Performance Analysis of Mixed Line Rate Optical WDM Networks under Link Failure

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Abstract- *Due to heterogeneous traffic in next generation Mixed Line Rate (MLR) networks are capable of delivering different bandwidth in a flexible manner. In this paper a simple routing algorithm is proposed to study the case of any link failure in MLR WDM networks. Here Poisson random traffic is used as a dynamic traffic for 24-hour duration. The proposed work can be achieved by deleting the failed link and then finding the new best possible shortest path between source and destination node. According to the traffic load light paths adjustments employ the addition of light paths under congestion and deletion of lightpaths which are not being used at a particular time. Simulation result shows the total number of lightpaths used, total number of addition and deletion of light paths under link safe and link failure case in mixed line rate (MLR) and single line rate (SLR) optical WDM networks.*

Keywords- lightpaths, mixed-line rate (MLR), dynamic traffic, WDM, Poisson traffic.

I. INTRODUCTION

Now a days optical network are widely used due to their capacity, reduced cost and variety of services. Communication demand is increasing day-by-day, as communication can be done via:- internet, calls etc. it means that the number of users surfing internet etc. are increasing day-by-day. Therefore, due to continuous increasing demand we can think about the high heterogeneous traffic in next-generation. Mixed line rate (MLR) concept is introduced to handle the heterogeneous traffic demand. Mixed line rate (MLR) optical WDM networks provide different bandwidth by using different modulation techniques.

Wavelength routed networks provide lightpaths to its users, where lightpaths are the optical connection between source and destination node on each intermediate link. The lightpaths are routed and switched from one link to another link between each intermediate node. These lightpaths carry data in the form of encoded optical signals. In the wavelength routed network no two lightpaths may use the same wavelength, if they share any fiber link [1]. MLR supports different rates (e.g.:- 10/40/100) Gbps on different wavelengths on same fiber. The transmission reaches for 10/40/100Gbps are 5000, 2400 and 2700km respectively, the transmission reach of 100Gbps is larger than 40Gbps due to coherent reception and advanced modulation techniques [2]. Without any wavelength converter data signals are a carried on a unique wavelength form source to destination node. So, there is an essential requirement that the network must be fully fault tolerant, because a single failure in the network can cause a big loss. There must be spare capacity in the network to make it fully fault tolerant. There are two main restoration strategies :- a) Link Restoration. b) Path Restoration.

In Link Restoration, the broken traffic is rerouted between the end nodes of the failed link while in Path Restoration the origin destination node pair are responsible for restoration and reroute the traffic over the entire path [3].

Here traffic routing is done for 24-hour duration under any link failure. Poisson dynamic traffic is considered here, which fluctuates over time. As the network traffic changes dynamically, so the traffic is measured periodically. Lightpaths load balancing decides the stability of lightpaths. A lightpath is said to be stable if the load is balanced i.e. there should be no congestion or underutilization of lightpaths. Basically, lightpath adjustments employ addition of lightpaths where congestion occurs and deletion of lightpaths which are not being used at a particular time. Our method is simple, efficient and cost effective as compared with previous studies.

The rest of this paper is organized as follows:-

Section-II explains main algorithm, Section-III and Section-IV contains the simulation results and conclusion.

II. MAIN ALGORITHM

In this section a new routing algorithm is explained to deal under any link fail in the network.

A. Assumptions:-

Each node in the network is equipped with OXC switch, without any wavelength converter. Signal can be transmitted and received bidirectional. Each fiber has fixed number of wavelengths (WL). Three different rates are input by the user for different traffic demands. Lower and upper limit of the input rate are arbitrarily taken. The input rates have same transparent reach (in terms of distance) as for 10/40/100Gbps.The number of transmitter and receiver of each node of WDM network are fixed and known.

