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Efficient Segmentation based heuristic approach for Virtual Topology Design in Fiber Optical Networks

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ABSTRACT

This paper presents segmentation based heuristic approach as a solution to the design of a logical topology for a given physical topology. For a given physical topology in fiber optic network and Traffic pattern, the objective is to design a logical topology and routing algorithm so as to minimize both the average weighted number of hops and Congestion. Two constraints are considered namely, the number of wavelengths required to embed the resulting logical topology and the number of transceivers per node. Two new segmentation based heuristic approaches i) Segmentation Based Left Top to Right Bottom Diagonal Heuristic (SLTRBH), ii) Segmentation Based Left Bottom to Right Top Diagonal Heuristic (SLBRTH) are proposed to design logical topology for a given traffic matrix to a physical topology in fiber optical network. The experimental results on 14 node NSFNET model obtained for the HLDA and the proposed heuristics SLTRBH and SLBRTH and their performances are compared for two wavelengths and different transceivers.

Keywords: - Physical Topology, Logical Topology, Traffic Matrix, Average Weighted number of Hops Count, Transceivers, Congestion, WDM Networks.

1. INTRODUCTION

Wavelength Division Multiplexing (WDM) [3], networks, an optical signal is converted to electrical signal, buffered, and transmitted again as an optical signal at every intermediate node before reaching the destination node in fiber optical network. While these networks enhance transmission capacity, they do not posses sufficient node processing capability. 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 the nodes. A message [1] is transmitted from the source to the destination by using a lightpath without requiring any electronic-optical conversion and buffering at the intermediate nodes. This is known as wavelength routing. At the optical path layer, lightpaths are established between a subset of node pair, forming virtual topology.

2. PHYSICAL TOPOLOGY AND VIRTUAL TOPOLOGY

The two layers commonly considered in WDM Optical Network design include the Physical topology defined by the physical network of optical fibers, and the virtual (Logical) topology defined by lightpaths established over the physical topology. The physical topology consists of optical WDM routers interconnected by point to point fiber links in an arbitrary topology in fig 1. In these types of networks, data transfer carried from the one node to another node using lightpaths. A lightpath is an all optical path established between two nodes in the network by the allocation of same wavelength on all links of the path. A physical link may be bidirectional, realized by two unidirectional fiber links in opposite directions. In a multitier network, a physical link between two nodes consists of a bundle of fiber links. Every fiber link carries a certain number of wavelengths. In IP over WDM networks lightpaths are established between IP routers [6].

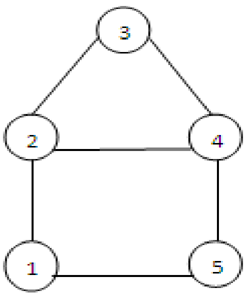

Figure 1: Physical Topology of the 5-node optical network

This set of pre-established lightpaths is called as Virtual Topology [6]. A virtual topology can be designed with the aim of minimize one of the objective functions namely Average Weighted number of hops. Virtual topology is a graph with nodes as routers in the physical network topology and edges corresponding to the lightpath between them. Virtual topology is a set of lightpaths established to provide all optical connectivity between nodes for a given traffic demand. Message traffic from applications is routed over the virtual topology. If two nodes are connected by an edge in a virtual topology, a message can be transmitted from one node to the other node in optical from, without requiring any electronic optical electronic conversion at the intermediate nodes. In this case, the message is routed in one (virtual or logical) hop in fig. 2. [3].

