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Reconfiguration with Prioritize Lightpath Requests in WDM Optical Network

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Abstract

Reconfiguration of a wavelength routed optical network with the use of priority scheduling algorithm to priotoriza lightpath request with the aim to utilizing or exhausting the resources. Preference has given to heavily loaded in establishing lightpaths between node pairs having large traffic and low preference to lightly loaded lightpaths. Applications such as grid computing, e-science, three dimensional (3D) teleconferencing consume large bandwidth and require that the lightpaths are available for the entire session although there might be intermittent periods with less traffic between the nodes. Hence, the reconfiguration process must not tear down these lightpaths. We propose to use a priority scheduling algorithm in which lightpaths requests are prioritize according to the class of traffic, and the lightpaths of high priority applications are entertained first by the reconfiguration process. For low priority applications such as email, the lightpath requests will be processed latter or the data can be transmitted by multihopping. Designing of logical topology is basically a set of connection requests to be processed. In this paper, we have given a solution through a program (based on priority scheduling algorithm) in MATLAB7.9. This algorithm takes low and high priority lightpath requests, first occupy all the connections with high priority requests and if still there is a room for few connections let it be filled with low priority data. Further we have performed simulation and obtained the simulated output through MATPLAN WDM5.

Keywords: Virtual topology, Reconfiguration, Prioritize data, Lightpaths, Optical Network and Logical topology.

Introduction

Phonetic networks are currently widely employed to support a variety of telecommunications and other applications. In order to provide the increased bandwidth needed by the existing and emerging applications, these networks rely extensively on wavelength division multiplexing (WDM).

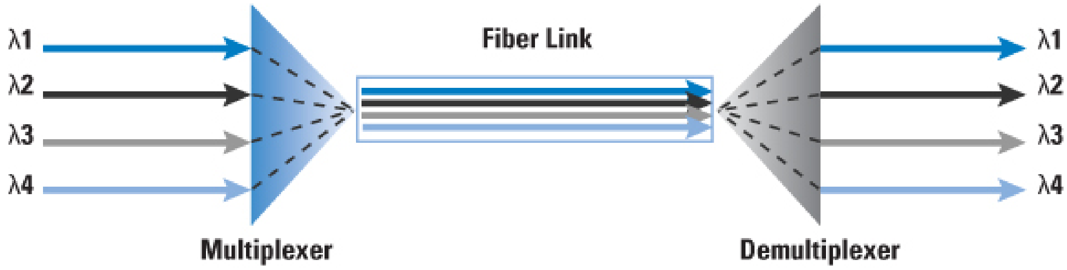

Figure 1: Fiber Link in WDM.

It is clear that providing complete flexibility assurance to each and every types of traffic supported by the network would be ideally desirable but this may be unnecessary and wasteful in terms of resource utilization resulting in cost inefficiencies. In this context priority scheduling network can assists a network supporting a variety of applications, would be a scheme that provides different traffic types in accordance with the respective priority for maximizing the network utilization. Therefore, in a network environment such as the new global and business oriented internet an important requirement will be to provide different types of traffic enabling higher priority demands to exploit higher network availability.

