A Collision-Free MAC Protocol for All-Optical Ring Networks

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Abstract —In this paper we propose a collision free MAC protocol for WDM all-optical ring networks. The protocol prevents contention for shared data channel among the nodes and destination conflicts; i.e., at any instant of time, no two nodes transmit on the same data channel, and no two nodes send data to the same destination respectively. The protocol is based on circuit-switching concepts, that is a circuit is established between the source and destination prior to the transmission of packets and the circuit remain established for a fixed duration. Packets remain in optical domain from the source to destination. Propose protocol is scalable. We studied the performances of the network by simulation and the result is found to be promising.

Keywords — optical ring networks, wavelength division multiplexing, MAC protocol, control token.

1 Introduction

The rapid growth in demand for bandwidth due to the Internet explosion can only be satisfied by optical networks, and by particularly using the wavelength-division multiplexing (WDM) technology. Now, a single fiber can support hundred of wavelength channels. With the successful deployment of WDM in core networks, access networks, viz., local area networks (LANs) and metropolitan area networks (MANs) are bottlenecks. A lot of works has been reported in the literature for the deployment of WDM technology in the access network. Most of the work employs either a star or a ring topology as the physical topology of the underlying access networks. Star topology is employed as the underlying physical topology for LANs in [1] ,[2],[3],[4],[5],[6] whereas ring is employed as the underlying physical topology in [7] ,[8],[9],[10].

Most of the work on LANs reported in the literature are based on star topology, only a few work to the best our knowledge are based on ring topology. This paper propose a collision free MAC protocol for an all-optical LANs based ring topology. The propose protocol operates in three stages: Reservation, Transmission, and Release, hence called Reserve-Transmit- Release (RTR); for gaining access to channels in an optical ring networks. In the first stage the destination and a data channel is reserved, then transmission takes place for a fixed duration, and then the reserved destination and data channel is released. RTR algorithm takes a ring latency to reserve, transmit for a period equal to ring latency, and takes a ring latency to release. The algorithm prevents contention among the nodes for shared channels, and for destination. Hence channel collision and destination collision never occurs. Our work fundamentally differs from those mentioned in [7], [8], [9] and [10] with the scalability of the network and tunability of the transmitter and receiver. In [7], [8], and [9] nodes are equipped with a tunable transmitter and a fixed receiver and the networks are mostly not scalable. Whereas in the propose method nodes are equipped with a tunable transmitter and a tunable receiver and the network is scalable. With the advancement made in laser technology [12], [13], [14], [15] it is possible to equip a node with tunable laser with fast tuning time among the channels. Most of the MAC protocol proposed for optical ring network operates on slotted mode which requires a mechanism for synchronization at slot boudaries. Protocol protocol is based on a reservation scheme, where the reservation information must be received by all the nodes in the network before data transmission could takes place. Unlike the methods proposed in [7], [8], and [9], RTR algorithm does not have slotted channels, hence synchronization among slots is not an issue. Like [10] nodes in the propose method are equipped with tunable transmitter and tunable receiver but differs with the range of tunability. In [10] the range of tunability (of tunable transmitters and tunable receivers) is a sub-set of available wavelengths whereas the range of tunability (of tunable transmitters and tunable receivers) is the entire set of available wavelengths. The algorithm is simple to implement. This paper is organized as follows. In Section 2 the system model is described. In Section 3 the contention free algorithm, RTR, is described. Simulation and Results are shown in Section 4 and we make some conclusions in Section 5.

2 System Model

System Assumption We consider a single hop WDM ring networks. There are N nodes in the network, numbered as 0,1,2, ..., $N-1$. Node i of the network is connected node j by an optical fiber such that $j = (i+1)$

mod N where $i \neq j$ and for all i, $j \in$ 0,1, ..., $N-1$; node j is the successor of node i and node i is the predecessor of node j. The system supports W wavelengths, λ_0, λ_1, ..., λ_{W-1}. There are $W-1$, *data channel* and one *control channel.* One of the wavelength, λ_0, is dedicated to control channel and rest of the wavelengths are used as data channels. A circuit is established on wavelength, λ_0, between every pair of adjacent nodes i and j. The circuit thus established is the dedicated control channel. A pair of nodes i and j are said to be adjacent if j is the successor of node i and node i is the predecessor of node j.

Each node is equipped with a fixed transmitter and a fixed receiver, a tunable transmitter and a tunable receiver. The fixed transmitters and fixed receivers are tuned to wavelength, λ_0, to transmit and receive control information between adjacent nodes. Tunable transmitters and tunable receivers are tuned to data channels, as and when required. For two nodes in the network to communicate, tunable transmitter of the source node and tunable receiver of the destination node must be tuned to the same wavelength (data channel).

