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A Survey: Sparse Traffic Grooming in Optical WDM Network

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Abstract -Traffic Grooming has become a very important issue on optical Network, as optical networks provide a very high speed data transmission for huge amount of data. A Sparse grooming Network with only a fractional of nodes having grooming functionalities may achieve the same performance as the one in which all the nodes are grooming, but with much lower cost. In literature different algorithms, models and techniques have been proposed to design the sparse grooming networks. With Proper assignment of routing and wavelengths in the network reduces the blocking probability ultimately increases the bandwidth of the network. In this paper, we studied and analyzed the different sparse traffic grooming and RWA assignment strategies with its performance metrics for optical mesh networks.

Keywords - *OXC - Optical Cross Connect, OC-Optical carrier, RWA- Routing & wavelength assignment, WDM – wavelength division multiplexing, G-Fabric - Grooming Fabric, G-Node Grooming Node, G-OXC – Grooming Optical Cross Connect, W-Fabric - wavelength-switching fabric.*

1. Introduction

Traffic grooming research has, in general, followed one of two directions. In *dynamic* grooming, it is assumed that the node grooming capabilities (in terms of available electronic ports, level of wavelength conversion, and switching capacity) are fixed and known, and the goal is to develop on-line algorithms for grooming and routing of connection requests that arrive in real time. Typical solution approaches transform the grooming problem into a shortest path problem on a new layered graph modeling both the underlying physical topology and the capabilities of individual nodes.

In *static* grooming, the starting point is the set of (forecast) long-term traffic demands, and the objective is to provision the network nodes to carry all the demands while minimizing the overall network cost. The cost metric frequently considered in the literature is the total number of electronic ports required to originate and terminate the lightpaths created to carry the traffic components.

In the past few decades, computer and telecommunication networks have experienced dramatic growth. With the growth of the Internet technology, there is a huge demand for network bandwidth. This demand is aggravated by the advent of new bandwidth hungry applications, such as multimedia communications e.g. voice mails, video on demand and high data traffic on Internet. The unprecedented growth of internet traffic and rapid advancements in the optical transport technologies have fueled the Internet transport infrastructure to evolve towards a model of high speed IP routers interconnected by intelligent optical networks.

1.1 Optical Transport Network

Optical transport networks are high-capacity telecommunications networks based on optical technologies and components that provide routing, grooming, and restoration at the wavelength level as well as wavelength-based services. Optical networks, based on the emergence of the optical layer in transport networks, provide higher capacity (in Tbps) and reduced costs for new applications such as the Internet, video and multimedia interaction, and advanced digital services. Optical networks are also being used widely nowadays in backbone networks that spans long distances, e.g., each link could be a few hundreds to a few thousands of kilometers in length., due to their high relatively low cost. The backbone network can be set up to provide nationwide or global coverage. Most telecom backbone networks are deployed today as an interconnection of "stacked" SONET/SDH rings, in which the fibers support multiple wavelengths using WDM transmission equipment. Ring networks, however, are inefficient in using the expensive bandwidth resources of the network. Thus, mesh networks, which consist of an arbitrary interconnection pattern, are being deployed as the backbone of choice for our future telecom networks.

1.2 Optical WDM Network

With the advancement of Dense Wavelength Division Multiplexing (DWDM) technology, the bandwidth of a fiber has significantly increased. Recent studies indicate that up to 360 DWDM wavelength channels can be sent through a single fiber. Similarly each wavelength channel can also carry up to 100 Gbps, with the advancements in switching equipments, tunable lasers and photo detectors. Even though fibers can offer very high bandwidth, user requests that come to optical fiber networks are of lower bandwidth. The capacity requirement of these low-rate traffic connections can vary in range from STS-1(51.84 Mbps or lower) up to full wavelength capacity.

This requires efficient grouping of individual connections onto the same wavelength as dedicating a unique wavelength for each demand will lead to huge wastage of bandwidth. Intelligent grouping is also required because each wavelength has to be dropped at the source and destination of each of the connections assigned to it. Dropping a wavelength at any node involves conversion from optical to electronic domain, and the equipment for performing this is the main contributor towards the cost of the network. This grouping of connections and assigning wavelengths to these groups, so as to optimize on some objective such as throughput or network cost, is reduced.

1.3 Traffic Grooming

1.3.1 Static Traffic Grooming

Static grooming is based on known long term traffic demands and the objective is to route all these traffic demands while minimizing the overall network cost. It is essentially an optimization problem that can be seen as a dual problem from different perspectives. One perspective is that, for a given traffic demand, satisfy all traffic requests as well as minimize the total network cost. The dual problem is that, for given resource limitation and traffic demands, maximize network throughput, i.e., the total amount of traffic that is successfully carried by the network.

