Simulating Wavelength Converter to reduce Call Blocking

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ABSTRACT: *In this paper wavelength converter is demonstrated to reduce call blocking. When a light path is established same wavelength has to be allocated on all the fibre links, this is wavelength continuity constraint. To overcome this constraint, wavelength converter is used. This paper gives the performance of the network in terms of blocking probability, throughput, and grade of service, for no wavelength conversion, sparse partial wavelength conversion and full wavelength conversion. It also shows that the performance of sparse partial wavelength conversion is closer to full wavelength conversion. Thus this reduces the number of wavelength converters and makes the conversion more cost effective.*

Keywords— *wavelength converter, wavelength continuity constraint, call blocking, sparse partial wavelength conversion.*

1. Introduction

Wavelength-Division Multiplexing (WDM) is an important technique which provides a large transmission bandwidth. In this technique, the data channel is modulated on an optical carrier with a certain wavelength. The optical carriers are transmitted on a single fibre. In WDM network optical cross-connects are used that can convert the wavelength from input to output link [1], [2]. Light paths can thus be setup between different nodes. Networks which use optical cross-connects to route data between the light paths through the network are called as wavelength routing networks. The nodes are interconnected by optical fibres, through which WDM signals are transmitted. Wavelength-routing networks reuse the wavelengths, by using same wavelength for different light paths in the same network. In this project I have handled the issue of call blocking. I have designed a prototype mesh network and in this network I have demonstrated sparse partial wavelength conversion and full wavelength conversion. One of the major problems for the telecommunication network is 'call blocking'.

Wavelength continuity constraint is the major problem in the telecommunication network. The signals have to be transmitted through the entire light path using the same wavelength on all the links in the light path. This is wavelength continuity constraint. The same wavelength may not be available at every router and every link of the light path. Even if any one link in the light path does not have a free wavelength, then the light path request will be blocked. Due to this constraint, there will be call drop. The solution to this constraint is wavelength conversion. The intermediate routers transfer the call from one wavelength to another. This is called wavelength conversion. To serve a big amount of traffic, wavelength conversion is best the solution. A wavelength converter is the device that enables wavelength conversion. i have then proved that sparse partial wavelength conversion reduces the call blocking probability to a larger extent and it gives a similar performance to full wavelength conversion. This makes wavelength conversion cost effective. In this project we have used a WDM mesh network. The nodes in WDM mesh network have connectivity between themselves. A node can connect to any other node within the network without any complexity. The nodes can select a path depending upon free wavelength at the node. A node is a wavelength convertible router that consists of a number of links to the destination. Each link has a different wavelength.

2. WAVELENGTH CONVERSION

The transfer of data at a node from one wavelength to another is called wavelength conversion. It is a prominent solution for call blocking.

2.1 Sparse partial wavelength conversion

In sparse partial wavelength conversion only a few selected routers are WCRs. Following are the benefits of sparse partial wavelength conversion.

- Call blocking probability is low.
- Only those light paths which are successfully setup require wavelength conversion.
- A proper wavelength assignment algorithm reduces the number of converters and thus also reduces the cost.

In the paper, the aim of wavelength conversion is to reduce call blocking. I have designed a wavelength-routed WDM mesh network with 25 nodes which is shown in Fig.1. Sparse partial wavelength conversion is done in this network which means that wavelength conversion is done only at few selected wavelength routers. Initially network parameters like wireless channel, propagation model, interface queue, link layer, type of antenna, number of nodes, initial energy are defined. Topography is set and configuration of wavelength routers is done. In fig.1 the large black circles indicate topology. The position of the wavelength routers is kept fixed. Source and destination wavelength routers are indicated in light red colour. Wavelength routers 2 and 21 which are indicated in light red colour are source and destination routers respectively.

