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DESIGN OF VIRTUAL TOPOLOGY USING HEURISTIC ALOGRITHM FOR WDM NETWORKS

Thorat Bhagyashri T.
Electronics & Telecommunication Dept.
Vidya Pratishthan's College of Engineering.
Baramati, Maharashtra
t.bhagyashri@gmail.com

S. B. Deosarkar
Electronics & Telecommunication Dept.
Vidya Pratishthan's College of Engineering.
Baramati, Maharashtra.
sbdeosarkar@yahoo.com

Bharat Chaudhari
Advanced Networking & Telecommunication Dept.
International Institute Of Information Technology
Pune, Maharashtra
bharatc@isquareit.ac.in

***Abstract*— Due to the advances in technology, WDM optical networks employing wavelength routing are becoming a reality. The end-to-end networking of wavelengths in fully optical domain requires new design methods to enhance transmission and node processing capabilities. In this paper we studied the problem of designing a logical topology over a wavelength-routed all-optical network (AON) physical topology using heuristic logical topology design algorithm (HLDA). For a given network physical topology and traffic pattern (relative traffic distribution among the source-destination pairs), our objective is to design the virtual(logical) topology and the routing algorithm on that topology so as to maximize single(virtual)-hop traffic flow and congestion will be reduced. This HLDA also solve lightpath route selection (LPRS), lightpath wavelength selection (LPWS).**

Keywords*— Virtual topology design(VTD), Wavelength devision multiplexing(WDM), heuristic logical topology design algorithm (HLDA), lightpath route selection (LPRS), lightpath wavelength selection (LPWS).

I. INTRODUCTION

WDM has emerged as promising technology for use in backbone transport networks. Due to advances in technology, WDM optical network employing wavelength routing are becoming reality. An advantage of this optical layer is that it is protocol transparent and can support different kinds of services at higher layer. The node together with set of lightpaths at the optical layer forms a virtual topology.

The virtual topology design problem is an important one. It requires good solution to efficiently utilize network resources such as wavelength, optical transmitters and receivers so as to optimise network resources. Several heuristic solutions for the virtual topology design problem and it's variants that are available in literature are explained with suitable examples. Due to electronic optical conversion at intermediate nodes , the message delay increases and also large buffers and more optical receivers and transmitters are required at nodes . This happens in point to point WDM networks. To overcome this, problem apply WDM technology to path layer. In this case message is transmitted from source to destination by using lightpath without requiring any electronic-optical conversion and buffering at intermediate nodes. This is called wavelength routing. At optical path layer lightpaths are established between subnet of node pairs forming virtual topology [2]. Given physical topology number of wavelength and resource constraints and long term average traffic flow between node pairs, the problem is to design the virtual topology so as to optimise a certain metric such as network congestion or message delay. The problem includes several subproblems to determine topology, physical route and wavelength for every ligthpath and also route on virtual topology for routing message traffic. Here it is assumed that the available wavelengths on fiber link are not sufficient to meet the traffic demand and hence new set of wavelength should be used by employing additional fiber between same node pair.

The remaining part of this paper is organized as follows Section II, we explain what is Physical and virtual topology over Wavelength Division Multiplexing network in section III we explain in detail the heuristic algorithm we propose for VTD and present an example in Section IV to outline its working. In section V the results of the simulations we conducted to compare the performance of our heuristic. Finally, we conclude and lay down some directions for future work in this area in Section VI.

II. PHYSICAL AND VIRTUAL TOPOLOGY OVER WDM NETWORK

A. *Wavelength Division Multiplexing(WDM)*

Theoretically, fiber has extremely high bandwidth (about 25 THz in the 1.55 low-attenuation band, and this is 1,000 times the total bandwidth of radio on the planet Earth.

However, only speeds of a few gigabits per second are achieved because the rate at which an end user can access the network is limited by electronic speed, which is a few gigabits per second. Hence it is extremely difficult to exploit all of the huge bandwidth of a single fiber using a single high-capacity wavelength channel due to optical-electronic bandwidth mismatch or "electronic bottleneck." The recent breakthroughs (Tb/s) are the result of two major developments: *wavelength division multiplexing* (WDM), which is a method of sending many light beams of different wavelengths simultaneously down the core of an optical fiber; and the *erbium-doped fiber amplifier* (EDFA), which amplifies signals at many different wavelengths simultaneously, regardless of their modulation scheme or speed.

