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WDM OPTICAL NETWORK: EXAMINING OF REROUTING APPROACHES

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To get better wavelength channel utilization, rerouting can be used. During the course of rerouting, throughput will be low down or even zero. Wavelength rerouting has two works the lightpath migration and rerouting algorithm. The former deals with the migration of lightpath. It is advantageous that a rerouting operation incurs shortest disruption time and makes switching manage at the routing nodes simpler. The later, determines the lightpaths can be rerouted and selects a few among them to create a wavelength continuous route to satisfy a connection request. It is advantageous that a rerouting algorithm be simple, run in polynomial time and minimize the number of existing lightpaths required to be rerouted. It is review paper, different rerouting strategies are compared and hybrid rerouting is an appropriate option. Passive rerouting is appropriate in case of Wavelength Conversion (WC).

Keywords: Lightpath Migration, Rerouting, Wavelength Conversion and Passive Rerouting.

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1. INTRODUCTION

In wavelength routed optical networks, control mechanisms are required to dynamically set up and tear down lightpaths. Research objectives in this field are mainly the development of control mechanisms which minimize the blocking probability of lightpath requests, the set-up delay and finally the control message overhead. In traditional telecommunication networks, network control is implemented as part of a layered management system. The approach adopted in IP networks separates the control from management focusing on the automation of provisioning and control. The new trends in optical Internet are also focused on developing such an automated optical control plane.

(a) Without Rerouting

(b) Passive Rerouting

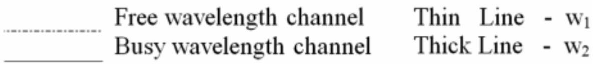

Fig.1: Passive Rerouting

Fig.2:(a) Path 5-1-2-3-4-6 Intentional Rerouting

Fig.2: (b) Path 5-6 Intentional Rerouting

Fig.2: Intentional Rerouting

Rerouting refers implicitly to dynamic traffic. Rerouting is simply the action of switching an existing lightpath or connection from one route to another route without changing the source and destination. In passive rerouting, the idea is that, once a lightpath request cannot be satisfied by the current network, we could try to reroute some existing lightpaths such that the new lightpath request can be accepted [6]. An example of passive rerouting is shown in Fig. 1, where each link can support two wavelengths. In Fig. 1 (a), assume lightpath L12 is originally setup between node 1 and node 2 using the wavelength w_2, and lightpath L23 is setup between node 2 and node 3 using the wavelength w_1. Due to the wavelength continuity constraint, a new lightpath request between node 1 and node

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3 has to be blocked. Consider the case in Fig. 1 (b), where passive rerouting is allowed: We can first reroute lightpath L23 from the wavelength w_1 to wavelength w_2 (using the same link); afterwards we can successfully setup the lightpath L13 between node 1 and node 3 using the thin wavelength. In this example, the physical path of lightpath L23 is not changed; instead, only its wavelength is changed. This is referred to as wavelength-retuning. In case the physical path of an establish lightpath is changed, we call it path-adjusting. In intentional rerouting, by which existing lightpaths are dynamically rerouted to a more suitable physical path to achieve a better load balancing during its whole life period. This technique could be very useful if a lightpath holds for a very long period. When a lightpath was setup at the very beginning, it could select a good physical path at that time; but the network traffic distribution is changing all the time, and it is possible that the previous physical path may not always be a good choice. Therefore it is possible to improve the overall blocking performance by dynamically changing the physical paths of existing lightpaths. It has shown in Fig. 2.

Rerouting algorithms may generally be categorized [8] as follows:

(i) Passive rerouting: Only after the normal routing procedure fails, the rerouting procedure tries to accommodate the new connection request by migrating some existing lightpaths/connections.

(ii) Active rerouting: The rerouting procedure is typically controlled by a timer, and it periodically migrates existing lightpaths/connections to better routes.

(iii) Lightpath level rerouting: Traffic of lightpaths at the full wavelength capacity granularity is rerouted.

(iv) Connection level rerouting: Traffic of connections at different bandwidth granularities is rerouted.

The paper is organized in the four sections. Section-1 has given a brief introduction about the WDM technology and rerouting used in optical telecommunication systems and networks. Section-2 gives a brief presentation of the evolution and current standing of optical networks, in order to support the following discussion in Section-3 presents comparisons, observation, main algorithm design issues of rerouting in WDM optical networks are discussed and presents the optimization issues in Optical Networks. These optimization problems are categorized in a few main classes such as physical and logical topology, routing and wavelength assignment, optimal placement of components, traffic grooming, and services provision optimization. Section-4 contains the discussion and concluding remarks.