B. Notations:-

- N= Total number of nodes in the network.
- L=Total number of links in the network.
- L_n=Total number of lightpaths per fiber link, where n=1, 2&3 (as considering three different rates).
- S=Count of source node in the given network.
- D=Count of destination node in the given network.
- R_n=different rates in Gbps, where n=1,2&3.
- WL= set of wavelengths used by a single fiber.
- T_{xn},R_{xn}= Total number of transmitters and receivers in the network (count of transmitters and receivers are equal), where n=1,2&3, in accordance with the mixed line rate (R_n) respectively.
- S_{fail}= Source node of failed link in the given network.
- D_{fail}=Destination node of failed link in the given network.
- Load=Total traffic (in Gbps) offered on a particular path from every source - destination pair.
- LP=total lightpaths 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 lightpaths in which addition of lightpaths takes place.
- W= Weights (distance in km) of direct link in the given network.
- [Dst]= represents the array of distance (in km) from the node where congestion occurs to all nodes which have free lightpaths.
- FL_n, FL_{nr}= array of free lightpaths and required lightpaths.
- SR_n=array of the required node where congestion occurs.
- S_n=array of the source node of free lightpaths.
- M=[$M_{s,d}$]=traffic demand matrix, represents the traffic in Gbps, between every source- destination pair.

C. Basic idea:-

In this, a new routing algorithm is proposed for any link break or fault for MLR-WDM networks.

As the network traffic is changing dynamically for 24-hour period. The traffic should be continuously monitored and decision mechanism is needed for every observation period. At first the shortest paths is computed for every source-destination pair of the network by using the proposed algorithm. If there is any link break or any link fault is found then that shortest path is dropped and the faulty link is removed from the network. Then, second shortest path is found for the faulty source-destination path. The distance for a lightpath is calculated and checked after every observation period. The distance should be less than or equal to the threshold distance (e.g.:-for 10/40/100Gbps, distance is 5000km, 2400km, 2700km). Check the traffic load after every observation period. New lightpaths are setup where congestion occurs and tear down the lightpaths when they are not used efficiently.

D. *Algorithm:-*

The detail of the proposed algorithm is shown as follows:-

1. Input the rates R_n(n=1,2&3) used in the network. Lower and upper limit of input rate R1:8-15Gbps, R2:38-105Gbps, R3:98-105Gbps (limits are arbitrarily taken).
2. Input the number of lightpaths (L_n, n=1, 2&3) taken for each node in the network.
3. Input the source node (S_{fail}) and destination node (D_{fail}) of failed link in the network [maximum 3 and minimum 0 failed source to destination link can be entered].
4. Enter the network details i.e. N, L, D, S, R_{xn}, T_{xn}, W, M etc.
5. Entered traffic demand matrix is multiplied by factor 5, to generate different traffic load. The traffic demand matrix can be multiplied by various factors 2/5/8/10 to generate different traffic loads.
6. *t=1*
7. *if* S_{fail}~=0&& D_{fail}~=0
   $S_{fail}(xf)$=[ ]
   $D_{fail}(xf)$=[ ]
   xf:- variable that represents the position of the failed source and failed destination link in the array 'S' and 'D'.
   {delete that source to destination link from the array 'S' and 'D' , which represents the direct links in the network}.
8. *[dist,path]=graphshortestpath(UG,S_{fail},D_{fail},'directed', false);* code that find the second shortest path and second shortest distance between failed source and destination link to route the traffic in the network.
9. Check the second shortest path and update the traffic matrix accordingly, i.e.
   $M(S_{fail}, D_{fail})$==0

M(x,y)=c; where x,y:-variable that point out the new links (source and destination) of the new shortest path in the network.
c:-traffic offered by faulty link whose source and destination node are S_{fail}, D_{fail}.
end

