition of uniform connection, the network load needs to be maintained within a reasonable range.

D. Simulation results under typical work conditions

In the bus FC-AE-1553 network, if the ranging mechanism is adopted, NC will be able to learn the precise time of each exchange and further enhance the bandwidth. The network performance is simulated and analyzed under typical work conditions. The simulation parameters are set as follows:

- Connection type: adjacent connection;
- Number of nodes and simulation time: 32 nodes, simulation time 20s;
- Node buffer: NC, NT node buffer 50M;
- Strong timeliness business: the time interval is exponentially distributed and the average time interval is 1ms.
- Cyclical business: cycle size 4ms, data size 512Byte, accounting for 4% of bandwidth resources;
- Burst traffic: the peak rate of bursty traffic is 500M, NC and NT are the same.
- DBA cycle: 4ms.

The simulation results of the FC-AE-1553 network under the 32 node bus structure are shown in Table II and the trend is shown in Figure 14.

Table II Network performance with different network load at 32 nodes under typical work conditions

Network load	Cyclical business, strong timeliness business and sudden business	throughput /Gbps

	Cyclical business /us		Strong effective business /us		Sudden business /ms		
	NT1	NT2	Max value	Avg value	Max value	Avg value	
0.64	1	11	46	23	755	67	3.637
0.60	1	11	46	23	422	58	3.446
0.40	1	11	46	23	120	45	2.285
0.20	1	11	46	23	83	19	1.132

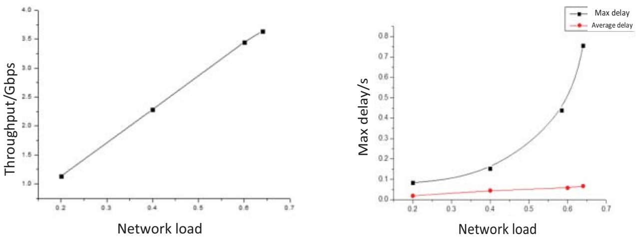

Fig. 14. The performance of network varies with load when the number of nodes is 32.

Network throughput increases with the increase of network load, and the trend of increase is basically linear. Under the typical conditions of adjacent connections, the maximum throughput of the 32 node network is 3.44Gbps, the maximum throughput of the 20 node network is 3.43Gbps, and the maximum throughput of the 10 node network is 3.44Gbps.

Strong time-consuming burst traffic delay: as shown in Table 2, the time delay of strong time burst business stays within 50us, meeting the requirements.

Burst traffic: the maximum delay of burst traffic increases with the increase of network load, and the average delay remains unchanged. When the network load is small, the maximum delay growth of burst traffic is slow. With the increase of load, the maximum delay of burst traffic grows faster. When the network load is greater than 0.6, the delay of burst traffic increases rapidly with the increase of load. Therefore, under the condition of uniform connection, the network load needs to be maintained within a reasonable range. When the 32 node network has a network load of 0.6, the maximum delay of burst traffic is 422ms and the average delay is 58ms.

V. CONCLUTION

In this paper, in view of the data transmission demand of large space sky information network payload, the FC-AE-1553 network based on passive optical network technology is carrying the mixed transmission of periodic service, strong aging service and sudden service. A network band wide scheduling mechanism based on credit value sorting is proposed, and the theoretical analysis and simulation are carried out. The verification method verifies the feasibility of the scheme. The simulation model of FC fusion network is built by OPNET simulation software. The simulation results show that the proposed strategy can reach 3.44Gbps under the typical network node number of 32, the average delay of the burst service is 58ms, and the average time delay of the strong aging burst service is 23us. The integrated network scheduling mechanism proposed in this paper can provide an effective solution for the design and optimization of key tasks in large aerospace information networks.

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REFERENCE

[1] PENG Li, Lv cong-min, LIU Ying-chun, HE Yu-feng, “Study of Topology Performance of FC-AE-1553 Network in Space Application”, Computer Technology and Development, 2013,Vol.23, No.9, pp.10-13

[2] FANG Liang, ZHAO, Guang-heng, CAO Su-zhi, Evaluation of network transmission performance in FC-AE-1553, Journal of Beijing University of Aeronautics and Astronautics, 2015,41(8):1396-1402

[3] Fiber channel-avionics environment INCTIS TR-31-2002[S].2002.

[4] CAO Su-zhi, ZHANG Shan-cong.Analysis on advanced features of FC-AE-1553(J). Optical Communication Technology, 2010, 34(2): 49-51

[5] FANG Liang, ZHAO, Guang-heng, CAO Su-zhi, Design of heterogeneous FC-AE-1553 network[C], Pro of 2014 CCSSE:130-134

[6] FC-AE-1553 INCTIS working draft proposed American national standard for information technology[S].2006

[7] Murdock J R, Koening J R. Opening systems avionics network to replaced MIL-STD-1553[J]. IEEE Aerospace and Electronic Systems Magazine, 2001,Vol.16,No.8 pp.15-19

[8] MaGarry, M.P, Reisslein, M, Investigation of the DBA Algorithm Design Space for EPONs, Journal of Lightwave Technology, 2012, 20(14):2271-2280

[9] DING Fan,XIONG Hua-gang,SONG Li-ru, “Modeling and simulation for FC-AE-1553 network”, Computer Engineering and Applications, 2008, Vol.44, No.8, pp.20-24.