The developments in optical networking enable switching and routing in the optical domain. Hence lightpaths, which are all-optical paths, can be established between nodes that are physically far apart and do not have a direct physical connection. The establishment of a lightpath between two nodes ensures that traffic between the nodes is carried without any opto-electro-optical (O-E-O) conversion at the intermediate nodes. Optical switching takes place at these intermediate nodes. The set of all the lightpaths constitutes the virtual topology. Due to resource constraints, i.e. limited number of transmitters, receivers and wavelengths, it is not possible to establish a lightpath between every node pair. It insists us to go for ring or bus topology instead of mesh topology. When a direct lightpath does not exist between two nodes, data must be converted from optical to electrical and back to optical domain at the intermediate nodes. This is called multihopping. In order to maximize the network performance, the nodes between which lightpaths are to be established must be carefully chosen. The set of lightpaths to be established for a given physical topology is determined based on the traffic matrix. In communication networks, routing generally performs the identification of a path (route), per connection request, between a source and a destination node, across the network. In optical networks, the particular wavelength(s) along the path should also be determined. The resulting problem is often designated as routing and wavelength assignment (RWA) problem in literature [4]. The virtual topology design requires virtual topology selection, lightpath route selection, lightpath wavelength selection and traffic routing over the virtual topology. If wavelength converters are available at the nodes, wavelength continuity constraint can be relaxed. It is therefore not necessary that the same wavelength must be available on all the links required to establish a lightpath. The set of lightpaths to be established for a given physical topology is determined based on considering optimization of one or more of the objective functions, can be the extension of the work. Reconfiguration requires setting up new lightpaths or tearing down existing lightpaths. Today's data convergent network carries data belonging to different applications such as e-science, e-medicine, 3D teleconferencing that require high priority compared to applications such as email, file transfer protocol for which best effort service is sufficient. Reconfiguration techniques can be categorized according to the nature of the algorithms used. The sub problems of selecting a new configuration and migrating to that configuration can be solved jointly or separately [6]. A key feature of optical networks based on WDM technology is the ability to optimize the configuration of optical resources, i.e. wavelengths, with respect to a particular traffic demand. Reconfiguration of virtual topology is necessitated due to dynamic traffic or component failure. The traffic in the upper layers of the network is dynamic, i.e. the traffic pattern changes over time. The virtual topology designed for a particular traffic demand might not be optimal for a different traffic demand. Hence, to make optimal use of the available resources, the virtual topology must be reconfigured. Similarly, reconfiguration for fault restoration is necessary when network components such as network links and nodes fail. The set of lightpaths along with the nodes forms the virtual topology. The objective of design of a virtual topology, given the network resources, is to maximize the number of connections that can be routed. Throughput, which is the fraction of successfully routed connections, measures the network resource utilization in the design of a virtual topology. As the connection requests are dynamic in nature, the demand set changes with time. The virtual topology designed to maximize the throughput for a given demand set may not maximize the throughput for the new demand set. With the existing network resources, a new virtual topology, that maximizes throughput for the new demand set, can be designed and this can be achieved by deleting certain lightpaths from the current virtual topology and adding new lightpaths. This process of addition and deletion of lightpaths to migrate from one virtual topology to another is called Virtual Topology Reconfiguration (VTR). Thus, VTR allows the WDM network to efficiently utilize the existing network resources and dynamically adapt to the changes in the demand set. The drawback of this process is that the deletion of lightpaths disrupts the traffic flow in the network. The nodes at the source of the removed lightpaths need to either buffer or reroute the packets temporarily till a route to the destination is found on the new virtual topology. Since lightpaths carry traffic of the order of Gbps, disrupting them even for a small duration will require huge buffer capacities or immediate re-routing capabilities at each node [5].

In this work, we consider reconfiguration for dynamic traffic. The design of a virtual topology for the given physical topology and reconfiguration of the virtual topology for dynamic traffic can be carried out using heuristic method. Instead of providing express highway for the valuable client (e.g. commercially, security wise, politically, influentially, nationally etc.), they can be facilitated by prioritizing them with the rest of the clients. It is a matter of research; I have initiated it with the little work in that direction.

Example

In road network, on square with the traffic signal, traffic is controlled, with the assignment of time, we can see this analogy with monitoring the traffic and adding the lightpath or tear down the lightpath accordingly. If we make changes in that system, I have proposed there are three signals Red, Green and Yellow, if we put these signals in vehicles also according to priority. So, square and vehicle both will have signals and with the comparison of signals the system will be operational. Instead of giving priority to path we prioritize vehicles. If we compare this analogy with our work paths will become lightpaths.

The rest of the paper is organized as follows: Section (2) focuses on the related work. The priority scheduling and reconfiguration algorithm is presented in Section (3). The simulation results are discussed in Section (4) and Section (5) concludes the paper.