WDM is conceptually similar to frequency division multiplexing (FDM), in which multiple information signals (each corresponding to an end user operating at electronic speed) modulate optical signals at different wavelengths, and the resulting signals are combined and transmitted simultaneously over the same optical fiber as shown in Fig. 1. Prisms and diffraction gratings can be used to combine (multiplex) or split (demultiplex) different colour (wavelength) signals. A WDM optical system using a diffraction grating is completely passive, unlike electrical FDM, and thus is highly reliable. Further, a carrier wave of each WDM optical channel is higher than that of an FDM channel by a million times in frequency (THz versus MHz). Within each WDM channel, it is possible to have FDM where the channel bandwidth is subdivided into many radio frequency channels, each at a different frequency. This is called *subcarrier multiplexing*. A wavelength can also be shared among many nodes in the network by electronic *time division multiplexing*.WDM eliminates the electronic bottleneck by dividing the optical transmission spectrum (1.55-micron band) into a number of non overlapping wavelength channels, which coexist on a single fiber, with each wavelength supporting a single communication channel operating at peak electronic speed. The attraction of WDM is that a huge increase in available bandwidth can be obtained without the huge investment necessary to deploy additional optical fiber. To transmit 40 Gb/s over 600 km using a traditional system, 16 separate fiber pairs and 224 ([600/40 − 1]16) regenerators are required, as regenerators are placed every 40 km.