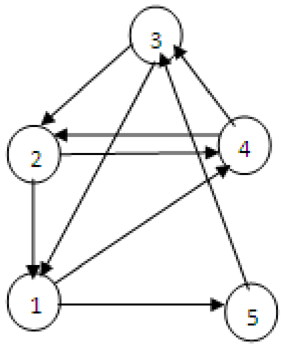

Figure 2: Virtual Topology of the 5-node optical network

3.RELATED WORK

3.1 Heuristic Logical Topology Design

First we select node path with the most nonzero traffic flow between them. A lightpath [5] is established between this node pair, if permissible. A lightpath is permissible for node pair X. If a physical route a wavelength on the route, a transmitter at the source node of X, and a receiver at the destination node of X are all available when a lightpath is established between pair X the traffic associated with X is updated by subtracting from it the traffic associated with pair Y. Here, node pair, Y has the maximum amount of nonzero traffic is chosen and the above procedure is repeated. Note that the chosen node pair could be either X, or Y. When all the node pair with nonzero traffic has been considered, the procedure stops [7]. It may so happen that few transmitters and receivers are available at some node when the procedure terminates. The HLDA creates lightpath between such nodes to exhaust the available transmitters and receivers. HLDA attempts to established lightpath between pairs of nodes in decreasing order of their corresponding traffic. The HLDA solves the LPRS, and LPWS [5].

3.2 Lightpath Route Selection (LPRS)

Determine the physical links, which each lightpath consists of the route the lightpaths over the physical topology.

3.3 Lightpath Wavelength Selection (LPWS)

Determine the wavelength each lightpaths uses, that is, assign a wavelength to each lightpath in the logical topology so that wavelength restrictions are obeyed for each physical link [3].

4. PARAMETERS

Listed below are the parameters used in the problem formulation

- Number of nodes in the network = N
- Number of wavelength per fiber = W
- Traffic matrix in Source to destination = T_{sd}
- Number of hops in source to destination = H_{sd}
- Node Pair =X
- Average traffic from source to destination = t (sd)
- Average Weighted Hop count for the Topology(AWHT)
- Congestion=T_{max}

4.1 Traffic Matrix

A traffic matrix which specifies the average traffic of data flow between every pair of nodes in the physical topology. If there are N nodes in the network the traffic matrix is an N*N matrix T= [t(s, d)] where t(s, d) is the average traffic from node s to node d in some suitable units, such as arriving packets per second.

4.2 Average Weighted Hop count

The average weighted number of (virtual) hops defined as the average number of lightpaths traversed by one unit. If T^{sd} is the offered traffic between node s and node d and $H_{s,d}$ is the number of hops between s and d on the virtual topology, then the weighted number of hops required by this <s,d> pair is given by $T^{sd}*H_{sd}$. Average Weighted Hop count for the Topology is given by

$$AWHT = \frac{\sum_{s,d} T_{ij}^{s,d}*H_{sd}}{\sum_{s,d} T_{sd}} \qquad (1)$$

4.3 Congestion

Congestion is defined as the maximum virtual load among all the lightpaths due to all possible source to destination pairs in a virtual topology.

$$T_{max}= max_{ij}T_{ij} \qquad (2)$$

5. PROPOSED WORK

This paper proposes two new segmentation based heuristics to design logical topology for a given physical topology traffic matrix and to find the average weighted number of hops and congestion.

5.1 SEGMENTATION BASED LEFT TOP TO RIGHT BOTTOM DIAGONAL HEURISTIC (SLTRBH)

The traffic demand matrix for the given physical topology is considered to have two partitions when divided along the major diagonal. Here the all major diagonal elements consist of zero values. Accordingly the heuristic is presented in two variations.

a) SLTRBH (L) with lower portion of major diagonal (excluding major diagonal values) to upper portion of major diagonal (including major diagonal values) lightpath establishment
b) SLTRBH(U) with upper portion of major diagonal (excluding major diagonal values) to lower portion of major diagonal (including major diagonal values) lightpath establishment

5.1.1. SLTRBH (L) with lower portion of major diagonal (excluding major diagonal values) to upper portion of major diagonal (including major diagonal values) lightpath establishment

Establishment of lightpaths through segmentation based heuristic approach starts from the lower protion of (excluding major diagonal values) the traffic matrix along the major diagonal, followed by the upper portion of major diagonal (including major diagonal values) of the traffic matrix.