1.3.2 Dynamic Traffic Grooming

The traffic request can be dynamic in nature, measured by the arrival rate and the holding time statistics of a connection request. In dynamic grooming algorithms are developed to groom and route the traffic request as they arrive in real time and the future traffic is unknown.

1.3.3 Sparse Traffic Grooming

Sparse grooming is an alternative in which, a selected subset of nodes are equipped with the grooming facilities and we call them G-nodes as in [Reference Num for G-node]. Research done in sparse grooming attempts to find the location of grooming sites.

The backbone network is mostly a mesh network with optical fibers. Optical fiber technology gives very high speed transmission speed because of its potentially limitless capabilities, a huge bandwidth (over 50 terabits per second (Tbps)). On the other hand, only a fraction of customers are expected to have a need for such a high bandwidth. Due to large cost of the optical backbone infrastructure it is necessary to combine low-speed traffic streams onto high-speed mesh network not all nodes need to have grooming capabilities. A network with only a fraction of nodes having grooming functionalities, called as a Sparse Grooming network. A node which has traffic -grooming capability is called as grooming node (G-Node). Hence, the problem of designing a sparse grooming WDM mesh network is a very important and practical problem.

Figure 1 shows a sample G-OXC architecture. There are two switching fabrics in this OXC, a wavelength-switching fabric (W-Fabric) and a grooming fabric (G-Fabric). Because a grooming OXC may be more costly than an OXC without grooming capability (i.e., the OXCs which only have the W- Fabric), and in some optical WDM mesh network, only a few network nodes may have traffic-grooming capability. This type of network, a “sparse-grooming network”, and a node which has traffic-grooming capability to be a grooming node (G-Node).

Once the sparse grooming network is designed from given physical optical backbone network, i.e. it forms a network with some nodes to be designated as grooming nodes. The grooming nodes along with the non-grooming nodes form a logical or virtual topology of the backbone network.

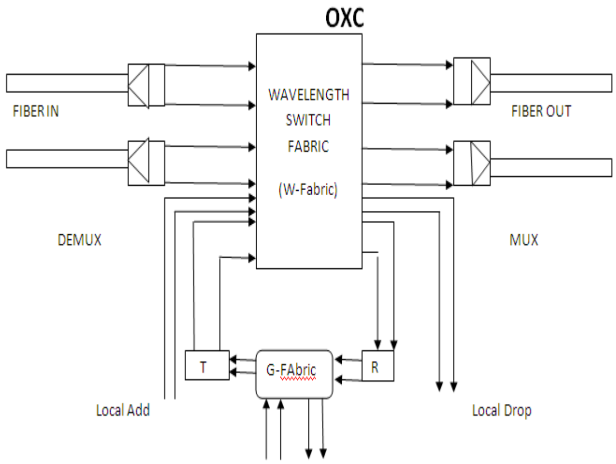

Figure 1: An OXC with a two-level hierarchy and grooming capability.

Based on the arrival of call or traffic request the light-paths are established between source and destination nodes. The light paths established are based on the k-shortest path routing, and depending on the availability of wavelength channels. To establish a lightpath in a WDM network, it is necessary to determine the route over which the lightpath should be established and the wavelength to be used on all the links along the route. This problem is called the routing and wavelength assignment (RWA) problem. Most of the previous research focuses on some routing and wavelength assignment schemes, which are summarized below.

1.4 Routing

The current used routing approaches are fixed routing, fixed- alternate routing, and adaptive routing.

1.4.1 Fixed Routing

In fixed routing, the connections are always routed through a predefined fixed route for a given source-destination pair. If there are not enough resources to satisfy a connection request, the connection gets blocked.

1.4.2 Fixed-alternate Routing

In fixed-alternate routing, multiple fixed routes are considered when a connection request comes. In this approach, each node in the network is required to maintain a routing table that contains an ordered list of a number of fixed routes to each destination node. It is simple as compared with other and widely used in the dynamic connection provisioning case.

1.4.3 Adaptive Routing

In adaptive routing, the route from a source node to a destination node is chosen dynamically, depending on the current network state. Adaptive routing will require more computation and a longer setup time than fixed-alternate routing, but it is also more flexible than fixed- alternate routing.

1.5 Wavelength Assignment Schemes

Wavelength Assignment is the main factor that affects the blocking probability and thereby the performance of the network. Proper assignment of wavelengths can lead to reduced or no use of wavelength converters which can significantly reduce the cost. As mentioned above, wavelength assignment can be broadly classified into two categories, static (off-line) and dynamic (on-line) assignment. In a static assignment scheme the same wavelength is assigned, if available, for every lightpath request generated at a node or else the request is blocked.

