WDM Local Network에서 선예약슬롯을 이용한 가변길이 메시지 지원 프로토콜

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Protocol supporting Variable-length Message using Pre-reservation Slots in WDM Local Network

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요 약

본 논문에서는 WDM 기반의 Local Network에서 가변길이 메시지를 수용하기 위한 스케줄링 프로토콜을 제안하였다. 제안된 프로토콜은 제어슬롯을 선예약슬롯과 예약슬롯으로 나누어 제어패킷의 충돌로 인한 액세스 지연시간을 최소화하였다. 즉, 전송할 메시지가 있는 노드는 빈 예약슬롯이 있으면 제어패킷을 예약슬롯에 전송하고 메시지를 전송한다. 그리고 메시지의 전송이 완료될 때까지 주기적으로 제어패킷을 전송하여 가변길이의 메시지를 전송할 수 있도록 하였다. 또한 빈 예약슬롯이 없는 경우에는 선예약슬롯을 이용하여 가장 가까운 시간에 메시지를 전송하기 위한 데이터 슬롯을 미리 예약하여 제어슬롯의 충돌로 인한 재전송 횟수를 감소시켰다.

제안된 스케줄링 프로토콜은 기존의 프로토콜과는 달리 망에 새로운 노드가 추가되더라도 망을 초기화하여야 하는 문제가 없으며, 선예약슬롯을 이용하여 제어패킷의 충돌이나 목적지 충돌로 인한 재전송 횟수를 감소시켜 액세스 지연시간을 줄이는 장점을 가진다.

ABSTRACT

A new WDM-based protocol for scheduling a variable-length message is proposed in this paper. Two control slots, Pre-reservation slot and Reservation Slot, are used to coordinate transmission and diminish the collisions of packet to minimize the access delay. When there is an idle reservation slot, a control packet is transmitted on that slot and message is transferred. And the node continues to transmit its control packet through the corresponding slot every cycle, until the message is completely transmitted. If an idle reservation slot is not available, the node schedules the transmission time of message in earliest available time using Pre-reservation slots.

The proposed scheduling protocol has several advantages; any new node can join the network anytime without network re-initialization. Moreover, with the pre-reservation slots, we can avoid the packet collisions and destination conflicts, and we can improve the access delay time for message transmissions.

Ⅰ. Introduction

Wavelength-division multiplexing(WDM) is an approach that can exploit the huge opto-electronic bandwidth mismatch by requiring that each end-users equipment operate only at electronic rate, but multiple WDM channels from different end-users may be multiplexed on the same fiber[1]. Under WDM, the optical transmission spectrum is carved up into a number of non-overlapping wavelength bands, with each wavelength supporting a single communication channel operating at Gbps[1].

WDM network architectures can be classified into two broad categories: broadcast-and-select architecture and wavelength routing architecture[2]. In a broadcast-and-select WDM network, a passive device in the middle of the network broadcasts messages to all the nodes. In this case, the device is a passive optical star coupler. The coupler combines the signals from all the nodes and delivers a fraction of the power from each signal on to each output port. Each node employs a tunable filter to select the desired wavelength for reception. And the nodes in the wavelength routing network are capable of routing different wavelengths at an input port to different output ports. This enables us to set up many simultaneous lightpaths using the same wavelength in the network; that is, the capacity can be reused spatially[3].

The nodes in such a network can transmit and receive messages on any of the available channels using on or more tunable transmitter(s) and/or tunable receiver(s). Several topologies have proposed for WDM networks, a popular one being the single-hop, passive star-coupled topology.

To use the WDM channels more sophisticated in single-hop WDM passive star networks, efficient access protocols and scheduling algorithms are needed to allocate and coordinate system resources optimally, while satisfying message and system constraints. Most of these protocols and algorithms can be divided into two main classes, namely preallocation-based and reservation-based techniques. Preallocation-based techniques use all channels of fiber to transmit messages. These techniques assign transmission rights to different nodes in a static and predetermined manner. Reservation-based techniques allocate a channel as the control channel, to transmit global information about messages to all nodes in the system. Once such information is received, all nodes invoke the same scheduling algorithm to determine when to transmit/receive a message and on which data channel. Reservation-based techniques have a more dynamic nature and assign transmission rights based on the run-time requirements of the nodes in the network[1].

