A High Performance Scheduling Priority Scheme for WDM Star Networks

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***Abstract*— A novel scheduling scheme for local area wavelength division multiplexing (WDM) single hop networks is introduced. The proposed protocol provides pre-transmission coordination schedule without collisions. It is based on a broadcast and select star architecture and uses a timeslot based access protocol. The proposed scheme incorporates a prediction based system, in order to reduce the amount of time spend in computing the schedule by predicting traffic requests. A series of simulation results is presented which indicates that when a specific schedule order is followed, starting from the node with the greatest demand, and completing to the node with the least demand (in transmission time) then a better network performance is achieved. Furthermore, the network throughput is higher, while the mean time packet delay at the waiting queues seems to be lower.**

***Index Terms*— Optical WDM networks, scheduling, reservation, traffic prediction.**

I. INTRODUCTION

An optical WDM network with a single hop topology, structured in a broadcast and select architecture is considered. In this network, a set of channels correspond to different optical wavelengths that can be multiplexed and demultiplexed onto a fiber optical media [1]. This letter focuses on a local area environment where all nodes can be connected in a passive star coupler, via two way optical fiber. A media access control protocol (MAC) comprises of all the methods and the ways of accessing the available media [2]. In our system the protocol belongs to pre-transmission coordination based category without collisions. So, the protocol is essential to coordinate transmissions between various nodes in the network. In this work we develop a novel scheduling algorithm to provide a better utilization of the available channels. For this purpose we suggest a different scheduling priority scheme, which modifies the service order of the nodes before the construction of the final schedule. In this manner our simulation results show that the new scheduling scheme offers a better network performance and results a high network throughput, while keeping mean packet delay at the waiting queues low. The rest of this letter is organized as follows. Section II describes our network background; Section III presents our new scheduling algorithm; Section IV shows and makes remarks about the simulation results; and finally Section V concludes the letter.

Manuscript received May 30, 2006. The associate editor coordinating the review of this letter and approving it for publication was Prof. Nasir Ghani.
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Digital Object Identifier 10.1109/LCOMM.2007.060824.

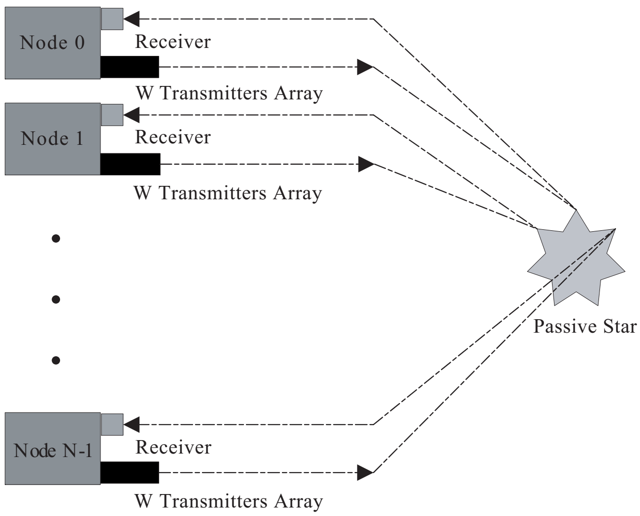

Fig. 1. Network topology.

II. NETWORK STRUCTURE

The network includes N nodes and W channels ($N \geq W$). Each node is equipped with a tunable transmitter, which provides the data transmission to the appropriate channels [3]. Moreover, each node has a fixed receiver, which allows receiving data in the particular channel, which is dedicated to each node, known also as home channel (Fig. 1). It is apparent that the effectiveness of such a TT-FR system strongly depends on the relation between nodes and channels. Hence, the application of a very operative protocol is needed, so as not to burden the network with huge time loss and a small throughput. The suggested protocol is defined in terms of frames, where each frame consists of two phases: a reservation phase and a data phase. During the reservation phase, the nodes broadcast their transmission requests for the available channels in a shared control channel. Then a distributed scheduling algorithm in each node operates independently, in order to compute the schedule for the data phase. In other words each node updates its common information, according to info obtained by the shared control channel. A very common global information is the $N \times W$ traffic or demand matrix D = $[d_{n,w}]$. Each row n represents the node and each column w the channel.

III. SCHEDULING ALGORITHM

We adopt on-line interval-based scheduling (OIS) algorithm [4] as our basis technique due to its simplicity. OIS maintains two sets of intervals for each frame. The first set consists of the intervals of each of the channels and the second one consists of the intervals of the node whose reservation is currently being scheduled. The intervals show the unallocated time on a specific channel or node. Whenever a node sends timeslots requests for transmission the list of available intervals are checked for their availability of the requested number of free timeslots on the channel. If we assume that node n_1 requests t_1 timeslots to transmit packets using channel w_1, the OIS algorithm searches for a group of continues free timeslots of duration t_1 in order to reserve for this node. When OIS finds a suitable timeslot beginning at time t, it reserves channel w_1 from time t to $t + (t_1 - 1)$. Of course, the algorithm is not allowed to assign more nodes at the same interval for the same channel, in order to keep the schedule collision free.

