Traffic Routing in Mixed Line Rate Optical WDM Networks Under Dynamic Traffic

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Abstract: **With the growing traffic demands Mixed Line Rate (MLR) WDM (Wavelength Division Multiplexing) provides different bandwidths by using different modulation types. In this paper, a new simple routing algorithm is proposed by monitoring the dynamic traffic of a network using Poisson random traffic model .The proposed work can be achieved by finding the best possible shortest path between source and destination node and adjusting the number of light paths. Adjustments employ addition or deletion of light paths according to traffic load at any time. Simulation results demonstrate the total number of light paths used total number of addition/deletion of light paths and shows the comparison between single line rate (SLR) and mixed line rate (MLR).**

Keywords— **lightpaths, mixed line rate (MLR), wavelength division multiplexing (WDM), and dynamic traffic.**

1. INTRODUCTION

Optical networks are high capacity telecommunication networks that provide higher capacity and reduced cost for internet, video and advanced digital services. Optical networks provide the full end-to-end wavelength services. Wavelength division multiplexing (WDM) optical networks provide additional capacity on existing fiber. The optical networks employ wavelength division multiplexing, which carries a number of optical carrier signals using different wavelength on a single fiber. It uses multiplexers at the transmitter end and demultiplexers at the receivers end. The transmitter consists of a modulator that generates the optical signal and the receiver consists of photo detector which converts an optical signal to an electrical signal.

Conventional WDM networks can transmit a single line rate, termed as single- line rate (SLR) WDM. But with the growing heterogeneous traffic Mixed-line rate (MLR) technique was investigated to provide different bandwidths using different modulation technique. As shown in the Fig 1, MLR network supports different rates (10/40/100Gbps) on different wavelengths on the same fiber [1].Transmission reaches for 10/40/100 Gb/s are 5000, 2400, and 2700 km, respectively, the transmission reach of 100 Gb/s is larger than 40 Gb/s due to coherent reception and advanced modulation techniques [2]. MLR network has a variety of capacities (10/40/100Gbps) and high bit rate transceivers (viz.40/100Gbps) can exploit the volume discount of transceivers for different traffic demands [3]. Light paths are set up configuring transreceivers between end nodes. Standard traffic is considered here, which fluctuates over time using Poisson random function.

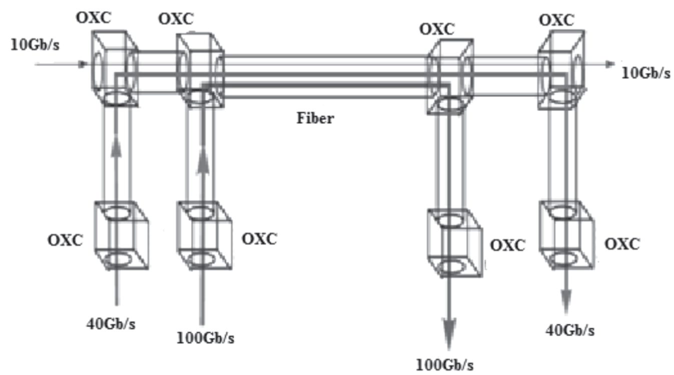

Fig.1 Optical multi-line rate network

In the previous work, static traffic was used for routing in optical networks i.e. traffic matrix was fixed for routing purpose. It means that, there is time invariant traffic matrix and once the lightpaths are setup between the ordered pairs of the end nodes, they will continue to exist for a relatively long period (months/ years). But practically it is not possible, the traffic demands are dynamic and vary with time i.e. lightpaths will be set on demand and when communication is over the corresponding lightpaths are taken down. Basically, WDM optical networks are being deployed not only in wide area networks but also in local area networks and metropolitan area networks and the traffic demands have shown different time domain variations. By considering the dynamic nature of traffic, traffic routing is performed for a long-haul mixed line rate NSF network (shown in Fig 2). High traffic of about 1Tb/s is routed over this standard network. Here, no assumption will be made in future traffic pattern. As the network traffic changes dynamically, so the network traffic is measured periodically and the load on the lightpaths decides the adjustments on the virtual links. These adjustments employ addition or deletion of light paths. Basically a new light path is added or deleted according to the congestion or underutilization of light paths. Our method is simple, efficient and cost effective as compared to previous studies.