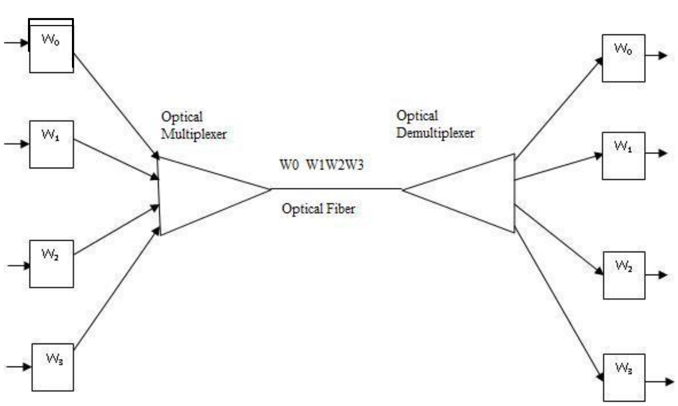


Figure 1: WDM System

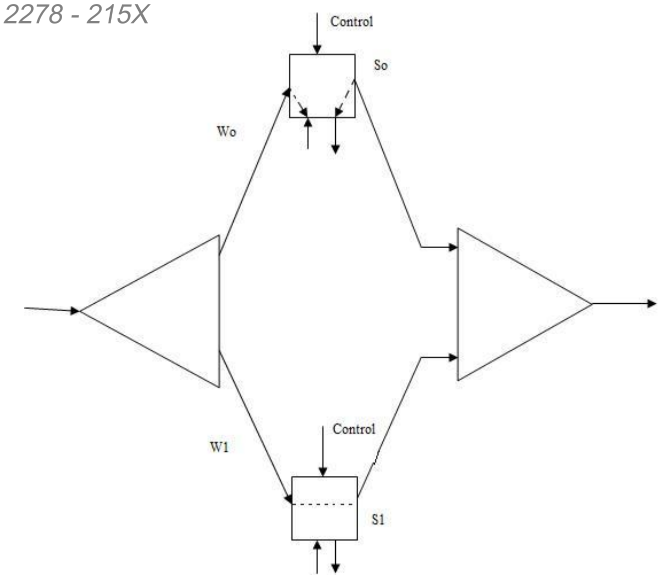


Figure 2: Add-drop Multiplexer

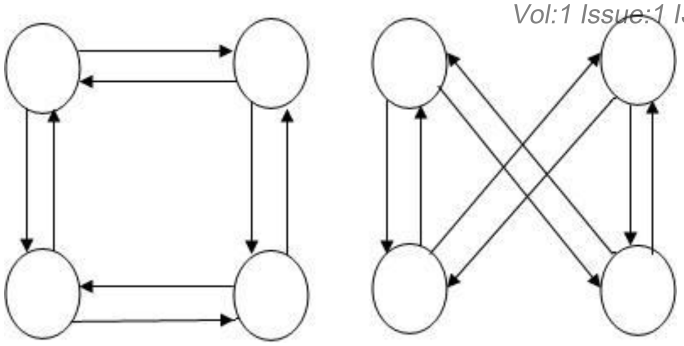
On the other hand, a 16-c*hannel WDM system requires only* one fiber pair and 4 (600/120 − 1) optical amplifiers, as amplifiers are placed every 120 km. WDM has been used to upgrade the capacity of installed point-to-point transmission systems, typically by adding two, three, or four additional wavelengths.

While WDM point-to-point links provide very large capacity between two widely spaced (300 to 600 km) (end) points (or terminals), in many networks it is necessary to drop some traffic at intermediate points along the route between the end points. Using a wavelength add/drop multiplexer (WADM), which can be "inserted" on a fiber link as shown in Fig. 2, one can add/drop necessary traffic (wavelengths) at the WADM location.

B. *Physical Topology and Virtual Topology*

The set of lightpaths established over a physical topology forms a virtual topology. The set of nodes and the set of physical links constitute the physical topology. Physical link may be bi-directional, realized by two unidirectional fiber link in opposite direction. Every fiber link carries number of wavelengths [2].

The virtual topology consist nodes corresponding to network nodes and edges correspond to lightpaths, The in degree of node is number of lightpath incident on that node and out degree of node is number of nodes leaving that node. The in degree and out degree of node are limited by number of optical transmitters and receivers at the node. Figure 3(a) and out degree of 2. Figure 3 (b) shows virtual topology. Each edge corresponds to lightpath. In virtual topology message is routed in one hop. Optical switching is performed at node for those messages which are designed to some other node. Electronic switching of message is performed at node using a fast electronic switch [5]. An incoming message in optical domain is first received by the node, converted to electronic form, and buffered. This message in electric domain is again converted to an optical message and is transmitted to outgoing



(a) (b)

Figure 3: Illustration of physical and virtual topologies

link if it is destined for some other node. If the message is destined for the local node, it is delivered in electronic from to the upper layer.

C. Example

Consider the physical and virtual topology shown in Fig 3 Assume that node 1 needs to send a message to node 3 and node 4 needs to send message to node 3. Further assume that virtual topology shown in figure 3(b) is used for routing the message. Since there is an edge from node 1 to node 3 can be sent directly. Here, the message is added at node 1 and node 3 only. If the light path that corresponds to edge 1 to edge 3 uses path 1 to 3 on physical topology, then there no optical switching in routing the message 1 as there is no intermediate node[3].

Since there is no edge from node 1 to node3 in virtual topology message 2 needs to travels more than one edge (lightpath). Assume that the message uses a shortest path 4 - 1 – 3.While this message carried optically on individual path it undergoes electronic – optical – electronic conversions between the two lightpaths at node 1. Here, the message is added at node 1 and dropped at node 3.Therefore,electronic processing is required at node 4 and node3. If the lightpath that corresponds to edge 4 to 3 uses path 4 – 2 – 1 on the physical topology, the optical switching is required at node 2. If the lightpath that corresponds to edge 1 to 3 uses path 1 to 3 on physical topology then there is no optical switching is required to route message to over this lightpath. as there is no intermediate node.

III. HEURISTIC LOGICAL TOPOLOGY DESIGN ALGORITHM

A. Problem definition

The physical optical network is modelled as a graph Gp=(V; Ep), where V is the set of nodes (|V | = N) and Ep is the set of physical edges. Edges are assumed to be bidirectional (each representing a pair of optical fibers-one fiber per direction) and have assigned weights representing their length or cost. Given is a long term traffic matrix $\Lambda = \lambda^{(sd)}$; s, d Є V; where each element represents the average traffic flow from a source node s to a destination node d. The number of available wavelengths W on each link, and the number of available transmitters Tx and receivers Rx at each node, are given.

