

Dynamic Bandwidth Allocation for Switching FC-AE-1553 Network in Avionics System

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Abstract— In order to meet the requirement of space payload system and the data transmission, the data business type was divided into periodic business, burst business and strong timeliness business. After analyzing the characteristics of the three kinds of business, a scheme of dynamic bandwidth allocation (DBA) algorithm with parallel and switching for FC-AE-1553 network was proposed. The burst business used the periodical and concurrent dynamic bandwidth allocations, the periodic business used the static bandwidth allocation and the strong timeliness business use the pre-emptive bandwidth allocation. A FC-AE-1553 network model, the node model and process model of NC, NT and switch were set up in OPNET Modeller. The performances of the system were analyzed based on both theoretical analysis and simulation approaches. Compared with traditional DBA solutions of FC-AE-1553 network, the network throughput was increased by 15 times from 2.8Gbps to 46Gbps at 32 nodes, and the time-delay was decreased by one order of magnitude from 258ms to 28ms at 32 nodes and the optimum DBA cycle and node buffer were set to 1ms and 150Mbit. Compared to the traditional scheme, the network throughput has been improved at least by 5 times.

Keywords—Fiber Channel-Avionics Environment, Dynamic Bandwidth Allocation, Periodical and Concurrent, Switch FC-AE-1553

I. INTRODUCTION

With the continuous expansion of the number of space missions, the species of payload, and the transmission rate, the control scheme become more complicated, the avionics networks has high demanding request for the business processing capability and system reliability [1-2]. Based on the characteristics of flexibly and highly configurable network technology, fibre channel-avionics environment (FC-AE) protocol is currently used in several avionics network applications. FC-AE-1553 as one of the protocols FC-AE is considered as the candidate protocol of aerospace due to the high real-time, high-bandwidth, high reliability and compatible with MIL-STD-1553 [3]. Meanwhile, fibre channel can support point-to-point, fabric network, and ring network topologies. And the switched fabric topology used widely in space missions due to the higher reliability and capability. Therefore, in order to improve network throughput effectively and ensure the fairness of business for the whole

network reasonably, the bandwidth allocation of the switched FC-AE-1553 network is an essential function to provide flexible management and high resource utilization for optical fibre networks. Though the bandwidth allocation has been extensively studied but the mainly focused on the optical communication networks [4-5], and it is not accommodated the switched FC-AE-1553 network.

Therefore, in order to meet the requirement of space payload system and the business transmission, a scheme of dynamic bandwidth allocation (DBA) algorithm with parallel and switching for FC-AE-1553 network was proposed. And in our scheme, the business type of payload was divided into periodic business, strong timeliness and application business. The application business used the periodical and concurrent dynamic bandwidth allocations, the periodic business used the static bandwidth allocation and the strong timeliness business use the pre-emptive bandwidth allocation. The performances of the proposed scheme is evaluated and discussed through both theoretical analysis and simulation approaches. Simulation results show that the optimum DBA cycle and node buffer were set to 1ms and 150Mbit, and the maximum throughput were approximately 16.5Gbps, 30.8Gbps and 46.2Gbps at 10, 20 and 32 nodes, respectively.

II. NETWORK ARCHITECTURE AND DBA METHOD

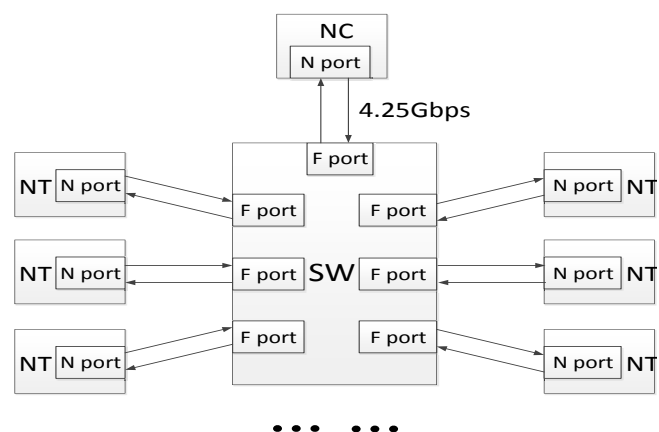


Figure 1. Switching FC-AE-1553 network architecture

Figure 1 shows the architecture of switching FC-AE-1553 network which consist network controller (NC), network terminal (NT), switch and many fibre links. FC-AE-1553 network is the command/response network, and NC is the master node of the network. The business transmission was controlled by NC, and each business transmission is launched by NC. NT is the slave node and receives or transmits the business based on the NC command. The function of switch is to forward the business. In the space payload system, the periodic business exists in NC to NT and not exists in NT to NT, application business exists in large-capacity equipment, and the application business is only generated by NC node.

