



State of the Art of Routing and Wavelength Assignment Algorithms in WDM Networks

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Abstract: The recent advances in the fiber optic technology are strongly affecting network data communications. One of the most promising long-haul communications in optical data communication networks technologies is Wavelength Division Multiplexing (WDM). Wavelength routing in WDM is most important technology for information transport in wide and metropolitan networks. Wavelength routing is used in WDM for realization of future large bandwidth networks. In this paper mainly discussed about routing and wavelength assignment (RWA) research contributions in routing and wavelength assignments problems for both static and dynamic RWA problems. RWA algorithms block calls if continuous wavelength flow from source to destination at that time degrades the network performance. The failure of RWA algorithms to find an available wavelength on all links from source to destination causes congestion resulting in packet loss.

Key Words: WDM, RWA, Blocking probability, Throughput

I. INTRODUCTION

Transmitting many light beams of different wavelengths simultaneously through an Optical fiber is called Wavelength Division Multiplexing (WDM). It is a strong technology for next generation high performance networks. Because it provides high bandwidth, low error rate, low power requirement and low data loss [1]. In WDM optical networks light path establishment and wavelength assignment combined known as Routing and Wavelength Assignments. Establish a light path in a WDM network, i.e., selecting the route and wavelength used to transport the traffic flow. This problem is known as Routing and Wavelength Assignment problem (RWA) and also different heuristics exist to cope with it.

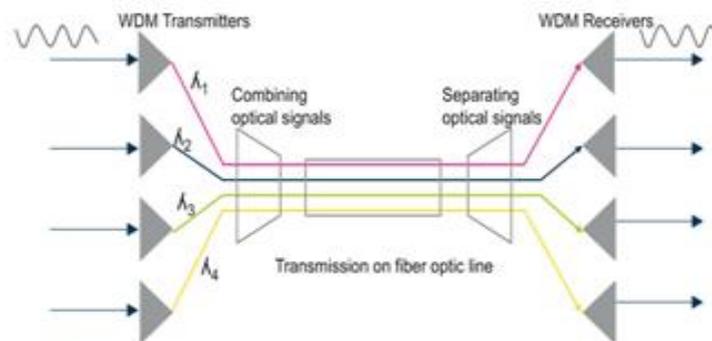


Fig 1: Wavelength Division Multiplexing

The rest of the paper is organized as 2) Light path establishment 3) Routing heuristics 4) Wavelength Selection heuristics 5) Literature Survey 6) Conclusions and Future scope

II. LIGHT PATH ESTABLISHMENT

In the RWA problem mainly two types of traffic are considered in the literature, namely 1) Static traffic 2) Dynamic traffic. In case of Static traffic demand, connection requests are known a priori. The traffic demand may be specified in terms of source-destination pairs. These pairs are chosen based on an estimation of long-term traffic requirements between the node-pairs. The objective is to assign routes and wavelengths to all the demands so as to minimize the number of wavelengths used. The dual problem is to assign routes and wavelengths so as to maximize the number of demands satisfied, for a fixed number of wavelengths. The above problems are categorized under the Static Light path Establishment (SLE) problem. The SLE Problem has been shown to be NP-complete (that is, it is computationally intractable or, in other words, the only known algorithms that find an optimal solution require exponential time in the worst case) [2]. Therefore, polynomial-time algorithms which produce solutions close to the optimal one are proffered [3].

In case of dynamic traffic demand, connection requests arrive to and depart from a network one by one in a random manner. The light paths once established remain for finite time. The dynamic traffic demand models several situations in

transport networks. it may become necessary to tear down some existing light paths and establish new light paths in response to changing traffic patterns or network component failures. Unlike the static RWA problem, any solution to dynamic RWA problem must be processed online. when a new request arrives a route and wavelength need to be assigned to the request with the objective of maximizing the number of connection requests honor (equivalent to minimizing the number of connection requests reject). Dynamic RWA algorithms perform more poorly than static RWA algorithms, because a dynamic RWA algorithm has to knowledge about future connection requests, whereas all the connection requests are known priori to a static RWA algorithm. A dynamic RWA algorithm process the connection requests strictly in the order in which they arrive, where as a static RWA algorithm process the requests in an order decided by some heuristic [4]

III. ROUTING

The important routing methods considered in the literature are A) Fixed routing B) Fixed Alternate routing C) Exhaust routing [5].

A) Fixed routing: In this method only one route is provided for a node pair. Usually this route is chosen to be the shortest route. When a connection request arrives for a node pair, the route fixed for that node pair is searched for the availability of a free wavelength.