Motivation and related work

Previous literature has seen and found that when priority is a matter in most of the work lightpath has taken into consideration. But, we have considered traffic and first we have classified the data and then worked with lightpaths. In any network, there is several kinds of data, such as real time data, network survivable data, commercially concern data, highly secured data, data required fast access, usual data, data which we get well in time etc. So, a priority could be made accordingly. Further, the work presented in this paper solves the problem of utilization of resources by the prioritize data, i.e. traffic requests arrive and get served according to priority without knowledge of future incoming requests. This makes this contribution valid for usage both in the network design and – most importantly – the traffic engineering field. In [2], we seen, techno-economic network planning, which address a more profound evaluation of the networks, which takes into account a concrete time period, where the capital expenditures, operational expenditures, demand assessment, and price policies, are analyzed. Techno-economic planning involves very heterogeneous processes that strongly depend on the particular network scenario. It has motivated us and we worked with techno-economic approach. We have used heuristic algorithm, but with different objective, we have considered prioritize data and tried to maximize the use of wavelength, because number of wavelength is fixed for a particular network design. Now a day, to increase the number of wavelength per fiber is a matter of research. An efficient heuristic algorithm based on greedy approach has given to construct multicast tree for a given multicast request. While in [3] shows that mechanism requires least number of wavelengths per fiber and total wavelength channels for a given session with respect to existing multicast tree generation algorithms. In [7], propose a scheduling algorithm in which the transmission of multicast packets with more destination addresses overlap are postponed in order to improve average packet delay and throughput, in a WDM singlehop network. By prioritizing the transmission of multicast packets with less destination address overlap, our algorithm can decrease the number of data packets prevented from transmission by the other multicast packets with more destination address overlap and can reduce average packet delay. Our work on prioritize data can be fruitful for the developing country like Tanzania, where Internet access needs to be given a priority so that it can be accessible by the majority of the population [1]. In [1], an optical WDM network have proposed, which mitigates the effects of system impairments, and provide simulation results to show that the data is successfully transmitted over a longer distance using a WDM network.

Algorithm specification

Mainly priority scheduling algorithm has used, but to watch the effectiveness of prioritize data, Heuristic Logical Design Algorithm (HLDA) has been used, it attempts to maximize single (virtual)-hop traffic flow. It aims at minimizing congestion in a given network. In the program it has called as below:

[netState] = HLDA(traff_trafficMatrix, phys, parameters)

Arguments: traff_trafficMatrix(NxN): Average traffic flow offered between node pairs. The Traffic Matrix is a two-dimensional matrix with N (N:number of nodes) rows and N columns. An entry(s,d) means the average traffic flow from node 's' to node 'd', expressed in Gbps. The main diagonal is full of 0s.phys: Phys Structure (Topology with Fiber Link information). parameters: algorithm parameters (Flow Routing Method), the flow routing method is the Shortest Path First (SPF). This program solves the four classic subproblems[9] into which the Virtual Topology Design Problem is possible to decompose:

1. Virtual Topology Subproblem
2. Lightpath Routing Subproblem
3. Wavelength Assignment Subproblem
4. Traffic Routing (over the Virtual Topology) Subproblem.

This program uses the algorithm HLDA to solve jointly the first three subproblems, and uses a traffic flow routing method to solve the fourth one. The flow routing method is selected by means of the input parameter.

Performance Study

Simulations of prioritize data on ring topology have been performed. The results presented here are generated based on Heuristic algorithm, network defined that comprises 4 nodes and 8 links. Links are considered bidirectional and if a link failure occurs the traffic flow in both directions will be disrupted. Lightpaths comply with the wavelength continuity constraint and connections requests are equally likely to have any of the network nodes as its source or destination. We study the performance of lightpaths separately for prioritize data, merely higher priority data and merely lower priority data with the simulated output obtained.

Table 1: Physical Information.

Node ID	Position		No. of available		
	X	Y	TXs	RXs	WL Converter :
1	0.5	1.5	10	10	Not used
2	1.5	1.5	10	10	Lightpath Capacity :
3	0.5	0.5	10	10	40 Gbps
4	1.5	0.5	10	10	

Table 2: Fiber Link Information.

Fiber Link ID	S	D	Link Length	No. of av. WLs
1	1	2		
2	2	1		
3	2	4		
4	4	2	1 km	40
5	4	3	Each	On each link
6	3	4		
7	3	1		
8	1	3		

Table 1 shows information about ring topology corresponding to Fig 2. We have used 10 transmitters and receivers at each node and we have used no wavelength converters, so wavelength continuity constraint is there.