The rest of this paper is organized as follows: -

Section-II explains the problem statement; in Section-III main algorithm is explained. Section -IV and Section -V, contains the simulation results and conclusion.

2. PROBLEM STATEMENT

Here the problem and the notations of the proposed algorithm are given. Various factors which are taken into account for the proposed work are also mentioned in this section. We considered a mixed line rate WDM network connected by N nodes and L bidirectional links. Each node is assumed to have T transmitters and R receivers. The number of transmitters and receivers are fixed. As the network is bi-directional, so the signal can be transmitted and received bidirectional. The whole traffic is to be routed on the network. To fulfill this requirement best possible path have been found to route the traffic [4]. Our main objective is to minimize the load on the lightpaths. The network traffic flow will continuously change. Using the traffic demand matrix as a base and using different scale factors of (2, 3, 4, 5, 10, and 20) we generate different traffic loads [5].

An assumption is taken, that each node is equipped with optical-cross connect (OXC) without any wavelength conversion capability. Basically, our approach includes the addition of light paths where congestion occurs and deletion of light paths which are not being used at a particular time. Here a standard traffic matrix is used for dynamic traffic which is to be routed. Every element of the traffic matrix is a continuous function of time representing the traffic rates during one day, rather than a single value [6]. Our main aim is to get better results under dynamic traffic conditions, by keeping the light paths load balanced. In such a problem there arise several issues such as:-

a) Traffic should be continuously monitored.
b) Decision mechanism is needed for every observation period.

Some notations are used in the proposed algorithm:

- N= Total number of nodes in the network.
- L= Total number of links in the network.
- L_n= Total number of light paths per fiber link where n=1, 2&3 (as considering three different rates).
- S= Count of source node.
- D=Count of destination node.
- R_n= different rates in Gbps where n=1, 2&3.
- T_{nx} ,R_{nx} = Total number of transmitter and receivers in the network (count of transmitter and receivers are equal),where n=1,2&3, in accordance with the mixed line rate (R_n) respectively.
- Load=Total traffic offered on a particular path from every source-destination pair.
- LP=total light paths required for routing between every source-destination pair.
- t=time period in hrs that vary from 1 to 24.
- $LP_{(a,b,c)}$=an array of available light paths in which addition of light paths takes place.
- W=weights (distance in km) of the direct link in the given network.
- [Dst1]=represents the array of distance from the node where congestion occurs to all nodes which have free lightpaths.
- $FL_{n,}$ FL_{nr}=array of free and required light paths.
- M= [Ms, d]; traffic demand matrix, represents the traffic in Gbps, between every source-destination pair.

Here routing is done for a specified network topology termed as NSFNET, that consists of 14 nodes with 22 bidirectional links [2].

3. MAIN ALGORITHM

In this section, a new routing algorithm is proposed to solve the above discussed problems. For the given network, the number of light paths is checked and the load on the light path is calculated after every observation period.

Explanation of the main algorithm is shown as follows:-

- Input the rates R_n (n=1, 2&3), used in the network for different traffic demands. Lower limit and upper limit of input rate R1:8-15Gbps, R2:38-45Gbps, R3:98-105Gbps (limits are arbitrarily taken). An assumption is made here that, the input rate have same transparent reach limit (in terms of distance) as for 10/40/100Gbps.
- Input the number of light paths (L_n) per fiber link.
- Enter the network details i.e. *N, L, S, D,* R_n, T_n, R_n, *etc.*
- Enter the weights (*W*) of direct links and traffic demand matrix (*M*) of NSFNET.
- The traffic matrix demands are multiplied by factors 5,8,10 to generate different traffic loads.
- *t=1*
- *while t<=24*
- *M=poissrnd (M)*; generates Poisson random traffic.
- *[distance]=graphshortestpaths(UG,'directed', false);* i.e. find the shortest distance for every source and destination node. Only that distance or paths are considered here which lie in the threshold region.
- Allocate rate (e.g.: 10/40/100Gbps) to the light paths according to the calculated shortest distance between every source-destination pair. Transparent reach limit for input rate R1-5000km, R2-2400km & R3- 2700km.
- *[dist, path]= graphshortestpath(UG, i, j, 'directed', false);*
  Disp (path);
  Find the appropriate path for every source-destination pair in the network, and then calculate the load on each shortest path.
- LP= Load/ Rate (capacity in Gbps); required number of

