A REVIEW OF STATIC AND DYNAMIC RWA PROBLEM FOR WAVELENGTH DIVISION MULTIPLEXING NETWORK

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ABSTRACT

This review focus on static as well as dynamic routing and wavelength assignment problem in wavelength routed WDM network. A wavelength routing network consists of optical cross-connects (OXCs) connected by a set of fiber links to form an arbitrary mesh topology. The main mechanism of transport in such a network is the lightpath, an optical communication channel established over the network of OXCs which may span a number of fiber links (physical hops). For establishing an optical connection, we need to select the suitable paths between source and destination edge nodes (Routing) and we need to allocate an available wavelength (Wavelength Assignment) for the connection. In this paper we examine the RWA problem and review various routing approaches and wavelength assignment approaches present in the literature.

Index Terms : Routing and wavelength assignment (RWA), Wavelength Division Network (WDM), Optical Cross Connect (OXC), Optical Network.

1. INTRODUCTION

Wavelength Division Multiplexing network is the dominant architecture for the optical networks. The Internet Protocol (IP) is enhanced to support traffic engineering & Quality of Service (QoS) support and Multi-Protocol Label Switching (MPLS) which is run by Label Switching Routers (LSR) are being deployed for faster switching. But the evolution of Optical technologies makes possible to move beyond point-to-point WDM transmission systems to an all-optical backbone network that can take full advantage of the available bandwidth. With WDM, a number of distinct wavelengths are used to implement separate channels. An optical fiber can carry several channels in parallel, each on a particular wavelength. The number of wavelengths that each fiber can carry simultaneously is limited by the physical characteristics of the fiber and the state of the optical technology used to combine these wavelengths onto the fiber and isolate them off the fiber.

Currently, there is tremendous interest within both the industry and the research community in optical networks in which OXCs provide the switching functionality. The Internet Engineering Task Force (IETF) is investigating the use of Generalized MPLS (GMPLS) and related signaling protocols to set up and tear down lightpaths. With GMPLS, the OXC backbone and the IP/MPLS subnetworks will share common functionality in the control plane, making it possible to seamlessly integrate all-optical networks within the overall Internet infrastructure. Also, the Optical Domain Service Interconnection (ODSI) initiative and the Optical Internetworking Forum (OIF) are concerned with the interface between an IP/MPLS subnetwork and the OXC to which it is attached as well as the interface between OXCs, and have several activities to address MPLS over WDM issues. Optical networks have also been the subject of extensive research investigating issues such as virtual topology design, call blocking performance, protection and restoration, routing algorithms and wavelength allocation policies, and the effect of wavelength conversion, among others.

The study report is organized as follows : Fist we present the issues related to static RWA problem then we discuss dynamic RWA problem. Next we discuss the available solutions for this RWA problem using Genetic algorithms. Finally we discuss about wavelength converters.

2. ROUTING AND WAVELENGTH ASSIGNMENT

A unique feature of optical WDM networks is the tight coupling between routing and wavelength selection. A light path is implemented by selecting a path of physical links between the source and destination edge nodes, and reserving a particular wavelength on each of these links for the light path. Thus, in establishing an optical connection we must deal with both routing (selecting a suitable path) and wavelength assignment (allocating an available wavelength for the connection). The resulting problem is referred to as the routing and wavelength assignment (RWA) problem and is significantly more difficult than the routing problem in electronic networks. The additional complexity arises from the fact that routing and wavelength assignment are subject to the following two constraints

1. Wavelength continuity constraint: a light path must use the same wavelength on all the links along its path from source to destination edge node.
2. Distinct wavelength constraint: all light paths using the same link (fiber) must be allocated distinct wavelengths

3. STATIC ROUTING AND WAVELENGTH ASSIGNMENT

The static RWA problem applies to the case in which the set of connections is known in advance, and a light path must be established for each connection. Studies on static RWA formulate the problem using integer linear program (ILP) formulations, or rely on heuristic approaches in an attempt to minimize the number of wavelengths required to establish a given set of lightpaths. The ILP formulations are NP-complete and therefore may only be solved for very small systems.

For larger systems, heuristic methods must be used. If the traffic patterns in the network are reasonably well-known in advance and any traffic variations take place over long time scales, the most effective technique for establishing optical connections (lightpaths) between edge nodes is by formulating and solving a static RWA problem.

Nina Skorin-Kapov[1] deals with the problem of Routing and Wavelength Assignment (RWA) of static lightpath demands which means that the set of demands is known a proiri. This NP-complete problem has been widely studied in literature and several heuristic algorithms have been proposed. The most common objective is to minimize the number of wavelengths used. Suggested is a simple and fast algorithm for the RWA problem motivated by an efficient existing algorithm for the same problem. Testing on a series of random networks indicates that these modifications yield solutions superior in quality to those obtained by the previously suggested algorithm.

