Blocking Parameter Driven Virtual Topology Reconfiguration for IP-Over-WDM Networks with QoS Parameters

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ABSTRACT

Internet Protocol (IP) over Wavelength Division Multiplexed (WDM) networking technology with Terabits per second bandwidth become a natural choice for the future generation internet networks (Optical Internets),wide area network (WAN) environments and backbone networks due to its potential ability to meet rising demands of high bandwidth and low latency communication. Recently Virtual Topology Reconfiguration of IP over WDM networks has received greater attention among researchers. In this paper, we have presented a new approach for reconfiguring virtual topology of IP over WDM networks driven by blocking parameter with Quality of Service (QoS) requirements. The simulation results show that this new approach achieves better QoS performance in terms of blocking probability, throughput and latency.

Keywords : Blocking Probability, Lightpaths, Logical Topology, Virtual Topology Reconfiguration, QoS.

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1. INTRODUCTION

In the last decade, WDM Optical fiber networking technologies brought a revolution in high-speed communication networks, which are now able to meet the high bandwidth demands of current voice and data traffic. The demand for bandwidth is growing at a rapid pace, and the Internet data traffic is expected to dominate voice traffic in the near future. With the IP playing a dominant role in wide area networking technology and advancements in wavelength routed WDM technology to provide enormous bandwidth, the IP over WDM networks [1] become the right choice for the next generation Internet networks.

The physical topology [2] consists of optical WDM routers interconnected by point-to-point fiber links and nodes in an arbitrary topology. In these types of networks, data transfer carried from one node to another node using lightpaths. A lightpath [3] is an all-optical path established between two nodes in the network by the allocation of same wavelength on all links of the path. In IP over WDM networks, lightpaths are established between IP routers.

A virtual topology [4] is a set of pre-established lightpaths established to provide all optical connectivity between nodes for a given traffic demand. The virtual topology is established logically through lightpaths, each identified by an independent wavelength, which provides end-to-end connectivity for transmission over the optical medium. The embedding of virtual topology over a physical topology results in minimizing the number of nodes that were actively involved in network transmission.

The virtual topology designed initially for a particular traffic may not be optimal for the changing traffic. The virtual topology designed over IP may need to be changed in response to changing traffic demands or due to failure of network elements. This process of changing the current virtual topology to a new one to adapt the dynamic change of traffic or failure of network elements is called Virtual Topology Reconfiguration [4].

Reconfiguration [5] is one of the significant characteristics of WDM optical network. The reconfiguration [6] is achieved by the fact that WDM optical networks provide an architecture in which logical connections can be embedded over the underlying physical connections. Reconfiguration [7] can be viewed as a process for providing a tradeoff between the objective function value and the number of changes to the current virtual topology. The objective function value decides how best the topology is suited for the changed traffic demand. Since the VTR problem is computationally intractable, heuristic solutions are desired to yield near optimal solution. There are two different approaches [8] of virtual topology reconfiguration to handle the dynamic traffic. In the first method, a new virtual topology is designed for each change in traffic. In the second method, reconfiguration is done with the objective of minimizing the objective function value and the number of light path changes.

This paper is organized as follows. A survey of the related work available in the literature is made in the section 2. Section 3 describes our proposed work including the QoS parameters. In section.4, the traffic model is described and section 5 and 6 present the heuristic algorithm and simulation results respectively. Finally, section 7 concludes the paper.

2. Related Work

Many researchers have extensively studied about optical network and its reconfiguration problem for WDM network. Virtual topology design problem for WDM mesh network with the objective of minimizing average packet delay is given [1]. Linear programming methods for Virtual topology design problem with the objective of minimizing network congestion is proposed [2] [3]. Linear programming for the virtual topology design problem becomes computationally intractable; therefore heuristic approaches are made use of. Wavelength continuity constraint for the virtual topology design problem has been considered [2], i.e. it is assumed that nodes are not equipped with wavelength converters. Therefore it becomes necessary that a light path use the same wavelength on all the physical links. An extensive survey of virtual topology design algorithms has been carried out [4]. Linear programming and heuristic methods for different topologies are described and compared. Routing and wavelength problem and reconfiguration of virtual topology have also been dealt with. The combined problem of physical topology and virtual topology design has been taken up [5] using genetic algorithm.