light paths (LP) for routing between every source-destination pair are calculated for every appropriate path.

- Calculate the total number of light paths used by different rates (e.g.:-10/40/100Gbps) for whole network.
- Generate an array of total number of free (FL_n) and required (FL_{nr}) light paths for whole network.
- Check for the input light paths per fiber link,

  If sum (FL_n) <sum (FL_{nr}); {input light paths (L_n) are insufficient} then

  Show Error

  Else

Calculate the free lightpaths and required light paths for each node pair to perform addition/deletion of light paths.

- Light paths addition/deletion algorithm:-
  1. Calculate distance from required node where congestion occurs to all nodes, which have free lightpaths.
  2. Sort all the distances in ascending order.
  3. While i<=n1 (n1: count of above sorted distances. i : variable that varies from 1 to n1) Take out the first minimum distance, and from this minimum distance node light paths are to be added to the required node.
  4. *[position]=find(Dst1==h);{*h=value of distance from the sorted array of distances}
  5. *Disp ([position]) ;{* displays the position of minimum distance node}.
  6. If [position] contains more than one value, that means that the array have more than one same value of minimum distance. Then, *count=numel ([position]);*{count =counts the number of position which have same minimum distances}
  7. *for i1=1: count* {i1: variable that varies from 1to count}.
  8. *u=*FL_n *([position (i1)])* ;{ u: number of free lightpaths stored in array FL1}.
  9. *disp(u);*

     u=u+FLnr (q);

     now *if u>0*

     lightpaths from the node which have free lightpaths are added to the node where congestion occurs.

     $LP_{(a,b,c)}(q)=LP_{(a,b,c)}(q)-FL1r(q);$addition of light paths.

     {$LP_{a,b,c:}$ contains the list of light paths where light paths are to be added}

     FLn ([position (i1)]) =u; updating the array of free lightpaths.

     break

     Else *if u<0*

     Continue

     LPa (q) =LPa (q) +FL1 ([position (i1)]);

     All light paths at from the node which have free lightpaths are added to the node where congestion occurs.

     FL1 ([position (i1)]) =0; updating the array of free lightpaths.

     i=i+1; Repeat step3 for next minimum distance.
- *t=t+1;*
- *end*

4. SIMULATION RESULTS AND ITS ANALYSIS

Simulation results were run on MATLAB 7 software with Windows 7 operating system. The network topology NSFNET with 14 nodes and 22 bidirectional links which is considered in this paper is shown in Fig. (2). The transparent reach (maximal distance of paths) of rate 10/40/100Gbps is 5000km, 2400km and 2700km respectively [7],[8]. The traffic matrix used for simulation is shown in Table 1. Here all the loads are multiplied 5/8/10 times to generate different loads and the observation period is set to 1hr i.e. 1 adaptation per hour. Fig 3 shows the traffic variations used for simulation purpose. Fig 4 shows the total number of light paths used for routing the traffic. Fig 5 shows the total number of addition/deletion for different traffic demands (5/8/10). Fig 6 (a) &6(b) shows the traffic and comparison between SLR and MLR.