Static routing and wavelength assignment (RWA) is usually formulated as an optimization problem with the objective of minimizing wavelength usage (MWU). Existing solution methodologies for the MWU problem are usually based on a two-step approach, where routing and wavelength assignment are done independently. Though this approach can reduce computational cost, the optimality of the solution is compromised. Ying Wang & Tee Hiang Cheng [2] propose a novel tabu search (TS) algorithm, which considers routing and wavelength assignment jointly without increasing the computational complexity. The performance of the proposed TS algorithm is compared with the Integer Linear Programming (ILP) method, which is known to solve the MWU to optimality. The results for both small and large networks show that our proposed TS algorithm works almost as well as the ILP solution and is much more computationally efficient.

Physical-layer degradations can severely limit the capacity of all-optical wavelength-routed networks, and powerful routing and wavelength assignment (RWA) algorithms are needed to minimize their effect. An optimal RWA technique is presented by J. He, M. Brandt-Pearce and S. Subramaniam [3] that minimizes the number of wavelengths needed to serve a set of static call provisioning requests. The optimal solution is compared to classical suboptimal algorithms and results show that route selection is more critical than wavelength assignment if multiple paths are available. Physical impairments become less significant in mesh networks than in tandem networks.

4. DYNAMIC ROUTING AND WAVELENGTH ASSIGNMENT

In dynamic routing and wavelength assignment problem, edge nodes submit to the network requests for light paths to be setup as needed. Thus, connection requests are initiated in some random fashion. Depending on the state of the network at the time of a request, the available resources may or may not be sufficient to establish a light path between the corresponding source-destination edge node pair. The network state consists of the physical path (route) and wavelength assignment for all active light paths. The state evolves randomly in time as new light paths are admitted and existing light paths are released. Thus, each time a request is made, an algorithm must be executed in real time to determine whether it is feasible to accommodate the request, and, if so, to perform routing and wavelength assignment. If a request for a light path cannot be accepted because of lack of resources, it is blocked.

DU Li, BI Xiao-Hong and WANG Xiao-Jing [4] aimed at optical networks with wave length conversion capacity, an algorithm for dynamic routing and wavelength assignment named WIC-RWA was proposed. Extended the layered graph model to optical networks with limited range wavelength conversion and limited count wavelength converters; Designed key degree and influence weight value for links in order to allocate the network resources reasonably; At the same time reduced the blocking probability of the network and the number of wavelength converters by setting wavelength conversion cost weight value and computing the path of minimum weight value. The simulation results showed that the new algorithm can effectively reduce the blocking probability of the entire network and limit the used number of wavelength converters.

Joan Triay, & Cristina Cervell´o-Pastor [5] propose the use of an ant colony optimization (ACO) algorithm to solve the intrinsic problem of the routing and wavelength assignment (RWA) on wavelength continuity constraint optical networks. The main advantage of the protocol is its distributed nature, which provides higher survivability to network failures or traffic congestion. The protocol has been applied to a specific type of future optical network based on the optical switching of bursts. It has been evaluated through extensive simulations with very promising results, particularly on highly congested scenarios where the load balancing capabilities of the protocol become especially efficient. Results on a partially meshed network like NSFNET show that the ant-based protocol outperforms other RWA algorithms under test in terms of blocking probability without worsening other metrics such as mean route length.

Xuefang Zhou [6] considers the dynamic wavelength assignment problem and improves a distributed algorithm to solve it. The algorithm is based on the assumption of the availability of equate processing power at the routers and light-paths are constructed dynamically when two end-nodes need to communicate. By introducing pre-releasing scheme and overtime-releasing scheme, novel distributed dynamic algorithm could effectively release wavelength resource.

5. GENETIC ALGORITHMS

Genetic algorithm is an iterative procedure maintaining a population of structures, are candidate solutions to specific domain challenges. The viability of each chromosome is measured with fitness function.

Each candidate solution is called as chromosome. Chromosomes can mate and mutate to produce the offsprings. The solution of this algorithm consists of population of individuals. Here each individual is characterized by fitness function. Based on the fitness, parents are selected to reproduce the offspring for the new generation. The fitter individuals have more chance to reproduce. The new generation will have the same size as that of the old generation, and the old generation will die. Offspring has the properties of the old generation. If well designed populations will converge to a optimal solution.

Ravi Sankar Barpanda, et., al [7] focuses on Integer Linear Programming (ILP) formulations for the Routing and Wavelength Assignment (RWA) problem in Wavelength Division Multiplexed (WDM) networks where end-users communicate with each other by establishing all-optical, non-interfering wavelength channels which are referred as lightpaths. The RWA problem is reducible to Graph Coloring problem in polynomial time and hence found to be NP-Complete. So, Soft Computing techniques along with Heuristic methods are applicable to solve large instances of the RWA problem. New ILP formulations is proposed by imposing additional constraints to the objective function, thereby, establishing lightpaths which are immune to signal distortion and crosstalk. After modeling the RWA problem as an Optimization problem, focus is given on applying Genetic Algorithms (GENETIC ALGORITHM) to find a sub-optimal solution for the RWA problem.