Step 1: i) Number of nodes = N, node = Ni, i=1, 2… N
ii) Traffic matrix T= (t_{ij})
iii) Wavelength Wi, i=1, 2….k, (Number of wavelengths = k)
iv) Transceivers Ti, i=1, 2 …m, (Number of transceivers = m)
v) Physical topology PT= (V, E)

Step 2: i) Select the lower diagonal matrix part
ii) Select the max value $tij_{(Max)}$ of lower diagonal
iii) If wavelength and transceivers are available from source to destination assign lightpath L_{ij}, reset traffic matrix value $tij_{(Max)} = 0$

Step 3: i) Select the traffic upper diagonal matrix part
ii) Select the max value $tij_{(Max)}$ of upper diagonal
iii) If wavelength and transceivers are available from source to destination assign lightpath L_{ij}, reset traffic matrix value $tij_{(Max)} = 0$

Step 4: Repeat steps 2 and 3 until all traffic matrix values become zero or wavelength and transceivers are not available

Step 5: Establish logical topology with the lightpath selected.

Step 6: Calculate the average weighted number of hops
Average weighted number of hops= Sum ($T_{sd}*H_{sd}$)/Sum (T_{sd})

5.1.2. SLTRBH (U) with upper portion of major diagonal (excluding major diagonal values) to lower portion of major diagonal (including major diagonal values) lightpath establishment

Establishment of lightpath through segmentation heuristic approach starting from the upper diagonal portion of the traffic matrix along the major diagonal, followed by the lower diagonal portion of the traffic matrix. The procedure for finding lightpaths is similar to steps presented in section 5.1.1 except that the procedure starts from lower portion (traffic demands) of diagonal followed by upper portion (traffic demands).

5.2. SEGMENTATION BASED LEFT BOTTOM TO RIGHT TOP DIAGONAL HEURISTICS (SLBRTH)

The traffic demand matrix for the given physical topology is considered to have two partitions when divided along counter diagonal. Here the all counter diagonal elements consists of non zero values. Accordingly the heuristic is presented in two variations.

a) SLBRTH (L) with lower portion of counter diagonal (excluding counter diagonal values) to upper portion of counter diagonal (including counter diagonal values) lightpath establishment

b) SLBRTH (U) with upper portion of counter diagonal (excluding counter diagonal values) to lower portion of counter diagonal (including counter diagonal values) lightpath establishment

5.2.1. SLBRTH (L) with lower portion of counter diagonal (excluding counter diaognal values) to upper portion of counter diagonal (including counter diagonal values) lightpath establishment

Establishment of lightpath through segmentation based heuristic approach starts from the lower portion of (excluding counter diagonal values) the traffic matrix along the counter diagonal, followed by the upper portion of counter diagonal (including counter diagonal values) of the traffic matrix.

Step 1: i) Number of nodes=N, node = Ni, i=1, 2… N
ii) Traffic matrix T= (t_{ij}),
iii) Wavelength Wi, i=1, 2….k, (Number of wavelength = k)
iv) Transceivers Ti, i=1, 2 …m, (Number of transceivers = m)
v) Physical topology PT= (V, E)

Step 2: i) Select the lower diagonal matrix part
ii) Select the max value $tij_{(Max)}$ of lower diagonal
iii) If Wavelength and transceivers are available from source to destination assign lightpath $L_{ij,}$
reset traffic matrix value $tij_{(Max)} = 0$

Step 3: i) Select the traffic upper diagonal matrix part
ii) Select the max value $tij_{(Max)}$ of upper diagonal
iii) If wavelength and transceivers are available from source to destination assign lightpath L_{ij},
reset traffic matrix value $tij_{(Max)} = 0$

Step 4: Repeat steps 2 and 3 until all traffic matrix values become zero or wavelength and transceivers are not available

Step 5: Establish logical topology with the lightpath selected.