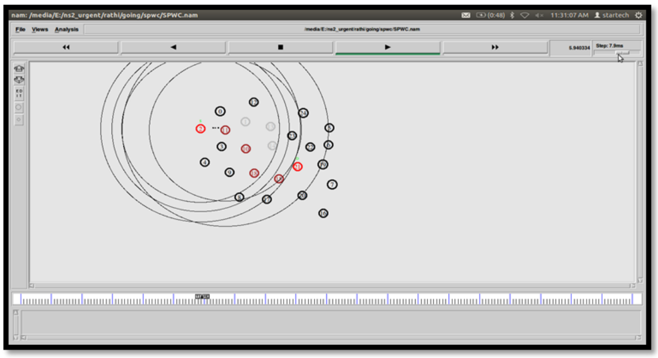

Fig.1.Lightpath.

A light path has to be setup between the source and destination routers. For this fixed shortest path routing algorithm is used. To find the possible route, with the help of this algorithm, routing packets are sent to the neighbouring routers. The shortest route to a WCR is chosen. To do this a routing table is defined which contains a list of neighbours of source router 2 and the routes between them. When a call request arrives at router 2, it sends routing packets to its neighbours, 0, 11 and 3.Depending upon free wavelength available a path between router 2 and 11 is setup. Similarly router 11 sends routing packets to neighbours 1 and 10.A path between router 11 and 10 is setup. In this way a light path is setup between source router 2 and destination router 21, which is 2 - 11 - 10 - 18 - 15 - 21.This route is shown in fig.3.4.Now to decide where to place the wavelength converter, I have used MBPF algorithm. I have assumed traffic of 100 Erlangs. According to Minimum Blocking Probability First algorithm the blocking probability of each router in the light path is calculated. WCRs 18 and 15 have higher blocking probability compared to others in the light path. So we have implemented wavelength conversion at WCRs 18 and 15.Data packets are now sent from source 2 to destination 21 through this route. Since we have implemented sparse partial wavelength conversion there is very less loss in the network and the data packets are successfully delivered to destination. A few number of wavelength converters can give a good performance which is closer to full wavelength conversion. A light path is divided into number of hops. Each hop has a wavelength convertible router which contains wavelength converters. Sparse partial wavelength conversion gives a combined effect of sparse wavelength conversion and partial wavelength conversion.

2.2 Full Wavelength Conversion

A routing process similar to sparse partial wavelength conversion is implemented in full wavelength conversion too. The path which is setup between source 2 and destination 21 is 2 - 11 - 10 - 18 - 15 - 21. Data packets are sent from source 2 to destination 21 through this route. Since this is full wavelength conversion, conversion is done at every WCR. So the data packets are successfully delivered to destination 21. Wavelength conversion can be implemented in some networks without much cost. Similar to sparse partial wavelength conversion, in full wavelength conversion also a path is setup between the source and destination. In full wavelength conversion each link uses a dedicated wavelength converter. Hence each node is capable of wavelength conversion. This adds to the cost of implementing wavelength conversion in the network. But if sparse partial wavelength conversion can effectively reduce call blocking probability of the network reducing the cost, then full wavelength conversion is absolutely not necessary. Full wavelength conversion is unable to detect the failure nodes since each node has the capability of wavelength conversion.

2.3 Packets and Traces

The details of the data packets can be seen in the trace format.

#r 1.941658354 _0_ MAC --- 0 SELF 48 [0 fffffff 3 800] ------- [3:255 -1:255 29 0] [0x2 2 1 [2 0] [0 4]] (REQUEST)

This trace format indicates that node 0 receives a request at time 1.941658354 seconds. Tracing is done at MAC layer. The packet ID is ‘0’ and packet size is 48 bytes. The source and destination MAC address is ‘fffffff’ and ‘0’.This is an IP packet running over Ethernet network with address ‘800’.IP source and destination address is ‘3’ and ‘1’.The source and destination port address is ‘255’.Time to live and address of next hop node is ‘0’ and ‘29’.This is a request packet with ID ‘0*2’.Number of hop counts is ‘2’ and broadcast ID is ‘1’.Destination IP address and sequence number is ‘2 and 0’.Source IP address and sequence number is ‘0 and 4’.