B. Heuristics Algorithm

1. Assume that the node pairs in nonincreasing order of their traffic. First select node pair (say, *x*) with the most nonzero traffic flow between them. A lightpath is permissible for node pair (*x*) if a physical route, a wavelength on route, a transmitter at the source node *x* and a receiver at destination node of *x* are all available. For wavelength selection we used here fixed order algorithm. All the wavelength are indexed, and they are searched in their index numbers.

2. When a light path is established between node pair *x*, the traffic associated with *x* updated by subtracting from it the traffic associated with pair *y*. Here, node pair has a highest traffic after pair *x*.

3. If a lightpath cannot be established between node pair *x*, the traffic associated with it is set to zero.

4. Goto 1 Consider second node pair with highest traffic and repeat the above procedure.

5. When all the node pairs with nonzero traffic is considered , algorithm is terminate .

TABLE I.

Iteration	Heuristic algorithm working		
	Lightpath	***Route***	***Wavelength***
A	2-4	2-4	W_0
B	4-3	4-3	W_0
C	1-2	1-2	W_0
D	3-2	3-4-2	W_0
E	1-4	1-3-4	W_1
F	2-1	2-1	W_0
G	1-3	No Tx is free at node 1	
H	4-2	No Rx is free at node 2	
I	4-1	4-3-1	W_1

IV. WORKING OF ALGORITHM

Consider fig 4(a) the traffic matrix shown in fig.4 is assumed every node is assume to have two Tx and two Rx every fiber is assumed to have two wavelengths w0 and w1 fig.4 depicts the trace i of HLDA . It shows the traffic matrix in every iteration of algorithm the iteration are labelled a through i. the node pair with the most traffic is shown by encircling the corresponding entry in the traffic matrix. In iteration a, node pair <2,4> has the most traffic or 0.9 a lightpath is established from node 2 to node 4 by using the physical route 2-4 on wavelength w0 the traffic associated with <2,4> is now updated since the next highest traffic is 0.8 the traffic associated with <2,4> is set to 0.1(0.9-1.8).In the next iteration node pair <4,3> is selected. a light path is established by using physical rote 4-3 on wavelength w0. The traffic associated with <4, 3> is now updated. Since the next

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highest traffic is 0.75 the traffic associated with<4,3> is set to 0.05(0.8-0.75) the light path established in various iterations

$$\begin{bmatrix} 0 & 0.75 & 0.4 & 0.5 \\ 0.45 & 0 & 0.1 & \underline{0.9} \\ 0.15 & 0.6 & 0 & 0.1 \\ 0.3 & 0.35 & 0.80 & 0 \end{bmatrix} \begin{bmatrix} 0 & 0.15 & 0 & .05 \\ 0.05 & 0 & 0.1 & 0.1 \\ 0.15 & 0.1 & 0 & 0.1 \\ 0.3 & \underline{0.35} & 0.05 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 0 & 0.15 & 0 & .05 \\ 0.05 & 0 & 0.1 & 0.1 \\ 0.15 & 0.1 & 0 & 0.1 \\ 0.3 & \underline{0.35} & 0.05 & 0 \end{bmatrix}$$

Figure 4: Traffic Matrix changes

are listed below. In iteration node pair <1,3>is selected as no lightpath can be established from node 1 to node 3 there is no Tx available at node 1 the traffic associated with this pair set to zero similarly in node pair <4,3>.At the end of iteration i only node 3 has one Tx and one Rx therefore no lightpath can be established after iteration i. The resulting virtual topology is shown in fig 4(b).

First 4× 4 matrix shows traffic matrix for given physical topology. Second, matrix shows traffic matrix at i iteration and third matrix shows last l (12) iteration. Then algorithm terminates and resulting virtual topology for this network is shown in figure 3(b).

