A Packet Pre-Classification CSMA/CA MAC Protocol for IP over WDM Ring Networks

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`***Abstract --*** *In this paper, a packet pre-classification MAC (Media Access Control) protocol based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) scheme has been investigated for supporting IP packet over the all-optical WDM ring networks. The intention of the protocol is to increase throughput of IP over optical networks in Metropolitan Area Network (MAN). This protocol avoids both packet collision and packet fragmentation [7]. In order to improve the utilization of network, the packets transmitted from Local Area Network (LAN) are pre-classified into various class queues of access point (AP) according their length. Simulations had been done to evaluate the performance of the protocol, and the simulation results show extraordinarily good network efficiency.*

Keyword- IP over WDM and CSMA/CA

I. Introduction

With the explosion of information traffic due to the Internet, electronic commerce, computer networks, voice, data, and video, the need for a transmission medium with the bandwidth capabilities for handling such a vast amount of information is paramount. Recently, advances in solid-state and photonic technologies. Bit rates in wavelength are 40Gbps and glass fiber is a transmission medium that permits light to travel through it without amplification for hundreds of kilometer. Recently, the total bandwidth of an optical fiber to reach 3.2 Tbps [1].Research has demonstrated that the number of wavelengths per fiber could increase to more than 1000, and this clearly is not a limit[2]. This indicates that WDM is the solution for bandwidth insatiability.

Due to the widespread services and tremendous user population on Internet, the traffic of IP packets dominates the utilization of data networks. However, they are now transferred, switched, and manipulated through complex protocol stacks, such as IP/ATM/SONET/WDM, IP/ HDLC/SONET/WDM, and so on. How to merge and collapse the middle layers to reduce cost, complexity, and redundancy has become an important research issue [3]. Additionally, since many WDM systems have been deployed in Wide Area Networks (WANs), the bottleneck of communications will be pushed ahead from backbone networks to local access networks. As a result, applying WDM to LANs and MANs gains much research interests [4-7].

A number of research works were done for WDM ring networks. Cai et al. proposed the MTIT access protocol for supporting variable size packets over WDM ring networks based on fixed transmitters and fixed receivers (FTs-FRs) architecture[4]. To achieve all optical communications, MTIT adopts the source removal policy for dropping packets from networks to prevent packet re-circulation. Shrikhande et al. developed HORNET as a test bed for a packet-over-WDM ring MAN [6]. To facilitate signal regeneration and destination removal, HORNET utilizes opto-electronic and electro-optic conversion, which may constrain the transmission rate of the network. Although the IP standard allows a packet length between 40 bytes and 64k bytes, a measurement trace from one of MCIs backbone OC-3 links shows a discrete packet-size distribution, from 40 bytes to 1500 bytes. The smallest packet of 40 bytes corresponds to Internet control message protocol (ICMP) messages (TCP header + IP header) and the 1500 byte packet is Ethernet's maximum transfer unit (MTU). Wen-Fong Wang et al. proposed an almost optimal MAC protocol based on avoid packet collision use fragment packet scheme, for all optical WDM multi-rings with tunable transmitter and fixed receiver (TT-FR) [7]. In order to avoid packet collision use fragment scheme that to make a large number fragment packet and complex. For this reason, we propose a new MAC protocol. In this protocol, it not only avoids packet collision, but also fragment scheme is not necessary. In subsequent descriptions, the WDM ring network and the node structure for our protocol are presented in Section II. The protocol design is illustrated in Section III. To evaluate the performance of the protocol, the simulation experiment and results are described in Section IV. Finally, a few remarks are given in the conclusions.

II. Network Architecture

Let us consider a single and unidirectional fiber ring network, which connects a number of nodes. The ring network is composed of N data channels as shown in Figure 1. Each data channel makes use of one specific wavelength to convey optical signal. Therefore, based on the WDM technology, channels can work independently without mutual interference to each other. Logically, the network can be treated as a multi-ring network.

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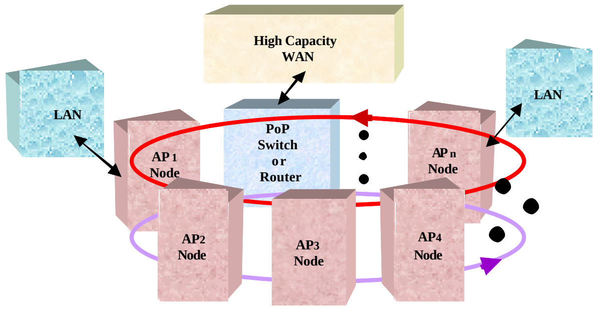

Figure 1. Logical architecture of a WDM ring

The node structure of the network is shown in Figure 2. Each node has one tunable transmitter and N fixed receivers with one for each data channel. For the optical signal sent from upstream nodes, a splitter is used to tap off a small portion of the optical power from the ring to the receivers. Every receiver detects the optical signal carried in its corresponding wavelength within the output branch from the splitter for node address identification. If the destination address in the incoming packet header matches the node address, the packet data is sent to the host. Meanwhile, the MAC control scheme is signaled to activate the FBG Filter for the corresponding data channel to remove the received packet carried in the major portion of the optical signal through the delay line. If the destination address is irrelevant to the node address, the detected packet is ignored and the process of scanning next new packet is started.