3. ROUTING AND WAVELENGTH ASSIGNMENT

A light path is a path which is established between two nodes to enable communication between those nodes. It depends on the availability of the wavelengths at the intermediate links. In a network with no wavelength converters, the same wavelength must be used for the entire light path. This is called the wavelength-continuity constraint in wavelength-routed networks. The routing and wavelength assignment (RWA) problem deals with routing and assigning wavelengths for the light path. The aim of routing and wavelength assignment (RWA) is to setup a light path without a call drop every time when a call request arrives [4]. The objective of the RWA is to increase the number of established connections. Each connection request needs a route and wavelength. Two connection requests can share the same optical link, but a different wavelength has to be used for both the connections. In the project I have used fixed shortest path routing algorithm. Each node in the network has a routing table that contains a list of a number of fixed routes to each node. When a connection request arrives, the source node establishes the connection on each of the route from the routing table in sequence, until a route with a valid wavelength is found. If no available route with valid wavelength is found from the list of alternate routes, the connection request is blocked. If more than one required wavelength is available on the selected route, a wavelength assignment method is used to choose the best wavelength. Whenever a call arrives at a wavelength router it will run a predefined algorithm and select a wavelength. The selection of the wavelength plays an important role in the performance of the algorithm and also on the overall blocking probability. Therefore a wavelength router has to find a route for the light path request and has to assign a wavelength that reduces the blocking probability. Node 2 is the source node and node 21 is the destination node. Node 2 will send request to nearby nodes 0, 11 and 3 for establishing a route. Depending upon free wavelength available the route between 2 to 11 is possible. Similarly all the other routes are found out, and a light path 2-11-10-18-15-21 is established. The blue node in figure 2 shows the routing process.

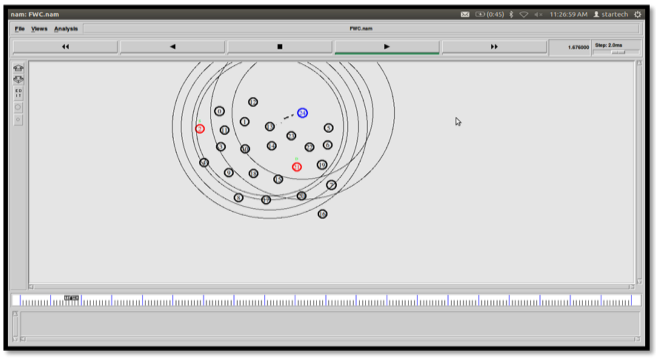

Fig.2. Routing process.

3.1 First Fit Wavelength Assignment

Wavelength Assignment is the important factor that affects the blocking probability and the performance of the network. If there is a proper assignment of wavelengths, it reduces the number of wavelength converters in the network and also reduces the cost. This is achieved by maintaining a list of used and free wavelengths. This assignment method selects the lowest wavelength from the list of free wavelengths and assigns it to the request. When the call is completed that wavelength is added back to the set of free wavelengths.

There are two methods for wavelength assignment, they are, First Fit and Random Fit. First Fit method selects the lowest wavelength that is available. Random Fit method randomly selects a wavelength that is available. The complexity of both the algorithms depends upon the number of available wavelengths. First Fit method gives a good performance than Random Fit method. So we have used first fit method for assigning wavelength. It has a good signal quality. The main aim of the routing and wavelength assignment algorithms is to reduce the number of wavelength converters.

3.2. Wavelength Converter Placement Scheme

The main aim of wavelength converter placement is to minimize the blocking probability and also the number of converters [10], [12]. In sparse partial wavelength conversion we place the converters only at a few nodes. But at which nodes the wavelength converters have to be placed is the question. For this the wavelength converter placement scheme is used. There are two converter placement schemes, and they are as follows.

- Minimum blocking probability first.
- Weighted maximum segment length.

I have used minimum blocking probability first wavelength converter placement algorithm.MBPF is used for mesh network. The converters are placed sequentially one after the other. The 25 nodes in the mesh network are called candidate nodes. A candidate node is the one which is without a wavelength converter. From these candidate nodes we have to select those nodes where if we install a converter, the blocking probability will be decreased. In MBPF algorithm the blocking probability of all the nodes in the light path is calculated. For this I have assumed a traffic of 100 Erlangs at source node 2.The WCRs that have highest blocking probability need wavelength conversion. So converters are placed at these nodes. By using this method I have identified nodes 18 and 15 for wavelength conversion.

