Packet Rescheduling in Real-Time using Token-passing Protocol in WDM Ring Access Networks

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Abstract

This paper proposes a novel real-time packet rescheduling algorithm using a token-passing protocol to achieve QoS on a WDM Ring Access Network. The proposed rescheduling algorithm is called PEM (PDS-EAC-MTD) algorithm. The PDS (Priority-Differentiated Scheduling) algorithm deals with real-time packets, and allows them to be transmitted first, such that the front line of the prescheduled nonreal-time packets can be inserted into the queue. The EAC (Earliest Available Channel) algorithm selects the earliest available data channel, independently of the availability of the destination. The MTD (Minimum Time Difference) algorithm selects the minimum-time-to-wait channel to transmit the nonreal-time packet and is quick to establish the path of the real-time packets. The updated information including the Scheduled Data Table and the Channel Available Time Table, is then broadcasting to other access nodes using token-passing protocol to maintain the status of packet scheduling/rescheduling consistency. Overall, the PEM algorithm has the best performance over the other three algorithms, NPEM, PEE, and EATS in terms of average delay time for different traffic loads and number of channels.

Key words: Packet rescheduling, Token-passing protocol, Quality of Service, WDM Ring Access Network, PEM algorithm.

1. Introduction

The growth of next-generation multimedia and real-time applications is demanding more and more from the access networks, such as that they support broadband Internet access and offer good Quality-of-Service (QoS) [1,2]. Recently, many MAC protocols have been proposed in the literature [3,4,5,6]. Jia [4] proposed a scheduling variable-length message in a single-hop multichannel local lightwave network. Two MAC protocols for WDM metropolitan access ring networks are proposed in [5,6]. In [7], a scheduled approach to optical flow switching is proposed. This method divides time into fixed-length timeslots and schedule transmissions to reach viability and scalability of a scheduled connection setup approach. Mondiano [8] proposes a centralized scheduler that uses first-come-first-serve input queues for unicast traffic and a window selection policy to eliminate head-of-line blocking, while multicast traffic is scheduled using a random algorithm.

Chu [3] proposed a PDS algorithm to reschedule real-time packets to preempt nonreal-time packets in the single-hop WDM star network. He showed that the PDS algorithm can dramatically reduce the delay of real-time packets, without sacrificing the performance of nonreal-time packets. However, long-haul access networks using WDM [9,10,11] become commercially available as backbone. The WDM ring access network actually consists of two independent networks - a feeder network and distribution networks, which are connected by access nodes. The access node is composed of reconfigurable Optical Add/Drop Multiplexer (OADM) [4]. The characteristics of OADM are as follows; (1) the transmission of packets among nodes is fully optical, (2) packets in different channels can be transmitted or received simultaneously, and (3) each distribution network aggregates data from local end-users.

This paper proposes a PEM (PDS-EAC-MTD) algorithm that uses a token-ring protocol to schedule/reschedule real-time packets and schedule nonreal-time packets on the WDM ring access network, which includes one control channel and other data channels. The access node has the token can reschedule real-time packets based on the PEM algorithm, and the control packet, which includes Scheduled Data Tables and Channel Available Time Tables, is updated and are broadcasted to the other access nodes through the control channel, to keep the information of the packets transmission consistent. The token is released when the access node has finished the scheduling/rescheduling packets. If the access node has no token, then it only transmits or receives prescheduled packets to/from data channels. The proposed PEM algorithm incorporates three algorithms, PDS, EAC, and MTD algorithms, to handle the different types of packets (real-time packets and nonreal-time packets). The PDS and EAC algorithms together deal with the real-time packets: the PDS algorithm allows real-time packets to preempt the prescheduled nonreal-time packets and the EAC algorithm selects the earliest available data channel to transmit real-time packets. The priority of the nonreal-time packet in the queue is upgraded after some time, to avoid the infinite waiting. The MTD algorithm is used to select the minimum-time-to-wait channel to transmit nonreal-time packets. Hence, the purpose of the MTD algorithm is to improve the channel utilization to help allow real-time packets to be transmitted through more available channels and to accelerate the establishment of lightpath efficiently.

The rest of this paper is organized as follows. Section II describes the design and operation of the system, and the proposed PEM algorithm. Section III presents the simulation results and compares the system performance with the performance of three other algorithms - NPEM, PEE and EATS algorithms - in terms of average delay time and average channel utilization. Section IV draws the conclusions.