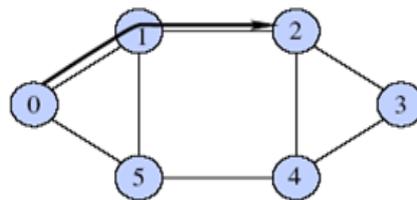


Fig 2: Fixed routing

B) Fixed alternate routing: In this method two or more routes are provided for a node pair. Those routes are searched one by one in a predetermined order. Usually these routes are ordered in non decreasing order of their hop length.

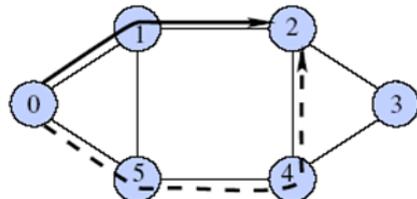


Fig 3: Fixed alternate routing

C) Exhaust routing: in this method all possible routes are searched for a node pair. The network state is represented as a graph and a shortest-path-finding algorithm is used on the graph. While this method is best among other two.

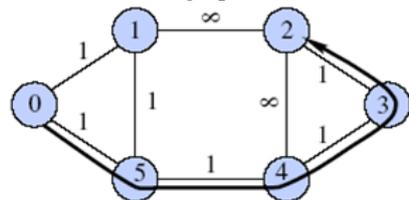


Fig:4 Exhaust routing

IV. WAVELENGTH ASSIGNMENT

Wavelength assignment methods are classified into many types for static and dynamic traffic.

A) Random-order(R): In this scheme first searched to find out the set of all available wavelengths on the required route. Amongst the available wavelengths, one is selected at random [6].

B) First-Fit (F): In FF scheme, all wavelengths are numbered. While searching for free wavelengths, a lesser numbered wavelength is given priority before a higher-numbered wavelength. The first free wavelength available is then selected. No global information is required in this scheme. The computation cost of this scheme is lower than random wavelength assignment, because search for the entire wavelength space for each route is not required. . FF also performs well in terms of fairness and blocking probability [7].

C) Least-Used (LU) /SPREAD: This scheme selects the least used wavelength in the network and tries to balance the load amongst all the wavelengths. The performance of LU is worse than Random, while also introducing additional communication overhead, requiring additional storage and computation cost; thus, LU is not preferred in practice [8].

D) Most-Used (MU) /PACK: In this scheme, the most-used wavelength in the network is selected. This scheme performs better than LU and FF. It packs connections into fewer wavelengths and conserves the less-used wavelengths' unused capacity [8].

E) Least-Loaded (LL): This heuristic is designed for multi-fiber networks, like MP, It selects the wavelength with the largest residual capacity on the most-loaded link along route. When it is used in single-fiber networks, the remaining

capacity is either 1 or 0; thus the lowest-indexed wavelength with residual capacity 1 is selected. Thus LL is reduced to FF in a single fiber networks. LL outperforms MU and FF in terms of blocking probability in a multi-fiber network [8].

F) Min-Product (MP): MP is used in multi-fiber networks. In a single-fiber network, MP becomes FF. The goal of MP is to pack wavelengths into fibers, thereby minimizing the number of fibers in the network Compared to the multi-fiber version of FF in which the fibers, as well as the wavelengths, are ordered MP does not perform well. Its computation costs are also high [8].

G) MAX-SUM (M_{Σ}): This scheme was proposed for multi-fiber networks but is also applicable to the single-fiber case. It considers all feasible light-paths with their pre-selected routes in the network and tries to maximize the remaining path capacities after light-path setup. This scheme is based on the assumption that the set of possible connection requests are known in advance and their routes are pre-selected [9].

H) Relative Capacity Loss (RCL): RCL scheme is based on the study that minimizing total capacity loss sometimes does not direct to the best selection of wavelength .Suppose a wavelength i is chosen, that results in blocking one light-path p_1 and another wavelength j , if chosen would reduce the capacity of light-paths p_2 and p_3 , but does not block them. In such a case wavelength j would be preferred over wavelength i irrespective of the capacity loss. Thus, RCL computes the Relative Capacity Loss for each path on each available wavelength and then selects the wavelength that minimizes the relative capacity loss sum on all the paths. Both MAX-SUM and RCL can be used for non-uniform traffic by taking a weighted sum over the capacity losses RCL has been observed to perform better than MAX-SUM in most cases [10].

I) Distributed relative capacity loss (DRCL): the DRCL was proposed to be applied in distributed environments. The routing is fixed and it computed by bellman ford algorithm where each node exchange routing tables with their neighbor nodes [8].