The system has a single *control token* that circulates around the ring on the control channel. Structure of the control token is shown in Fig. 1. Control token consists of *header field* and *information field.* Header field specifies the number of bytes in the information field. The information field is of m-bytes, where

$m = \lceil a/8 \rceil \times N + N$

$a = \lceil \log_2 N \rceil + \lceil \log_2 W \rceil$

$\lceil \log_2 N \rceil$ is the number of bits required to encode, N, nodes in the network

$\lceil \log_2 W \rceil$ is the number of bits required to encode, W, wavelengths

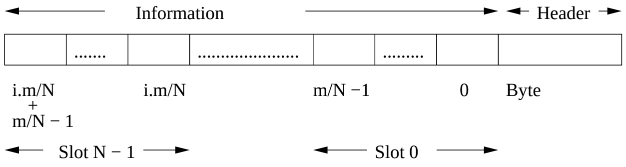

Figure 1: Control Token

Each node is assigned b consecutive bytes of the information field where $b = \lceil a/8 \rceil + 1$. Of the b bytes, $\lceil a/8 \rceil$ bytes are for encoding destination identity (id) and selected data channel and the extra one byte is for specifying other control information such as reservation, release, priority of the packets etc. Node i is allocated byte number $(i \cdot m/N)$ to $(i \cdot m/N)$ + ($m/N - 1$) of the information field of the control token. We call this b consecutive bytes allocated to a node as *slot.* There are N slots in the information field of the control token with slot i allocated to node i. A node inserts its control information such as destination id, data channel selected for communications etc. in its allocated slot. The least significant $\lceil \log_2 W \rceil$ bits of a slot are *wavelength bits* for encoding data channel, next $\lceil \log_2 N \rceil$ bits are *destination bits* for encoding destination id, and the rest of the remaining bits are used for control information such as to indicate modification of slot, priority of packets, to indicate reservation / release of destination and data channel by a node etc. Wavelength bits of a slot will have non-zero entries as the wavelength λ_0 is dedicated for control channel, and all-one entry indicates the corresponding node is not requesting for any data channel. All-one entry in the destination bits indicate no reservation request for destination has been made by the corresponding node. A node on receiving the control token process each slot, l, for $0 \leq l < N$ to update its knowledge about node l in the network. Prior to the communication between a pair of nodes, the source must reserve the destination and data channel. A node reserve the destination and a data channel by writing the control information at its allotted slot in the information field of the control token. Reservation mechanism is explained latter. A slot is processed by a node in-case it is modified by its corresponding node. A node i writes control information only in slot i whereas it reads all the N slots of the control token for processing. A node writes control information such as destination id, data channel selected, whether it is resreving or releasing the data channel and destination node, priority of packets etc. in the slot allotted to it.

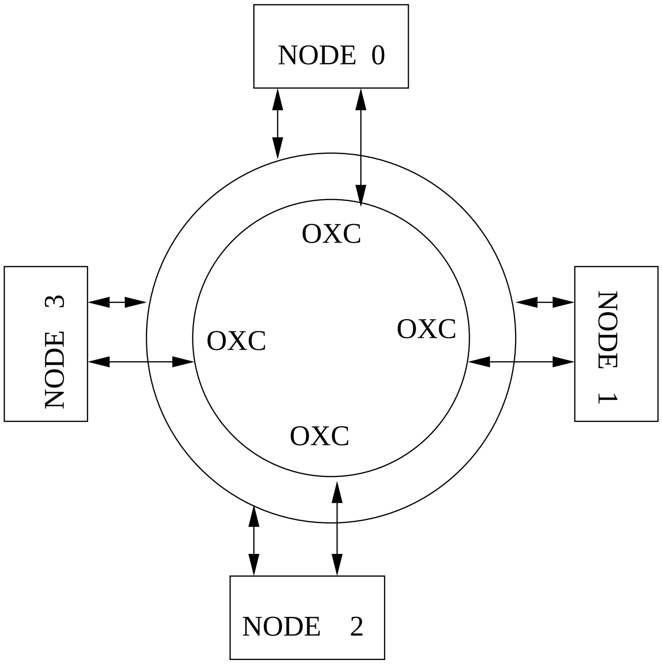

Figure 2: Optical Ring Network

A node has N buffers, one for each node. At node i buffer j for $j \neq i$ holds packets that are destined for node j, whereas buffer i receive packets that are sent to node i from other nodes in the network.

Data Structure Each node maintains status of other nodes, and data channels in the network. Each node has the following vectors : *Destination Available Table*, DAT, and *Destination Release Table*, DRT, both are of N elements, *Channel Available Table*, CAT, and *Channel Release Table*, CRT, both are of W elements. The purpose of these vectors are explained below

$DAT_i[j] = 0$ indicates receiver of node, j, as seen by node, i, is free , whereas

$DAT_i[j] = 1$ indicates receiver of node, j, as seen by node, i, is busy, for $0 \leq j < N$ and $i \neq j$

$DRT_i[j] = 1$ indicates; source node is releasing destination node, j

$CAT_i[c] = 0$ indicates wavelength, λ_c, as seen by node, i, is free whereas

$CAT_i[c]$ =1 indicates wavelength, λ_c, as seen by node, i, is busy for $1 \leq c < W$

$CRT_i[c] = 1$ indicates; source node is releasing the wavelength channel, λ_c.