2. Design and operation of system

The WDM Ring Access Network has n access nodes and w channels (a control channel and the rest are data channels). Each access node stores information about the transmission of all packets from access nodes i, i=1,2,…,n, in two tables – the Scheduling Data Table (SDT) and the Channel Available Time Table (CATT), i.e. SDTi and CATTi, i=1,2,…,n. The format of SDT for each packet is that each packet has a packet id (PI) with a packet length (PL) and a packet priority (PP). The transmission from the source node (SN) to the destination node (DN) is through the selected channel (SC) and the delay time is from the starting time (ST) to ending time (ET). The CATT is a table to record the available time (AT) when the channel is free.

These two tables, restored in each access node, must be kept consistent at all times. Figure 1 details the operation of the system as follows.

Step 1) When an access node holds the token and a new packets is generated, it determines the priorities of packets is high or low. If the packet is high, go to step 2(a), else go to step 2(b).

Step 2(a) The real-time packet preempts the prescheduled nonreal-time packet and the lightpath is selected by EAC algorithm.

Step 2(b) The MTD algorithm allocates the channel to transmit this nonreal-time packet.

Step 3) The latest information is transmitted to all access nodes and the token is released to the next access node.

Each access node with a token-ring can update its SDT and CATT, based on the proposed PEM (PDS-EAC-MTD) algorithm. After the rescheduling algorithm is executed, the updated tables will be broadcasting to all other access nodes and the token is released to the next access node through the control channel. Thereafter, the scheduled/rescheduled packets can transmit according to the updated SDT tables.

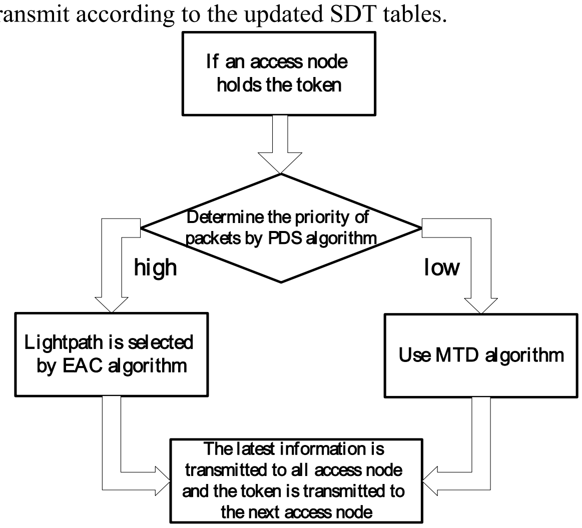


Fig. 1 Flowchart of system operation

Five access nodes are assumed in the WDM Ring Access Network to be connected by unidirectional fiber with three channels; one is the control channel (channel 0) and the others (channel 1, 2) are data channels. Nine packets in all access nodes are presumed to be scheduled/rescheduled by the PEM algorithm, as shown in Table 1(a). In this example, the overall real-time packet delay with PEM is 9+6+4=19, whereas with EATS, it is 9+8+4=21. Clearly, PEM has a lower overall real-time packet delay than EATS.

3. Simulation results and discussion

We simulate a dynamic network environment to evaluate the performance of OADM and its corresponding scheduling algorithms, using the proposed algorithms PEM and the other three different algorithms. The simulation environment is setup as follows:

1. Numbers of access nodes (N) are 32 and 64.
2. Numbers of channels (C) are 4,8,16,32 and 64.
3. The bandwidth of each channel is 2.5 Gbits.
4. The packets are randomly generated.
5. The average size of a real-time packet is smaller than that of a nonreal-time packet.
6. Packet size is variable and the maximum packet size is smaller than 5Mbits.
7. The ratio of the number real-time packets of to number of nonreal-time packets (denoted as R_NR) generated by random is 3 to 7 and 5 to 5 [1].
8. The delay time of the token is ignored.

The traffic load is defined as total throughput to total bandwidth. The delay time of the packet transmission is defined as the duration from the time at which a packet is scheduled to be transmitted to the time at which the transmission of the packet is finished. The simulation compares the proposed PEM algorithm with three algorithms - NPEM (with no PDS algorithm), PEE (PDS-EAC-EAC) and EATS (Earliest Available Time Scheduling algorithm) [4] in terms of average delay time for different traffic loads and the different number of channels. The major objectives of the simulations are: we demonstrate the superior performance of the PDS algorithms by showing that the average delay of the real-time traffic can be reduced significantly and demonstrate that the proposed MTD works much better than EATS in terms of average delay.

