A Novel Aggressive Intermediate-Node Initiated Reservation (AIIR) Protocol for Wavelength Routed Optical WDM Networks

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Abstract—This paper focuses on distributed wavelength reservation protocols in WDM networks. A modified version of Intermediate node Initiated Reservation (IIR) protocol i.e. Aggressive-IIR is proposed to improve the success rate of connection establishment by reducing the vulnerable time and race condition. The AIIR protocol is compared with Destination Initiated Reservation (DIR) and Source Initiated Reservation (SIR) protocols through computer based simulation by measuring the connection probability and delay per connection. The simulation result gives an estimation of appropriate segment length for AIIR protocol to get better call connection probability with respect to the SIR and DIR.

Index Terms— Optical WDM Networks, Distributed Wavelength Reservation Protocols, Destination Initiated Reservation, Source Initiated Reservation, and Intermediate node Initiated Reservation.

I. INTRODUCTION

Wavelength Division Multiplexing (WDM) technique ensures the high availability of the bandwidth for data communication. The routing problem in the wavelength routed networks is characterized as routing and wavelength assignment. It requires an end to end light path establishment over the selected route. [1-4] Light-path establishment can be done either in a centralized or a decentralized manner. In a centralized manner a single master node is responsible for route selection and wavelength assignment while in distributed scheme all the nodes in the network carryout their own routing and wavelength assignment decisions and require complex signaling protocols for the coordination among the nodes. But this approach does provide more scalability as compared to the centralized approach. Distributed schemes are also more resilient to network failures as they are not vulnerable to becoming a single point of failure. [5-8]

Light-path establishment in a distributed environment requires a control protocol that is responsible for a light-path establishment and teardown process. These protocols are categorized based on their working mechanisms and the knowledge of network state information. Further reservation process is classified as parallel and hop by hop reservation.

Requirement of global state information of the topology and wavelength usage information on each of the links in the given network reduces the call setup delay but increases the control overhead in parallel reservation process. A hop-by-hop reservation process doesn’t require the wavelength usages information in the network necessarily hence reduces the control overhead. Three protocols are mainly classified into this category named as Source Initiated Reservation (SIR), Destination Initiated Reservation (DIR) and Intermediate node Initiated Reservation (IIR). [9-10]

In SIR protocol, wavelength resources are reserved along the forward path towards the destination on a hop-by-hop basis. The method of reserving wavelengths depends on whether or not global state information is available to the source node. In general SIR has high blocking probability particularly in networks under heavy load. Global wavelength information can be very helpful to reduce blocking probability in this scheme. Setup delay is low in case light-path is established in the first attempt. [11-12] In DIR, a control message originated from the source node travels from source to destination on a hop by hop basis collecting wavelength usage on each node in the route. When this control message reaches at the destination node it selects a wavelength from a set of free wavelengths along the entire path and then initiates a reservation message in the reverse direction from destination to source. DIR has generally lower blocking probability as compared to SIR because of the knowledge of wavelength usage information that it collects along the path from source to destination. The performance of DIR degrades as the time difference increases, between collecting the wavelength usage information and reserving the wavelength on the link. This problem becomes more prominent for longer paths. [13-14]

The time delay between collection of wavelength usages information and wavelength reservation process in DIR can be reduced by enabling the intermediate nodes to send the wavelength reservation message. The IIR tries to reduce blocking in backward direction by dividing the network in segments. A complete path from source to destination is partitioned in to multiple segments with the wavelength conversion capability at boundary nodes of each segment. The blocking probability on each of the segments is independent of each other. When a reservation request reaches to the last node of a segment it issues a segment reservation request that towards first node of that segment to reserve resource on that segment.
When reservation request reaches destination it issues a primary reservation request that will reserve wavelengths on the last segment and tell the source node if a light-path has been established successfully or not. This reduces the chances of race condition because of improvement in vulnerable period as compared to DIR. It reduces the blocking in backward direction due to outdated information. But this scheme does have extra control overhead due to intermediate nodes participation in reservation process. Also a wavelength utilization can be slightly less because a wavelength is reserved for slightly more time before actual data transfer takes place. But reduced blocking in backward direction far outweighs these disadvantages. [15-18]

II. AGGRESSIVE INTERMEDIATE-NODE INITIATED RESERVATION (AIIR) PROTOCOL

As IIR reserves the free wavelength in a segment once the connection request reaches the end of segment. In general first it collects the information about the available free wavelengths in a segment; once it reaches the end of segment it initiates the request for blocking free wavelength by choosing one of the common free available wavelengths through out that segment, which may lead to race condition. In that case it resends the connection request with other common available free wavelength. To avoid this situation a variant of IIR is proposed which is referred as AIIR protocol. The next section explains the working of the proposed protocol.