Step 6: Calculate the average weighted number of hops
Average weighted number of hops=Sum (T_{sd}*H_{sd})/Sum (T_{sd})

5.2.2. SLBRTH (U) with upper portion of counter diagonal (excluding counter diagonal values) to lower portion of counter diagonal (including counter diagonal values) lightpath establishment

Establishment of lightpath through segmentation heuristic approach starting from the upper portion of (excluding counter diagonal values) the traffic matrix along the counter iagonal, followed by the lower diagonal portion of counter diagonal (including counter diagonal values) of the traffic matrix. The diagonal values are includes in upper portion of counter diagonal. The procedure is presented as given below

Step 1: i) Number of nodes=N, node = Ni, i=1, 2… N
ii) Traffic matrix T= (t_{ij}),
iii) Wavelength Wi, i=1, 2….k, (Number of wavelength = k)
iv) Transceivers Ti, i=1, 2 …m, (Number of transceivers = m)
v) Physical topology PT= (V, E)

Step 2: i) Select the upper diagonal matrix part
ii) Select the max value $tij_{(Max)}$ of upper diagonal
iii) If wavelength and transceivers are available from source to destination assign lightpath L_{ij},
reset traffic matrix value $tij_{(Max)} = 0$

Step 3: i) Select the traffic lower diagonal matrix part
ii) Select the max value $tij_{(Max)}$ of lower diagonal
iii) If wavelength and transceiver are available from source to destination assign lightpath L_{ij},
reset traffic matrix value $tij_{(Max)} = 0$

Step 4: Repeat steps 2 and 3 until all traffic matrix values become zero or wavelength and transceivers are not available

Step 5: Establish logical topology with the lightpath selected.

Step 6: Calculate the average weighted number of hops
Average weighted number of hops=Sum (T_{sd}*H_{sd})/Sum (T_{sd})

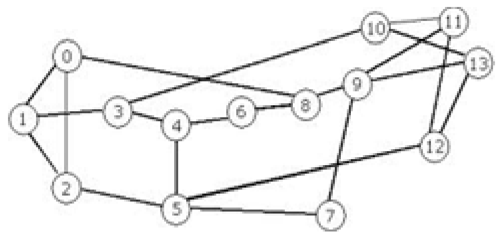

Figure 3: Physical Topology of the 14-node NSFNET optical network

Table 1: Traffic Demand Matrix for 5-node optical network

	1	2	3	4	5
1	0	20	9	24	28
2	28	0	12	26	15
3	27	21	0	21	13
4	14	29	22	0	17
5	10	6	6	7	0

Table 2: Traffic Demand Matrix for the 14-node NSFNET optical network

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
0	0.00	0.11	0.03	0.15	0.08	0.17	0.14	0.13	0.18	0.09	0.13	0.19	0.26	0.17
1	0.22	0.00	0.20	0.26	0.06	0.18	0.09	0.22	0.09	0.14	0.10	0.04	0.14	0.10
2	0.15	0.13	0.00	0.21	0.18	0.13	0.02	0.29	0.16	0.17	0.27	0.17	0.06	0.18
3	0.05	0.08	0.13	0.00	0.28	0.13	0.11	0.24	0.16	0.22	0.14	0.27	0.20	0.17
4	0.28	0.06	0.26	0.23	0.00	0.12	0.21	0.27	0.22	0.17	0.16	0.21	0.14	0.01
5	0.29	0.14	0.32	0.07	0.25	0.00	0.20	0.15	0.23	0.11	0.06	0.16	0.08	0.28
6	0.18	0.09	0.14	0.13	0.18	0.24	0.00	0.17	0.17	0.07	0.16	0.18	0.19	0.19
7	0.10	0.12	0.07	0.19	0.11	0.32	0.20	0.00	0.13	0.08	022	0.29	0.04	0.10
8	0.24	0.15	0.23	0.26	0.11	0.15	0.28	0.08	0.00	0.26	0.11	0.13	0.16	0.26
9	0.22	0.07	0.06	0.17	0.17	0.15	0.17	0.06	0.03	0.00	0.14	0.28	0.27	0.27
10	0.23	0.16	0.27	024	0.06	0.13	0.24	0.11	0.15	0.14	0.00	0.20	0.21	0.25
11	0.33	0.13	0.21	0.19	0.16	0.17	0.07	0.21	0.14	0.13	0.06	0.00	0.05	0.15
12	0.26	0.20	0.21	0.21	0.16	0.15	0.03	0.17	0.17	0.16	0.21	0.11	0.00	0.24
13	0.25	0.20	0.11	0.09	0.19	0.16	0.08	0.09	0.18	0.19	0.15	0.08	0.27	0.00