4. PERFORMANCE ESTIMATION

I have analysed sparse Partial Wavelength Conversion and shown that it can achieve very good blocking performance. We have considered a WDM mesh network of 25 nodes within an area of 500m * 500m.Node 2 is source node and node 21 is destination node. We have selected a path 2-11-10-18-

15-21. There are 4 fibre links between each pair of nodes. Consider there are 20 wavelengths on each link and total 20 wavelength converters available. I have assumed traffic of 100 Erlangs at source node 2.Using MBPF algorithm it is found that nodes 18 and 15 need wavelength converters. So there are only 2 WCRs in the light path with wavelength conversion capability, they are nodes 18 and 15.

4.1 Blocking Probability

We have put up a simple model to calculate the blocking probability of a wavelength routed WDM network. The overall blocking probability B is defined as the ratio of blocked traffic to offered traffic. I have assumed traffic of 100 Erlangs at source node 2.Hence with this traffic blocking probability is calculated for no wavelength conversion, sparse partial wavelength conversion and full wavelength conversion. In sparse partial wavelength conversion blocking probability is greatly reduced.

Nodes	Blocking Probability for no conversion	Blocking Probability for SPWC	Blocking Probability for FWC
Node 2	20 %	3 %	2 %
Node 11	31.25 %	2.06 %	1.02 %
Node 10	18.18 %	3.15 %	2.06 %
Node 18	44.44 %	4.34 %	3.15 %
Node 15	60 %	3.40 %	2.17 %

4.2. Wavelength Assignment

A small number of light paths bypass a node at a time. We further show that most of these bypassing light paths do not need wavelength conversion if a proper wavelength assignment algorithm is used. We have used First-fit wavelength assignment algorithm in our simulation [6]. A very small number of wavelength converters can achieve almost the same performance as full wavelength conversion.

4.4. Performance Analysis

We have assumed traffic of 100 Erlangs at node 2.In case of sparse partial wavelength conversion the blocked traffic is 3 Erlangs then the blocking probability is 3%.In case of full wavelength conversion the blocked traffic is 2 Erlangs then the blocking probability is 2%. In case of no wavelength conversion the blocked traffic is 20 Erlangs then the blocking probability is 20%.In case of sparse partial wavelength conversion the blocking probability is 3%.Hence the network performance i.e. throughput is 97%.In case of full wavelength conversion the blocking probability is 2%.Hence the network performance is 98%. In case of no wavelength conversion the blocking probability is 20%.Hence the network performance is 80%.In case of sparse partial wavelength conversion the blocking probability is 3%. The network performance i.e. throughput is 97%.The grade of service is 0.97.In case of full wavelength conversion the blocking probability is 2%.The network performance is 98%. Hence the grade of service is 0.98. In case of no wavelength conversion the blocking probability is 20%.Hence the network performance is 80%. Hence the grade of service is 0.80.Due to wavelength continuity constraint, most of the calls are blocked in case of no wavelength conversion. Sparse partial wavelength conversion implements wavelength conversion at specific nodes which greatly reduces the call blocking probability. The throughput of the network for no wavelength conversion is very less, whereas the throughput for sparse partial wavelength conversion is high. The grade of service for no wavelength conversion is very less and the grade of service for sparse partial wavelength conversion is high. The grade of service depends on call blocking probability. The blocking probability for sparse partial

wavelength conversion is closer to that of full wavelength conversion. The throughput for sparse partial wavelength conversion is closer to that of full wavelength conversion. The grade of service for sparse partial wavelength conversion is closer to that of full wavelength conversion.

Table.2. Call blocking probability.

Nodes	Throughput for no conversion	Throughput for SPWC	Throughput for FWC
Node 2	80 %	97 %	98 %
Node 11	68.75 %	97.94 %	98.98 %
Node 10	81.82 %	96.85 %	97.94 %
Node 18	55.56 %	95.66 %	96.85 %
Node 15	40 %	96.60 %	97.83 %

Table 1.Throughput.