There are many research work previously done in the reconfiguration of WDM networks. Reconfiguration of virtual topology for dynamic traffic is carried out with the aim of minimizing one or more objective functions, in order to maximize resource utilization. An integer linear programming method and resource budget for virtual topology reconfiguration problem with the objective of minimizing average hop distance has been proposed [6].

The authors also discuss on reconfiguration aimed at minimizing the number of lightpath changes for a mesh network. The dynamic reconfiguration for optical networks with tradeoff between optimality of the network and network disruption is described in [7]. The reconfiguration problem for wireless optical network is described in [8]. An adaptive mechanism without prior knowledge of the future traffic pattern is proposed [9]. Here the authors consider a slowly varying traffic pattern and consider addition or deletion of one lightpath at a time. A higher and lower watermark level is used to find when to reconfigure the network by adding or deleting the lightpaths.

A two-stage approach of reconfiguration with objective of minimizing average weighted hop count with a tradeoff between the objective function value and the number of changes to the virtual topology is considered [10]. The first stage is reconfiguration stage and the second stage is an optimization stage, which reduces the deviation from the optimal objective function value. Integrated services, differentiated services and multi protocol label switching (MPLS) have been discussed and the various possible service classes are also detailed. In differentiated services, packets are marked differently based on the service requirements. Constraint based routing enables determination of routes based on constraints like bandwidth or delay.

The dynamic reconfiguration problem with priority based addition and deletion of light path was presented in [11]. The QoS aware routing and trafficgrooming problem was described in [12]. The dynamic reconfiguration [13] of virtual topology requires a lot of control overhead and results in network disruption. In the present day WDM networks, a typical reconfiguration process in the order of tens of milliseconds corresponds to tens of megabits of traffic that must be buffered or rerouted at each node that is being reconfigured. If this disruption is not taken care properly, it will result in severe congestion and heavy data loss in the network as the traffic on the light paths is order of gigabits per second. The traffic generated belongs to various QoS classes and the service requirement for each QoS class is different. Hence the QoS parameters for the changing traffic to be taken into consideration while reconfiguring the virtual topology for an IP over WDM network.

3. Proposed Work

In the literature, simple reconfiguration algorithms were given for optical network [7],[8] without considering QoS parameters. The VTR algorithms [4], [10], [11] available are yielding minimum congestion. These all affect the performance of the IP-over-WDM networks, in particular Quality of Service (QoS) [12][13]. In this paper, reconfiguration algorithm for IP/WDM network driven by blocking parameter under dynamically changing traffic is proposed with QoS parameters namely, minimum delay, minimum blocking probability and maximum throughput.

3.1. Problem Statement

The reconfiguration of virtual topology for optical network using IP over WDM technology is usually handled by modeling it as a Mixed Integer Linear Programming [13] or optimization problem which minimizes the objective function such as Average Weighted Hop Count of the Virtual Topology (AWHT), Congestion, number of lightpath changes, etc. There is a trade off between problem objectives and QoS parameters like, Blocking probability, Throughput, Delay, etc. In our research work we propose a new heuristic of blocking parameter driven reconfiguration of virtual topology for IP over WDM networks for dynamic traffic changes considering QoS parameters stated above. In this paper, the VTR problem is formulated as an optimization problem of minimizing network congestion with improvising QoS. The total traffic on the virtual link from node i to j is given by,

$$T_{i,j} = \Sigma_{s,d}\, T_{i,j}^{s,d} \qquad \text{-------- (1)}$$

where $Ti,j^{s,d}$ gives the traffic from node s to d that employs the virtual link i to j. Congestion is defined as the maximum traffic flow in a light path due to all source destination node pairs and is given by,