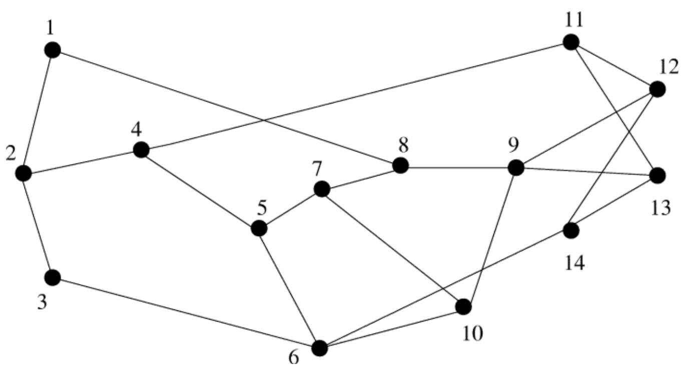

Figure 4: NSFnet network Topology

V. RESULTS

To determine the optimality of our algorithm, we tested it on networks of various physical topologies with a wide variety of traffic distributions. Here, we give the result of testing on a standard network along with their corresponding measured traffic demands as given in the literature. The network considered is the NSFNET (shown in Fig. 4), which has 14 nodes and 21 links, with the measured traffic demand taken from Ref[6]. Figure 5 shows that how lightpaths are established.

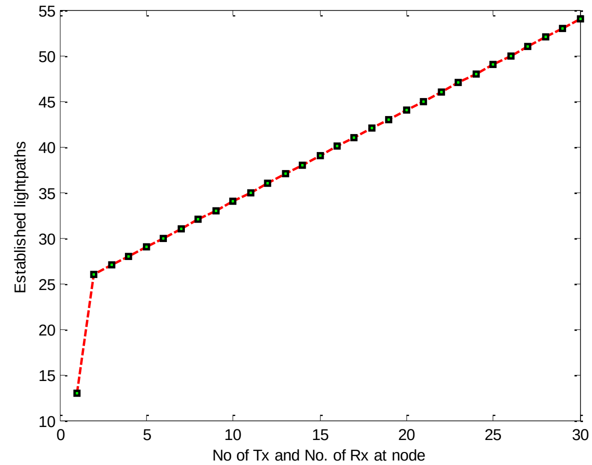

Figure: 5 Established lightpaths vs No of Tx and Rx at node

VI. CONCLUSION

We considered the problem of virtual Topology design(VDT) in wavelength-path (VWP) routed networks and took up the novel approach to maximizing single(virtual)-hop traffic flow. By doing this, the congestion will be also reduced. The HLDA solves the lightpath route selection (LPRS) and lightpath wavelength selection (LPWS) problems as observed by example. Whenever a node pair is considered a shortest delay path is chosen the wavelength with lowest index among those which are free on the chosen path is selected in this way by using this algorithm the congestion will be reduced.

Virtual topology design (VTD) problem is NP-Hard and poses several challenges. But using HLDA algorithm we can try to find optimal solution for given topology. Using different optimization metric ex. message delay, traffic offered to a lightpath we can find optimal solution. In this algorithm we used Fixed-order wavelength assignment procedure for wavelength assignment but for better result try most-used, least-used and random-order and find optimal solution.

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REFERENCES

[1] Vittal J. Gond,Aditya Goel, “Design of virtual topologies for wavelength routed all optical WDM network,Journal of advanced research in computer engineering, Vol.4,January- June 2010,pp 25-30.

[2] C.Siva Ram Murthy,Mohan Guruswami,”WDM Optical Networks”,Chap 5,pp 189-221,Prentice Hall of India,New Delhi,2002.

[3] Gang Feng, Christos, Douligeris,Ramon M. Rodiguez Dagnino, “Virtual Path Topology Design, Control and Optimization”

[4] Harry J. R. Dutton,”Understanding Optical Communications International Technical Support Organization”

[5] Pablo Pavon-Marino , Ramon Aparicio-Pardo ,Belen Garcia-Manrubia ,Nina Skorin-Kapov “Virtual topology design and flow routing in optical networks under multi-hour traffic demand”

[6] MatPLAN WDM toolbox for Matlab.