With the rapid development of space application system, the demanding of the exchanging information and sharing between electronic devices become higher, the business types of payload were divided into periodic business, strong timeliness business and application business. Periodic business is accordance with a certain frequency transmitted business between nodes, such as timecode, telemetry business and power supply parameters. Application business is a large amount of business in some storage equipment, such as the business of science experiment or remote sensing. Strong timeliness business is the application directive business which generated by controller.

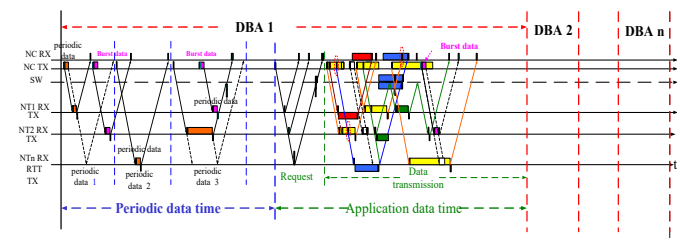


Figure 2. The scheduling mechanism of the DBA

In the switching network, competition and concurrent operation exist in the same link due to the characteristics of the switcher. Therefore, we design a combination of periodical and concurrent scheduling scheme based on the features of the three type payload business, which is shown in Fig.2. The bandwidth of FC-AE-1553 network is consider as the multiple timelines which are NC sending timeline, NC receiving timeline, and all NT receiving timelines. Periodic business use the static allocation scheme which is strictly synchronized with the DBA cycle. The strong timeliness business use the pre-emptive allocation scheme because of the higher delay requirement. The application business which is sent by NC use the periodic and centralized request dynamic allocation, and the scheduling mechanism is on-demand assignment algorithm based on first in first out. The flow chart of the application business DBA algorithm is shown in Fig.3.

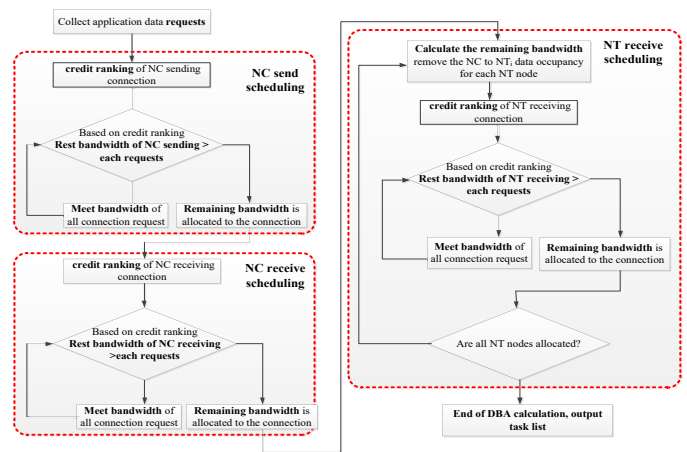


Figure 3. The flow chart of application business DBA algorithm

III.SIMULATION AND DISCUSSIONS:

The simulation configuration of the system is shown in Fig.4 and is simulated by OPNET software. In our switching FC-AE-1553 network simulation consists one NC nodes, thirty-two NT nodes and one switch. In our simulation, the business source exists in NC and NT nodes, the periodic and strong timeliness business sources can generate 512 byte FC frame, but the time interval obey the exponentially distributed, application source use the ON/OFF model to realize the performance of self-similarity.

