A New Priority Scheme for WDM Star Networks

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***Abstract*— This paper presents a new scheduling protocol for WDM star networks. The new protocol (Priority Scheme Earliest Available Time Scheduling - PS-EATS) is based on the previously proposed EATS protocol which assigns the earliest available data channel to each node that has a message to transmit. PS-EATS modifies the order in which the nodes' requests are processed and allows long messages to be processed ahead of shorter ones. Simulation results show that PS-EATS improves network performance in terms of throughput and also marginally reduces the mean packet delay.**

I. Introduction

The constantly increasing demand for high speed connections and network bandwidth has led to the prevalence of optical fiber as a transmission medium. Optical networks can support data rates in the order of terabits particularly when wavelength division multiplexing (WDM) is employed [1]. In this work we consider a local area optical WDM network with a single-hop broadcast-and-select architecture. Network nodes are connected via a passive star coupler. Each node generates data messages destined to other nodes. In order for such a network to operate effectively, some form of access control and channel allocation is required. This is the purpose of the Medium Access Control (MAC) protocol [2]. This paper proposes a new pre-transmission coordination based collision-free MAC protocol which is called priority scheme Earliest Available Time Scheduling (PS-EATS). The novel aspect of PS-EATS is that it prioritizes the transmissions of long messages regardless of the source and destination nodes. By serving long messages ahead of others, the mean packet delay is reduced. Furthermore, channel utilization is increased because idle time periods are minimized. Messages are reordered in the service queue based on a two dimensional array of priorities which stores messages awaiting transmission in their corresponding positions.

II. Network structure

We consider a network composed of N nodes. Each node is connected to the star coupler via two optical fibers (in order to achieve bidirectional transmission) as depicted in Fig.1. The bandwidth in each optical fiber is divided into $W+1$ channels with W channels used for data transmission (data channels) and one channel reserved for pre-transmission coordination between nodes (control channel) [3]. All nodes are equipped with a tunable transmitter and a tunable receiver used for data transmission (in all W data channels) as well as a pair of fixed transceivers used for control packet transmission and reception. Each transmission frame is divided into two phases, a control phase and a data phase. The data transmission phase and the control phase are divided into data and control timeslots respectively. The duration of a data timeslot is equal to the time required for the transmission of a data packet whose size is a network design parameter. Network nodes generate variable length messages composed of variable numbers of data packets. The control phase is divided into N control timeslots with each timeslot handling the transmission of a single control packet; therefore a total of N control packets are transmitted in the control phase, one for each network node. Control packets contain the address of the destination node and the number of data packets to be transmitted. Medium access is based on time-division multiplexing.

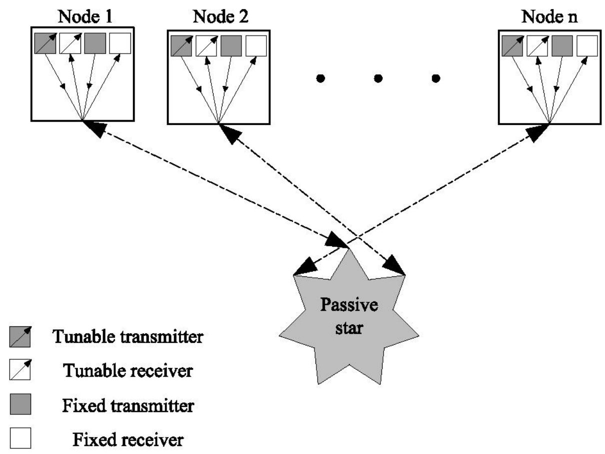

Fig. 1. Network structure.