Considering transmission performance, Hao Qin, Zengji Liu, Shi Zhang, and Aijun Wen [8] were proposed a new optimization objective, which is to establish the maximum number of connections with the least number of wavelength converters. The modified Max-RWA problem is formulated as an integer linear programming (ILP), and then solved using genetic algorithm. The extended layered-graph approach is used to assign routes and wavelengths when necessary, thus reducing the complexity of the genetic algorithm. Numerical results obtained for NSFNET are presented .

In [9] Demetris Monoyios and Kyriakos Vlachos, the routing and wavelength assignment problem in all optical networks is considered. A solution to the RWA problem is proposed through a Genetic Algorithm (GENETIC ALGORITHM) based approach to search for the most suitable set of paths from many possible ones. GENETIC ALGORITHMs are used to solve this problem by introducing a new fitness function based on the mean value of occurrence of the common edges between the different genes of a single chromosome. In addition, performance and particularly execution times are improved by considering the maximum quantity of edge disjoint paths (EDPs) to initialize the population with some indigo chromosomes. These EDPs are pre-computed and inserted in the GENETIC ALGORITHM-RWA problem.

6. WAVELENGTH CONVERTERS

Wavelength division multiplexing (WDM) divides the bandwidth of an optical fiber into multiple wavelength channels, so that multiple users can transmit at distinct wavelengths through the same fiber concurrently. In all-optical WDM networks, the information remains in optical form throughout the network, so that the electronic bottleneck can be avoided. In an all-optical wide area network (WAN), a source to-destination path usually consists of multiple hops. If a transmission can occupy the same wavelength on every hop, it can remain in optical form within the network. Otherwise, it encounters wavelength conflict and it has to be blocked. To reduce the blocking probability, the network nodes are equipped with *wavelength converters* (WC's) to resolve wavelength conflict. Specifically, when a transmission encounters a wavelength conflict on a hop, a wavelength converter can be used to convert its wavelength to another one, so that it can remain in optical form on this hop.

Xiaowen Chu, Bo Liz, Jiangchuan Liu andLizhong Li [10] demonstrates that the wavelength converter placement and RWA algorithms are closely related in that a well designed wavelength converter placement mechanism for a particular RWA algorithm might not work well with a different RWA algorithm. Heuristic algorithm called Weighted Maximum Segment Length (WMSL) algorithm for limited wavelength converter placement for arbitrary mesh networks under a dynamic RWA algorithm adopting least-loaded routing and wavelength assignment algorithm. The objective is to minimize the average blocking probability, Extensive simulation studies have been carried out over three typical mesh networks, including the 14-node NSFNET, 19-node EON and 38-node CTNET. It is observed that the proposed WMSL algorithm not only outperforms existing wavelength converter placement algorithms by a large margin, but it also can achieve almost the same performance comparing with full wavelength conversion under the same RWA algorithm.

Sparse wavelength conversion and appropriate routing and wavelength assignment (RWA) algorithms are the two key factors in improving the blocking performance in wavelength-routed all-optical networks. Xiaowen Chu, Bo Li, and Imrich Chlamtac [11] demonstrates that the wavelength converter placement and RWA algorithms are closely related in the sense that a well-designed wavelength converter placement mechanism for a particular RWA algorithm might not work well with a different RWA algorithm. Therefore, the wavelength converter placement and the RWA have to be considered jointly.

In large dynamic networks it is extremely difficult to maintain accurate routing information on all network nodes. An algorithm called Bypass Based Optical Routing (BBOR) proposed by Xavier Masip-Bruin et al can reduce the effects of having inaccurate routing information in networks operating under the wavelength-continuity constraint. Then they extended the BBOR mechanism (for convenience it's called EBBOR mechanism below) to be applied to the networks with sparse and limited wavelength conversion. But it only considers the characteristic of wavelength conversion in the step of computing the bypass-paths so that its performance may decline with increasing the degree of wavelength translation. Yanting Luo, Yongjun Zhang and Wanyi Gu [12] introduces a novel algorithm which modifies both the lightpath selection and the bypass-paths computation in comparison to EBBOR algorithm. Simulations show that the Modified EBBOR (MEBBOR) algorithm improves the blocking performance significantly in optical networks with Conversion Capability.

CONCLUSION

In this work we have provided an overview of various approaches that can be used to route and assign wavelengths to connections in a wavelength routed optical WDM networks.The combined routing and wavelength assignment problem can be formulated as an integer linear program, which is NP-Complete. While the use of simplifying the assumptions and problem size reduction may allow the ILP to be solved for small networks, it may be more practical to decouple the RWA problem into its routing component and its wavelength assignment component for larger networks. Finally we conclude with the suggestion that the choice of selecting algorithm for routing in RWA problem may be based on the network size. For smaller size network, we may select the traditional Dijiksra's algorithm and for lager size network we may use Genetic algorithm for routing.

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