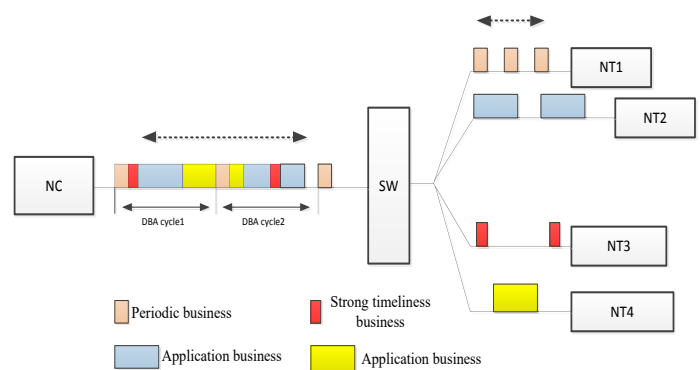


Figure 4. The simulation configuration of the system

Based on the features of the space payload system, there are two main influence factors of the network throughput which are the overhead proportion and the node buffer. At a certain number of nodes and node buffer, network throughput of the system as the DBA cycle changing at 10, 20, 32 nodes are shown in Fig.5. From the results, with increase of DBA cycle, the network throughput increases rapidly and reaches saturation at 1ms due to the decreasing of overhead proportion, and the maximum throughput are 16.46Gbps, 30.81Gbps and 46.14Gbps at 10, 20, and 32 nodes respectively. And the overhead proportion is close to 0 under the larger DBA cycle, the buffer size becomes the main factor that affects the network throughput, which leads to the decrease of the throughput with the increasing of the DBA cycle.

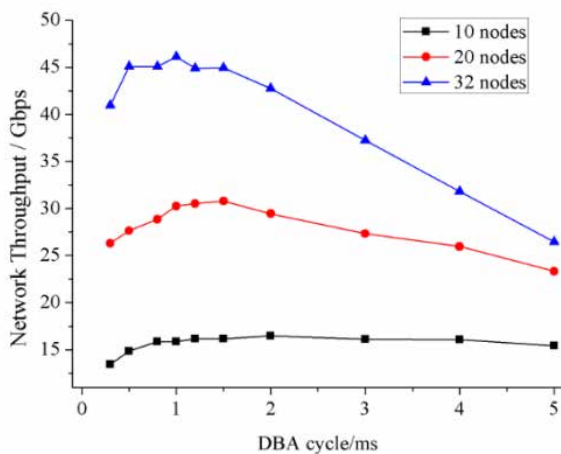


Figure 5. The throughput of the system at 10, 20, and 32 nodes

The time delay is another important performance indicator of the system. Due to the proposed scheduling, the periodic business is allocated at the start of the DBA cycle, and the maximum and average time delay of the periodic business is no difference, which is the transmission delay. The maximum and average time delay of application business is increasing slightly with the increase of the number of nodes due to the pre-emptive allocation. Therefore, the maximum and average time delay of application business is the main factor affecting performance of the system, and the maximum and average time delay of the application business at different nodes is shown in Fig.6. From the results, the optimum values of the DBA cycle are 1.2ms, 1ms, and 1ms at 10, 20 and 32 nodes respectively. Therefore, consider on the performances of network throughput and delay and the convenience of node configuration and the realization of the network, the optimum value of the DBA cycle is set to 1ms.

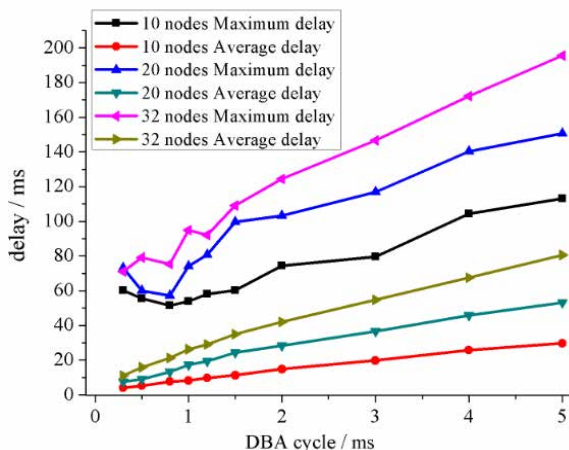


Figure 6. Max and average delay of application business versus DBA cycle

The buffer of the node is another important affecting factor, and the performances of the network throughput, maximum average delay versus the node buffer at different nodes are simulated by Fig7-8. From the results, the network throughput increases with the increasing of the node buffer and reaches

saturation at 150 Mbit. The network throughput of system is 15.84Gbps, 30.26Gbps and 46.12Gbps at 10, 20, and 32 nodes respectively when the node buffer is set 150Mbit.