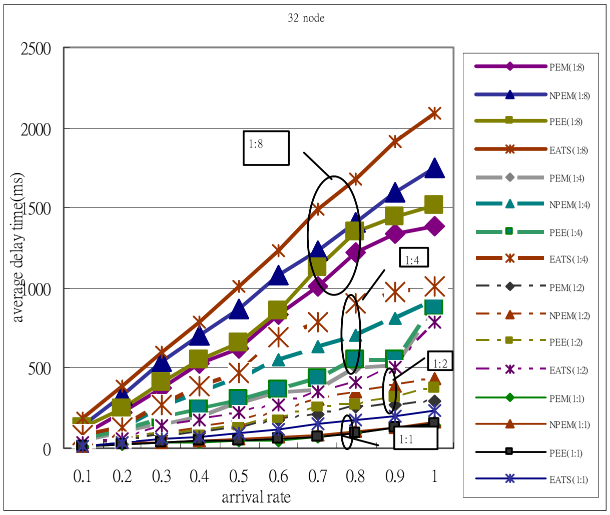
● Average delay time vs. arrival rate

Fig. 2 depicts the average delay time in steady state for different ratios (C_N) from numbers of channels to numbers of nodes = {1:1, 1:2, 1:4, 1:8}. The access network with PEM algorithm shows the best network performance. In Fig. 2(a), we set N = 32 and make the following observations.

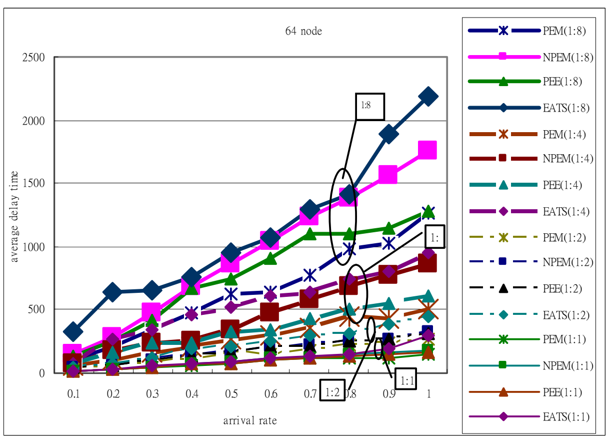
(1) It is interesting to notice that average delay time for different four algorithms is PEM<PEE<NPEM<EATS. The reason is that the PEM and PEE algorithms can arrange the high-priority packets to be served faster than the other packets, therefore, resulting in delay reduction.

(2)The PEM algorithm can reduce the average delay time significantly. For example, when arrival rate is 0.9 and C_N ratio is 1:4, the average delay time with PEM is less 90% than that with EATS.

(3)Even without PDS, our proposed algorithm NPEM leads to a smaller average delay time than EATS. It is because that the MTD algorithm changes the priority of packets from low to high when the delay time of low-priority packet is too long.



(a)



(b)

Fig. 2 Average delay time with four channels vs. arrival rates for different C_Ns={1:1, 1:2, 1:4, 1:8} and number of nodes, when (a) N=32 and (b) 64.

Fig. 2(b) depicts the average delay time vs. traffic loads for different C_Ns={1:1, 1:2, 1:4, 1:8} when N=64. We make the following observations.

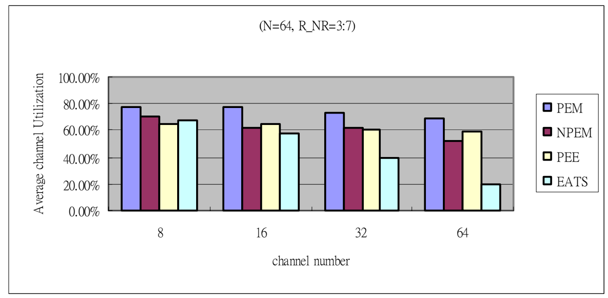
(1) The simulation results reveal that the average delay time associated with the PEM algorithm is less than those associated with other three algorithms, which are independent of the arrival rate because the PDS algorithms can arrange for real-time packets to be transmitted faster than the nonreal-time packets. PEM and PEE algorithms significantly outperform the other two algorithms when the traffic load is heavy. For example, the average delay time obtained using PEM is 26.5% lower than that obtained using NPEM, and is 50% lower than that obtained using EATS when the arrival rate is 0.9

(2) For arrival rate = 0.2, as we have already seen, the PEM algorithm (C_N ratio is 1:8) outperforms the EATS algorithm (C_N ratio is 1:4) by an average delay time of less than 35% for EATS algorithm.

