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NOVEL RECONFIGURATION TECHNIQUE FOR HIGH CAPACITY WDM NETWORK

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ABSTRACT: Optical Wavelength Division Multiplexing (WDM) networks are high capacity telecommunications networks based on optical technologies and components that provide routing and restoration at wavelength level. High Capacity Optical WDM Networks are reconfigured to meet the dynamic traffic demand of the various applications. However the demand varies with time and infrastructural development. The reconfiguration techniques play vital role in this context. It consists in being able to alter the reconfiguration of the network to adjust it to the new traffic demand. Normally it is required to break off partially or totally the traffic to reconfigure a network. Considering the amount of data flowing on it, it may not be feasible to frequently stop the network, even for a short span of time. Many parameters have to be taken into account to find out a good solution, and many metrics can be used in order to measure the quality of a solution. In this paper with the use of Heuristic Virtual Topology Design Algorithm [HVTDA] a novel reconfiguration technique has been proposed. Further it has work out with modifying the way of variation in the traffic. We have found improved performance. Finally the results of this proposed novel reconfiguration technique has been validated with previously published results.

Index Terms: WDM, Heuristic Algorithm, wavelength routing and Virtual Topology.

1. INTRODUCTION

With the exponential growth of traffic demands, Wavelength Division Multiplexing (WDM) has emerged as an attractive solution for enhancing the existing transmission capacity of optical networks. The enormous capacity offered by optical fibers, can be divided into hundreds of different transmission channels, using the WDM technology [1,10,11,12]. WDM allows multiple data streams to be transmitted simultaneously using the same fiber, as long as each data stream occupies a different wavelength. In recent optical networks, the introduction of the WDM technique has opened the road to a new paradigm of transport infrastructure evolution characterized by high capacity and high reliability. In the past ten years, we have witnessed the huge success and explosive growth of the Internet, which has attracted a large number of users surging into the Internet. Individual users are using the Internet insatiately for information, communication, & entertainment, while enterprise users are primarily relying on the Internet for their daily business operations. As such, Internet traffic has experienced an exponential growth in the past ten years, thereby resulting in vast bandwidth requirement. As the core of this revolution, optical fibers have proved to be an excellent solution for providing enormous bandwidth to the internet users. Theoretically, a single single-mode fiber has a potential bandwidth of nearly 50 Terahertz (THz) [2], which is about four orders of magnitude higher than the currently achievable electronic processing speed of few Gigabits per second (Gbps). WDM optical network is composed of optical nodes and optical fiber links, typically forming a mesh topology. The WDM divides the tremendous bandwidth of a fiber into many non-overlapping wavelengths called WDM channels. Each channel can be operated asynchronously. Due to the huge transmission bandwidth of the optical fiber the WDM optical network is used as the transport infrastructure.

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2. LITERATURE REVIEW

A wavelength-routing network consists of wavelength routers and the fiber links that interconnect them. Wavelength routers are optical switches capable of routing a light signal at a given wavelength from any input port to any output port, making it possible to establish end-to-end lightpaths, direct optical connections without any intermediate electronics.

Using a generalized reduced load approximation scheme the blocked traffic for the optimal network model for two routing schemes fixed routing and least loaded routing was calculated. Wavelength-routed networks can effectively utilize the bandwidth of the optical fibers. Wavelength converters help to reduce the blocking probability of the network and enhance the fiber utilization [3].

An alternate routing method with limited trunk reservation in which connections with more hops are prepared to provide more alternate routes. Through developing an approximate analytic approach, it has been demonstrated that this method keeps good performance when compared with the existing alternate routing methods, and also that the fairness among connections can be improved [4].

The problem of designing VTs, for multihop optical WDM networks, when the traffic is self-similar in nature there are two algorithmic approaches: *Greedy (Heuristic) algorithm and Evolutionary algorithm*. While the greedy algorithm performs a least cost search on the total delay along paths for routing traffic in a multi hop fashion, the evolutionary algorithm uses genetic methods to optimize the average delay in a network [5].