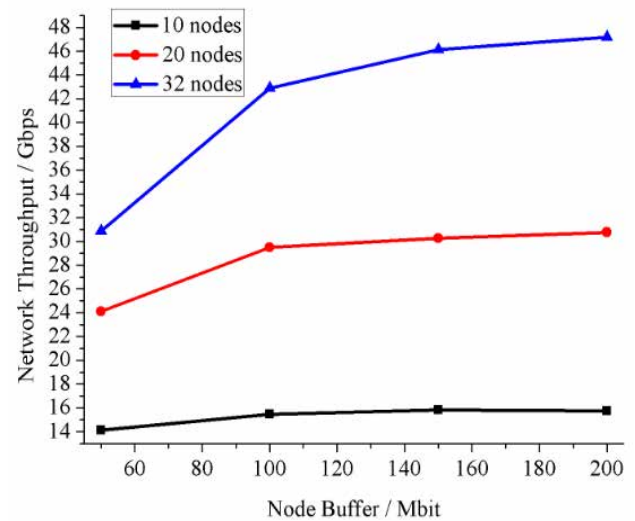


Figure 7. Throughput versus node buffer

The maximum delay and average delay of application are increase with the increasing of the node buffer, and the maximum delay is lower than 100ms. While the delay time of the application business is not changing with the node buffer increase, and the max delay is 20us. Therefore, the optimum value of the node buffer is set to 150Mbit based on the network throughput and delay results of application business.

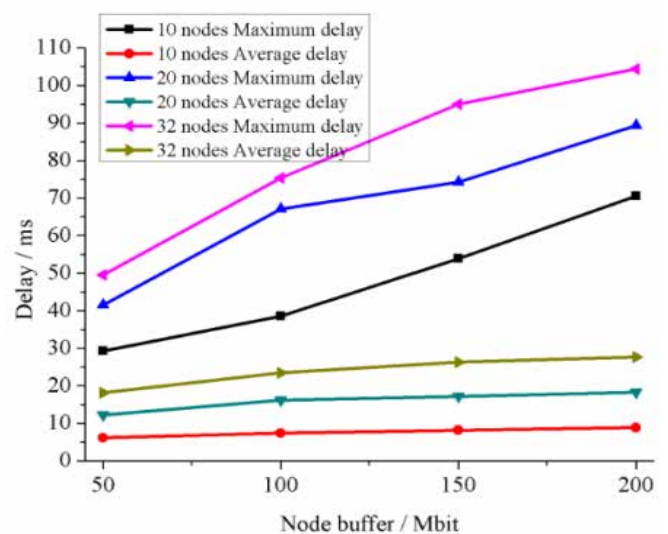


Figure 8. Max and average delay of application business versus node buffer

IV. COMPARISON WITH THE TRADITIONAL SCHEDULING SCHEME

In our paper, we proposed the periodical and concurrent DBA scheme, which are the application business used the periodical and concurrent dynamic bandwidth allocations, the periodic business used the static bandwidth allocation and the

strong timeliness business use the pre-emptive bandwidth allocation. At one DBA cycle, the NC centrally arranges each node to report bandwidth requests, and after receiving all the requests for bandwidth, NC performs bandwidth allocation for the business within this cycle.

However, in the traditional scheme, the periodic business and the strong timeliness business used the static bandwidth allocation, and the application business according to the business cycle from small cycle P_{min} to large cycle P_{max} . In a large cycle, the business request of the node is carried in the status frame where the completion of the business transmission is returned. After the NC receives the request, each application business (length of business is L_i , business rate is v) is scheduled, the sending time in each small cycle

$$P_{min} \text{ is } \frac{L_i}{v(P_i / P_{min})}, \text{ and it is split into } \frac{P_i}{P_{min}} \text{ times.}$$

We compare the network throughput and the maximum an average delay of the application business at different nodes in the two scheduling schemes. The node buffer, generation node and time interval of the strong timeliness business, the cycle and business size of periodic business, and the load of NC and NT are same in the two schemes. And the DBA cycle of the periodical and concurrent DBA scheme is set 1ms, while the DBA cycle of the traditional scheme is set 4ms.