In this paper, the reservation-based scheduling algorithms in broadcast and select WDM network are mainly concerned. Most of such protocols are based on the transmission of fixed-sized data packets. However, when there is a need to accommodate circuit-switched traffic or traffic with long holding times(e.g. file transfer service), it is necessary for a protocol to efficiently support such variable-sized messages. In this paper, several researches which have been addressed are surveyed their behavior with benefits and weak points and a new scheduling algorithm is proposed. The new algorithm can support variable-sized messages without requiring global information and network re-initialization. Moreover, the access delay is reduced comparing with existing method.

This paper is organized as follows. In Section 2, several scheduling algorithms supporting variable-length messages are shown with their mechanism, benefits, and drawbacks. In Section 3, the details of new scheduling algorithm and the performance results are described. Finally, the conclusions are shown in Section 4.

II. Scheduling Protocols supporting Variable-length Messages

In this section, we discuss the behavior of several existing scheduling protocols to support the variable-length messages in single-hop broadcast-and-select WDM networks and show their characteristics. The protocols supporting variable-length messages are as follows; Reservation Aloha, Jias method, Lees method, and TDMA-C. Because all of them are reservation-based algorithm, they adopt same strategy with control channel to reserve the data channel and to notify the nodes to tune the receiver with specified wavelength. After successful reservation, the scheduling algorithm invoked in all nodes schedules the transmission time.

1. Reservation Aloha

Reservation Aloha[4] protocol is a revised version of slotted Aloha protocol to accommodate circuit-switched traffic or traffic with long holding times, e.g., file transfer. In this protocol, each node has one tunable transmitter and one tunable receiver for transmitting and receiving a control packet as well as a data packet. The fiber bandwidth is divided into (N+1) channels, each using a different wavelength. There are M(M>N) nodes in the network.

When a message is generated in node i destined to node j, the node i select a control channel randomly with contention-based method and transmit a control packet(which contains the source address, destination address, and the chosen data channel) on the selected control channel. After then the node i immediately transmit a data packet(L minislots) on the chosen data channel in the same cycle. If the node j is idle at that time, it will receive control packet and tune its receiver to data channel specified in the control packet. This fixed assignment of a control minislot to each data channel ensures that successful control packet, successful data packet. The Reservation Aloha protocol is quite wasteful since data channels are unused during the N minislots, and control channels are unused while transmitting the data packet.

The Reservation Aloha protocol uses the jam signal to transmit the variable-length packet. After a control packet and a data packet are successfully transmitted, and if message are remained, the subsequent control slot is reserved by using jam signal till the transmission is finished.

The Reservation Aloha protocol is simple but the destination conflict can be occurred frequently.

2. Jia's Method

To overcome the large latency(i.e., tuning time) of tunable devices when they are tuned from one wavelength(channel) to another, three scheduling algorithms are proposed in [5].

The network consists of M nodes, and (N+1) non-interfering channels(wavelengths) with the same capacity; N of channels are used for data transmissions and the other channel is dedicated to control packet transmission (control channel) for pretrasmission coordination. Each node is equipped with a fixed transmitter/fixed receiver tuned to the control channel. In addition, a tunable transmitter and a tunable receiver are employed at each node to enable it to access the data channels.

Data channels are slotted by a fixed data packet and control channel is consisted of M minislots that are accessed via TDMA scheme to avoid collision of control packets. Both channels are not synchronized with each other unlike Reservation Aloha protocol.

When a message is generated in a node i, the node i sends a control packet(is consisted of destination node, the number of data packets in a message) to assigned control minislot. After one round-trip propagation delay, the node i receives the control packet. Then the Jias scheduling algorithm is invoked by the node i to determine the data channel and message transmission time. After a message is scheduled, the node i tunes the transmitter to the selected data channel before transmission time and at the transmission time the message is transmitted. Also destination node tunes the receiver to the same data channel and receives the message.

To work the scheduling algorithm it needs three global information; Receiver Available Time(RAT), Channel Available Time(CAT), and Destination Channel(DC). RAT is an array of M elements, one for each node and the value of each element means that node i's receiver will become free after that value. CAT is an array of W elements, one for each data channel and the value of each element means that data channel will be available after that value. And DC is an array of M elements, one for each node and means which node is scheduled to what data channel. These three global information are updated at all nodes in each data slot.