J) Best-fit: here 'w' copies of the network topology are made available at each node. Each copy represents the current topology [11].

K) Wavelength reservation: In this scheme, a given wavelength on a particular link is held in reserve for a traffic flow, usually a multi hop flow even if the wavelength is available This scheme minimizes the blocking for multi-hop traffic, but increases the blocking for single-hop traffic that is connections that go across only one fiber link[8].

L) Protecting threshold: In Protecting Threshold, a single-hop connection is assigned a wavelength only if the number of idle wavelengths on the link is at or above a given threshold this scheme makes use of the current network state information, hence can work on-line. It can also work off-line, if the network traffic is static. This is done by managing the static set of light-paths in sequence. Another issue when assigning wavelengths to the static problem is of arranging the light-paths [8].

V. LITERATURE SURVEY

S.Ramamurthy et. al. [12], proposed fixed-alternate routing and wavelength conversion. These two are improves the blocking performance and average link utilization of network. Alternate routing provides multiple possible paths between node pairs that's why it provides more benefits than wavelength conversion in denser network topologies at lower loads. the proposed methods use in future work is applied to a subroutine for use in iterative network design & optimization procedures,. to make empirical observation as blocking performance of network topologies configurations and, to design alternate routing tables.

Huizang et. al. [13], study focuses on the RWA problem in wavelength routed optical networks. In this paper they are proposed Adaptive routing and Distributed Relative Capacity Loss (DRCL) which work well in distributed controlled network. Here routing decisions play a significant role in determining the blocking performance of a network. They propose ongoing research include comparison of Relative Capacity Loss (RCL) and (DRCL) on several other aspects like bandwidth requirement of control messages and computation overhead.

G Shen et. al. [14], this paper presents heuristic algorithms that may be used for light path routing and wavelength assignment in optical WDM networks under dynamically varying traffic conditions. here two methods are done greedy algorithm was taken under wavelength conversion WDM, and exhaustive algorithm taken under non-wavelength conversion WDM. Greedy and least loaded algorithms are better compare to others in non-wavelength comparison environment, this provides less blocking probability. Here compromise no conversion approach of wavelength conversion and full conversion requirement of non-wavelength conversion areas are future research topics.

Jun Zhou et. al. [15], addressed in large networks maintaining precise global network state information is almost impossible. Many factors affected such as non-negligible propagation delay, infrequent state up-dates due to overhead concern and hierarchical topology aggregation. here they proposed Dynamic Routing and Wavelength Assignment (DRWA) under single and multi fiber systems with three wavelength assignment heuristics First-Fit, Random-fit, Most-used. here first-fit and most used perform poorly in the presence of imprecise global network state information, then conclude that the new RWA algorithm that can tolerate imprecise global network state information may need to be developed for the dynamic connection management in the future WDM networks.

Bo Li and Xiaowen Chu et. Al. [16], described that blocking is the main performance index in the design of an all optical networks, here they have to take both RWA algorithms are consider with wavelength conversion. here two methods are proposed 1. Weighted Least Congestion Routing and First-Fit wavelength assignment (WLCCR-FF) algorithm outperforms all existing RWA algorithms (Static, fixed-alternate & least-loaded routing) in sparse or full wavelength conversion. 2. Weight Maximum Segment Length (WMSL) algorithm for Dynamic RWA algorithm can outperform all existing wavelength converter placement algorithm in terms of call blocking performance by a large margin.

Johannes hamonangan siregar et. al. [17], showed that RWA problem for large-scale WDM Optical networks were each request of light path is without wavelength conversion. here two heuristic RWA algorithms are proposed in order to minimize wavelength required for given connection below two algorithms are compared with existing algorithms under realistic networks. i.e., 1. Longest First Alternate Path (LFAP) → wavelengths are selected as Knapsack problem. 2. Heaviest Path Load Deviation (HPLD) → wavelengths are selected as routing problem. these two are efficient for large networks. in large scale network the no of nodes grows alternate paths find quickly in case of failures by comparing two existing algorithms (MNH, LFFP).

Anwar Alyatama et. al. [18], addressed problem of fairness is one of the serious issues in WDM networks without conversions, here proposed based on solving the call blocking probabilities for static routing with random/first-fit wavelength assignment algorithms. We use the fairness index and the total network performance as objective of our capacity planning and RWA design. We showed that improves the network fairness without dramatically affecting network overall throughput. The optimization techniques are used in future network. Experimental analyses are conducted on mesh, ring topologies.