PD_{ij} = Propagation Delay between node i and j

R = Ring Latency

Status = A variable indicating whether a node is reserved or free. 0 indicates free and 1 indicates reserved

Finish = A variable indicating completion of transmission by a node. 1 indicates the transmission is completed.

Busy = A variable indicating whether a node has started its transmission or not. 1 indicates the node is busy in transmitting whereas 0 indicates the transmission has not started.

3 Collision Free Algorithm

First, we illustrate the algorithm with an example. We consider a four node optical ring network shown in Fig. 2. For illustration, we simplified the information in a slot i to contain a triplet (x, y, z) where x can take the value 0,1 or 2 to indicate that node i is transmitting, requesting for reservation or releasing respectively. A slot is processed only if x is non-zero. y indicates the destination id that node i is requesting and z indicates the data channel selected by node i for transmission. We use the notation $a \rightarrow b$ to denote, node a wants to communicate with node b.

Let at an instant, t, the content of DAT and CAT are as shown in Fig. 3(a), node 0 received the control token and $0 \rightarrow 2$, $1 \rightarrow 3$, $3 \rightarrow 2$. The content of DAT and CAT at each node after processing the control token received by that node is shown in Fig. 3(b). The content of DAT and CAT at each node after sending the control token to its successor node is shown in the Fig. 3(c). The control token received by a node from its predecessor and sent by the node to its successor is shown in Fig. 3(d). Node 0 received the control token at t, the content of DAT and CAT at node 0 after processing the control token is shown in Fig. 3(b). Node 0 wants to communicate with node 2. For communication to takes place, node 0 must reserve node 2 and a data channel. Node 0 checks for DAT[2] equal to zero, and find c for which CAT[c] equal to zero where $1 \leq c < W$. Finding DAT[2] and CAT[1] equal to zero, node 0 starts reserving the destination and data channel by performing the following action : sets DAT[2], CAT[1], and Status to one, tune its transmitter to λ_1, writes the control information in slot 0 of the control token. Node 0, then sends the control token to its successor; node 1. Node 1 on receiving the control token performs the above action to reserve, node 3, and data channel λ_2. Node 2 on receiving the control token releases the destination, i.e., node 1 and data channel λ_3. For releasing the destination it sets CRT[3] and DRT[1] to one , DAT[1] and CAT[3] to zero, writes necessary information in the slot 2 of the control token. Node 2 sends the control token to node 3. Note, the algorithm takes a ring latency to reserve, transmit, and release respectively. In a slot, x is set to 0,1, and 2 during transmission/idle, reservation, and release respectively. The content of DAT and CAT at node 3 after processing the control token is shown in Fig. 3(b). Node 3 wants to communicate with Node 2. It makes an attempt to reserve node 2 and a data channel but find DAT[2] is set to one. Hence, its attempt to reserve node 2 fails. The control token sent by node 3 is shown in Fig. 3(d). When node 0 gets back the control token, finds Status is set to one; sets Busy to one and start transmitting. It takes a *Token Period* for a node to reserve a destination id and data channel. Similarly it takes a token period to release the destination id and the data channel. A node releases both the destination id and data channel after completion of transmission. Token period is defined as the time period between two successive receive of the control token by a node. We assume token period is equal to the ring latency. During a token period, a node informs every other node, the destination id and the data channel it is reserving/ releasing. We further assumed that the tuning time of the laser is less than a ring latency.

