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QoS provisioning by novel parallel LSP based routing/signaling protocol in GMPLS network

Anshu Oberoi [a,*], J.S. Sohal [b], R.S. Kaler [c]

[a] Kanya Maha Vidyalaya, Jalandhar, India
[b] Ludhiana College of Engineering and Technology, Ludhiana, Punjab, India
[c] Thapar University, Patiala, Punjab, India

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ABSTRACT

In this paper, we have developed the new algorithm based on parallel Label Switched Path (LSP) generation using a quantized threshold for reducing the blocking probability by efficiently using the available WDM network resources on the basis of weighted routing/signaling. We suggested three different models with various levels of wavelength conversion at IP/MPLS router for implementing the algorithm. We proposed the measure of reservation factors for the quantized parallel λLSP for each model. The reservation factor ratio comparative graph shows the effectiveness of the algorithm. Further the QoS routing for the purposed algorithm by measuring blocking probability of each model and the effect of o-e-o conversion is investigated against the fixed model. The improvement has been shown over the existing models.

1. Introduction

WDM is conceptually similar to frequency division multiplexing (FDM), in which multiple information signals each corresponding to a different end user, modulate optical signals at different wavelengths [1]. With IP remaining the internet backbone of high-capacity networks the next generation networks are IP-over-WDM. Application of WDM technology has introduced the optical layer between the lower physical link layer and upper client layer [2].

Multi Protocol Label Switching (MPLS) [3] was proposed as the integrating structure between IP and optical layers. Besides having a strong potential for traffic engineering options it also maps naturally with WDM if labels become the wavelengths. Later extensions [4] of the MPLS have been proposed with differentiated services and constraint based routing for IP/WDM integration. This is called the Multi-Protocol Lambda Switching (MPλS) now evolving to Generalized MPLS (GMPLS) which equates wavelengths to labels with QoS capabilities providing the pathway for a better multiservice network [3]. GMPLS consists of three main aspects: routing, signaling, and link management [4]. There are many sub-problems involved in the performance optimization of operational GMPLS networks. Three of the most significant problems include: (1) constraint-based routing, (2) traffic partitioning and assignment, and (3) restoration [5].

In the absence of effective control over traffic routing, any aspiration toward IP/WDM network performance optimization and quality of service (QoS) provisioning is likely to remain elusive. The goal of traffic engineering in the IP/MPLS layer is to reduce the blocking due to lack of wavelength channel availability.

Zhang [6] proposed advanced wavelength assignment heuristics for routing which rely on complete network state information. It is assumed in these heuristics that the set of possible future lightpath connections is known in advance. Zang et al. [7] showed improvements by special heuristics such as first-fit, least-used, or most-used assignment in terms of blocking probability. Kodialam [8] considered integrated routing of bandwidth-guaranteed paths in integrated IP/WDM networks. Routing of bandwidth-guaranteed paths has earlier been considered for IP–MPLS networks in [9].

Chen [10] discussed wavelength routing and assignment algorithm for optical networks with focus on maximizing the wavelength utilization at the switches. Gençata [11] suggested an on-line virtual-topology adaptation approach. Wason [12] proposed wavelength rerouting is a viable and cost-effective mechanism which can improve blocking performance. Anjali [13] discussed similar improvement on utilization of wavelength channels by establishing the threshold based lambda LSPs.

All the above studies focused on no wavelength conversion network model and designed the network off-line with a given traffic matrix for the network. Also the approaches are concerned only with the optical network and does not relate to dynamic modification at the MPLS level.

* Corresponding author.
E-mail address: anshukmv@gmail.com (A. Oberoi).

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In this paper, we purpose the algorithm that will allow the dynamic modification of the virtual topology at the MPLS level according to the bandwidth requirement of the request in-coming.

Our proposed algorithm achieves a lower blocking ratio by efficiently using the available network resources. It is based on distributing lesser capacity IP traffic into many fold capacity channel of optical fiber on a weighted threshold. We then discussed three different models of network against resources considering no wavelength conversion, partial wavelength conversion and full wavelength conversion provision at IP/MPLS routers and compared them with a fixed model. We proposed reservation factor for the quantized parallel λLSPs for each model separately. The method is computationally simple but clearly shows small but significant percentage improvement on reservation of resources. Further we investigated the QoS routing for the purposed algorithm through the blocking probability measurement. The size of the λLSP though calculated a priori maintains the dynamism as it is based on the cost coefficient of the routing/signaling parameters representing state of the network.

The paper is organized as follows: Section 2 discusses the proposed mathematical model for the size of the threshold for the λLSP to be established in the MPLS network layer. It also gives the definition of reservation factor for the wavelength channels in the fiber. Section 3 discusses the routing scheme and the algorithm for the same is proposed. In Section 4 results and discussion is put forward based on the graphs derived for blocking probability and percentage improvement on reservation factor for each network model. The authors hence put forward conclusions in Section 5.