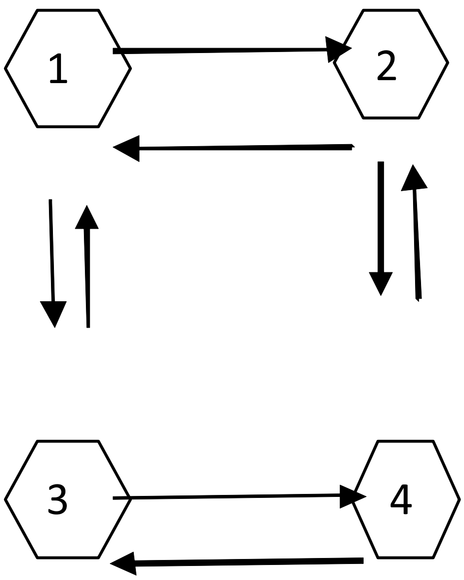

Figure 2: Ring topology made with the information in Table 1 & 2.

Lightpath requests

Table 3: Prioritize Lightpath request.

0.000	9.340	7.431	67.970
0.357	0.000	5.853	7.060
27.603	6.787	0.000	0.318
8.491	70.936	6.555	0.000

Table 4: High priority Lightpath request.

0.000	9.340	7.431	0.000
0.357	0.000	0.000	7.060
0.000	6.787	0.000	0.318
8.491	0.000	6.555	0.000

Table 4: Low priority Lightpath request.

0.000	1.190	0.000	67.970
0.000	0.000	5.853	2.551
27.603	9.597	0.000	0.000
0.000	70.936	7.513	0.000

Lightpath requests produced by the processing of suggested program (based on priority scheduling algorithm) in MATLAB R7.9. It continuously takes lower and higher priority data and produces prioritize data one by one in the form of lightpath request. One of them has shown in Table 3. Similarly, there are several higher and lower priority lightpath requests which we supply as input, one by one to the priority scheduling algorithm. Few of such matrices have shown in Table 4 & 5.

Table 5: Lightpath observations for the prioritize data.

LP ID	S	D	Sequence
1	4	2	4 2
2	1	4	1 2 4
3	4	2	4 2
4	1	4	1 2 4
5	3	1	3 1
6	4	1	4 2 1
7	1	3	1 3
8	2	4	2 4
9	3	2	3 1 2
Avg. Virtual Hops			1.1293
Average Distance			1.4444

Table 6: Lightpath observations for the merely higher priority data.

LP ID	S	D	Sequence
1	1	2	1 2
2	4	1	4 2 1
3	1	3	1 3
4	2	4	2 4
5	3	2	3 1 2
Avg. Virtual Hops			1.156
Average Distance			1.4

Table 7: Lightpath observations for the merely lower priority data.

LP ID	S	D	Sequence
1	4	2	4 2
2	1	4	1 2 4
3	4	2	4 2
4	1	4	1 2 4
5	3	1	3 1
6	4	3	4 3
7	2	3	1 3
8	3	2	1 2

Summary information:
Average Virtual Hops: 1.1141
Average Distance(km): 1.5

In per lightpath observations (Table 5), we have reduced average virtual hopes in the case of prioritize data as compared to Table 6, which is for merely higher priority. Reduced virtual hope means reduction in processing time between particular source and destination, while transferring data. As compared to Table 7, observation shows, average distance has reduced. In the subsequently produced matrices for prioritize lightpath requests, trend shows that, consistency in the reduction has maintained as compared to merely lower and merely higher priority.

Table 8: Observation for per link WL utilization.

Link ID	S	D	Prioritize data	High priority data	Low priority data
1	1	2	3	2	3
2	2	1	1	1	1
3	2	4	3	1	2
4	4	2	3	0	2
5	4	3	0	0	1

6	3	4	0	0	0
7	3	1	2	1	2
8	1	3	1	1	1
Avg. used WL/ link:			1.625	0.875	1.5

Table 9: Routed traffic/ Link for the prioritize data.