Algorithm

The following steps are performed when a node i receives the control token

```
Step 1 If Status is set to one and Busy set to zero then
    Step 1.1 Set Busy to one
    Step 1.2 Transmit for a period equal to the ring latency
    Step 1.3 Set Finish to one when Step 1.2 is completed
Step 2 Examine each slot in the information field of the control token beginning with slot 0
    Step 2.1 If $x$ is set to one
        Step 2.1.1 If destination id is equal to id of node $i$, then set $DAT_i$[destination id] and $CAT_i$[wavelength id] to one, tune the receiver of node id to wavelength id
        Step 2.1.2 Else, set $DAT_i$[destination id] and $CAT_i$[wavelength id] to one
    Step 2.2 If $x$ set to two, set $DAT_i$[destination id]
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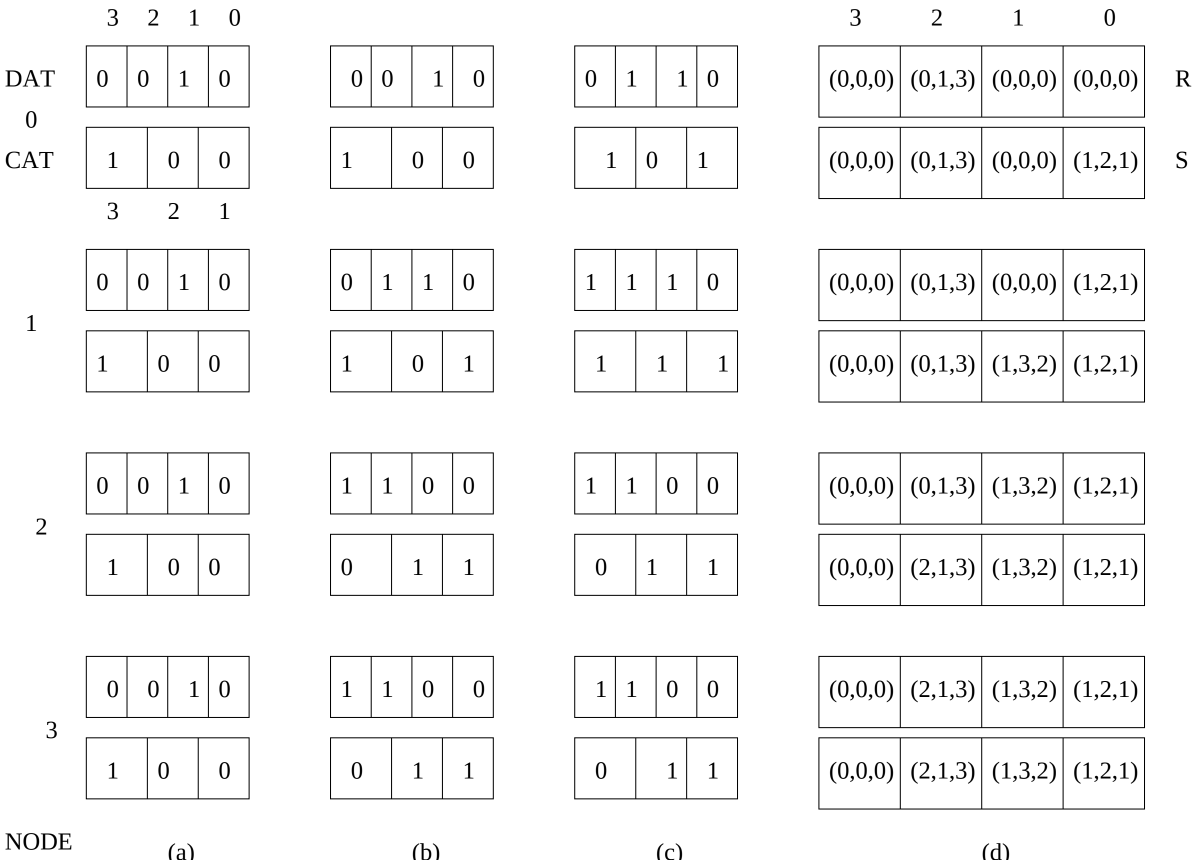

Figure 3: Shows (a) Content of DAT and CAT at each node before receiving the control token (b) Content of DAT and CAT after processing the control token (c) Content of DAT and CAT after sending the control token to successor node (d) R – Control token received by a node from its predecessor node and S – Control token sent by a node to its successor node

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    and $CAT_i$[wavelength id] to zero and
    $CRT_i$[wavelength id] and $DRT_i$[destination id]
    to one
Step 3 If node $i$ has data to send to node $j$ for $i \neq j$
and Status set to zero then
    Step 3.1 If DAT[j] is set to zero then
        Step 3.1.1 Find k for $1 \leq k < W$ s.t.,
        CAT[k] and $CRT_i[k]$ both set to zero, if
        such $k$ exists, then set Status, $DAT_i$[j],
        $CAT_i$[k] to one.
Step 4 Write the control information in the slot $i$ of the
information field of the control token
Step 5 Set $CRT_i$[wavelength id] and $DRT_i$[destination
id] to zero. Send the control token to the successor of
node $i$.
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Destination collision occurs when a destination node receives data from two different nodes at the same time and Channel collision occurs when two different nodes select the same data channel for transmission.

We claim the following

Claim 1 No two nodes i and j can reserve the destination node m during the interval t to $t+R$.

Proof Suppose node i and node j both reserved the node m at t and t_1 respectively, during the interval t to $t+R$ where $t < t_1 < t+R$. This implies that when node i reserved m at t both $DAT_i[m]$ and $DAT_j[m]$ are zero, also, when node j reserved m at t_1 both $DAT_i[m]$ and $DAT_j[m]$ are zero.

Form the algorithm a node can reserve a destination only when it receive the control token. Node i has reserved node m at t, this implies that node i has received the control token at t, and have taken the following action. DAT at node i is updated, node m is reserved by setting $DAT_i[m]$ to one, and the control information is written in slot i of the control token. Node i then sends the control token to its successor node.

Node j has reserved m at t_1, this implies that node j has received the control token at t_1. On receiving the control token, node j shall update its DAT setting $DAT_j[m]$ to one. To reserve node m, node j checks $DAT_j[m]$ for zero. But $DAT_j[m]$ has been set to one which indicates that some other node has already reserved node m. Hence, node j fails to reserve node m. This contradicts that node j reserved node m at t_1 when node i has reserved m at t for $t < t_1 < t+R$. Similarly it can be shown that, when node j reserved node m at t, node i can not reserve node m at t_1 for $t < t_1$. Thus, we conclude that no two node i and j can reserve a destination node m during the interval t to $t+R$. Note that when a node reserve a destination or a data channel, it informs every other node of its reservation, and this takes a ring latency.

