Dynamic Routing and Wavelength Assignment using Adaptive Weight Function for All - Optical WDM Networks

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Abstract

We propose a novel WDM aware weight function for solving the Routing and Wavelength Assignment (RWA) problem in optical WDM networks taking into consideration factors like number of used wavelengths, availability of free wavelengths and route length jointly under dynamic traffic conditions. The performance of proposed routing strategy is studied in combination with first-fit, and most used wavelength heuristics using simulation with and without wavelength continuity constraint. Firstly we demonstrate that the recently proposed weighted least congested routing algorithm with first-fit wavelength assignment (WLCR-FF) if instead used with most used wavelength assignment, gives better blocking performance. We further compare the performance of new weight function with most used wavelength assignment with systems employing WLCR-FF and FAR-FF algorithms for ring and mesh networks. The results show that the routing based on proposed weight function together with most used wavelength assignment achieve better performance in terms of blocking probability.

1. Introduction

Wavelength division multiplexing is emerging as a dominant technology for next generation optical networks. In WDM, several optical signals share the same fiber using different wavelengths [1][11]. With each wavelength channel operating on its peak speed, the capacity of such fiber links can be very huge, even multi terabits per second. A wavelength routed all-optical network (WRON) composed of wavelength routers connected by WDM links. When a request comes for connection between a source destination pair, s-d pair, it establishes a lightpath. A lightpath is a set of links through intermediate nodes from source to destination. Given a set of connection requests, the network needs to decide on the route and assigning wavelength (s) for each connection request in order for setting the lightpaths. This problem is known as Routing and Wavelength Assignment Problem [2][3]. In the absence of wavelength conversion facility at different nodes along the lightpath it is required that all the links that constitute the path must occupy the same wavelength due to Wavelength Continuity Constraints. On the other hand the wavelength converters that convert optically, the data on an incoming wavelength into data on a different outgoing wavelength depending upon full or limited conversion capability can be used to improve utilization of available link wavelengths, reduce lightpath blocking and to enhance the WDM system survivability [12].

In this paper, we address the problem of dynamic routing and wavelength assignment of lightpaths in WRON with and without wavelength conversion. The RWA problem consists of determining a route and assigning wavelength for each requested lightpath in a dynamic scenario where lightpaths are established on demand and released after a random holding period. This is done assuming no rerouting of existing lightpaths is allowed and with the objective of minimizing the call blocking probability. We propose a novel adaptive weight function based routing for solving the routing subproblem and then wavelength assignment is done using first fit and most used heuristics. We have studied the performance of the proposed weight function with different wavelength assignment heuristic using extensive simulation on ring and mesh-torus topology. The proposed weighted least congested routing with most used wavelength assignment yields significant improvement in terms of request blocking probability over traditional techniques and in particular over recently reported WLCR-FF algorithm Chu and Li [4][5].

2. RWA in WDM Networks

The blocking probability is one of the key performance parameter in the design of a RWA algorithm [6] with minimum computational complexity. Many studies have been reported on solution of RWA problem based on static as well as dynamic routing. The static routing involves pre-computation of routes based on traffic load known in advance without considering the current status of the network. Routes can be determined using shortest path routing (SPR) including many variants of it or fixed alternate path routing (FAR) algorithms. The SPR is easy to implement and uses minimum resources but yields non uniform and under utilization of link on an average and tends to lead to a high blocking probability Barry [6]. Alternatively FAR algorithm proposed in [7] by Harai et al computes more then one candidate routes using k-shortest path algorithm for each s-d pair. If first route is unavailable then alternate route is chosen thereby distributing links in the network. It is reported to yield significant improvement in blocking performance. The static routing algorithms though well suited for small sized network with fixed traffic perform poorly in case of frequently changing traffic scenario.
On the other hand, dynamic routing decisions the routes taking the cognizance of current network status and can accommodate new traffic demands as and when they come. Many Dynamic routing approaches have been reported in the literature with significant gain in blocking performance [3]. Most of the approaches perform routing and wavelength assignment separately. On the arrival of a connection request, a route is chosen from a pre-calculated set as in case of static routing, and then a wavelength is assigned to it based on wavelength selection criteria. If no wavelength is available on the chosen route, a new route is selected. If no free wavelength is found free on any of the routes in the set, then the call is blocked. Adaptive routing within this category of algorithm performs better than fixed alternate routing algorithm, which search candidate route in a fixed order. On the contrary to a limited search space (pre-computed routes), Mokhktar and Azizoglu [8] proposed a number of adaptive unconstrained routing (AUR) algorithms, which dynamically searches for shortest available route using each wavelength on arrival of a connection request. Adaptive algorithms are more efficient but have more complexity of computation. Routing based on the availability of maximum numbers of free wavelengths on any link along the path has been suggested in Li and Somani [9]. The authors claimed that their proposed fixed-path least congested routing algorithm (FPLC) outperforms FAR algorithms in terms of blocking performance. Dynamic RWA algorithms in the presence of wavelength converters taking into consideration free wavelengths and hop length have been proposed in [4][5][9]. Hsu et al suggested a weighted shortest path algorithm in which path selection is made on the basis of minimizing the resource cost keeping the traffic load balanced among the links [10]. In [5] Chu and Li, demonstrated that the existing dynamic RWA algorithms do not work well in the presence of wavelength conversion as they usually only take into account current traffic and do not explicitly consider the route length and proposed a weighted least-congestion routing and first-fit (WLCR-FF) algorithm taking both the factors into account jointly. Authors claim to achieve much better blocking performance in the presence of sparse or/and full wavelength conversion.