10. *[distance]=graphallshortestpaths(UG, 'directed' ,false);* code that finds the shortest distance for every source to destination pair. Distances which lie in the threshold region are considered here.
11. *While t<=24*
12. According to the calculated shortest distance for every source-destination pair, allocate rates to the lightpaths (e.g.-10/40/100Gbps).
13. *[dist,path]=graphshortestpath(UG ,i ,j, 'directed', false);* code that finds the shortest path for every source –destination pair in the network.
14. Calculate the total load offered on that appropriate shortest path using the traffic demand matrix of the network.
15. LP=Load/R_n; total lightpaths required for routing are calculated for every source-destination pair in the network.
16. Calculate the total number of lightpaths used by the three different rates (R_1, R_2, R_3) for the whole network at every observation period.
17. Generate an array of free lightpaths (FL_n), required number of lightpaths (FL_{nr}), required number of nodes where congestion occurs (SR_n).
18. Check for the input lightpaths per fiber link for different rates (R_1, R_2, R_3), that means that the input lightpaths are sufficient or not for routing in the network.
    If sum(FL_n)<sum(FLnr); it means that the input lightpaths are insufficient for routing then
    Show ERROR.
    Else
    Lightpaths are sufficient; continue the next algorithm for addition/deletion of lightpaths.
19. *Lightpaths addition/deletion algorithm:-*
    a) *for q=1:SR_{nc}*
       for m=1:S_{nc} ; where SR_{nc}: count of the required source node where congestion occurs.
       S_{nc}: count of the source node having free lightpaths.
       q, m: variables that varies from 1 to SR_{nc} and S_{nc}.
    b) Calculate the distance from required node where congestion occurs to all source nodes having free lightpaths and form an array (Dst).
    c) Sort all the distances in ascending order and form an array (Dst_n).
    d) *While i<=n1*
       Where n1: count of above sorted distances
       i: variable that varies from 1 to n1.
    e) *[position]=find(Dst==h)*
       Where h: distance value from the above sorted array of distances.
       Code that finds the position of the sorted distance in the array (Dst).
    f) *Count =numel([position]);*
       calculates the number of position which have same minimum distances.
    g) *For i1=1:count;*
       u=FL_n([position (i1)])
       where i1: variable that varies from 1 to count.
       u: contains the number of free lightpaths stored in the array FL_n.
    h) *u=u+FL_{nr}(q)* ; free lightpaths from the array (FL_n) are stored in 'u' and added to the required node where congestion occurs.
    i) *If u>=0*
       *$LP_{(a,b,c)}(q)=LP_{(a,b,c)}(q)-FL_{nr}(q)$;*lightpaths from the array of free lightpaths are added to the array of lightpaths, where addition is to be done.
       $FL_{nr}(q)=0$; array of required number of lightpaths is updated , as the requirement of lightpaths is fulfilled.
       FL_n([position(i1)])=u; updating the array of free lightpaths.
    j) *Else if u<0*
       $LP_{(a,b,c)}(q)=LP_{(a,b,c)}(q)+FL_n$([position(i1)]);
       All the lightpaths from the array of free lightpaths (FL_n) are added to the node where lightpaths are required.
       $FL_{nr}(q)=FL_{nr}(q)+FL_n$([position (i1)])
       FL_n([position(i1)])=0;
       Updating the array of free and required lightpaths.
       End
       i=i+1;
       end

end

20. *M=poissrnd(M);* code that generates Poisson random traffic .
21. *t=t+1;*
    end

III. SIMULATION RESULTS AND DISCUSSION

Simulation results were run on MATLAB7.0 software with Windows operating system. The famous NSF network topology NSFNET with 14 nodes and 22 bidirectional links is considered in this paper. Here the results are shown for rates R_1=10Gbps, R_2=40Gbps, R_3=100Gbps. The transparent reach (maximal distance of paths) of rate 10/40/100Gbps is 5000km, 2400km, 2700km respectively [5]. The algorithm shown above is implemented here.

The simulation results are shown for a link failure network as well as no link fail in the network. In the simulation results all traffic loads are multiplied 5 times. The observation period is set to 1hr i.e. 1adaptation per hour. Networks are characterized by logical network topology and physical lengths of the cable ducts. The NSF-network used in this paper is shown in Fig.1. The traffic demand matrix of NSFNET is shown in Table(1). The traffic matrix shown sums to total traffic of 1Tbps.

The results of traffic variations used for simulation purpose are shown in Fig.(2). The results of traffic variations shown that if there is any link failure in the network and that failed link traffic is routed by another link then the network traffic load will increase. Fig.(3) shows the total number of lightpaths obtained to route the traffic in the network under normal and faulty condition. Fig.(4) shows the total number of addition/deletion of lightpaths. The number of addition/deletion of lightpaths shows that congestion on the number of nodes increases after any link failure in the network. Fig.(5) shows the total number of nodes in the network where addition/deletion of lightpaths takes place for 24-hour duration. Fig.(6), (7) shows the total number of lightpaths under single line rate of 10Gbps and 40Gbps .