Claim 2 No two nodes i and j can reserve the wavelength (data channel), λ_c, during the interval t to $t+R$.

Proof Suppose node i and node j both reserved the wavelength, λ_c, at t and t_1 respectively during the interval t to $t+R$ where $t < t_1 < t+R$. This implies that when node i reserved λ_c at t both $CAT_i[c]$ and $CAT_j[c]$ are zero. Also, when node j reserve λ_c at t_1 both $CAT_i[c]$ and $CAT_j[c]$ are zero.

From the algorithm a node can reserve a wavelength only when it receive the control token. Node i has reserved the wavelength λ_c at t, this implies that node i has received the control token at t, and have taken the following action. CAT at node i is updated, wavelength λ_c is reserved by setting $CAT_i[c]$ to one, and the control information is written in slot i of the control token. Node i then sends the control token to its successor node.

Node j has reserved the wavelength, λ_c, at t_1 which implies that node j has received the control token at t_1. On receiving the control token, node j update its CAT setting $CAT_j[c]$ to one. To reserve wavelength, λ_c, node j, checks $CAT_j[c]$ for zero. But $CAT_j[c]$ has already been set to one, which indicates that some other node has already reserved wavelength λ_c. Hence, node j fails to reserve λ_c. This contradicts that node j reserved wavelength λ_c at t_1 when node i has reserved wavelength λ_c at t for $t < t_1 < t+R$. Similarly it can be shown that, when node j reserved wavelength λ_c at t, node i can not reserve wavelength λ_c at t_1 for $t < t_1 < t+R$. Thus we conclude that no two nodes i and j can reserve wavelength λ_c during the interval t to $t+R$.

Claim 3 Destination collision never occurs.

Proof Let node i start transmitting to node j at t and the transmission continues for $t+R$.

Since node i started its transmission at t, it must have reserved node j during the interval $t-R$ to t . This reservation is possible only if some other node, say x has released node j during the interval $t-2R$ to $t-R$, or node j is free during the interval $t-2R$ to $t-R$ and no other node is reserving node j during this interval. Also, the following condition holds

$$DAT_m[i] = 0, \forall m = \{0, 1, \cdots, N-1\} \text{ at } t-R \quad (1)$$

$$DAT_m[i] = 1, \forall m = \{0, 1, \cdots, N-1\} \text{ at } t \quad (2)$$

Suppose destination collision occurs at node j. For destination collision to occur at node j, there must exist a node k, that transmits to node j during the interval $t-R+PD_{ik}$ to $t+R+PD_{ik}$.

We consider the two extreme cases, i.e., $t-R+PD_{ik}$ and $t+R+PD_{ik}$ to show that there does not exist a node k, that transmits to node j during the interval $t-R+PD_{ik}$ to $t+R+PD_{ik}$.

Case 1 There does not exist a node which transmits to node j at $t-R+PD_{ik}$.

Suppose node k transmits to node j at $t-R+PD_{ik}$. For node k to transmit at $t-R+PD_{ik}$ it must reserve node j during the interval $t-2R$ to $t-R$ and the following conditions must hold

$$DAT_m[i] = 0, \forall m = \{0, 1, \cdots, N-1\} \text{ at } t-2R \quad (3)$$