2. THE EVOLUTION AND CURRENT STANDING OF OPTICAL NETWORKS

Being in a transient phase of quick growth, the technological circumstances in optical networks, is quite problematical and is inevitably a fusion of photonic and electronic technologies, resulting thus in the electronic bottleneck situation where we cannot make full use of the optical fiber's tremendous bandwidth. Today's networks are characterized as opaque and optical signal undergoes optical-to-electronic-to-optical (OEO) conversion regeneration at intermediate nodes. Typical cases of those networks are the widely deployed SDH and SONET networks. The evolution of optical networks is aimed towards the realization of a fully transparent all-optical network where, a single infrastructure based on photonic technology can carry data flows using different protocols, modulation schemes and/or bit rates without OEO conversion. WDM technology is a giant step towards the efficient use of optical bandwidth and currently is applied extensively in point-to-point and ring networks, having reached a quite mature level. This massive increase in networks bandwidth due to WDM consequently drives the need for faster and more efficient switching. Point-to-point and ring WDM networks using electronic switching are evolved towards all-optical switching, based on the concept of optical circuit switching (OCS) which is currently underway in transport networks. A network based on OCS consists of optical cross connects (OXCs) arranged in an arbitrary topology, providing interconnection to a number of subnet works. An OXC can switch the incoming optical signal carried in a wavelength, on an output fiber link. The output can be in the same wavelength or in a different wavelength if OXC is equipped with wavelength converter devices. The functionality of the later case is much greater. The communication channel established in a OXCs network is called 'lightpath' and can be extended over a number of fiber links (multi hop). If OXCs have no WC capability then the lightpath is associated with a single wavelength on each hop, where OXC with WC are used then the lightpath can have different wavelength in each hop. WRN that are based on OCS suggest a significant step toward all-optical networks. However, one drawback is that optical channels are reserved regardless data is being transmitted or not. The granularity in other words of wavelength routed networks is one wavelength. To make efficient use of a lightpaths capacity there is need for traffic grooming. Further to 'transparency' another characteristic of optical networks is re-configurability where the networks should have the capability to be properly adjusted in order to accommodate dynamically changing traffic demands. Because of the coarse granularity of the WRN they cannot efficiently address the re-configurability issue, if traffic grooming (TG) is not employed. Moreover the main application of optical networks, the Internet is not ideally suited to WRN concept, given that Internet applications rely on packet switching. Optical packet switching (OPS) is inevitably the future switching platform providing arbitrarily fine transmission and switching granularity, towards a flexible and efficient bandwidth use that can support the concept of all-optical Internet. The implementation however, of OPS is a very challenging target because of the significant problems in the required underlying photonics technology. The realization of OPS requires practical and cost-effective implementations for optical buffering, and all-optical photonic switches that can perform all-optical packet address recognition. Given that real today's networks do not yet employ all-optical address recognition is very important to reduce the duration of electronic header inspection, avoiding the control and management overhead (in the electronic domain) from intermediate layers such as SDH, SONET, ATM. The current developing solution which is essentially an intermediate step between wavelength routing and OPS, is optical burst switching (OBS), where there the basic switching entity is a variably sized burst. A burst is an aggregate flow of data packets with a single burst header. This is usually a group of IP packets heading for the same destination with the same quality of service (QoS) requirements. Grouping packets into bursts with a single burst header reduces header inspection duration and buffering at intermediate nodes. Given that the three main switching techniques (WRN, OBS, OPS) have also different application domains, is a more pragmatic approach to expect the coexistence of all three technologies in the future optical networks. The freedom also to select the appropriate technology for specific applications would also make the implementation much more cost efficient.