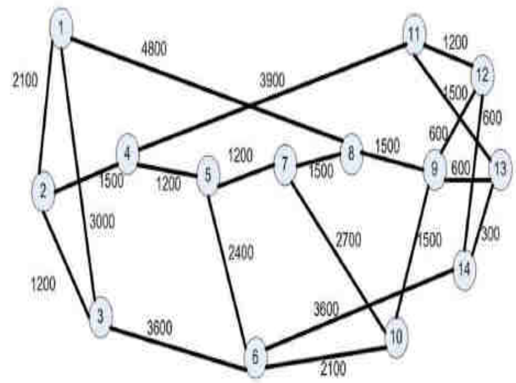

Fig.1: NSF network (link lengths in km)

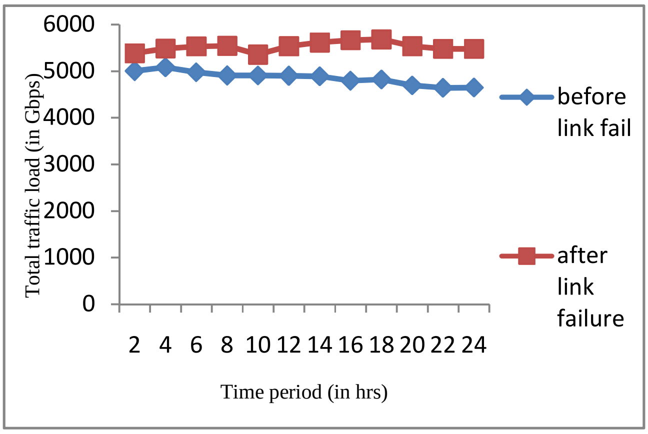

Fig.2: Traffic variations (in Gbps) for 24-hrs period

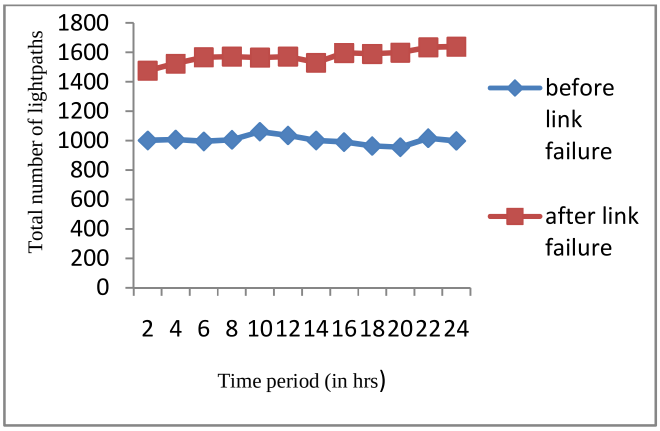

Fig.3: Total number of lightpaths for MLR

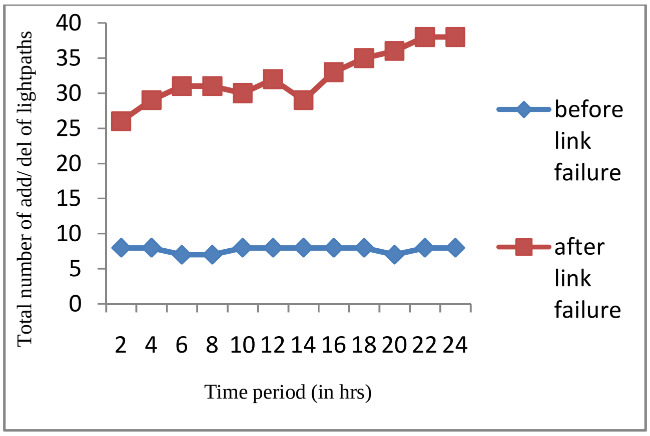

Fig.4: Total number of addition/deletion of lightpaths under dynamic traffic for MLR