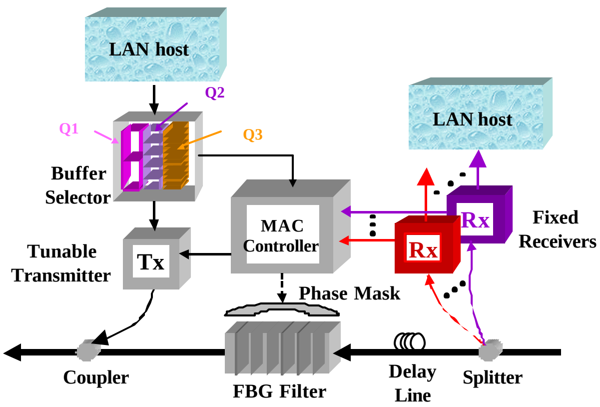

Figure 2. The node structure of the network

III. CSMA/CA MAC Protocol

In our network, all nodes can access any wavelengths and statistically share the bandwidth of each data channel. A MAC protocol is to choose the appropriate wavelength and transmit the appropriate sized packet from buffer selector queues. A fixed length fiber delay (1500Bytes) was installed the channel accounts for Receiver, MAC, and Transmitter processing. The processes are discussed as followings:

(1)The LAN Network packets are pre-classified to three kinds of different queues (Q1, Q2, and Q3) with the buffer selector. The three kinds of queues are storage 40 bytes, 41~552bytes, and 553~1500bytes, respectively. MAC controller is then informed by storage message in the buffer selector.

(2)Since each node is equipped with a receiver for each data channel, a packet can be transmitted via any available data channel to its corresponding destination node. The receivers both detects responsible the checking the destination address of incoming packets and detecting available channel to notify MAC.

(3)According the information (1) and (2), MAC controller to deliver a message to buffer selector that is active to transmit the Q1, Q2, or Q3 buffers packet. Figure 3 show The MAC controller model.

Figure 4(a) to Figure 4(d) shows the operation of this MAC scheme. The downstream access point recognizes the

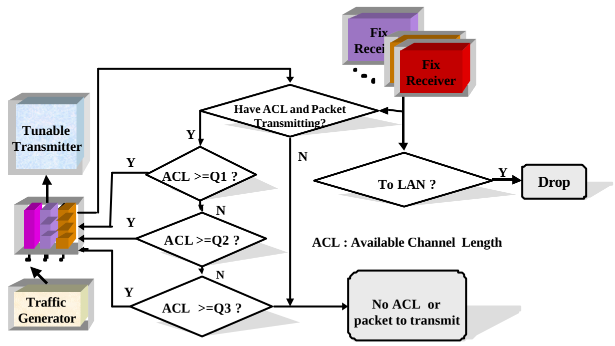

Figure 3. The MAC Controller Model

incomplete packet by the presence of the sub-carrier signal and pulls it off the ring. The carrier-sense can to checking available channel length to notify Tx transmit Q1, Q2, or Q3 buffers packet. Based on the protocol, each node monitors the wavelengths and to detecting the available channel length provided that there are packets for transmission. Given that a packet is being transmitted onto a target

