A Review of Various Wavelength Assignment Algorithms for WDM Network

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Abstract
Wavelength Division Multiplexed switching networks are important for the future transport networks. This paper analyzes the wavelength assignment problem in optical WDM networks. Analysis is based on the calculation of Blocking Probability in the network. Analysis shows that Blocking Probability is less when wavelength conversion is performed as compared to when no wavelength conversion takes place. Further, in case of no wavelength conversion, First-Fit method gives less blocking probability as compared to Random-Fit method.

Keywords
WDM Networks, Blocking Probability, First-Fit method, Random-Fit method.

I. Introduction

Routing can be defined as the transfer of information (data) from source to destination through intermediate links. In optical networks, a light path must be assigned to the data when it is transferred within the optical network. For each connection request, a physical route is selected first or decided by the algorithm and then a wavelength is assigned, so that the information is transferred on that path. So the first part is the routing and second part is the wavelength assignment.

II.Routing and Wavelength Assignment

A connection needs to be established in the optical layer in order to carry the information between the clients of the network. The optical connection that is maintained between a source node, s and destination node, d is known as an optical path or light path. The problem of finding a route for a light path and assigning a wavelength to the light path is referred to as the routing and wavelength assignment problem (RWA).

The problem of RWA is divided into two parts:-

- Routing
- Wavelength Assignment

In the traffic model, the RWA problem is considered as two:-

- Static Light path Establishment (SLE): The idea is to reduce the number of wavelengths needed to accommodate the given connection set.
- Dynamic Light path Establishment (DLE): The idea is to reduce the blocking probability.

A. Static RWA

In static RWA, the set of connection request is known in advance. Its purpose is to establish as many connection requests as possible while minimizing the number of wavelengths used in the network. The static RWA is also called SLE problem.

1. Static Lightpath Establishment

SLE problem accommodates a given set of Connection requests over an established Physical Topology. In SLE, lightpath request are known in advance and the routing and wavelength assignment operations are performed offline.

Purpose:

- Minimize the number of wavelengths to establish lightpaths for a given set of connection requests.
- Maximize the number of lightpaths for the given connection requests and a given number of wavelengths.

SLE problem can be formulated as an integer linear programming problem (ILP). There are two cases of ILP in static RWA. First case is without wavelength conversion (Wavelength Continuity), which is further solved in two ways:

1. By minimizing the number of wavelengths to establish the lightpaths, which in turn minimizes the number of lightpaths on each link.
2. By maximizing the number of lightpaths for a given set of wavelengths and given set of connection requests.

The second case with wavelength conversion is solved by minimizing the number of wavelengths to establish lightpaths that will minimize the number of lightpaths on each link.

B. Dynamic RWA

In dynamic RWA, the connection request arrives dynamically in a random order to the network and dynamic RWA algorithm must establish a connection for each request as it arrives. Dynamic RWA works online and the objective of RWA problem is to route and assign a wavelength so that connection blocking probability is minimized and the lightpath establishment is maximized.

III Routing Algorithms

A. Fixed Routing

In fixed routing a route is pre-computed, between the source and destination and the same precomputed route is used when there is any connection between the same source and destination nodes. The route is calculated offline through standard shortest path algorithm like Dijkstra or Bellman-ford. High blocking probability occurs if:

- No wavelength available on any link of shortest path route. (route with wavelength converters).
- No common wavelength available on all the links of the shortest path route. (route with wavelength continuity).

B. Fixed Alternate Routing

In fixed alternate routing a set of alternate routes are pre-computed for each pair of network nodes. These routes are computed offline and stored in a routing table having an ordered list of fixed routes to each destination (With first entry as the primary path and the rest as the alternate paths). To establish a connection request, the network controller will search a route from the set of alternate routes and if no route is found then the connection will be blocked .

Pros:

- Provides some degree of fault tolerant capability.
- Less blocking probability than fixed routing.

Cons:

- Blocking occurs if no available route is found from the list of available routes (primary and alternate).

C. Adaptive Routing

In adaptive routing, a route between a source and destination is selected online depending on the current state of the network as well as path selection policy like least cost path or least congested path first. Global network state information is used by network controller to establish a route between two nodes.

Pros:

- Less blocking probability than fixed alternate.
- Higher degree of fault tolerance.