Table1. Traffic matrix demand 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

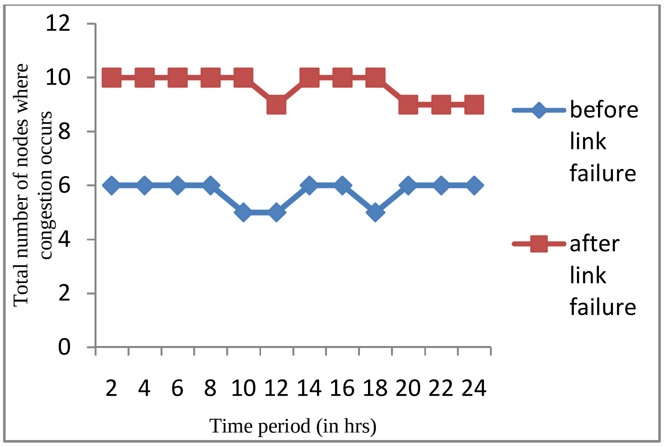

Fig.5: Total number of nodes where congestion occurs for MLR

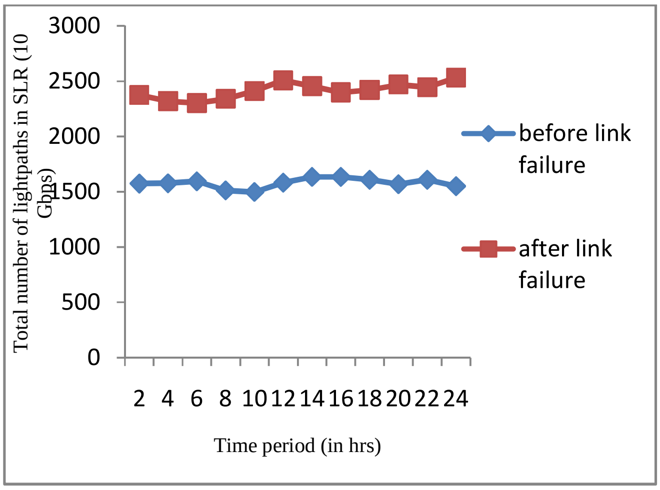

Fig.6: Total number of lightpaths for SLR of 10Gbps

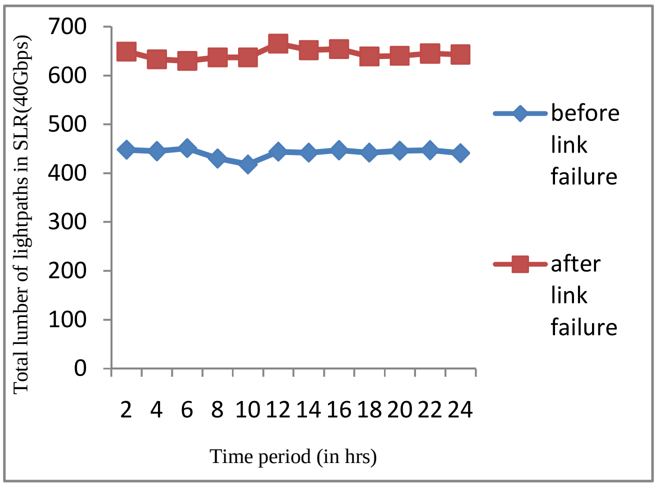

Fig.7: Total number of lightpaths for SLR of 40Gbps

IV. CONCLUSION

In this paper new, simple routing algorithm is presented under dynamic traffic demand. Basically the work is based on the traffic which dynamically changes during 24 hours. So an algorithm is presented for stabilization of traffic demands over the network. It is believed that the work presents the simplest algorithm to study the case of link failure in the network. Variations in the algorithms can also include the addition and deletion of light paths before and after link failure in the network at each step. The proposed approach works well for any other network and traffic demand. A future extension can include the use of regenerator where the shortest distance is beyond the threshold distance. The link failure in the network causes the delay and a big disaster in the network so prior indication of faulty links and nodes is required. Specifically, it is found that MLR WDM network is well suited for dynamically changing traffic.

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