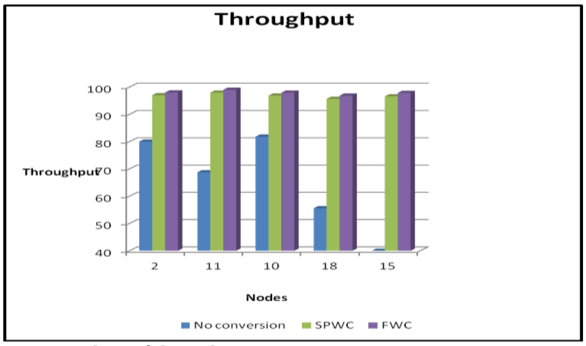

Figure 3.Chart of throughput.

Table 2 indicates blocking probability for no wavelength conversion, sparse partial wavelength conversion and full wavelength conversion. The blocking probability for no wavelength conversion is high, whereas blocking probability for sparse partial wavelength conversion and full wavelength conversion is low and closer to each other. This shows that sparse partial wavelength conversion gives a good performance and at the same time reduces the number of wavelength converters and hence the cost. Figure 4 indicates a chart showing blocking probability of no wavelength conversion, sparse partial wavelength conversion and full wavelength conversion Table 3 shows grade of service of the network for no wavelength conversion, sparse partial wavelength conversion and full wavelength conversion.Figure 5 indicates a chart for grade of service. Thus we have analysed the performance of a mesh network for no wavelength conversion, sparse partial wavelength conversion and full wavelength conversion in terms of call blocking probability, throughput and grade of service.

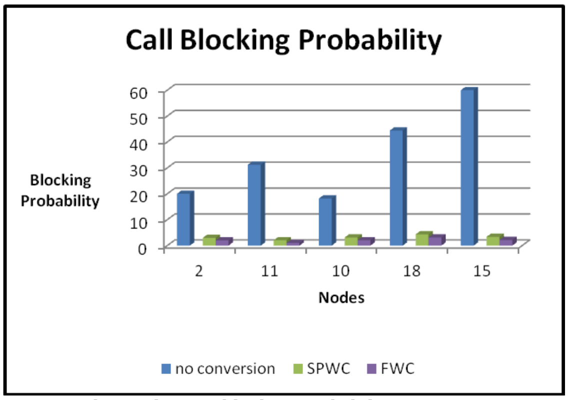

Figure 4.Chart indicating blocking probability

Nodes	Grade of service for no conversion	Grade of service for SPWC	Grade of service for FWC
Node 2	0.8	0.97	0.98
Node 11	0.68	0.97	0.98
Node 10	0.81	0.96	0.97
Node 18	0.55	0.95	0.96
Node 15	0.4	0.96	0.97

Table 3.Grade of service.

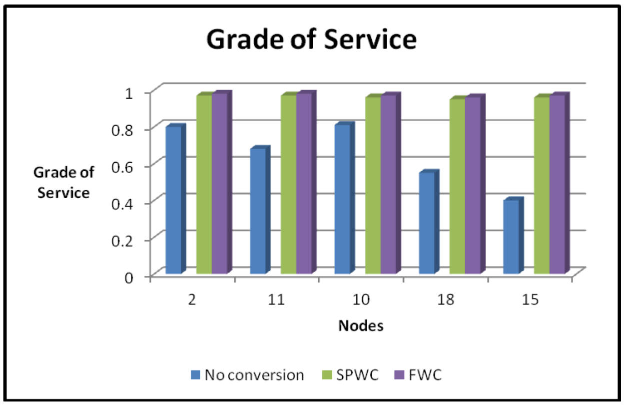

Figure 5.Chart for grade of service

5. CONCLUSION

This paper deals with an important issue of call blocking and about how to efficiently use limited number of wavelength converters to reduce it. We have explained sparse partial wavelength conversion and also compared sparse partial and full wavelength conversion. Both analytical and simulation results are shown. By using proper wavelength converter placement algorithm and wavelength assignment algorithm, only a very few number of wavelength converters are needed to achieve very close performance to that of the Full Wavelength Conversion. Results prove that wavelength conversion is very necessary to prevent call blocking. Adding to it, sparse partial wavelength conversion gives a performance closer to full wavelength conversion, and hence using sparse partial wavelength conversion will reduce the number of converters in the network and also the cost.

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