The failure of a single optical link or node in a WDM network may cause the simultaneous failure of several optical channels. This occurs when the higher level is not aware of the internal details of network design at the WDM level. This phenomenon is known as "failure propagation [6].

A two stage approach is adopted at reconfiguration stage and optimization stage. First provides a tradeoff between the number of changes and objective function value which decides how best the VT is suited for given traffic, and the number of changes limit the disruption in the traffic. The later stage prevents the degradation of the solution due to continual approximation. By varying the frequency of the stage, the number of changes can be controlled. The effectiveness of the approach is evaluated by simulation and found that the frequency at which the optimization is performed has an effect on performance [7].

The problem of allocating fibers (each supporting only a limited set of wavelengths) on the links of a WDM network at minimum cost is reported. It quantifies the increase in the total fiber cost due to the simple routing strategy. In particular, it proves that the cost of a solution induced by routing along shortest path pairs is *guaranteed* to lie within a certain factor of the minimum possible cost. This leads also to the fact that the cost of this solution is asymptotically least in heavily loaded networks, and in networks that are large, sparse and supporting all-to-all communications [8].

3. FORMULATION OF WAVELENGTH ROUTING AND HEURISTIC ALGORITHM

If every node in the network has full Wavelength Continuity Constraint (WCC), then it will yield the same performance as that of a conventional circuit switched networks. When a connection request arrives, a Wavelength Routing (WR) algorithm is used to choose a lightpath to satisfy the request. A good WR algorithm is critically important in order to improve network performance in terms of blocking probability (or equivalently, average call acceptance ratio) of connections. A WR algorithm has two components [9], route selection and wavelength selection. A WR algorithm is also known as Routing and Wavelength A Algorithm (RWA). The route is chosen based on some criterion such as the hope length and the wavelength is chosen based on some criterion such as wavelength usage factor in the entire network. In WR Networks, Reconfiguration Techniques are also based on these components.

3.1 Heuristic Algorithm

The VTD problem is computationally intractable. It becomes almost impractical to solve when the network size become larger. This is the requirement of heuristic solution. It gives reasonable results close to optimum. It aims at minimum congestion in the network. It takes physical topology and traffic as input and it attempts to maximize single virtual hop traffic flow. The assumptions are (*a*) number of wavelengths/ fiber is fixed (*b*). The number of transmitters and receivers available at node are given. By that way we are reducing congestion. We have taken decreasing order of traffic and accordingly node pairs. First it takes first node pair from the decreasing order list and a lightpath will be established if permissible. A lightpath is permissible for the node pair if a physical route, a wavelength on the route, a transmitter at the source node of the pair and a receiver at the destination node of the pair are all available. When a lightpath is established between the pair the traffic associated with the pair is updated by subtracting from it the traffic. Here, next node-pair y has the highest traffic after the previous pair. If a lightpath cannot be established between the node pair the traffic associated is said to zero. Now the node pair which has maximum amount of non-zero traffic is chosen and the above procedure is repeated. The chosen node pair could be either. When all the node pairs with non-zero traffic have been considered, the procedure stops. It may so happen that a few transmitter and receivers are available at some nodes when the procedure terminates. A WDM network can be viewed as a multi graph with the nodes corresponding to the routing nodes. For each pair of nodes, a fiber between them implies the presence of W wavelength links between the node pair in the multi graph, where W is the number of wavelengths on the fiber [9]. The Virtual Topology can be seen as a directed graph and edges is present between a pair of nodes if, correspondently, a lightpath has been established between these two nodes. An edge represents the path on which resources transceivers and wavelengths need to be reserved to set up the lightpath.