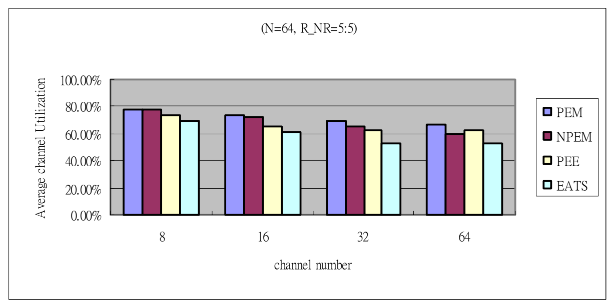
(3) The MTD algorithm achieves the best performance than the other three algorithms, NPEM, PEE, and EATS for nonreal-time packets. The average delay time obtained with PEM is 12% lower than that obtained with PEE when the traffic load is 72%.

We can see that the average delay time is similar to EATS, in that the NPEM algorithm does not handle real-time packets. However, it achieves a better performance than EATS. Hence, the NPEM algorithm can be used for a system without the need to handle real-time traffic. The simulation results show that the PEM algorithm for real-time packets and nonreal-time packets outperforms the other three algorithms.

● **Average channel utilization vs. number of channels**



(a)



(b)

Fig. 3 Average channel utilization for different R_NRs (a) for 3:7 and (b) for 5:5, when N=64.

Fig. 3 compares the network performance (the average channel utilization versus number of channels) by using different numbers of nodes under different ratios R_NR. Shown in Fig. 3(a) is the average channel utilization versus different numbers of channels for N = 64 and R_NR = 3:7. The PEM algorithm has the best average channel utilization than the other three algorithms due to rescheduling the real-time packet preempted to non-real time packets. Another important simulation result is that when C is 64, the average channel utilization with EATS is at least less 30% than the other three algorithms. It is because that more non-real packets lead to the call blocking of real-time packet and the average channel utilization is decreased. In Fig. 3(b), we set N =64 and R_NR = 5:5. The average channel utilizations are decreased for all algorithms, but the PEM algorithm still performs the best. That is because PEM algorithm not only deals with real-time packet to preempt prescheduled nonreal-time packets, but also upgrades the priority of nonreal-time packet from low to high when the waiting time is too long.

4. Conclusion

This paper proposes the PEM algorithm, using a token-passing protocol, to reach the QoS of real-time packets on the WDM ring access network. The system not only allows the real-time packets to preempt the nonreal-time packets using the PDS algorithm and chooses the proper channels to set up lightpaths of real-time packets using the EAC algorithm, but also uses the MTD algorithm to schedule non-real-time packets. Then, the updated information is broadcasting to all access nodes using the token-passing protocol. The simulation results show that the average delay time obtained with PEM algorithm is better than those obtained using the other three algorithms (PEE, NPEM, and EATS algorithm) for real-time packets when the traffic load is high. The MTD algorithm can increase the channel utilization. Therefore, under the same traffic load and same number of channels, the algorithms in order of increasing average delay from low to high is PEM, NPEM and EATS algorithm. Overall, the PEM algorithm has the best performance over the other three algorithms, NPEM, PEE, and EATS in terms of average delay time for different traffic loads and number of channels.

References

[1] B. keepence, "Quality of service for voice over IP," in Services Over the Internet—What Does Quality Cost?," ser. IEE Colloquium, No. 99, pp. 4/1-4/4, 1999.

[2] B. Li and Y. Qin, "Traffic scheduling with per VC QoS guarantee in WDM networks," IEEE GLOBECOM'98, pp. 339-344, 1998.

[3] P.L. Chu and J. Diao, "Packet rescheduling in WDM star networks with real-time service differentiation," Journal of Lightwave Technology, Vol. 19, pp. 1818–1828, Dec 2001.

[4] F. Jia, B. Mukherjee and J. Iness, "Scheduling variable-length messages in a single-hop multichannel local lightwave network," IEEE/ACM Transactions Networking, Vol. 3, No. 8, pp. 477-488, Aug 1995.