III. Background - Previously proposed scheduling algorithms

According to the EATS (Earliest Available Time Scheduling) protocol proposed in [4], each node examines the contents of all control packets received by its fixed receiver and assigns the earliest available data channel for transmission. In terms of global state information, EATS maintains two tables. The Receiver Available Time (RAT) table has N elements with $RAT[j] = t$ meaning that receiver j will be available after t timeslots. The second table is called Channel Available Time (CAT) and has W elements. The values of CAT elements are interpreted as follows: $CAT[c] = t$ means that channel c will be available after t timeslots. The protocol logic can be summarized in the following steps: select the channel

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with the minimum CAT value for transmission, calculate the transmission time of the message based on data from both tables and update both tables accordingly. Thus, each network node calculates when its message should be transmitted and on which channel and all types of collisions are avoided.

IV. The Proposed Scheduling Algorithm

The proposed protocol PS-EATS attempts to improve performance by altering the order in which data messages are processed. Each data message is assigned a priority level according to the number of packets it contains. Long messages are assigned higher priorities and are therefore processed ahead of shorter ones. The new scheduling algorithm assumes that there is an upper bound on the length of a message (in packets) denoted by K. Therefore, the priority of a message is a number between 1 and K and messages are served in a descending order of priority. Message priorities are stored in a priority table P with K rows. Row i contains all messages with priority equal to i. If multiple messages have the same priority, they are stored in the same row of table P in adjacent columns. Once table P has been filled out for the current frame, protocol PS-EATS uses the same scheduling algorithm as EATS starting with row K.

In order to illustrate the operation of the PS-EATS protocol, we provide a numerical example. Consider a network with 5 nodes and 3 channels and the following messages for transmission:

Source node	Destination node	Message length (in packets)
1	2	2
2	4	3
3	5	1
4	1	5
5	1	4

EATS will process messages in the order of arrival (node 1 to 5) as follows:

	Timeslots										
	1	2	3	4	5	6	7	8	9	10	11
w_1	n_2	n_2						n_1	n_1	n_1	n_1
w_2	n_4	n_4	n_4								
w_3	n_5	n_1	n_1	n_1	n_1	n_1					

On the contrary, PS-EATS will assign priorities to messages and therefore the service order will be node 4 - node 5 - node 2 - node 1 and node 3. Apart from the order in which requests are processed, PS-EATS operates in the same manner as EATS. The new schedule will be generated as follows:

	Timeslots									
	1	2	3	4	5	6	7	8	9	10
w_1	n_1	n_1	n_1	n_1	n_1	n_5				
w_2							n_1	n_1	n_1	n_1
w_3	n_4	n_4	n_4	n_2	n_2					

PS-EATS will also produce a shorter schedule (with a length of 10 timeslots) than EATS (11 timeslots).

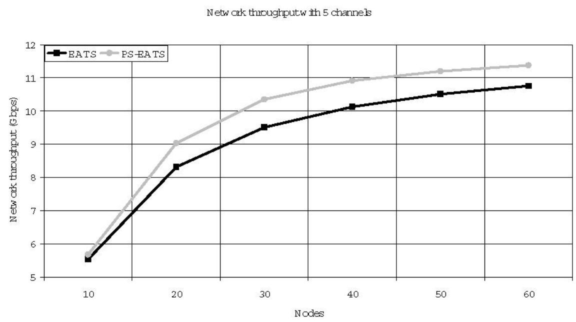

Fig. 2. Network throughput with 5 channels.

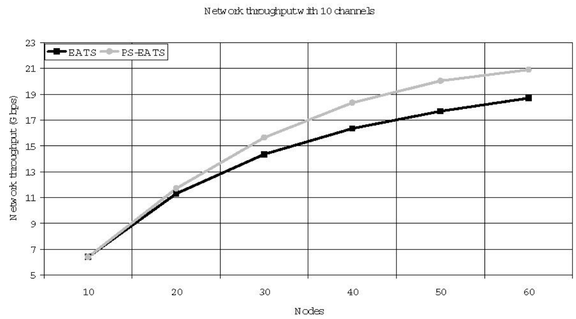

Fig. 3. Network throughput with 10 channels.