Cons:

- Increased computationally complexity

Table 1: Routing Table

Routing algorithms	Pros.	Cons.
Fixed routing	The route is calculated offline through shortest path algorithm like dijkstra.	High blocking probability occurs if no wavelength available on any link of the shortest path route.
Fixed alternate routing	Provides some degree of fault tolerant capability ,less blocking probability then fixed routing.	Blocking occur if no available route is found from the list of available routes (primary and alternate).
Adaptive routing	Less blocking probability than fixed alternate.	Increased computational complexity.

IV.Wavelength Assignment Algorithms

A. Random

It searches all the wavelengths available on each link of the route and then chooses one available wavelength randomly with uniform probability. This method of wavelength assignment has no communication overhead. The only drawback is that it has computation cost. In this algorithm, first all possible routes between a source-destination node pair is determined. Then all the free wavelengths (which are currently not being used) are found out. Then randomly a wavelength is assigned for data transmission to take place.

B. First Fit

All the wavelengths are indexed and searched according to their wavelength numbers. Finally the lowest numbered wavelength is selected first. No global information (communication overhead) is required having less computation cost as compared to random [2]. Here, each and every wavelength is numbered. When a connection request is made, the wavelength which is having the lowest assigned number is selected from the available wavelength set.

C. Least Used

This approach selects the least used wavelengths to be assigned in the network thereby maintaining the load on all the wavelengths equally. This allows for more number of wavelengths to be available for the newly arriving requests. However since more computational cost is involved, this approach is mostly preferred in the centralized control systems rather than the distributed ones. Further this method has less performance than the random and has extra storage cost [2].

D. Most Used

This approach works in contrast to the least used by selecting most used wavelengths for assignment in the network and packs the connections into fewer wavelengths. This approach has almost the similar disadvantages as that of the least used. The wavelength that is used by the highest number of links in the network is the most used wavelength. The most used wavelength is selected by the most used algorithm from the available wavelength on the path.

E. Least loaded

This approach selects the least loaded wavelength on a most loaded link. This wavelength needs to be available on maximum number of fibers in that path along the route for transmissions.

Table 2: Wavelength Assignment Algorithms

Wavelength assignment algorithms	Advantages	Disadvantages
Random	No communication overhead	High computational cost
First fit	No global information required.	Less computation cost as compared to Random
Least used	Mostly preferred in the centralized control systems	Less performance than the random and has extra storage cost
Most used	Packs the connections into fewer wavelengths	Similar disadvantages as that of the least used

V. Related Study

Barry and Pierre [1] introduced a traffic model for circuit-switched all-optical networks which they then use to calculate the blocking probability along a path for networks with and without wavelength changers. They investigate the effects of path length, switch size, and interference length (the expected number of hops shared by two sessions which share at least one hop) on blocking probability and the ability of wavelength changers to improve performance.

Mokhtar and Azizo˜glu [2] considered routing and wavelength assignment in wavelength-routed all-optical networks with circuit switching. The conventional approaches to address this issue consider the two aspects of the problem disjointly by first finding a route from a predetermined set of candidate paths and then searching for an appropriate wavelength assignment. They adopt a more general approach in which we consider all paths between a source–destination (s–d) pair and incorporate network state information into the routing decision. This approach performs routing and wavelength assignment jointly and adaptively, and outperforms fixed routing techniques. They present adaptive routing and wavelength assignment algorithms and evaluate their blocking performance. They obtain an analytical technique to compute approximate blocking probabilities for networks employing fixed and alternate routing. The analysis can also accommodate networks with multiple fibers per link. The blocking performance of the proposed adaptive routing algorithms is compared along with their computational complexity.

Mewanou and Pierre [3] considered dynamic routing in all optical networks without wavelength converters which are very expensive and always not effective. We propose two new heuristic algorithms

to manage optical routing based on link-state and reduce blocking probability of request arriving in the network. The first one uses a technique similar to 'fixed paths least congested" (FPLC) routing by analyzing the first k link on each path whereas the second is based on an estimation of the link-congestion in the network. Both algorithms achieve good performance, for different types of network topologies, when compared to existing methods like FPLC, LLR, and FPLC-k.