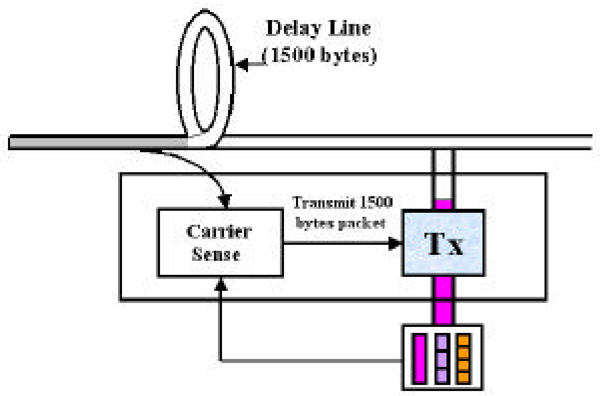

Figure 4(a). Incoming 1500 bytes packet is sensed

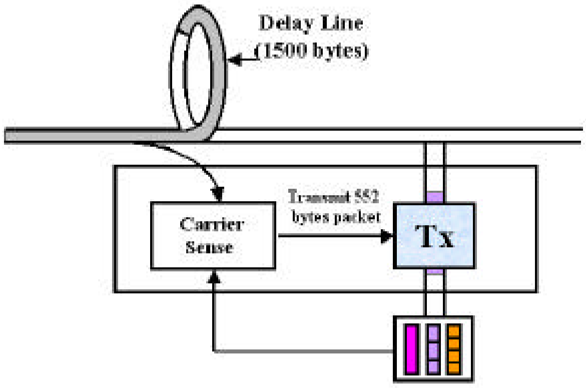

Figure 4(b). Incoming 552 bytes packet is sensed

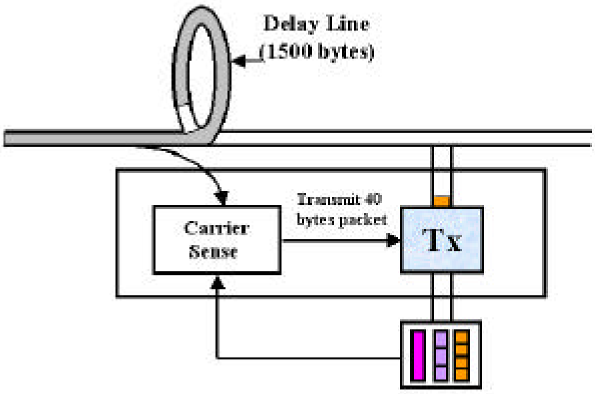

Figure 4(c). Incoming 40 bytes packet is sensed

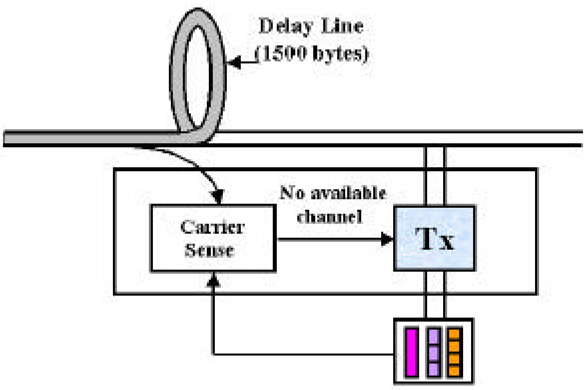

Figure 4(d). No available channel to transmit

channel while the node detecting another packet arriving on the same channel at its input, a dilemma of ring access (an access collision) has occurred. The cause for access collisions is due to the fact that the node cannot know if the opening is long enough to accommodate the packet. By the carrier access scheme, to guarantee the correctness of the protocol operations, the delay line inside nodes must be used to delay the incoming packet. In addition, the delay line should be long enough to cover maximum packet length (1500Bytes) so that unnecessary fragmentation can be avoided packet collision and improve the utilization of facilitate spatial on the bandwidth.

To support the carrier access scheme, the frame format adopted is shown in Figure 5. The carrier sensing mechanism for finding transmitted packets in optical fiber can be based on sub-carrier signaling [8] or receiver monitoring. For sub-carrier signaling, each wavelength is

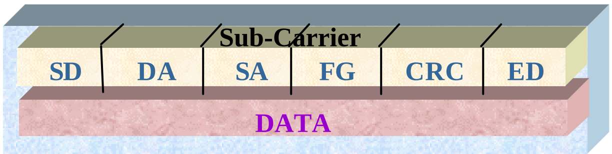

Figure 5. The frame format

associated with a sub-carrier frequency. When a node transmits a packet, it multiplexes the corresponding sub-carrier frequency. The nodes determine the occupancy of all wavelengths in parallel by monitoring the sub-carriers in the RF domain. In addition, since each receiver extract the optical signals from the corresponding data channel (or wavelength), receiver monitoring can be another approach to determine the occupancy of all wavelengths. It seems natural that the receivers are associated with the auxiliary function to monitor the status of the optical ring network. Nowadays, the cost of such receivers is still so high that is not economical to manufacture, but it may be realized later. For the start delimiter (SD) and the end delimiter (ED), they mark a physical data frame conveyed in data channels for packets. The source address (SA) and the destination address (DA) serve as the address information in the network. To prevent the possible transmission errors in midway, the cyclic redundancy check (CRC) is employed. The flag (FG) field is reserved for extended protocol functions.

IV. Simulations

For the simulation model, it is shown in Figure 6. There are four processes used in the model: Traffic Generator, Rx, INS, and CHK. Traffic Generator is responsible for generating IP packets based on balance traffic 40~1500 bytes to simulate traffic load. INS is responsible for coordinating the transmission of packets size in transmission queue and the shift of packets from the delay line. Rx is the receiver process that receives packets and to check available channel length. CHK is responsible for checking the destination address of incoming packets. To simulate the delay line and the input fiber link of nodes under the condition of multi-channels, three queues for every node.