A prediction mechanism is considered, which is based on predictive on-line scheduling algorithm (POSA) [5]. POSA is a very effective traffic prediction mechanism and targets to reduce drastically the computation time of the schedule. In this manner POSA maintains a set of $N \times W$ predictors, which attempt to predict the traffic demand matrix for the next frame, according to the history of the recent actual reservations. In this way in each frame POSA predicts the requests of each node for the following frame and simultaneously it transmits according to the predictions of the previous frame. At the same time it inputs the actual requests of the current frame to the history queues of the predictor. So the adopted prediction system saves valuable time since the scheduling algorithm allows the transmission of the packets at the same time with the prediction of the requests for the next transmission. This parallel elaboration leads to a significant decrease (if not minimization) of the schedule estimation time.

The new scheme is called put requests in order (PRO) and is a continuation of our previous work check and sort predictive on-line scheduling algorithm (CS-POSA) [6]. CS-POSA tries to minimize the unused timeslots that increase the size of the frame by changing the order of service and examination of the nodes while the scheduling matrix is formed. Moreover the extension of CS-POSA is based on shifting of the schedule computation of the nodes or in other words, on guiding the order of checking and programming of the nodes. Shifting is based on the total workload of each node, for all the channels. PRO shifts the order of processing of the nodes based on the amount of the transmission time demand of each node per channel. The request $d_{n,w}$ with the highest value has the maximum priority and the transmission of node n on channel w is scheduled first. Then PRO searches for the next highest value on demand matrix D and so on. This search continues until all the nodes are scheduled. In this way we collect the values of the traffic demand matrix with a declining order in order to feed OIS with a priority based order of processing.

Each predictor outputs a value form 0 to K, where K denotes the upper bound on a node's request on a channel. For example if K is equal to five then each node requests five timeslots on a channel at most. This assumption is necessary to construct a probalistic based, deterministic predictor [5]. So, the predictor outputs a predicted demand matrix D, where each entry in the matrix is an integer number between 0 and K (both inclusive). PRO examines the predicted demand matrix and prioritizes the cells of the matrix based on the amount of each request. It is obvious that the cell with the maximum priority has request equal to K and the cell with the minimum priority has request equal to 0. The priority table can be expressed as a dynamic table P. This priority table has two dimensions and the count of rows and columns starts from 0. It has K+1 rows, one for each (request) value from 0 to K and two columns at least. The first (even) column stores the number of node that requests the specific amount of timeslots and the second (odd) column stores the number of channel, on which the transmission will be carried. Hence, if node n requests $d_{n,w}$ timeslots on channel w has priority equal to the value of $d_{n,w}$, so P[$d_{n,w}, 0$] = n, and P[$d_{n,w}, 1$] = w. If two or more nodes have the same priority then matrix P dynamically assigns more columns. PRO algorithm can be described in five steps:

1) Collect the value $d_{n,w}$ from the predicted demand matrix of POSA.
2) Assign to value $d_{n,w}$ a priority and store node n and channel w into the appropriate row and column of P.
3) If two or more requests demand the same amount of timeslots then PRO will designate the same priority and the final selection for the schedule will be random.
4) Repeat the steps 1 to 3 for all values of matrix D.
5) Feed OIS with the values of table P starting with the row K and finish with the row 0.

In order to understand better the usage of the priority scheme a specific example is examined. We suppose that the network consists of three nodes (n_0, n_1, n_2) and two channels (w_0, w_1) with upper bound on node's requests (K) equal to five. The following traffic matrix has been constructed by six individual predictors.

$$D = \begin{pmatrix} 1 & 2 \\ 3 & 2 \\ 5 & 4 \end{pmatrix} \tag{1}$$

According to demand matrix D, node n_0 requests one timeslot for channel w_0 and two timeslots for channel w_1. Node n_1 requests three timeslots for channel w_0 and two timeslots for channel w_1. Finally, node n_2 requests five and four timeslots for w_0 and w_1 respectively. PRO will construct the priority matrix P, which will be formed as follows:

$$P = \begin{pmatrix} - & - & - & - \\ n_0 & w_0 & - & - \\ n_1 & w_1 & n_0 & w_1 \\ n_1 & w_0 & - & - \\ n_2 & w_1 & - & - \\ n_2 & w_0 & - & - \end{pmatrix} \tag{2}$$

In this way, PRO will feed OIS with this service sequence, beginning with the demands of the row K and ending with the demands of the row 0 of the matrix P.

IV. Simulation Results

To study the performance of each algorithm (POSA, CS-POSA, and PRO) we assume the following.

1) Traffic pattern is uniform, i.e., data requests are destined to every other node with equal probability.
2) For each frame, nodes may generate data requests from 0 to K with equal probability.