[5] C. S. Jelger and J. M. H. Elmirghani, "A simple MAC protocol for WDM metropolitan access ring networks," IEEE CLOBECOM 2001, Vol. 3, pp. 1500-1504, 25-29 Nov. 2001.

[6] K. Bengi and H. R. Van, "CONRAD a novel medium access control protocol for WDM local lightwave networks enabling efficient convergence of real-time and data services," Proceedings on Local Computer Networks 2001, pp. 468-476, 14-16 Nov. 2001.

[7] B. Ganguly and V. Chan, "A scheduled approach to optical flow switching in the ONRAMP optical access network testbed," OFC 2002, pp. 215-216.

[8] E. Modiano and R. Barry, "A novel medium access control protocol for WDM-based LAN's and access networks using a master slave scheduler," Journal of Lightwave Tech. Vol. 18, No. 4, pp. 461-468, April 2000.

[9] I-Shyan Hwang, San-Nan Lee and Yi-Shiu Lin, "Stochastic generative model of cost effective OADM using the neural network in a WDM Access Network," *1st* PNC/*6th* JCIS 2002, pp. 1314-1318, Mar. 8-13, 2002.

[10] San-Nan Lee and I-Shyan Hwang, "Stochastic generative model of cost-effective OADM using a three-dimensional neural network in a WDM Access Network", *The Fifth Pacific Rim Conference on Lasers and Electro-Optics* (*CLEO/PR 2003*), pp. 391, Taipei International Convention Center, Taipei, Dec. 15-19, 2003.

[11] N. Takachio, H. Suzuki, M. Fujiwara, K. Jun-ichi Kani, K. Iwatsuki, H. Yamada, T. Shibata and T. Kitoh, "Wide Area Gigabit Access Network Based on 12.5 GHz Spaced 256 Channel Super-dense WDM Technologies," Electronics Letters, Vol. 37, No. 5, pp. 309-311, Mar. 2001.

(a)

PI	SN	DN	SC	PL	ST	ET	PP
P1	***1***	***4***	***1***	***3***	***0***	***2***	***0***
P2	1	5	2	8	1	8	1
P3	1	3	1	2	7	8	1
P8	***1***	***2***	***1***	***2***	***5***	***6***	***0***

(b)

SDT1

PI	SN	DN	SC	PL	ST	ET	PP
P1	***1***	***4***	***1***	***3***	***0***	***2***	***0***
P2	1	5	2	8	1	8	1
P3	1	3	1	2	4	5	1

SDT2

PI	SN	DN	SC	PL	ST	ET	PP
P1	***2***	***4***	***1***	***3***	***3***	***5***	***0***
P4	2	1	1	2	1	2	1
P5	2	5	1	4	6	9	1

SDT3

PI	SN	DN	SC	PL	ST	ET	PP
P1	***3***	***4***	***1***	***3***	***6***	***8***	***0***
P6	3	4	1	3	3	5	1
P7	3	2	2	2	4	5	1

SDT4

PI	SN	DN	SC	PL	ST	ET	PP

SDT5

PI	SN	DN	SC	PL	ST	ET	PP

(c)

SDT1

PI	SN	DN	SC	PL	ST	ET	PP
P1	***1***	***4***	***1***	***3***	***0***	***2***	***0***
P2	1	5	2	8	1	8	1
P3	1	3	1	2	7	8	1
P8	***1***	***2***	***1***	***2***	***5***	***6***	***0***

SDT2

PI	SN	DN	SC	PL	ST	ET	PP
P1	***2***	***4***	***1***	***3***	***3***	***5***	***0***
P4	2	1	1	2	1	2	1
P5	2	5	1	4	6	9	1

SDT3

PI	SN	DN	SC	PL	ST	ET	PP
P1	***3***	***4***	***1***	***3***	***6***	***8***	***0***
P6	3	4	1	3	3	5	1
P7	3	2	2	2	4	5	1

SDT4

PI	SN	DN	SC	PL	ST	ET	PP
P8	***4***	***2***	***1***	***2***	***1***	***2***	***0***
P9	***4***	***5***	***2***	***4***	***1***	***4***	***0***

SDT5

PI	SN	DN	SC	PL	ST	ET	PP
P8	***5***	***2***	***1***	***2***	***3***	***4***	***0***

Table 1 (a) Initial information on different access nodes before scheduling/rescheduling; (b) processes from access node 1 to access node 3, and (c) the final status after access node 4 has scheduled/rescheduled packets.