In dynamic allocation the node uses a following algorithm that selects a particular free wavelength at that node, if available, and then assigns it to that request and routes it, otherwise the request is blocked. Most of the assignment strategies available in the literature are dynamic in nature. The algorithm for every assignment scheme maintains a list of used and free wavelengths at each node. Whenever a call is generated the node selects a wavelength from the set of free wavelengths and assigns it to that call. Some of the proposed wavelength-assignment algorithms are as follows:

1.5.1 Random Wavelength Assignment

In given topology, the node maintains a list of free wavelengths at every moment, whenever a call is arrived the node randomly chooses a any wavelength from the set of free wavelengths and assigns that wavelength to that call.

1.5.2 First-fit Wavelength Assignment

This strategy maintains the predefine order on the wavelengths; it maintains a list of used and free wavelengths. The assignment scheme always chooses the lowest indexed wavelength from the list of free wavelengths and assigns it to the request.

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1.5.3 Most-used Wavelength Assignment

It uses the free wavelength that is used for maximum times in the network and assigned to called request. The Problem with Most-used wavelength assignment: Firstly, it requires the entire knowledge of the network.

1.5.4 Least-used Wavelength Assignment

It is similar to the most-used wavelength strategy, but in this strategy the least used wavelength in the network is assigned.

The main purpose of this approach is to achieve a near-uniform distribution of the load over the wavelength set.

2. Literature Survey

Keyao Zhu et. al. [1] has investigated the problem of designing a sparse-grooming WDM mesh network with static traffic. As with proper design of sparse network, increases the network throughput. In the design part some selected nodes do grooming functionality hence ultimately it reduces the overall network cost also. Previously in the literature, it is assumed that every network node has traffic-grooming capability, which may not be practical or cost-effective solution in a WDM backbone network. The problem is mathematically formulated and the proposed a heuristic approach which compares the network throughput with the number of grooming nodes selected from the given network. The groom nodes are selected on the basis of three criterion which are described below.

- Nodal degree selection
- Amount of bypass traffic
- Random selection.

Nodal-Degree Selection: The nodal degree of a node in a network is the number of connections the node has to other nodes. In this scheme, the nodes which have the maximum nodal degree are picked to be G-Nodes. If several nodes have same nodal degree and only some of them can be chosen, random selection is used to break any ties. Bypass-Traffic Selection: In this scheme it selects G nodes based on, the node which bypasses maximum amount of traffic. This will be analyzed by counting the number of call blocks on each node. And finally the nodes which have maximum blocked calls can be selected as the G-Nodes. Random Selection: In this scheme, the nodes are randomly picked to be G-Nodes. Wang Yao et. al.[2] had proposed the maximize-lightpath sharing multi-hop (MLS-MH) grooming algorithm to provision dynamically arriving multi-granularity connections in sparse grooming networks. This model support dynamic traffic grooming in sparse grooming networks. They have evaluated the performance in terms of call blocked in the network. Partha Paul et. al.[3] proposed a heuristic approach using max- connectivity grooming for solving GRWA problem with dynamic traffic requests. As their results prove that max-connectivity grooming uses minimal number of grooming devices and thus effectively reduces the network cost compared to other grooming schemes. The system also focus on the formulation of grooming, routing and wavelength assignment (GRWA) problem in WDM mesh networks with dynamic traffic under the constraints of the number of grooming devices used and wavelength continuity. It uses first fit wavelength assignment procedure. Osama Awwad et. al.[7] had proposed two novel Heuristics approach that minimize the cost of the traffic grooming and wavelength conversion equipment used in optical network without disturbing the network blocking performance.

As this approach focus on both traffic grooming with RWA problem hence it named as GRWA problem, previously in literature was shown that the problem of traffic grooming ,routing and wavelength assignment handles separately ,but genetic approach described by author handle it combine. The grooming problem can be performed at single-hop the performance was evaluated in terms of the total cost of traffic grooming and wavelength conversion devices used of the network. Jun Zhou et.al. [8] investigate the impact of non accurate state information on the performance of dynamic routing and wavelength assignment (RWA) algorithms. This study shows that effective RWA algorithm must be able to tolerate the imprecise global network state information and make effective routing and wavelength assignment decisions in the presence of imprecise global network state information.