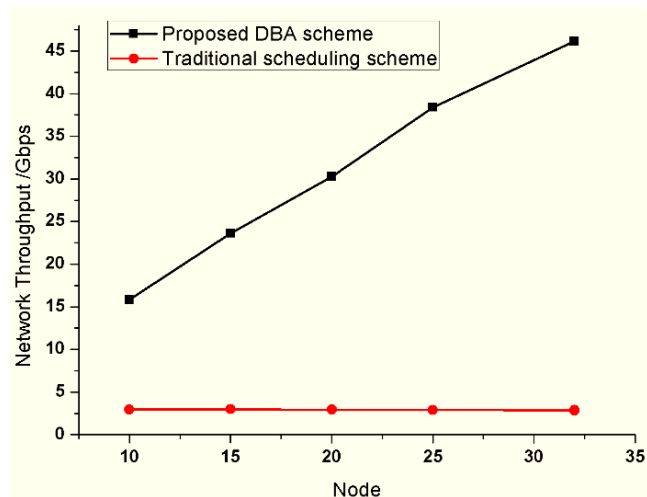


Figure 9. Throughput comparison between at two schemes

Figure 9 illustrates the network throughput under two scheduling schemes. Based on the simulation results, the proposed periodical and concurrent DBA scheme greatly improves the network throughput, and the more nodes, the more network throughput is improved. Compared with the traditional scheme, the network throughput has been improved at least by 5 times.

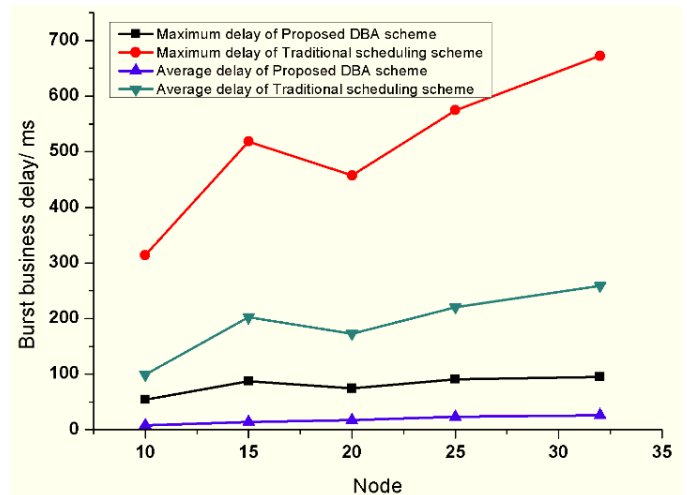


Figure 10. The maximum and average delay of application business comparison between at two schemes

The maximum and the average time delay of application business comparison between at different scheduling schemes are shown in Figure.10. Based on the results, the maximum and average time delay at the proposed scheme are better than the traditional scheme. Under the 32 nodes, the maximum values are 94.991ms and 672.231ms, the average values are 26.289ms and 258.8ms at different schemes.

V. CONCLUSIONS

Demand for the features of space application network, the paper design a combination of static + dynamic periodical and concurrent scheduling scheme. The DBA proposal was analyzed theoretically and the performances of switching FC-AE-1553 network were simulated and investigated. Simulation results show that the optimum DBA cycle and node buffer were set 1ms and 150Mbit, and the maximum throughput were approximately 16.5Gbps, 30.8Gbps and 46.2Gbps at 10 nodes, 20 nodes and 32 nodes and increased 10 times compared tradition DBA scheme. And finally, we compared the proposed periodical and concurrent DBA scheme and the traditional scheduling scheme, based on the simulation results, the network throughput has been improved at least by 5 times, and the maximum and average time delay at the proposed scheme are better than the traditional scheme. Therefore, the proposed DBA scheme can provide effective solutions for switching FC-AE-1553 network design and optimization in the future aerospace missions.

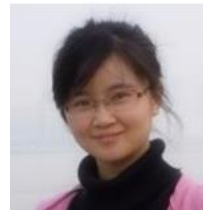
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