Three kinds of the scheduling algorithms are presented in [5], one of them is described in this paper. Earliest Available Time Scheduling(EATS) schedules the transmission of a message at the earliest possible time. EATS selects a data channel from the CAT that contains the smallest value and checks available time of the destination node from the RAT. With these values, EATS schedules the tuning time of transmitter and the message transmission time. The message transmission time will be various to transmit a variable-length message.

The Jias method shows good performance, but when a new node is inserted into network, the network should be re-initialized. Moreover, the global information should be kept in each node.

3. Lee's Method

To schedule the variable-length messages in WDM network, the [6] proposes the synchronous reservation protocol. Like other methods, this protocol can be operated in M (M>N) nodes and with (N+1) WDM channels. And also each node prepares the fixed transmitter/fixed receiver for control packet transmission and tunable transmitter/tunable receiver for data packet transmission. In [6], the tuning time of transceiver is assumed to be zero.

All channels are slotted with the size of the transmission time of a fixed-sized data packet and the control slot is further divided into minislots with the size of the transmission time of a control packet. The control channel shared by all nodes on a contention basis using the slotted aloha protocol.

The message transmission procedure is composed of 5 phases. In first phase, when a message is generated to transmit, a data channel and a control channel is randomly selected and the node monitors whether the control and data channel are used in other node. If no other node use the control channel, the sending node transmits the control packet on the next slot. And in 3rd phase, the node checks the control packet during another slot time. If the control packet is not collide, the transmitter of sending node tunes the transmitter with the selected data channel and the destination node also tunes the receiver with that channel. And in the last phase, the control packet is transmitted on the selected control channel in every slot until the message is completely transmitted. After the node sends all data packets of the remaining message, and goes to the first phase.

The Lees method has several advantages, network re-initialization is not required when a new node inserted into network, no global information is needed, etc.. However as the offered load is growing the retransmission of control packet is occurred frequently, so the access delay of data channel is larger than other methods.

4. TDMA-C

In the TDMA-C protocol, each node is equipped with the fixed transmitter/fixed receiver for control packet transmission and tunable transmitter/tunable receiver for data packet transmission. And N data channels and one control channel are prepared with M(M>N) nodes in network.

Time is slotted by the size of fixed data packet and control slot is further divided M minislots by the size of control packet.

To avoid the data collision and receiver collision, TDMA-C protocol uses two status tables maintained in each node. A table(channel status table) tracks the status of the data channels to eliminate data channel collision, and another table(node status table) avoids destination conflict(receiver collision) by tracking the status of the receiver at each node. Two status tables are updated at the end of each control slot after receiving and decoding a control packet.

If node i transmits a control packet targeting j on data channel k, all nodes add the (propagation delay+data transmission delay) to entry j in their node status table and entry k in the channel status table. The entries indicate the number of time slots that the resources will be busy. All positive entries of each table are decremented at the end of every control slot to update the remaining busy control slots.

TDMA-C has two problems; the network re-initialization is required when a new node is added, the global information should be maintained at each node.

III. A New Proposed Method

1. Channel Structure

As shown in figure 1, both control and data channels are slotted using the same time reference. This we call as one cycle. The duration of a cycle equals the fixed-length data packet. The control channel is further divided into 2W minislots, where W is the number of channels(wavelength). Due to the fixed assignment of a control slot for each slot for each channel, if a control packet is successful in a control slot then the corresponding data message will be successful. The first W minislots is Pre-reservation slots and the second is Reservation slots . Pre-reservation slots are used for reservation when all the Reservation slots are busy. And Reservation slots transmits control packet to reserve the data channel.

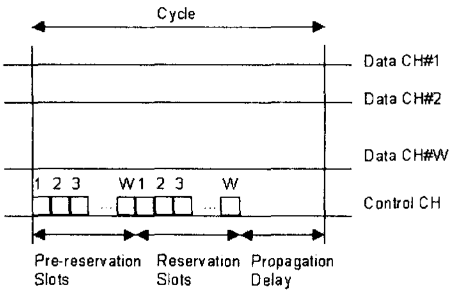

Figure 1. Channel Structure

2. Scheduling Algorithm

The existing scheduling algorithm retransmits the control packet continuously in each cycle until the reservation of data channel is successful. Therefore the access delay of data channel is incremented in the heavy offered load environments. In order to reduce the access delay of data channel, the proposed algorithm uses the pre-reservation mechanism shown in figure 2.