$$T_{max} = \max_{i,j} T_{i,j} \qquad \text{-------- (2)}$$

3.2. Network Model

We consider a network [6] of N nodes connected by bi-directional optical links forming an arbitrary physical topology. Each optical link supports w wavelengths, and each node is assumed to have T transmitters and R receivers. We assume that each node is equipped with an optical cross connect (OXC) with full wavelength conversion capability, so that a lightpath can be established between any node pair if resources are available along the path. Each OXC is connected to an edge device like an IP router, which can be a source, or a destination of packet traffic and which can provide routing for multi hop traffic passing by that node. Our network model considers network with an initial traffic matrix and reconfiguration decisions are based on traffic changes whenever such changes are necessary.

3.3. Traffic Model

The traffic models used for simulation of the VTR algorithm for IP over WDM network are:

i. independent and identically distributed (i.i.d.) traffic model

ii. traffic cluster model

The independent and identically distributed (i.i.d) traffic model is taken to arrive QoS parameters. The i.i.d traffic model assumes uniform distribution between 0 and a maximum traffic density.

3.4. Notations

The following are the notations used in the problem formulation and in the algorithm.

i,j : end nodes

sd: source-destination pair

3.5. Parameters

Listed below are the parameters used in the problem.

i. Number of nodes in the network = N

ii. Number of wavelengths per fiber = w

iii. Capacity of each wavelength channel = C bps

iv. Number of transceivers per node = R

v. Average Weighted Hop count =$AWHT$

3.6. QoS Parameters

The QoS parameters considered in this research work are blocking probability message delay and throughput. These parameters are defined as follows.

i. *Blocking Probability (B)*:

Blocking probability of a network at a particular instant of time is defined as the ratio of number of traffic calls blocked to the total number of traffic requests.

ii. *Message Delay (D)*:

Message delay in a network at a particular instant of time is defined as the average delay incurred for a message to travel from a source node to destination node.

iii. *Throughput* (τ):

Throughput of a network is defined as the ratio of number of packets received at the destination node to the number of packets transmitted from the source node.

The assumptions made for the calculation of blocking probability are as follows.

i. The packet arrivals are uniform and Poisson distributed at a rate of λ

ii. The packet inter-arrival times are exponentially distributed

iii. Blocked calls are cleared

The Erlang loss formula [14] is given by,

$$B = B_R + \frac{\frac{A^C}{C!}}{1 + A + \frac{A^2}{2!} + K + \frac{A^C}{C!}} \quad \text{------- (3)}$$

which gives the ***blocking probability(B)*** for the IP over WDM network, where A is the traffic load (λ/μ) in erlangs, B_R is the blocking probability due to reconfiguration and C is the channel capacity of one wavelength.

The ***throughput*** (τ) of the network is estimated by the formula given by,

$$Throughput = \frac{No.\ of\ packets\ received}{No.\ of\ packets\ sent} \quad \text{----- (4)}$$

The ***latency*** (***D***) of the network is delay incurred by the data packet from a source node to a destination node and is given by,

$$Latency = D_q + D_p + D_t + D_r \quad \text{-------- (5)}$$

where,

D_q: Queuing delay =

$$\sum_{ij} \sum_{sd} T_{ij}^{sd} \frac{1}{\left(C - \sum_{sd} T_{ij}^{sd}\right)} \quad \text{-------- (6)}$$

where, T_{ij}^{sd} is the traffic demand between a source destination pair using the link ij.

D_p: Propagation delay = $\sum_{ij} T_{ij}^{sd} d_{ij} p_{ij}$ -------- (7)

where, d_{ij} is the distance between physical i and j p_{ij} is the physical link between end points i and j.

D_t: Transmission delay = $\frac{packet\ length\ l}{channel\ bit\ rate\ r}$ --- (8)

Dr: Processing delay = $\frac{1}{\left(\Re - \left(T_{sd} + X_i\right)\right)}$ --(9)

where, $\Re$ - processing capability of router in Mbps T_{sd} is the traffic demand between a sd pair X_i is the sum of traffic routed by router i except the traffic originating at the node i., and is given by,

$$X_i = \left[\sum_j T_{ji} + \sum_j T_{ij} + \sum_j T_{sd} \beta_{ij}^{sd}\right] - Tij \quad \text{---(10)}$$

where β - binary variable for lightpath existence

4. Heuristic Algorithms

In this section, a heuristic algorithm for blocking parameter driven Virtual Topology Reconfiguration (VTR) considering QoS parameters is presented.