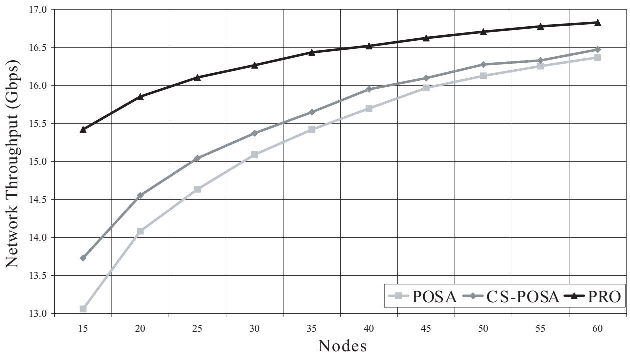

Fig. 2. Network throughput with eight channels.

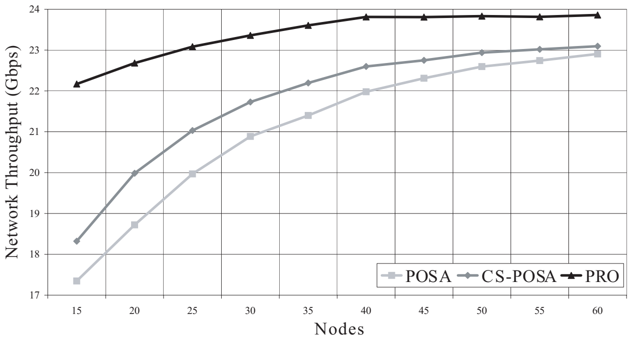

Fig. 3. Network throughput with 12 channels.

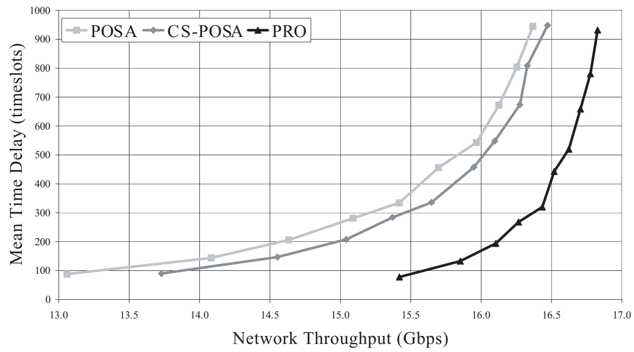

Fig. 4. Network throughput vs. mean time delay with eight channels.

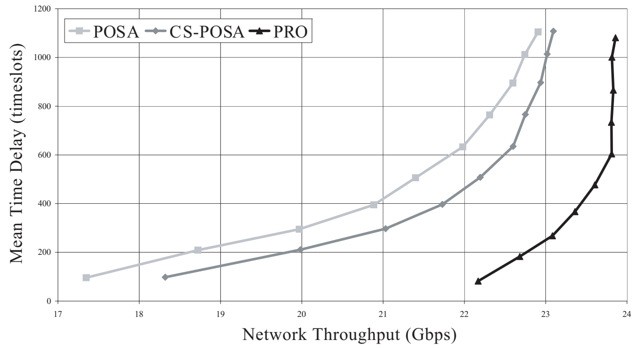

Fig. 5. Network throughput vs. mean time delay with 12 channels.

3) The line is defined at 2.4 Gbps per channel and the tuning time is ignored for simplicity reasons.
4) The results were produced during 10000 frames, from which the first 1000 were learning frames and PRO functioned as OIS.

Network throughput represents the amount of transmitted packets during each frame or the average number of bits transmitted per transmission frame per channel. Mean time delay represents the waiting time in timeslots from the arriving of a packet at the queues till the beginning of the transmission of the packet. The set of nodes is 15, 20, 25, 30, 35, 40, 45, 50, 55, and 60 and K is equal to FLOOR(N*W/5) for scalability reasons [5]. Fig. 2 and Fig. 3 present the network throughput for eight and 12 channels respectively. PRO has much improved the network performance and the maximum difference seems to be equal to 4.8 Gbps with POSA (15 nodes and 12 channels) and the minimum is equal to 400 Mbps with CS-POSA (60 nodes and eight channels). The reason is that PRO firstly serves the long time requests and so allocates more free slots for the rest to be scheduled. It is crucial for the scheduling algorithm to avoid the increment of extra mean packet delay at the waiting queues. Fig. 4 and Fig. 5 plot the relation between the network throughput and the mean packet delay. Fig. 4 shows the effect of varying load (the maximum value of K), with eight channels and Fig. 5 shows the same comparison with 12 channels. As we can observe PRO keeps mean packet delay lower, while improves the network performance, in terms of throughput. More specifically, PRO offers a better network throughput for both channels and at the same time decreases a little the delay. For example, with 30 nodes and 12 channels PRO offers 23.3 Gbps and generates 367 timeslots as mean delay, while POSA offers 20.8 Gbps and generates 395 timeslots and CS-POSA offers 21.7 Gpbs and generates 398 timeslots.

V. Conclusion

In this work a new priority based scheduling algorithm was introduced. Our purpose is to reduce the amount of idle timeslots, by prioritize the requests of nodes with criterion the length of transmission request time. The simulation results show that if we start the construction of the schedule with the node with the greatest demand on a specific channel and we finish with the node with the least demand then the network throughput is raised and the packets wait in queues less time.

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