4. VERIFICATION AND VALIDATION OF THE RECONFIGURATION TECHNIQUE

The reconfiguration can be performed either on line or offline. In offline reconfiguration the network is switched off completely and the required lightpaths are established. The traffic disruption is very high. In online reconfiguration, the network is not switched off completely. The required lightpaths are established depending on the availability of wavelengths and transceivers. If these resources are not available, then some existing lightpaths may be disturbed and the resources made available. The traffic disruption thus depends on the number of lightpaths that are disturbed. Hence, the online reconfiguration problem has twin goals of minimizing the total number of changes and objective function values. In this paper Heuristic algorithm [7] has been implemented in MATLAB and verified it with same traffic and later on different traffic pattern as shown in Table 1 and 2. Physical topology has been shown in Figure 1. Table 1 and the physical topology of Figure 1 has been taken and design the virtual topology shown in Figure 2. Table 3 shows the establishment of routes and assignment of the wavelength to those routes.

Table 1
Traffic matrix T1

0	19	10	23	29
27	0	12	27	14
26	20	0	22	12
15	28	23	0	16
9	7	7	8	0

Table 2
Traffic Matrix T2

0	21	10	23	7
29	0	12	13	14
28	7	0	20	13
28	27	21	0	18
9	27	22	8	0

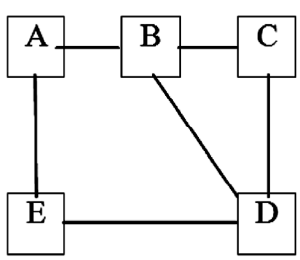

Figure 1: Physical Topology

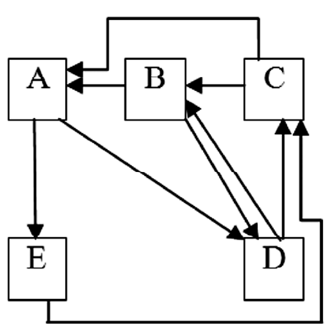

Figure 2: Virtual Topology VT1 using T1

Table 3
Establishment of Routes for T1

	Route		*Wave Length*
	→	→	
A	B	D	w_2
A	E	-	w_0
B	A	-	w_0
B	D	-	w_1
C	B	A	w_1
C	B	-	w_0
D	B	-	w_0
D	C	-	w_0
E	D	C	w_1

Table 4
Establishment of Routes for T2

	Route		*Wave Length*
	→	→	
A	E	-	w_0
B	A	-	w_2
B	C	-	w_0
C	D	-	w_1
C	D	E	w_2
D	B	A	w_0
D	B	-	w_2
E	A	B	w_1
E	D	-	w_0

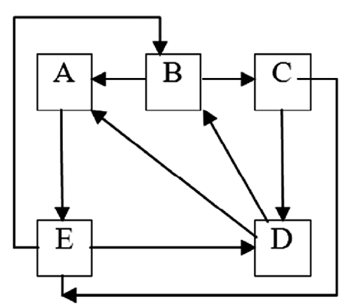

Figure 3: Virtual Topology VT2 Using T2

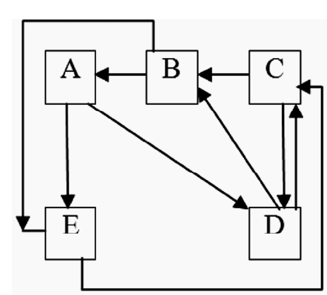

Figure 4: VT3 [Migration of VT From VT1] Using Reconfiguration Technique

Table 5
Updating of Routes for T2 from Routes of T1

	Route		*Wave Length*
	→	→	
A	B	D	w_2
A	E	-	w_0
B	A	-	w_0
B	A	E	w_1
C	B	-	w_0

	Route		*Wave Length*
	→	→	
C	D	-	w_2
D	E	-	w_0
D	C	-	w_0
E	D	C	w_2

Now Average Weighted Hop Count (AWHC) was computed for the traffic of Table 1 using VT of Figure 2. The AWHC was met 1.4746. Now traffic matrix T2 has taken with the same VT and AWHC was computed and it has found 1.5734. Virtual topology was designed for traffic matrix of Table 2, the physical topology taken is shown in Figure 1. This VT has shown in Figure 3 and in the process of designing it, Table 4 was created for the establishment of routes and assignment of wavelengths to those routes. The AWHC obtained is 1.5367 and if previous case is considered number of changes are 12 in context of disruption of the traffic.