The principle of the protocol is described in terms of the control messages exchanged between the nodes to establish a light-path between a source and the destination. The steps are as follows:

1. **PATH message**: In first step source node sends the message for collecting information about the availability of free wavelengths.
2. **BLOCK message**: Once PATH message reaches the end of segment it sends the message back, which blocks all the common free wavelengths available in that segment and simultaneously it also forwards PATH message to the next segment in the path.
3. **RESERVE message**: After BLOCK message reaches the start of the segment it select the one common blocked wavelength and notifies the other nodes in the segment to release other blocked wavelengths.
4. **NOTIFY message**: Once PATH message reaches to the destination, it notifies the source that wavelength reservation process is completed and it can start sending the data.
5. **RELEASE message**: Once data transmission is over the source notifies all the nodes in the path that data transfer is completed and they can release the wavelength allocated for that connection.

III. SIMULATION AND RESULT ANALYSIS

Network is simulated to test the AIIR performance over DIR and SIR. Circular topology with N nodes is assumed. Each node initiates the traffic by sending connection request of length N. Each node is treated as a process and it has message queue associated with it for inter process communication. If a node wants to communicate with other node, it just needs to connect to the message queue associated with that node and push a message in that queue. Each node can only send message to either its right neighbor or left neighbor as we assumed a circular topology. If a wavelength required for connection is not available at intermediate node, it sends a failure message to source. The inter arrival rate for each connection is taken as 8 seconds and data transfer time for each connection assumed as 2 seconds. The simulation is run on 15, 20, 25 and 30 nodes ring topology networks as shown in table 1, table 2, table 3 and table 4 respectively. Protocols are compared on two metrics called as connection probability and average delay per connection. Delay per connection metric indicates the control overhead as it is caused due to the queuing up of messages at each node.

### TABLE 1
RING TOPOLOGY OF 15 NODES

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Connection Probability (%)</th>
<th>Delay per Connection (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIR</td>
<td>18.55</td>
<td>7.6</td>
</tr>
<tr>
<td>DIR</td>
<td>21.42</td>
<td>15.4</td>
</tr>
<tr>
<td>AIIR (Segment length = 4)</td>
<td>55.55</td>
<td>17.9</td>
</tr>
<tr>
<td>AIIR (Segment length = 2)</td>
<td>20.13</td>
<td>15.4</td>
</tr>
<tr>
<td>AIIR (Segment length = 7)</td>
<td>20.34</td>
<td>17.2</td>
</tr>
</tbody>
</table>

### TABLE 2
RING TOPOLOGY OF 20 NODES

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Connection Probability (%)</th>
<th>Delay per Connection (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIR</td>
<td>20.32</td>
<td>6.7</td>
</tr>
<tr>
<td>DIR</td>
<td>25.67</td>
<td>20.1</td>
</tr>
<tr>
<td>AIIR (Segment length = 4)</td>
<td>42.23</td>
<td>24.3</td>
</tr>
<tr>
<td>AIIR (Segment length = 5)</td>
<td>45.23</td>
<td>27.9</td>
</tr>
<tr>
<td>AIIR (Segment length = 2)</td>
<td>19.12</td>
<td>18.3</td>
</tr>
<tr>
<td>AIIR (Segment length = 10)</td>
<td>18.34</td>
<td>20.3</td>
</tr>
</tbody>
</table>
Call connection probability is one of the major characteristics of a wavelength reservation protocol. This paper analyzes the connection probability and connection establishment delay for SIR and DIR protocols. Further a modified version of IIR protocol called as AIIR is proposed which outperforms the SIR and DIR in terms of call connection probability. At higher traffic rate more requests compete for free wavelengths and increase the chances of race condition. The AIIR performs well and gives better connection probability for high request rate by handling the race condition nicely. The control overhead needs to be diminish for AIIR to reduce the delay for connection establishment.

REFERENCES