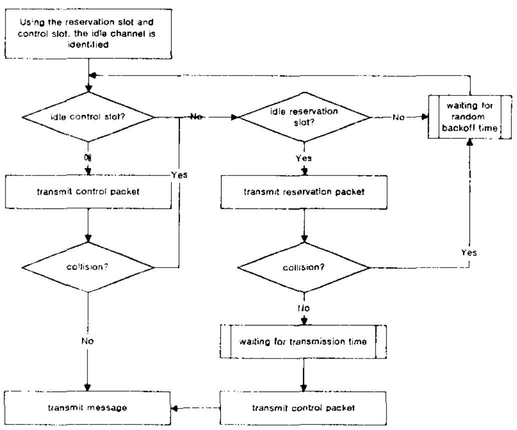

Figure 2. Proposed Algorithm

When a data message arrives at a network node, the node selects a reservation minislot using the information collected on the previous cycle. If there is an available reservation minislot, the node transmit a control packet consisted of destination node and message length. And next cycle, the node observes the collision of control packet or destination conflict. If any collisions are not occurred, message transmission is processed and until the completion of message the control packet is transmitted on the reserved minislots.

However when there is no available reservation minislots or some collisions are occurred, the pre-reservation processing is operated. If there exists an available pre-reservation minislot, the control packet of pre-reservation is transmitted. The control packet of pre-reservation is composed of destination address and busy time that is calculated using the information of previous cycle. The busy time is selected the soonest value among the message length of control packet in reservation minislot. When no collision is occurred in control packet of pre-reservation on next cycle, the control packet is transmitted continuously until the busy time is zero. After busy time, the message and control packet of reservation are transmitted.

3. Performance Analysis

The existing scheduling algorithm[6] monitors for a cycle after selection of control slot and data channel randomly. During the monitoring procedure, it checks the occurrence of packet collision and destination conflicts. If any collisions are not occurred, the control packet is transmitted and monitors one more cycle observing occurrence of packet collision and destination conflicts. When no collision is detected, the data message is sent. Therefore the existing method uses at least two cycle times before transmitting data message, and the access delay is growing, as the offered load is heavy.

The proposed method also transmits the control packet into control slot after monitoring the control slot for a cycle. But using the pre-reservation slots, the previous reservation algorithm is operated although the packet collision and destination conflict exists. Therefore, the minimum of access delay of data channel is two-cycle time and in heavy load environments the access delay time is not growing seriously. Using the computer simulation, the access delay time of existing and proposed method is analyzed. The figure 6 shows the comparison of access delay time between existing and proposed method. As depicted in the figure, the access delay is decreased more 30% than existing method.

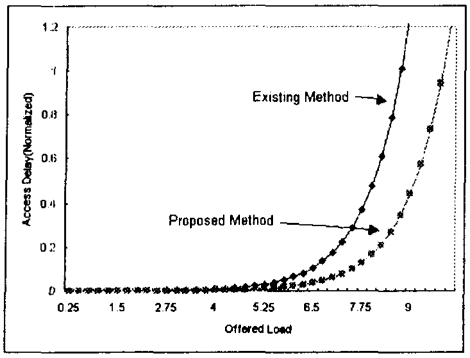

Figure 3. Access Delay

VI. Conclusions

The existing scheduling algorithms for supporting variable-length messages in the WDM network have several serious problems; network re-initialization, global information kept in each node, occurrence of destination conflict and long access delay. Therefore, in this paper, we propose a new scheduling algorithm supporting variable-length messages. The algorithm especially uses the pre-reservation minislots as well as reservation minislot like other protocols. Using the pre-reservation minislot, the collided control packets can be recovered and when no idle reservation minislots are existed, the reservation of data channel can be processed early. The performance of proposed method is analyzed by computer simulation, and shows smaller access delay than existing methods.

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