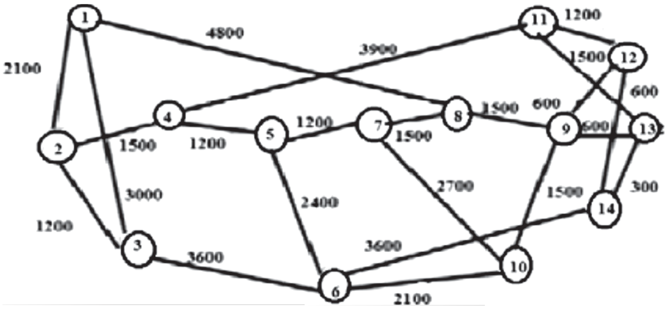

Fig. 2 NSF network (link lengths in km)

Table1. Traffic Matrix for NSFNET (in Gbps)

node	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	2	1	1	1	4	1	1	2	1	1	1	1	1
2	2	0	2	1	8	2	1	5	3	5	1	5	1	4
3	1	2	0	2	3	2	11	20	5	2	1	1	1	2
4	1	1	2	0	1	1	2	1	2	2	1	2	1	2
5	1	8	3	1	0	3	3	7	3	3	1	5	2	5
6	4	2	2	1	3	0	2	1	2	2	1	1	1	2
7	1	1	11	2	3	2	0	9	4	20	1	8	1	4
8	1	5	20	1	7	1	9	0	27	7	2	3	2	4
9	2	3	5	2	3	2	4	27	0	75	2	9	3	1
10	1	5	2	2	3	2	20	7	75	0	1	1	2	1
11	1	1	1	1	1	1	1	2	2	1	0	2	1	61
12	1	5	1	2	5	1	8	3	9	1	2	0	1	81
13	1	1	1	1	2	1	1	2	3	2	1	1	0	2
14	1	4	2	2	5	2	4	4	1	1	61	81	2	0