3. Comparisons of Rerouting Approaches and Discussion of Algorithm Design Issue and Optimization

Algorithm	Approach	Brief Description of Algorithm	Result
Source-initiated Active Rerouting [4]	Actively packs existing connections of different bandwidth granularities.	At first it estimates the potential resource gain of each existing connection and then reroutes only a small number of candidate connections that may give the largest gains.	It can efficiently reduce the rerouting costs, i.e., the required overheads and computations, while maximizing the amount of resources that can be conserved for future requests.
Passive rerouting[3]	Rerouting of existing lightpaths to accommodate new lightpath requests that will otherwise be blocked.	It combines passive rerouting and intentional rerouting, so it is called hybrid rerouting.	It gives the following: (A) When there is WC, passive rerouting works much better than intentional rerouting, and hybrid rerouting can only improve the performance over passive rerouting slightly, and (B) when there is no wavelength conversion, a naive-wavelength-retuning algorithm can achieve the most benefit of passive rerouting, whereas path adjusting does not help any further; however, the hybrid rerouting can improve the blocking performance significantly.
Intentional rerouting [3]	It intentionally reroute existing lightpaths during their life period to achieve better load balancing.		
shortest path wavelength rerouting (SPWRR) algorithm[2]	An efficient wavelength rerouting approach for dynamic provisioning of lightpath.	SPWRR algorithm for dynamic traffic in WDM optical networks. Low complexity algorithm has been developed which is used for the calculation of blocking probability of network.	It is used to improve throughput and to reduce blocking probability. The results have shown that SPWRR algorithm can improve blocking performance of the network.
M-DWP (Modified-Distributed discovery Wavelength path selection algorithm)[5]	Constraint-based path selection approach for dynamic routing and wavelength allocation in optical networks based on WDM.	Refined and Enhanced Distributed discovery Wavelength Path selection algorithm (DWP).	Takes a lesser amount of time to select a path and also preserves the advantage of overcoming the conflicting constraints imposed by electronic regenerators and also provide lesser blocking probability.

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Dynamic Least Congested Routing (DLCR) algorithm [7]	It dynamically switches the lightpath between the primary route and alternate route according to the network traffic distribution.	The basic principle of the DLCR algorithm is to dynamically switch the route of a lightpath to the leastcongestedroute. Usually a lightpath will hold for a very long period as compared with the lightpath setup time; therefore it is feasible to reroute existing lightpaths to vacant routes without paying too much traffic overhead.	DLCR algorithm can achieve much better blocking performance than traditional routing algorithms, including shortest path routing, fixed-alternate routing, and least congested path routing. The performance gain is more significant when wavelength conversion is available.
Connection Level Active Rerouting [8]	a novel rerouting approach which actively packs existing connections of different bandwidth granularities.	algorithm at first estimates the potential resource gain of each existing connection and then reroutes only a small number of candidate connections that may give the largest gains.	It can efficiently reduce the rerouting costs, i.e., the required overheads and computations, while maximizing the amount of resources that can be conserved for future requests. This approach keeps the rerouting costs at a low level but it can improve the blocking performance significantly.
Rerouting to optimize network resources [1]	Rerouting to optimize network resources allocation in order to set up an incoming lightpath demand to be blocked for lack of resources. It proposes a new lightpath rerouting scheme Permanent Lightpath Demands (PLDs), scheduled lightpath demands (SLDs), and random lightpath demands (RLDs).	Rerouting aims at reassigning the wavelength and/or the path of one or several established connections in order to free enough wavelengths to satisfy the incoming demand.	PLDs are static, whereas SLDs and RLDs are dynamic. SLDs are preplanned, whereas RLDs are stochastic. PLDs may be seen as a particular case of SLDs. PLDs and SLDs correspond to guaranteed services, whereas RLDs correspond to best-effort services. Thus, PLDs and SLDs cannot be rerouted.

Previously proposed active rerouting blindly attempts to reroute many existing lightpaths. Active rerouting maximizes the amount of resources that can be conserved for future requests. Hybrid rerouting combines passive rerouting and intentional rerouting, so it is called hybrid rerouting. When there is wavelength conversion, passive rerouting works much better than intentional rerouting. Hybrid rerouting can only improve the performance over passive rerouting slightly.

The DLCR algorithm has four main advantages: First, it is simple to be implemented since the lightpaths are always rerouted to a vacant route. Rerouting of a lightpath does not affect other existing lightpaths. Second, there is no extra computation requirement. Third, the lightpath disruption time is minimized to the physical limitation of switching the optical signal from one lightpath to another, since the data transmission is preserved on the old lightpath during the setup of the new one. Finally, DLCR algorithm can improve the blocking performance over LCR algorithm significantly. M-DWP takes a lesser amount of time to select a path and also preserves the advantage of overcoming the conflicting constraints.