$$DAT_m[i] = 1, \forall m = \{0, 1, \cdots, N-1\} \text{ at } t-R \quad (4)$$

But (4) contradicts (1). That means when node i reserved node j during the interval $t-R$ to t, node j was not reserved by node k during the interval $t-2R$ to $t-R$. Therefore node k can not transmit to node j at $t-R+PD_{ik}$. Thus, there does not exist a node which transmits to node j at $t-R+PD_{ik}$.

Case 2 There does not exist a node which transmits to node j at $t+R+PD_{ik}$.

Suppose node k transmits to node j at $t+R+PD_{ik}$. This to possible only if node k has reserved node j during the interval $t-R$ to t. But from Claim 1, no two nodes can reserve a destination during the same interval. Node i has already reserved node j during the interval $t-R$ to t, so node k can not reserve it during the same interval. Therefore node k can not transmit to node j at $t+R+PD_{ik}$. Thus there does not exist a node which transmits to node j at $t+R+PD_{ik}$.

From Case 1 and Case 2 we conclude that destination conflict never occurs.

Claim 4 Channel (data channel) collision never occurs.

Proof Let node i, begin its transmission on wavelength λ_m at t, and the transmission continues for $t+R$. To transmit at t, node i must reserve the wavelength λ_m during the interval $t-R$ to t and the following condition holds

$$CAT_n[m] = 0, \forall n \in \{0, 1, \cdots, N-1\} \text{ at } t-R \quad (5)$$

$$CAT_n[m] = 1, \forall n \in \{0, 1, \cdots, N-1\} \text{ at } t \quad (6)$$

Suppose channel collision occurs on wavelength λ_m. For this to happen, there must exist a node j that transmits on wavelength λ_m during the interval $t-R+PD_{ij}$ to $t+R+PD_{ij}$

We consider the two extreme cases, i.e., $t-R+PD_{ij}$ and $t+R+PD_{ij}$ to show that no node other than node i transmits on wavelength λ_m during the interval $t-R+PD_{ij}$ to $t+R+PD_{ij}$

Case 1 There does not exist a node that transmits on wavelength λ_m at $t-R+PD_{ij}$.

Suppose there exist node j that transmits on wavelength λ_m at $t-R+PD_{ij}$. This is possible only if node j has reserved wavelength λ_m during the interval $t-2R$ to $t-R$, and the following condition holds

$$WAT_n[m] = 0, \forall n \in \{0, 1, \cdots, N-1\} \text{ at } t-2R \quad (7)$$

$$WAT_n[m] = 1, \forall n \in \{0, 1, \cdots, N-1\} \text{ at } t-R \quad (8)$$

But (8) contradicts (5). That means when node i has reserved wavelength λ_m during the interval $t-R$ to t, wavelength λ_m was not reserved by node j during the interval $t-2R$ to $t-R$. Hence, node j can not transmit on wavelength λ_m at $t-R+PD_{ij}$. Therefore there does not exist a node that transmits on wavelength λ_m at $t-R+PD_{ij}$.

Case 2 There does not exist a node that transmits on wavelength λ_m at $t + R + PD_{ij}$.

Suppose node j transmits on wavelength λ_m at $t+R+PD_{ij}$. For this to happen node j must reserve the wavelength λ_m during the interval $t-R$ to t. But from Claim 2, no two node can reserve a wavelength during the same interval. Node i has already reserved the wavelength λ_m during the interval $t - R$ to t, therefore node j can not reserve it during the same period. This contradicts that node j transmits on wavelength λ_m at $t + R + PD_{ij}$

From Case 1 and Case 2 we conclude that wavelength collision never occurs.

4 Simulations and Results