The simulation experiments are based on the codes by

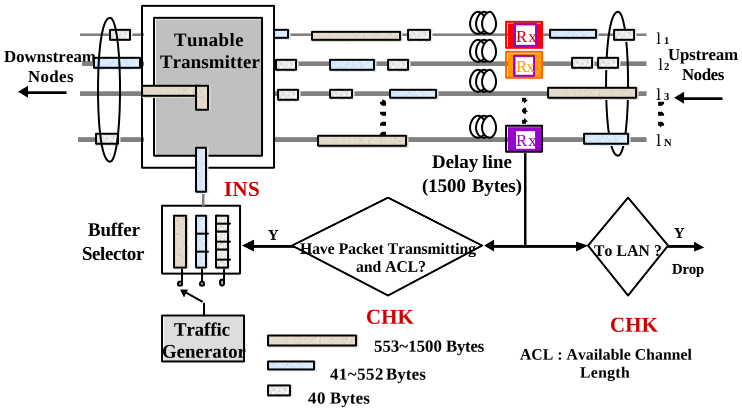

Figure 6. The simulation model

SIMSCRIPT II and are replicated corresponding to variance reduction technique with different sequences for pseudo random numbers. For simulation parameters, they are listed below Table 1.

Table1. *The simulations parameter*

Number of node	16 (separated by 5 km)
Number of channels	8,4,2,1
Ring Network length	50km
Channel speed	10 Gbps (OC-192)
Size of the delay line	1500 Bytes
IP packet size	Balance traffic: 40~1500 Bytes
Average Packets	512 Bytes

The performance rate of Access Link Load (for each node in Gbps) vs. Average Transmission-Delay (us) is shown in Figure 7. Every node, the received load can be seen that the saturated rates for the balance traffic is 72%. It can be seen the performance of the network is good efficiency. For example channel 8, the total offered load are 8*10G=80G, but the total received load are 72%*10G*16=115.2G, so the performance of the protocol show extraordinarily good network efficiency under balance traffic condition. The balance traffic is obtained by distributing the output load of every node to other nodes uniformly. Since the propagation delay of signals is fixed through fiber links, we are interested in the performance of access delay. Figure 8 shows the relationship of Access Link Load (for each node in Gbps) V.S Average Queuing-Delay (us). It shows that the access delay is quite lower under the balance traffic. So we unnecessary considering propagation delay for install delay line.

V. Conclusion

In summary, in this paper has investigated a novel MAC protocol for all optical WDM ring networks. The protocol supports the transmission of IP packets directly over WDM from LAN to MAN. Meanwhile, the investigation has been made about how to merge and collapse the middle layers between IP and WDM for next generation optical LANs/MANs. This protocol can avoid collision packet, reuse wavelength, and no fragment packet scheme. The utilization on the bandwidth of all optical ring networks, our protocol displays the excellent characteristics of high throughput and low delay in the way of all optical

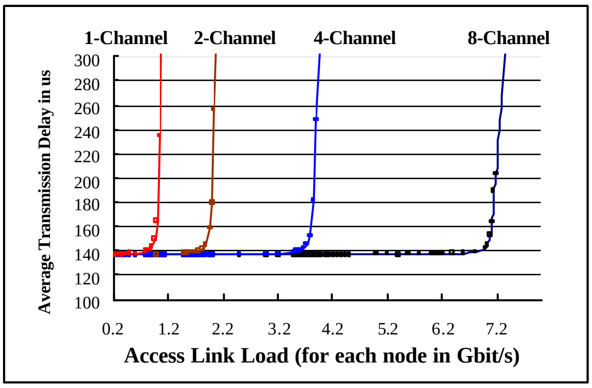

Figure 7. Average Transmission-delay

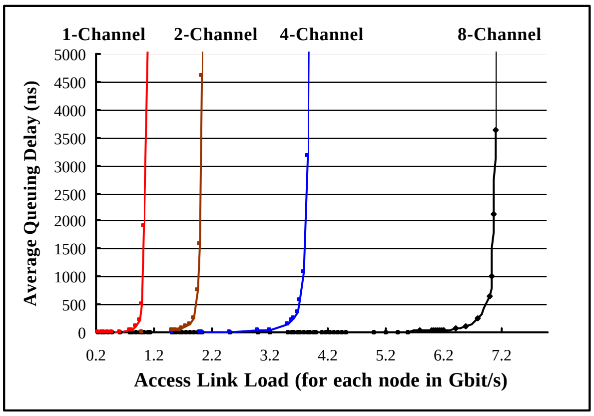

Figure 8. Average queuing-delay

communications. Furthermore, the pre-classification packets function of the proposed protocol can also support in the QoS and priority scheme.

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