4.1 VTR Algorithm with QoS

Input: Physical Topology; Current Virtual Topology, Traffic Demands,

Output: Reconfigured Virtual Topology

Algorithm:

for all sd pairs

compute : $WHT=T_{sd}*H_{sd}$;

end for

sort sd pairs in non-increasing WHTs

for all sd pairs

compute shortest paths using allpair shortest path algorithm

if no lightpath exists

if free wavelength available

if free transceiver available

establish lightpaths

else lightpaths deletion:

find different set of lightpaths to be deleted

sort lightpaths in non-decreasing order of load

delete the first lightpath in the set

establish lightpaths

if the topology is connected then break;

else continue

compute B for the new topology

if $(B_{new} < B_{th})$

if $(N_{ch} < N_{th})$ *include the new topology in to VT set*

else discard the new topology

end for

select the VT with min B

5. Results And Discussion

The heuristic algorithm for VTR is implemented for an IP/WDM network having 14 nodes with NSFNET topology [15][16] shown in fig 1. The data structures required for simulating this algorithm were written using Java [17]. The performance of the algorithm is measured for the dynamic traffic with the parameters shown in fig 2.

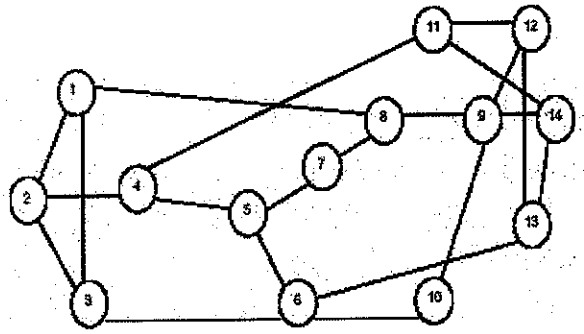

Figure 1 : NSF Network with 14 nodes

> **Parameters:**
>
> i. Number of nodes, N=14
>
> ii. Number of wavelengths per link, w =10
>
> iii. Capacity of each wavelength = 1 unit
>
> iv. Packet size = 512 bits
>
> v. Channel bit rate = 1Gbps
>
> vi. Propagation delay = 1 μS
>
> vii. Distance between nodes = 1 unit

Figure 2 : NSF Network Parameters Used for Simulation

The Average Weighted Hop Count measured by varying % of change in traffic for dynamic network with i.i.d traffic model is plotted in the fig. 3. From this graph, it is observed that the AWHT is minimal compared to the two-stage reconfiguration approach given in [10]. The reduction in AWHT is due to the optimal path found by the RWA algorithm, which is described in detail in [18]. The blocking probability measured for different virtual