In has seen the impact of WDM to the efficient use of optical bandwidth, which resulted to the tremendous increase of transmitted information and consequently to the need for faster and more flexible switching technologies in order to accommodate the increased traffic and support advanced guaranteed services. The resource contention between two lightpaths or connections may result in the blocking of one lightpath or the use of an inefficient long path for one of the two lightpaths. In a dynamic traffic environment, the contention is a more serious problem. Therefore, it is not possible to make the optimal routing decisions for all lightpaths and connections at the same time so that the total network throughput can be maximized. Unfortunately, in traditional dynamic traffic grooming, once a connection has been setup, its physical route will not change. Therefore, it is possible that, a connection is originally established on an inefficient long path, but after a while, some existing connections are torn down and they release their allocated resources (wavelengths, transceivers, converters), then that connection should be established in another path that employs less resources.

Optical networks are a field quite rich of optimization issues ranging from simple distinct problems, to multiobjective combinatorial ones. Considering WRN problems we face classical optimization problems such as physical and logical topology design, and routing and wavelength assignment (RWA). The main design issues of optical networks by reviewing characteristic applications of computational intelligence in the optimization process of those design problems, such as: (i) Physical and logical topology. (ii) Virtual topology reconfiguration. (iii) Routing and wavelength assignment. (iv) Multicast routing and wavelength assignment. (v) Optimal placement of components. (vi) Traffic grooming. (vii) Survivability. (viii) Protection and restoration on optical layer. (ix) Control and management. (x) QoS routing. (xi) Services optimization. However, many of the problems are combined and often is better to consider them jointly, in order to obtain better more robust solutions. The design of WRNs based on OXCs is a key issue, attracted intense research,in the implementation of optical networks. In order to reduce the complexity of the whole problem and make it more intuitive, the problem typically is divided in two sub problems network design, and routing and wavelength assignment (RWA). The network design part can be divided in two distinct problems, the physical topology design and the configuration design. For the WRN/OXC networks the physical topology problems seek to determine the count of OXCs and their interconnectivity, while the network configuration is related to the size of OXCs, the number of fibers and the set of lightpaths. The network design involves also the placement of key components such as amplifiers, wavelength converters, power slitters, as well as the consideration of additional constraints like protection schemes due to OXC failures, geographical issues etc. Establishing a set of lightpaths creates a virtual (logical) topology on top of the physical topology while the physical topology represents the physical interconnection of WDM nodes by actual fiber links in the WDM optical network. The links in the virtual topology represent all-optical connections or lightpaths established between pairs of nodes. On the other hand the purpose of RWA and issue is again two fold but usually the problem is considered jointly. Routing is the establishment of a lightpath between two edge nodes by mapping such a path on the physical topology. The allocation of a wavelength for the connection of those two nodes via the established lightpath is called Wavelength Assignment.

The RWA problem is more complicated than in electronic networks, because of the following two constraints:

- Wavelength continuity constraint, where lightpath must use the same wavelength along a multihop fiber link from the start to destination node.
- Distinct wavelength constraint, where all lightpaths mapped on the same fiber link on the physical topology, must use distinct allocated wavelengths. The RWA problem can be classified in two main classes, the static RWA where the traffic requirements are well known in advance and they remain unmodified, and the dynamic RWA where lightpath requests from nodes follow a dynamic random pattern. The Static RWA problems are usually refereed as virtual topology design problem as they are essentially equivalent. The objective of RWA is often to minimize the number of wavelengths used or to maximize the number of lightpaths given the constraint of a limited number of wavelengths. WC works as a two-port device where information carried in one wavelength can be identically transformed in another wavelength at the output port. By deploying WCs in a multihop fiber link is obvious that the wavelength continuity constraint can be relaxed, leading thus to more flexible network design strategies. A wavelength routed network based on OXCs equipped with WCs network becomes more flexible in terms of routing choices and more efficient in terms of wavelength – and thus bandwidth – use, improving this way the call blocking probability, and the overall throughput for a given number of available WDM channels. However due to the increased cost of WCs, is necessary to make careful use of WCs only in carefully selected OXCs or other wavelength convertible nodes of the network. Optimization can target to the minimization of components count (e.g. WCs) or in their optimal placement also. Considering the problem more generally the physical topology problem in a way deals also with the problem of the optimum placement of a minimum number of OXCs in order to solve a given traffic problem in a cost-effective way.

4. CONCLUSION

In this review paper we discussed the current research in the design and implementation of WDM Optical networks, focusing on the rerouting in relevant optimization issues. Different approaches have compared and found combination of approaches is preferable. The review tried to make clear the existence of the extremely broad range of technological areas and design issues that are related to the evolution of optical networks. All these uniquely related characteristics of optical networks lead to complex design issues with multiple constraints and a variety of diverse in nature parameters. This work can be extended with results of simulation and emulation followed by further investigations.

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