Link ID	S	D	Prioritize data	High priority data	Low priority data
1	1	2	84.4	16.4	81.3
2	2	1	21.3	15.4	8.4
3	2	4	90.6	7.7	79.6
4	4	2	101.3	15.4	80.0
5	4	3	0.0	0.0	7.5
6	3	4	0.0	0.0	0.0
7	3	1	35.0	7.1	39.8
8	1	3	20.1	14.0	8.4
Average routed traffic per link:			44.081	9.5096	38.1206

We are working on prioritizing the data and as shown in Table 8, we have increased the utilization of wavelength/ link in that case, as compared to merely higher priority or merely lower priority. Improvement in per link wavelength utilization increase means we have eight links and collectively we have enhanced the utilization of the entire network. In Table 9, in the case of prioritize data per link routed traffic is more as compared to the rest of the cases. If we increase routed traffic while entertaining the higher priority data is an achievement. It is per link information, if we see it for all the link, it is like we have injected the huge data in the network and the network has entertained it.

Table 10: Observation of each node for ingress, egress and grooming traffic.

	Prioritize data			High priority data			Low priority data		
Node ID	Ingress traffic	Egress traffic	Grooming traffic	Ingress traffic	Egress traffic	Grooming traffic	Ingress traffic	Egress traffic	Grooming traffic
1	84.7	36.5	12.7	16.8	8.8	6.6	69.2	27.6	10.4
2	13.3	87.1	0.0	7.4	16.1	0.3	8.4	81.7	0.0
3	34.7	19.8	0.3	7.1	14.0	0.0	37.2	13.4	2.6
4	86.0	75.3	15.3	15.0	7.4	0.4	78.4	70.5	9.1
Average	54.6752	54.6753	7.069	11.5848	11.5848	1.8075	48.3033	48.3032	5.51

As seen in Table 9, we have increased the routed traffic per link, by that way we have worked on grooming also, It can be seen in Table 10. So it is the byproduct of our work. Increase in routed traffic means, Lightpath is multihope, in multihoping optical to electrical and electrical to optical conversion has involved and there is always a gap between optical to electrical and vice versa. So, the traffic has groomed.

Conclusion and future scope

It has been shown that after the classification of the traffic according to the application it has prioritized with priority scheduling algorithm followed by processing of lightpath requests by the heuristic algorithm. By the performance study, it has shown that better results have achieved by the prioritize data as compared to either merely high priority data or lower priority data. In future, along with addition of the priority scheduling algorithm for uplifting of the system heuristic algorithm can be modified.

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Dr. Aditya Goel did his B.E.(Hons) in Electronics & Communication and M.Tech in Communication Engineering from I.I.T. Bombay. Subsequently he was awarded with the Ph.D. degree in Electronics and Communication Engineering in the year 2000. He has teaching and research experience of more than 16 years. Presently he is working as Senior faculty member in the department of Electronics & Communication Engineering at Maulana Azad National Institute of Technology(Deemed University), Bhopal, India. He has published more than 60 Research paper in reputed International Journals & Conferences including IEEE. His area of interest are Optical Communication, Digital Signal Processing, Computer Communication. He has guided several M.Tech. thesis on these area. He had been principal Investigator of the research project titled “Broadband Lightwave communication systems”, sanctioned by Government of India, New Delhi. He worked as Principal Investigator of the R&D Project “High speed optical components for WDM systems” sanctioned by M.H.R.D. Govt. of India, New Delhi. He has reviewed many research papers of International conferences and journals including SPIE. He is a Life Fellow member of Institution of Electronics & Telecommunication Engineers and Life Senior member of Computer Society of India.

Prof. Manish Shrivastava had started his carrier with Software companies like SIS (P) Ltd. and TCS, after finishing his BE in Computer Technology from UIT (Earlier GEC), RGPV(Technical University), Bhopal, India in 1993. He left software field in 1999 & switched to academic and worked with reputed private engineering colleges for more than ten years. He did M.Tech. in Digital Communication from Maulana Azad National Institute of Technology (Deemed University), Bhopal, India and presently here he is a Research Scholar and perusing his Ph.D. in Electronics and Communications. In all he has more than seventeen years industrial, teaching and research experience.