Table 3: Average weighted number of hops the 5-node logical topology

Number of Nodes	**Number of Transceivers**	**Number of Wavelengths**	**Heuristic Logical Topology Design**	**Segmentation Based Left Top to Right Bottom Diagonal (SLTRBH)**		**Segmentation Based Left Bottom to Right Top Diagonal (SLBRTH)**	
			HLDA	**Lower to Upper**	**Upper to Lower**	**Lower to Upper**	**Upper to Lower**
5	2	2	1.473239	1.473239	1.473239	1.459155	1.492958
5	3	2	1.250704	1.191549	1.250704	1.200000	1.383099

Table 4: Average weighted number of hops the 14-node NSFNET logical topology

Number of Nodes	**Number of Transceivers**	**Number of Wavelengths**	**Heuristic Logical Topology Design**	**Segmentation Based Left Top to Right Bottom Diagonal (SLTRBH)**		**Segmentation Based Left Bottom to Right Top Diagonal (SLBRTH)**	
			HLDA	**Lower to Upper**	**Upper to Lower**	**Lower to Upper**	**Upper to Lower**
14	2	2	2.615719	2.615719	2.615719	2.498997	2.667559
14	3	2	1.950168	1.950168	1.950168	1.946823	1.986957
14	4	2	1.682609	1.680936	1.677592	1.672240	1.685953

14	5	2	1.534114	1.529097	1.531773	1.515719	1.568562

Table 5: Congestion values the 5-node logical lopology

Number of Nodes	Number of Transceivers	Number of Wavelengths	Heuristic Logical Topology Design	Segmentation Based Left Top to Right Bottom Diagonal (SLTRBH)		Segmentation Based Left Bottom to Right Top Diagonal (SLBRTH)	
			HLDA	Lower to Upper	Upper to Lower	Lower to Upper	Upper to Lower
5	2	2	6	6	6	5	6
5	3	2	5	5	6	5	5

Table 6: Congestion values the 14-node NSFNET logical topology

Number of Nodes	Number of Transceivers	Number of Wavelengths	Heuristic Logical Topology Design	Segmentation Based Left Top to Right Bottom Diagonal (SLTRBH)		Segmentation Based Left Bottom to Right Top Diagonal (SLBRTH)	
			HLDA	Lower to Upper	Upper to Lower	Lower to Upper	Upper to Lower
14	2	2	18	18	18	20	19
14	3	2	15	15	15	14	18
14	4	2	15	16	15	15	17
14	5	2	14	14	14	14	13

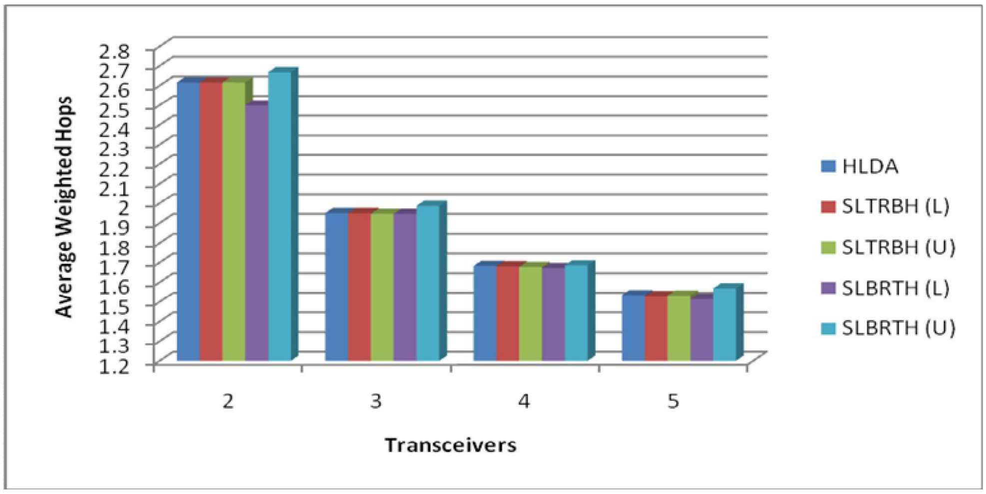

Figure 4: Comparision of Average Weighted Hops of HLDA, SLTRBH (L), SLTRBH (U), SLBRTH (L), SLBRTH (U)