Soon-bin yim et. al. [19], presented RWA is an important issue in WDM optical networks. the main objective is to find light paths for given demands with minimal use of wavelengths. it is solved using ILP and graph coloring or heuristic path selection algorithms. Here RPSP (RWA based on Priorities of Shortest Path) utilizes the lengths of the shortest paths for source destination demand pairs and assigns disjoint light paths to the ordered demands. According to simulations for NSF Network & Random networks RPSP reduced no of assigned wavelengths than the existing one at identical running time.

Urmila Banja et. al. [20], presented DRWA problem in WDM under wavelength continuity constraint. Here assume three wavelength heuristics first-fit, random, round robin. the round robin algorithm can be used to enhance the operation of current WDM light wave networks under DRWA problem based on evolutionary programming algorithm.

Paulo H.G. Bezerra et. al. [21], presented the evaluates and performance of three algorithms for allocating wavelengths in WDM, namely first-fit, least-used, most-used, the main objective of the problem is to simulate algorithms on two parameters like blocking probability and throughput. in this paper Restricted Routing Technique (RRT) for fixed routing algorithm used for routing first-fit and most used are more competitive in terms of cost effectiveness. for future work GOF (Generic Object Function) is considered.

M. Arunachalam et. al. [22], proposed a new MFWA (Multilevel Feedback queue wavelength assignment) algorithm to minimize the blocking probability of connection requests considerably in survivable WDM networks. in survivable networks finding physical routes and assigning wavelengths is important than assigning routes. This algorithm achieves reduced connection drop rate and delay with increased bandwidth utilization and throughput compare to random-fit, most-used, least-used and round robin heuristics.

Anwar alyatama [23], showed evaluate the blocking probability in multicast WDM networks under no-wavelength conversion. Here the approach is to solve the multicast call blocking probabilities for fixed-routing with first-fit assignment algorithm with split incapable or capable nodes. WDM networks as a set of layers (colors) where blocked traffic in one layer is overflowed to another layer. Simulation results are accuracy for future research on random wavelength assignment.

M. Arunachalam et. al. [24], this paper analyses the performance of the wavelength assignment strategies to reduce the network block rate of the request in survivable optical networks. Here various wavelength assignment heuristics like random-fit, first-fit, round robin are used. The performance metrics are used in this network are network block-rate, packets received and channel utilization. Simulation results indicate that round robin achieves reduced network block-rate and delay with increased bandwidth utilization and throughput.

Vikas kaushik et. al. [25], presented analyzes the performance of various wavelengths assignment algorithms and their effect on the blocking probability of the connection request in optical network with traffic grooming. Here first-fit, random-it, mostused, leastused, wavelength **conversion** algorithms used. Here 16 node optical ring network taken for simulation work. The experimental shows that most-used algorithm achieves reduced network blocking rate with and without traffic grooming.

Bijoy chan chaterjee et. al. [26], addressed that RWA is key tasks for optical networks, here different conventional RWA approaches in the wavelength routed optical networks and compare them with proposed priority based RWA under no wavelength conversion. in this paper first-fit wavelength assignment and adaptive routing with first-fit are analyzes with blocking probability. PRWA also conducted in terms of blocking probability, so AR with FF gives best with respect to blocking probability. At last different RWA approaches and identified several challenges for future research directions which will full fill the demand of bandwidth due to the ever increasing traffic.

P. Sakthivel et. al. [27], proposed dynamic RWA for WDM network. The route and wavelengths are selected for each light-path based on wavelength availability, adaptive routing and first-fit wavelength-assignment (AR_FFWA) algorithm used. in order to establish an efficient path for a given source and destination pair, initially the bandwidth and delay will be calculated for every link which can form a path between node pair. Finally the performances will be evaluated by using NS2 compare proposed system with existing one, the overall blocking probability will be low.

VI. CONCLUSIONS AND FUTURE SCOPE

In this survey on RWA algorithms, various routing and wavelength selections mechanisms which were proposed in for data transmissions in WDM networks are discussed. All RWA algorithms performance is measured with respect to parameters like blocking probability, throughput, fairness, channel utilization, network block rate, packets received

capacity etc., the above parameters are evaluated by using different routing heuristics and wavelength assignment heuristics. In this WDM networks routing and wavelength assignment are most important. For reliable data to destination by considering dynamic traffic load and link failure recovery, proposing adaptive alternate minimum hop rank based routing method as RWA routing algorithm. The proposed routing algorithm will be tested with different wavelength assignment heuristics for maximum utilization of bandwidth without failures in large WDM optical networks.

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