We considered a 48 kilometer ring network, number of wavelength, W, is 6, the number of data channel is $W-1$ that is 5, each data channel is of 1 Gb/s, and packets are of fixed size (1000 bits). Latency of the ring is 240000 bits or 240 packets. Number of buffers at each node is equal to the number of nodes, N, in the network. Each buffer can store up to 300 packets. We further assume that nodes are equally spaced in the ring network and the processing time of the control token is negligible. At each node packets are generated using Poisson process. Destination of the packets is selected from a uniform distribution, so that destination of each packets is uniformly distributed among all the nodes except its source. Same load is maintained at each node by keeping the mean arrival rate fixed for all nodes. Load at the nodes are varied by varying the mean arrival rate. In our simulation number of data channels are kept fixed and the number of nodes in the network are varied to 8, 12, 16, and 24 . We studied the netwrok performances such as throughput, delay, jitter, wavelength utilization by varying the load at nodes as well as varying the number nodes in the network.

The typical activity in a data channel consists of idle periods, reservation or release time, and packet transmission time. The *data channel efficiency* is given by

$$Data\ channel\ efficiency = \frac{TT}{ResT + TT + RelT}$$

where TT = Transmission time
$ResT$ = Reservation time
$RelT$ = Release time

We have assumed that TT, $ResT$ and $RelT$ are all same and is equal to ring latency. This gives data channel efficiency to 33%. *Data channel effiency* is the fraction time the data channel is busy in transmitting packets.

For a given number of nodes the throughput of the network increases with the increase in the load of nodes (load is specified in terms of mean arrival rate of packets per second at nodes) shown in Fig. 4. Throughput is defined as the number of packets successfully received at the nodes per unit of time. As the load of a node increases, the number of packets to a destination node increases. Once a circuit is established the source can transmit a larger number of packets to the destination node. From Fig. 4 it is seen that with increase in the number of nodes, throughput of the network increases. With increase in the number of nodes in the network and keeping the mean arrival rate same at all the nodes, the number of packets arriving to the network at any point of time increases. Hence nodes will have more packets to send to a destination at any instant of time, giving higher throughput.

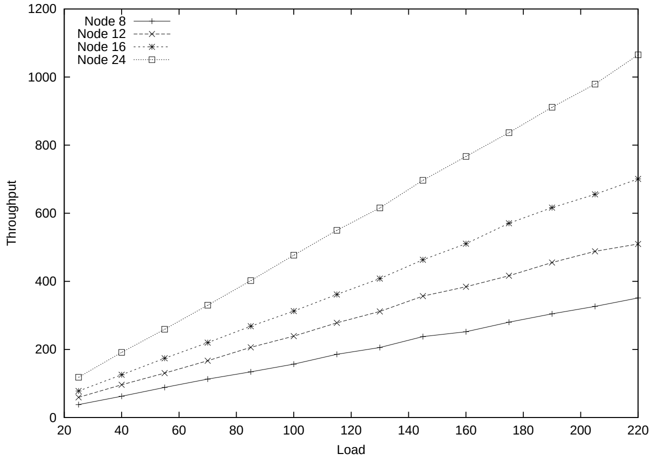

Figure 4: Load vs Throughput

Wavelength utilization in the network is poor, shown Fig. 5. This is in accordance with any circuit-switching network, where the bandwidth utilization is poor. Note that our proposed method is based on circuit-switching concept. Utilization of wavelength increases with increase in load and decreases with increase in the number of nodes in the network shown in Fig. 5 . With the increase in load the number of packets generated at the node increases, and a source node will have more packets to send to the destiantion. So, once a circuit is established a larger number of packets are transmitted for the duration of the circuit, giving higher utilization of wavelength at higher load. The decrease in the wavelength utilization at a given load with increase in the number of nodes in the network is due to the evenly distribution of packets among all the nodes. Because of evenly distribution of packets, number of packets