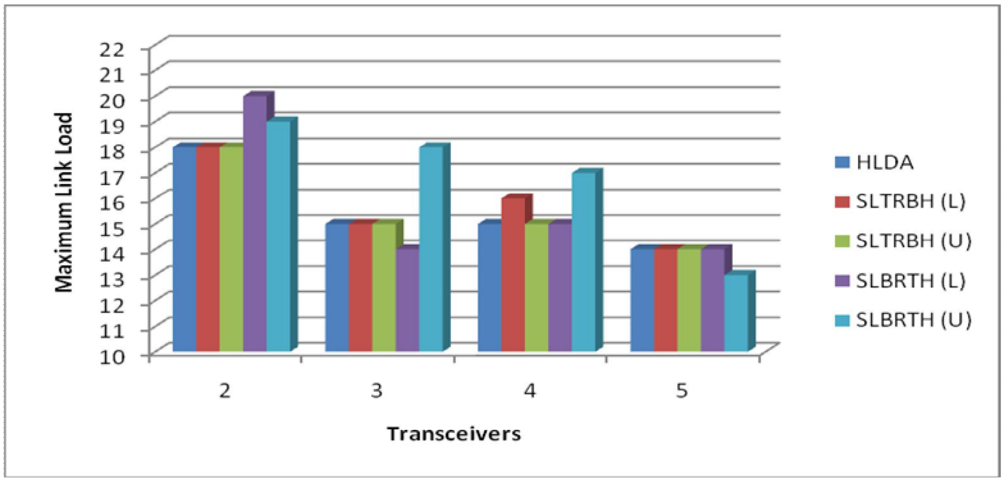

Figure 5: Comparision of Maximum Link Load of HLDA, SLTRBH (L), SLTRBH (U), SLBRTH (L), SLBRTH (U)

6. RESULTS

To determine the new segmentation based heuristic approach for virtual topology design is implemented in C++ language for 14 node NSFNET topology shown in fig 3. In our algorithm we have presented four variations of segmentation based heuristics are (i) SLTRBH(L) (ii) SLTRBH(U) (iii) SLBRTH(L) (iv) SLBRTH(U). The experimental results shown in form Table 1 and Table 3. It is oberserved that for 5-node network, the AWHT is best for the proposed segmentation based heuristic SLBRTH (L) than existing HLDA. The results obtained 14-node network, we are shown in Table 2 and Table 4 in which is observed results pertaining to AWHT the proposed heuristic SLBRTH (L) perform better that the existing algoritn HLDA and other heuristcs SLTRBH(L), SLTRBH (U), SLBRTH(U) also observed the results are consisists that when number of transceivers are increased. In case of maximum congestion value T_{max} from Table 5 and Table 6 it is formed the similarly on comparision with the results of congestion it is formed the proposed heristic SLBRTH (L) and HLDA gives same performance as the number of transceivrs increases.

7. CONCLUSION

In this paper presents segmentation based heuristic approach as a solution to the design of logical topology for a given physical topology. The objective is to desing a logical topology and routing algorithm so as to minimize both the average weighted number of hops and congestion. We discussed the behaviour among the number of transceivers in each node, the number of wavelengths of fiber and average weighted number of hops. The obtained expermental results show that the new segmentation based heuristic approach achieves better performance in terms of Average Weighted Number of Hops (AWHT) and Congestion (T_{max}) than the existing HLDA as the numbers of transceivers are increased with fixed number of wavelengths.

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