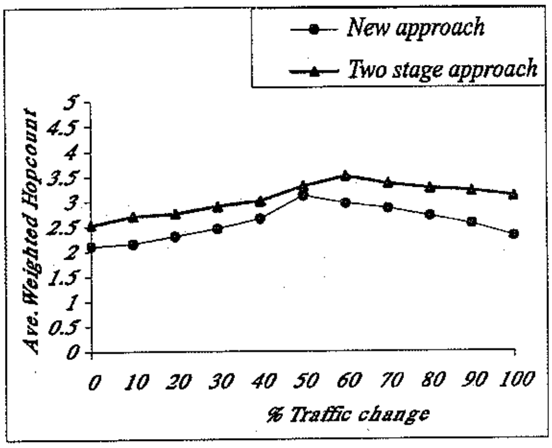

Figure 3 : AWHT Vs % Traffic Change

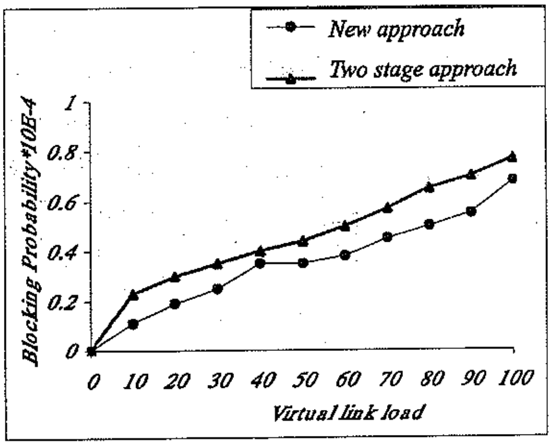

Figure 4 : Blocking Probability Vs Virtual Link Load

load of the dynamic network for i.i.d traffic model is plotted in the fig. 4. From this graph, it is observed that the blocking probability is much less than that of two-stage approach.

The network throughput measured for different virtual load of the dynamic network for i.i.d traffic model is plotted in the fig. 5. From this graph, it is observed that the network throughput is maximal for the new heuristic approach till the virtual link load is 50. After that a slight decrease in throughput and reaches a steady state value at the load value of 100.But for the same case, the existing approach has network throughput, which is much less than that for new approach. Thus the throughput of the proposed VTR heuristic for the i.i.d. traffic model is significantly better than that of the existing approach.

The network latency measured by varying % of change in traffic for dynamic network with i.i.d traffic model is plotted in the fig. 6.

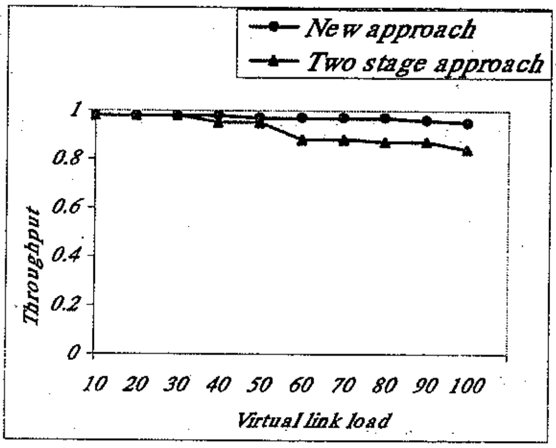

Figure 5 : Throughput Vs Virtual Link Load

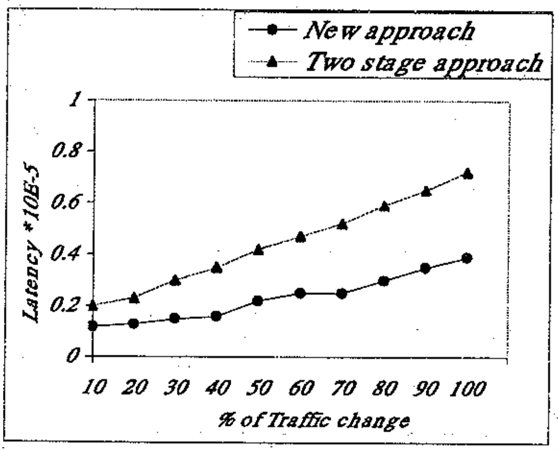

Figure 6 : Latency Vs % Traffic Change

From the above graphs, it is observed that the AWHT is minimal, blocking probability is minimal, network throughput is maximal and network latency is minimal, compared to the two-stage approach given in [10].

6. Conclusion

In this paper, it is proposed an algorithm for Blocking Parameter driven VTR algorithm with considering QoS parameters for IP over WDM optical networks with i.i.d. traffic model. The proposed heuristic approach was validated using simulation. The simulation results show that the new approach achieves better QoS in terms of blocking probability; throughput and latency for i.i.d. traffic model for dynamic IP over WDM networks, compared to the existing two stage approach [10]. The future work includes devising VTR algorithms for distributed GMPLS networks with TE/QoS and implementing the algorithms for the above stated GMPLS networks using GLASS [19] [20].

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