destined to a particular node decreases as the number of nodes increases at a given load. Hence there are less packets to send, to a particular destination giving rise to low utilization of wavelength. However, even at larger number of nodes in the network, wavelengths can be effectively utilized if the mean arrival rate of packets at nodes are sufficiently large enough. Fig. 6 shows the wavelength utilization for a network with 24 nodes, at a higher mean arrival rate of packets this is much higher in comparision to the wavelength utilization for 24 node network shown in Fig. 5.

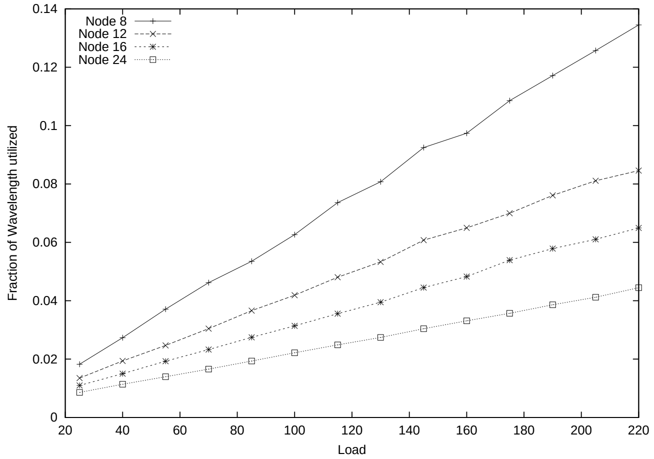

Figure 5: Load vs Wavelength utilization

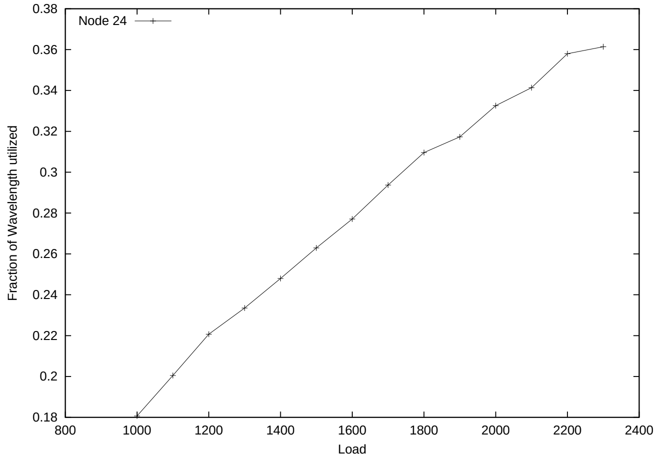

Figure 6: Load vs Wavelength utilization for 24 node netwrok at higher mean arrival rate of packet/s

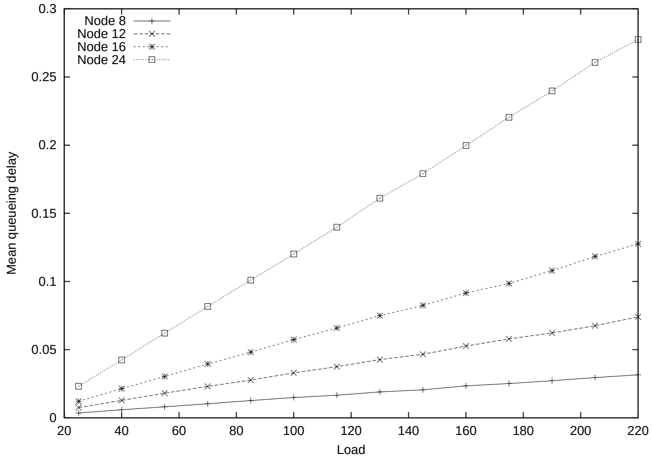

Figure 7: Load vs Mean queuing delay

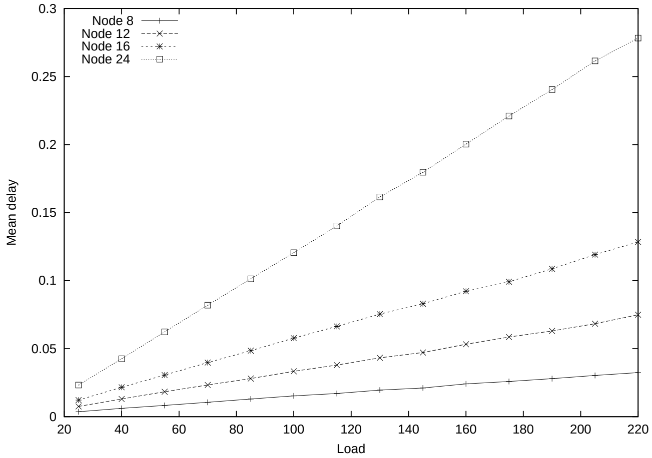

Figure 8: Load vs Delay

The mean queuing delay experienced by packets increases with increase in the number of nodes in the network as well as with the increases in load shown in Fig. 7. Queuing delay is the amount of time a packet spends in a node; that is the time period between when a packet arrives at a node to the time when it leaves the node. As the number of nodes increases the mean time to access a data channel increases giving rise to higher queing delay. Note that in our simulation we have kept the number of data channel to be fixed. At higher number of nodes in the network a source may find some destination node to be free but may not find a free data channel. Increase in the mean queuing delay also contribute to the mean end-to-end delay shown in Fig. 8.

The variation in jitters shown in Fig. 9 is not significant with increase in load and number of nodes in the network. Jitters is the difference between the maximum and the minimum delay that a packet experienced at a particular load in the network. The insignificant variation in the jitters is attributed to the nature of Poisson traffic that we consider, which is not an accurate model for the present day Internet traffic and the traffic in LANs.

5 Conclusions

In this paper we proposed a MAC protocol, RTR, for an optical ring network. The proposed scheme is based on circuit switching concept. That is, a circuit is established between the source and destination prior to the data transmission and the traffic remain in optical domain from the source to destination. In the proposed scheme, networks are scalable by varying the size of the control token. The proposed scheme requires no synchronization among nodes; this is different from most of the MAC protocol proposed in the literature for optical ring

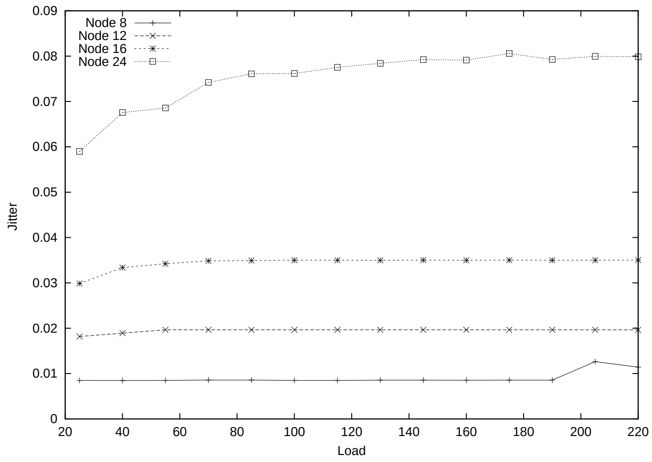

Figure 9: Load vs Jitters

network where synchronization among nodes is required. We proved that destination collision and data channel collision does not occur in the RTR algorithm. Hence, loss of data due to destination collision or data collision never occurs. We also studied the network performance by simulation. We found that the network throughput increases with the increase in the number of nodes in the network. Like any circuit-switching network the bandwidth utilization is low. However, we have shown that the wavelengths can be efficiently utilized if the mean arrival rate of packets at each node of the network is high.

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