They have assumed a timer-based link state update scheme which updates link state periodically with a given time interval. The main objective of a dynamic routing and wavelength assignment algorithm is to select a path and a wavelength on each link along the path such that the blocking probability is minimized. As this study focus on two types of network called WS (Wavelength-selective) in such a network, a connection can only be established if the same wavelength is available on all links between the source and the destination. Another type is WI (wavelength-interchangeable) networks which allow to change the wavelength from source to destination path. With respect to the WI network it has three different wavelength assignment algorithms like first, most and best fit. This study shows that the performance of network in terms of blocking probability with respect to the traffic load by selecting appropriate wavelength assignment scheme. Ashok Kumar Pradhan et. al.[9] has addressed multi cast traffic grooming problem to maximize the bandwidth in optical network. Proposed heuristic approach Prioritized multicast traffic grooming (PMTG) was used to reduce maximum number of wavelengths in optical network, only when grooming of incoming request call performed successfully. Result have proved that PMTG gives better performance than Multi cast traffic grooming with shortest path algorithm(MTG-SP) .The performance was measured in terms of wavelength required for any connection request.

Amrinder S. Arora et. al.[10] addressed the problem of optimally placing a limited number of wavelength converter in WDM optical Mesh network. A new heuristic algorithm proposed for the placement of wavelength converters ultimately minimizes the average blocking probability. The performance of heuristic approach measured using analytical model. Gangxiang shen et. al.[11] focuses on sub-wavelength traffic grooming in translucent optical network. A Virtual nodal degree ranked algorithm was proposed to select the best place of opaque switch node. Mixed-integer linear programming (MILP) optimization model was developed to groom sub-\ wavelength traffic request in network. This model maximizes served sub-wavelength traffic demand and minimizes the required wavelength capacity.

Paper No	Title	Author	Remark
1	"Design of WDM Mesh Networks with Sparse Grooming Capability".	K. Zhu, H. Zang, B. Mukherjee,	In this paper problem of designing a sparse-grooming WDM mesh network with static traffic is given
2	"Performance analysis of sparse traffic grooming in WDM mesh networks".	W. Yao, M. Li, and B. Ramamurthy,	maximize-lightpath sharing multi-hop (MLS-MH) grooming algorithm to provision dynamically arriving multi-granularity connections in sparse grooming networks is given
3	"Dynamic Traffic Grooming in WDM Optical Networks with Full Wavelength Conversion and Grooming Devices on Max-Connectivity Nodes".	Partha Paul, Balbeer. S. Rawat, Swapan K. Ghorai,	Proposed a heuristic approach using max-connectivity grooming for solving GRWA problem with dynamic traffic requests.
4	"Traffic grooming in an optical WDM mesh network".	K. Zhu and B. Mukherjee.	In this paper traffic grooming concept is given.
5	"Optimal traffic grooming in WDM mesh networks under dynamic traffic".	M. EI Houmaidi, M. A. Bassiouni and G. Li,	In this paper traffic grooming in mesh network in dynamic traffic grooming is given
6	"Design of Sparse Grooming Networks for Transporting Dynamic Multi-granularity Sub-wavelength Traffic".	W. Yao, M. Li. and B. Ramamurthy.	This paper gives the concept of design of transporting sparse traffic grooming in dynamic multigranularity subwavelength traffic
7	"Performance of WDM Mesh Networks with Limited Traffic	Osama Awwad, Ala Al-Fuqaha and Ammar Rayes	In this paper two novel Heuristics approach that minimize the cost of the traffic

	Grooming Resources".		grooming and wavelength conversion equipment used in optical network without disturbing the network blocking performance.
8	"A study of dynamic Routing and Wavelength assignment with Imprecise network State information".	Jun Zhou and Xin Yuan.	Concept of dynamic routing and wavelength assignment is given
9	,"A heuristic approach for multicast Traffic grooming in optical WDM Mesh network",.	Ashok Kumar Pradhan,S.Barat and Tanmay De.	Traffic grooming in mesh network is given
10	Converter placement in Wavelength Routing Mesh Topologies".	Amrinder S.Arora and Suresh Subraamaniam	This paper addressed the problem of optimally placing a limited number of wavelength converter in WDM optical Mesh network.
11	"Sparse Traffic Grooming in Translucent Optical Networks"	Gangxiang shen and Rodney S.Tucker	This paper focuses on sub-wavelength traffic grooming in translucent optical network.
12	"A Review of Routing and Wavelength Assignment Approaches for Wavelength-Routed Optical WDM Networks"	H. Zang, J. P. Jue, and B. Mukherjee,	This is a survey paper on routing and wavelength assignement.
13	"Optical WDM Networks",.	Bishwanath Mukherjee,	This is basic book for traffic groming network.

3. Conclusion

In recent years, most of attention has been given on the Traffic Grooming, Routing and wavelength assignment schemes, as it is very crucial factor of the Optical Network. Many researchers have worked on Sparse Traffic Grooming in order to minimize the Blocking probability of the network ultimately it improves the performance as well. In this paper I have tried to summarize various techniques used for sparse traffic grooming and RWA schemes in optical network.

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