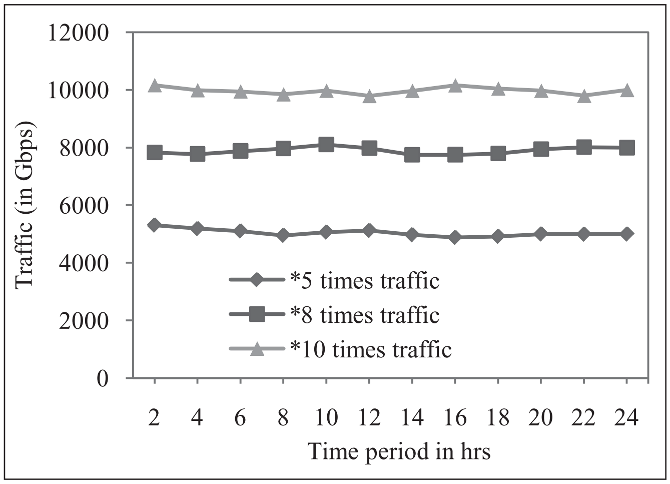

Fig. 3 Traffic variations for 24 hour period in Gbps

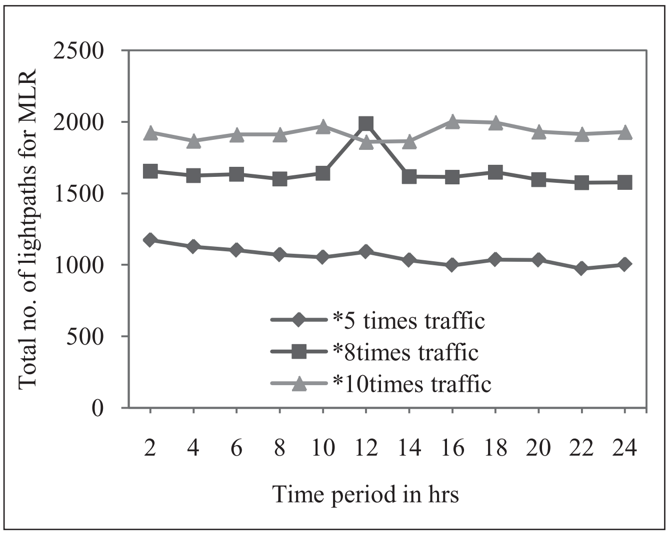

Fig. 4 Total number of lightpaths for MLR network

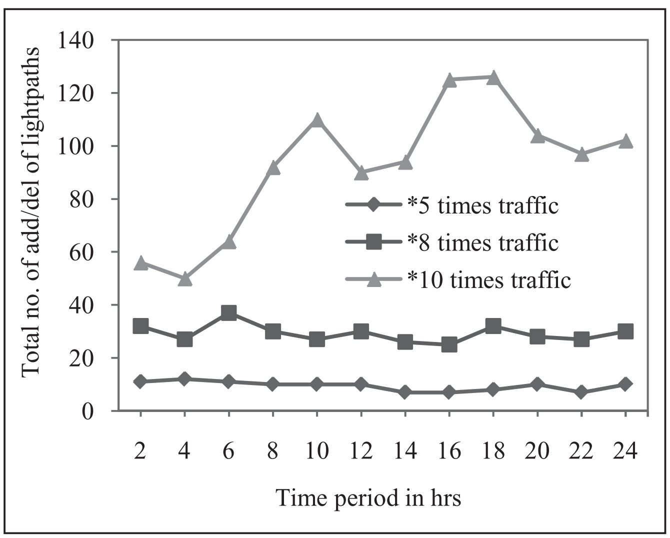

Fig. 5 Total number of addition/ deletion of lightpaths

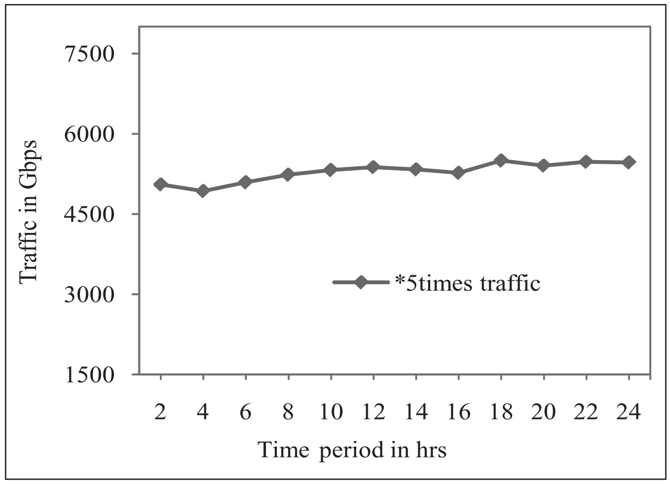

Fig. 6(a) Traffic variation used for comparison between SLR and MLR

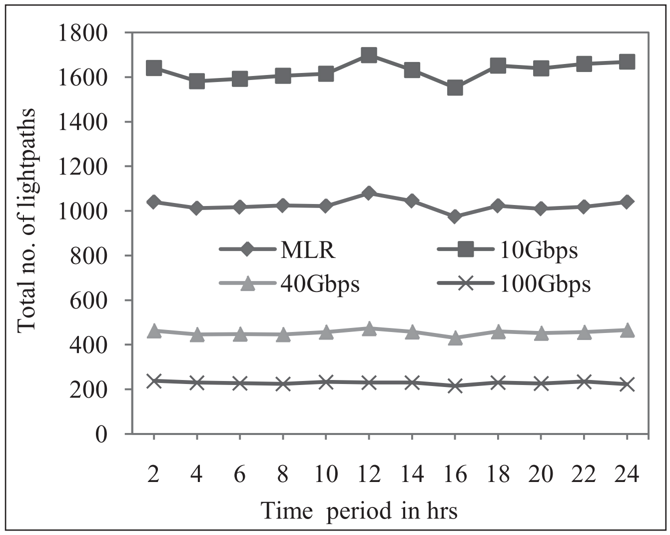

Fig. 6(b) Comparison between SLR and MLR case

5. CONCLUSION

In this paper a new routing algorithm is presented for Mixed Line Rate optical WDM networks under dynamic traffic demand. Basically the work is based on the routing of the traffic which dynamically changes during 24 hours. So an algorithm is developed for stabilization of traffic over the network. It is believed that the work presents the simplest solution for the problem mentioned above. From the above results we conclude that proposed approach works well for any other network and traffic pattern. Specifically, it is found that MLR WDM network is well suited for dynamically changing traffic as compare to SLR WDM networks

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