V. Simulation Results

Simulation results presented are based on the following assumptions:

1) The data message arrival process for all nodes is based on a uniform distribution.
2) Each message can be destined to any of the other nodes with equal probability.
3) Message length is computed as a random number between 0 (= no message) and K.
4) Data rate is equal to 2.4 Gbps per channel.
5) Simulation time is equal to 10000 frames.
6) The transceivers tuning latency T and the propagation delay of messages R were assumed to be constant and their values are 1 and 2 respectively.
7) The maximum message size K was not assumed fixed but equal to $k = \lfloor (n * w)/5 \rfloor$ [5] for scalability reasons [5].

The graphs that follow were produced by simulation experiments in which the number of nodes varied from 10 to 60.

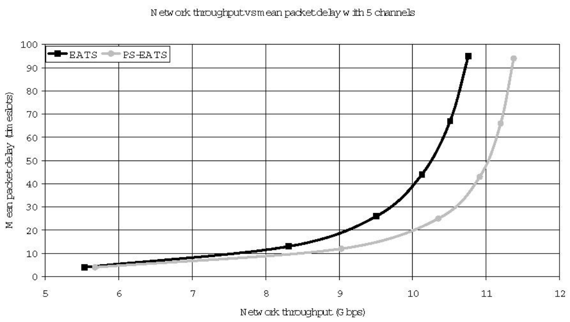

Fig. 4. Network throughput vs. mean packet delay with 5 channels.

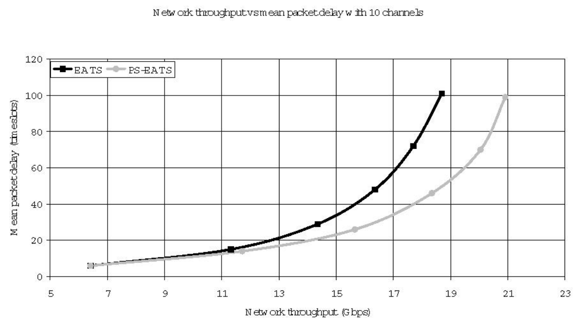

Fig. 5. Network throughput vs. mean packet delay with 10 channels.

In graphs 1 and 3 the number of channels is equal to 5 while in graphs 2 and 4 the number of channels is equal to 10.

Fig.2 depicts the network throughput for 5 channels while Fig.3 depicts network throughput for 10 channels. The performance of PS-EATS is constantly superior to that of EATS for all numbers of nodes. For instance, when the number of nodes is 30 and the number of channels is 5, the difference between the two algorithms equals 0.7 Gbps (in favor of PS-EATS of course) while for 50 nodes and 10 channels PS-EATS outperforms EATS by approximately 2.35 Gbps. The observed improvement in network throughput can be explained as follows: by allowing long messages to be processed first, the schedule is optimized and idle slots are reduced. Fig.4 and 5 illustrate the network throughput versus the mean packet delay for 5 and 10 channels respectively. From the graphs, it is evident that PS-EATS not only improves performance but also marginally reduces the mean packet delay. For instance, for 40 nodes and 5 channels, the mean waiting time for EATS is 44 timeslots while the mean waiting time for PS-EATS is 43 timeslots. For 60 nodes and 10 channels the mean waiting times are equal to 101 (EATS) and 99 (PS-EATS). This can be attributed to the fact that the waiting time of a large number of packets (those contained in long messages) is minimized. This means that the improvement in performance offered by PS-EATS does not come at the cost of additional packet delay.

VI. Conclusions and Future Work

As part of our future work, we intend to study the performance of PS-EATS under bursty network traffic in order to draw more realistic conclusions regarding its applicability in optical local area networks. Furthermore, we have already devised an extension of PS-EATS to support prespecified traffic priorities. In this protocol which will provide quality of service support, the length of messages awaiting transmission will not be the only criterion that determines the processing order but traffic priorities will also be taken into account (for example, real-time/ delay-sensitive traffic such as video streaming will be served ahead of data traffic).

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