2. Mathematical model

In the GMPLS environment, the user IP packets are switched using MPLS at the upper layer and MPλLS at the lower layer. Thus, a virtual MPLS network lies over the lightpath network. Each node comprises of a WXC (Wave length Cross Connect) switches for optical switching in the case of network model where no o-e-o conversion is designed. But the node of the model with full wave length conversion comprises of WXC and IP/MPLS router for the total wave length granularity whereas in the model with partial wave length conversion the node consists of WXC and IP/MPLS router for a fixed number of wave lengths connected to WXC via ports.

Since we have assumed that MPLS overlays the optical layer, thus the path $P_{\mathrm{MPLS}}(i, j)$ is the mini hop path between source node and destination.

All the bandwidth requests between i and j are routed preferably on direct LSP(i, j) or on $P(i, j)$, a combination of multiple default LSP$_S$ over $P_{\mathrm{MPLS}}(i, j)$. The length of the $P(i, j)$ is denoted by h.

2.1. Cost based function for threshold Q and reservation factor ρ

The threshold value Q defining the size of LSP has to be based on the factor affecting the grant of the request at the time of generation of the request and also on the after effects on the network if such a request is met, so that the future requests can be provided with complete independence of the previous requests and the network is left with maximum resources available. Hence the cost of generating the value of Q in any network is primarily based on:

- the switching action required depending on the type of network nodes i.e. whether full wavelength conversion occurs or partial wavelength conversion or no wavelength conversion can occur;
- the cost for carrying the bandwidth requested by the signal;
- the mesh network design, the number of nodes and the physical links between them and hence the degree of connectivity of the network;
- the signaling cost for setting up of the LSP by the MPLS layer over the optical nodes and involved routers.

It is important to understand that the decision of setting new direct LSP is required if the bandwidth request exceeds the available capacity of existing direct LSP or if no direct LSP exists. Once the first new direct LSP is required to be set up the threshold Q is generated and all the future new LSPs will have the same capacity. Hence the information of available capacity on any LSP at any time 't_n' is most important factor for the decision to begin with the formation of new direct LSPs. Further we assume that a typical mesh network topology provides a few disjoint shortest path opportunities hence the cost of carrying a bandwidth request in the network is same irrespective of whether it is routed on $P(i, j)$ or on a direct LSP.

The cumulative cost function based on switching in a network is proposed as

$$W_{\mathrm{switching}} = W_{\mathrm{conv}} \times n + (W_{\mathrm{IP}} - W_{\mathrm{MPLS}}) \times (h - 1) \tag{1}$$

where W_{IP} is the cost coefficient for switching in IP, W_{MPLS} is the coefficient for switching in MPLS mode. Where W_{CONV} is coefficient of cost of conversion and n is the number of ports of the IP/MPLS router which can perform the conversion.

The cost incurred because of the mesh network design is given by the coefficient W_{conn}. Since both W_{conn} and the signaling coefficients are inversely proportional to d, the degree of connectivity of the network, the signaling cost is proposed by

$$W_{\mathrm{signal}} = \frac{h \times W_{\mathrm{s}} + W_{\mathrm{a}} + W_{\mathrm{conn}}}{d} \tag{2}$$

where W_{s} is the coefficient of signaling per hop; W_{a} is the constant coefficient for network load.

The proposed threshold is

$$Q = \frac{W_{\mathrm{signal}}}{W_{\mathrm{switching}}} \tag{3}$$

The total traffic between the node pair has thus been quantized into tunnels of size $Q(i, j)$. Each of these tunnels is routed on a path that is disjoint from the others.

The reservation of the total fiber capacity hence is determined by the size of Q. If the fiber contains λ number of channels, as per the WDM network, then capacity of each being assumed to be same will be equal to C_{λ}. The reservation factor of the channel of fiber link is defined as;

$$\rho = \frac{Q}{C_{\lambda}} \tag{4}$$

The assumption that considers all the wavelengths available free at any time 't_n' would be overestimation of the results and allocation of complete channel bandwidth for a single session is under reservation of resources. Hence the blocking probability model used in [14] has been modified against the proposed scheme as

$$P_{\mathrm{B}} = [1 - (1 - \rho)^{h}]^{\eta} \tag{5}$$

where ρ is reservation factor for each fiber link given in (Eq. (4)), h is the number of hops in the $P(i, j)$ and η is the connectivity factor for $P(i, j)$ which depends upon the network model.

3. Proposed routing scheme

This work suggests a routing scheme where the large capacity of the optical fiber channel is used in the form of tunnels of pre calculated size so that the total capacity is utilized economically. The routing is dynamic as the size of the tunnel is based on the coefficients representing the state of the network.