Table 6
Randomly Established Lightpath, Links, Wavelength and Path Length

Lightpath Established	*Fiber link path*	*Wavelength used*	*Path length*
5-6	5-6	w_1	1
6-10	6-10	w_1	1
1-3	1-2-3	w_1	2
5-8	5-7-8	w_1	2
5-11	4-5-11	w_1	2
11-13	11-12-13	w_1	2
1-13	1-3-6-13	w_1	3
1-14	1-8-9-14	w_1	3
4-5	4-5	w_1	1
2-3	2-3	w_2	1
1-9	1-8-9	w_2	2
6-9	6-10-9	w_2	2
9-11	9-14-11	w_2	2
1-11	1-2-4-11	w_2	3
1-5	1-3-6-5	w_2	3
6-11	6-13-12-11	w_2	3
6-8	6-5-7-8	w_3	3
1-2	1-2	w_3	1
1-7	1-8-7	w_3	2
1-6	1-3-6	w_3	2

Table Cont'd

Table 6 Cont'd

To proceed ahead in that work a NSFNET topology has been taken as shown in Figure 6 and set of lightpaths as mentioned in Table 6 are taken. The AWHC has been computed by varying the traffic load.

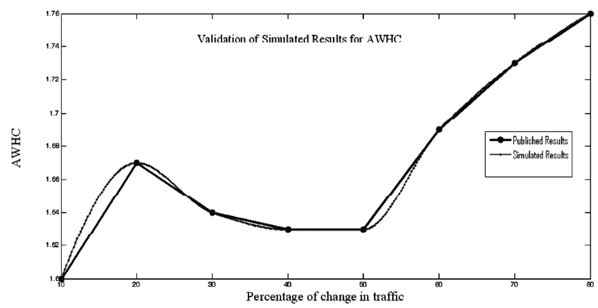

Figure 5: Validation of Simulated Results for AWHC

With these simulation results a curve has been plotted with red color on the graph as shown in Figure 5. On the same graph for validation purpose another curve with blue line has been plotted for the results published in [7].

In X-axis percentage change in traffic has been taken and on Y-axis AWHC has been taken. In [7] percentage of interchange in traffic pattern has been taken into consideration while in this work percentage of modification in the traffic pattern has been considered. As evident from Figure 5, the two curves coincide reasonably well with each other, hence our simulated results are in good agreement with the previous reported results of [7]. Once we have validated our simulated results, we can now extend our work considering variation in percentage in initial traffic pattern in leiu of variation in percent of interchanging traffic.

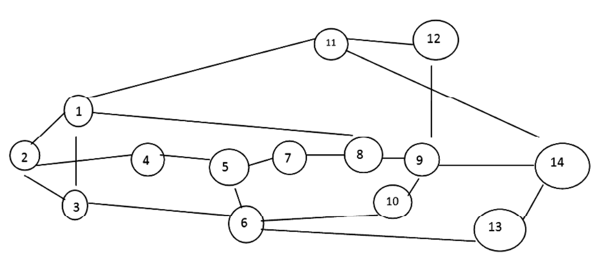

Figure 6: NSFNET - Topology

5. CONCLUSION AND FUTURE SCOPE

This particular work of our research has been commenced from the physical topology and preceded with designing and migrating of the virtual topology with traffic engineering, subsequently computation of AWHC has been carried out. Computation of AWHC has been also validated with the previous work. Designing of physical topology with potential and pattern of traffic may be considered before that and then AWHC can be more reduced towards its ideal value. Thus this may be the extension of that work.

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