He et al [4] discussed and presented a new heuristic offline wavelength ordering algorithm for wavelength allocation. Also they studied the impact of guaranteeing QOS, by combining both BER and latency constraints, on the performance of wavelength assignment algorithms in shortest path (sp) and fixed alternate routing. From the results it is observed that heuristic algorithm minimizes the crosstalk due to adjacent wavelength power leaking through the WDM demultiplexers

Sharma et al. [5] proposed that Wavelength Division Multiplexed switching networks are considered as an important candidate for the future transport networks. As the size of network increases conventional methods used in teletraffic theory to model these networks become computationally difficult to handle as the state space grows exponentially. This paper analyzes the wavelength assignment problem in optical WDM networks. Analysis is based on the calculation of Blocking Probability in the network. Analysis shows that Blocking Probability is less when wavelength conversion is performed as compared to when no wavelength conversion takes place. Further, in case of no wavelength conversion, First-Fit method gives less blocking probability as compared to Random-Fit method.

He et al. [6] reviewed that The quality of an optical signal degrades due to physical layer impairments as it propagates from a transmitter to a receiver. As a result, the signal quality at the receiver of a lightpath may not be sufficiently high, leading to increased call blocking. Consequently, an all-optical network's routing and wavelength assignment algorithm must verify the quality of the lightpath before accepting it. In this paper, analytical expressions for the total blocking probability are derived for first-fit wavelength assignment for networks suffering from transmission impairments. The new technique effectively predicts the performance of wavelength selection techniques that consider either a single candidate channel or all channels for quality of transmission compliance. The analysis is also applicable to first-fit algorithms with different static channel orderings.

Sharma et al. [7] introduced a Fiber Optic Simulator (FOSP), used to optimize Physical properties of fiber in order to get high velocity. Further wavelength assignment techniques (First Fit, Random Fit) & WDM networks with wavelength conversion is analyzed in terms of their blocking probability. Analysis shows that WDM networks designed with wavelength converters gives the best performance among all the wavelength assignment techniques .A shortest path algorithm (Dijkastra's algorithm) is followed in order to select shortest path among the network to speed up the data transfer.

Wang and Wen [8] proposes two lightpath-level active rerouting algorithms, namely, the least resources rerouting algorithm and the load balanced rerouting algorithm, in all-optical WDM networks with alternate routing and traffic grooming. The proposed algorithms consist of three major components to be determined: i) when the rerouting algorithm initiates, ii) which lightpath is rerouted, and iii) which routing path and wavelength for the rerouted lightpath is newly allocated. The proposed active rerouting algorithms initiate the rerouting procedure when a connection leaves and a lightpath is released. The lightpath to be rerouted is selected according to the objectives of two different algorithms. The routing path and wavelength allocated to the rerouted lightpath is that the departure connection released. Simulation results show that the proposed load-balanced active rerouting algorithm yields much lower connection blocking probability than the least resources rerouting algorithms. We also observe that the number of rerouted lightpaths is very small. This result implies that the overhead for rerouting a lightpath is small and the performance of the networks can be significantly improved.

Singal and Kaler [9] proposed a new simulation technique for the performance analysis of First-fit, Random, Most-used and Wavelength conversion Algorithms for wavelength assignment in WDM unidirectional optical ring network. The blocking probability of various algorithms with the variation in number of events has been compared. The performance of the wavelength conversion algorithms is best but there is burden of using expensive hardware. Without the need of wavelength converter the Most-used algorithm performs better than the Random and First-fit algorithms.

Vikas Kaushik [10] Wavelength Division Multiplexed switching networks are important for the future transport networks. This paper analyzes the performance of various wavelength assignment algorithm and their effect on the blocking probability of the connection request in the optical network with traffic grooming. The wavelength assignment is a unique feature in wavelength routed network that distinguish

them from the conventional networks. The wavelength assignment algorithms are classified as First fit, Random fit, Most used, Least used and wavelength conversion algorithms. Simulation is done for the 16 node optical ring network. The experimentation results indicate that the most used algorithm achieves reduced network blocking rate with and without traffic grooming. These approaches are very effective for the minimization of blocking probability of optical.

VI. Conclusion

In this paper, the performance of various wavelength assignment approaches has been analyzed. Blocking probability in the network increases when the requested wavelength is not available for any connection request. Wavelength assignment approaches are very effective for the minimization of blocking probability of optical WDM networks. There are a number of models covered in literature for calculation of blocking probability of optical networks. Wavelength converters are very expensive now a days, much research work focuses on sparse wavelength conversion, in which only a part of network nodes have the capability of wavelength conversion .

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