3. Proposed Solution

3.1. System Model, parameters and assumption

WDM network can be modeled as a network topology consisting of a set of N nodes connected together by a set of L fiber links assuming that each fiber link is bi-directional. The total bandwidth of each fiber link is divided into W number of channels with each channel carried on a distinct wavelength $\lambda$ and are labeled as 1 to W. The network traffic is generated in terms of connection request from source (s) to destination (d) and served by establishing a lightpath passing through a set of links and intermediate nodes. The connection occupies the channel until it is terminated. The connection requests arrive at every node independently and are assumed to follow Poisson distribution with mean arrival rate of $\lambda$ connections per unit time. The connection holding time is assumed to follow an exponential distribution. The traffic per node is represented in Erlangs and calculated as product of mean arrival rate and mean holding time of the connection. Each path between a given source-destination pair for which connection is requested is characterized by two parameters namely the hop length $l(P)$ and number of free wavelengths $f(p)$ on that path. The hop length $l(P)$ is defined as number of physical links traversed by a connection from source to destination. The free wavelengths $f(p)$ on a path is measured in terms of number of common free wavelengths available on all the links of that path at a given point of time in the absence of wavelength conversion. In case of full wavelength conversion the $f(p)$ is measured in terms of minimum number of free wavelengths on any link along the path.

3.2. WDM Aware Adaptive Weight Function

We propose a WDM aware adaptive weight function designed by taking into consideration following factors: (1) Total available wavelengths; (2) Number of available free wavelengths; and (3) the hop length.

$$ W(P) = \begin{cases} f(p) & \text{if } f(P) < W \\ (W - f(p))\sqrt{f(p)} & \text{if } f(P) = W \\ 100 \text{ (an arbitrary max. value)} & \text{if } f(P) = W \\ \end{cases} $$

The factor $\sqrt{f(p)}$ balances the selection of too short or too long path and have a major impact on route selection in case of presence of wavelength conversion. The weight function is adaptive as number of free wavelengths and wavelength use factor $(W - f(P))$ is changing constantly.

3.3. Steps for Routing and Wavelength Assignment

Given the network topology, on arrival of a call request for determination of appropriate route and wavelength assignment, the proposed algorithm works as follows:

- For each source destination pair paths have been pre-calculated. We assume that paths are edge disjoint to deal with the occurrence of link failure if any. Our assumption makes the system survivable. (In simulation we have considered two edge disjoint paths for each node pair).
- On arrival of a connection request for a node pair, the weight is computed for each candidate path using weight function defined in section 3B.
- The route selected on the basis of path having the maximum value of the weight function.
- Finally the wavelength is assigned to the chosen route using most used wavelength selection heuristic and a lightpath is established. (For the purpose of comparison we also tried using first fit wavelength assignment policy).
- If no wavelength is available on any of the route, the request is blocked.
4. Performance Evaluation

This section presents the performance analysis of the proposed weight function with first fit and most used wavelength assignment and also that of WLCR-FF [5] but with most used instead of first fit wavelength assignment scheme. To carry out the simulation studies we have developed simulation program using C-language. Blocking probability is used as performance metrics for investigation and comparison.

4.1. Simulation Environment

The network topologies considered for performance investigation includes 8-node ring topology (Fig. 1) and 25-node mesh-torus topology (Fig. 2). As explained in section 2, connection requests arrival are assumed to follow Poisson distribution and connection holding duration is considered as exponentially distributed. The traffic per node is expressed in Erlangs. The simulations for ring network were run on wavelengths ranging from 10 to 30 for both without and with wavelength conversion. The results for W = 30 are presented here. The simulation for mesh-torus were done on W = 8 and W = 10 and results for 8 wavelength is presented here.

4.2. Results and Discussion

4.2.1 Performance of WLCR-MU Algorithm

Firstly we compare the performance of WLCR-MU algorithm with that of WLCR-FF reported in [5] and FAR-FF for ring network as well as mesh-torus network without and with wavelength conversion in Figure 3, Fig 5, Fig 7 and Fig 9 respectively.

![Figure 3: Overall blocking probability Vs total traffic load in 8-node ring network, without wavelength conversion](image)

It is clearly observed that weighted least congested routing performs much better in all the cases when used with most used wavelength assignment. It is also observed that both WLCR-FF and WLCR-MU results in significant improvement in blocking performance as compared to FAR-FF algorithm.
We have investigated the performance of new proposed weight function based routing in conjunction with both first fit and most used wavelength assignment using extensive simulation on the above specified topology. The results are plotted in Fig 4 and 6 for ring networks and in Fig 8 and 10 for mesh–torus network, in both the absence and the presence of wavelength conversion respectively. We observe that in most of the cases our proposed MDWLCR-MU achieve reduction in the blocking probability as compared to WLCR-FF algorithm and perform marginally better then WLCR-FF in case of mesh–torus topology with wavelength conversion.
In this paper we study the dynamic routing and wavelength assignment problem in all-optical WDM network. We demonstrated with simulation that in comparison with WLCR-FF algorithm WLCR-MU algorithm perform better both in the absence and presence of wavelength conversion. We proposed a new dynamic weight function that takes into consideration total available wavelength, free wavelength and hop length in order to decide a route and wavelength assignment is then implemented using most used scheme. We have investigated the performance of proposed algorithm using simulation for which we had written codes in C. The simulation results clearly indicates that our algorithm achieve significant improvement in blocking performance as compared to FAR-FF and WLCR-FF algorithms.

6. References


