Traffic Grooming Techniques in Optical Networks: A Survey

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Abstract—Traffic grooming has become a very important issue in optical networks as optical networks provide a very high speed of data transmission for huge amount of data. These are useful for short distance networks (LAN) as well as for long-distance networks (WAN), because light propagates through the fiber with high speed and offers very little attenuation as compared to electrical cables. Performance of any optical network can be measured on various parameters such as blocking probability, speed, cost, failure rate etc. Various algorithms, models and techniques have been proposed to measure, control and improve all these parameters. These algorithms, models, techniques etc. will be studied and analyzed so that necessary improvements can be performed.

Keywords—Traffic Grooming, Blocking Probability, Optical Networks.

I. INTRODUCTION

TRAFFIC Grooming is a term used to describe the optimization of capacity utilization in data transmission systems by means of cross connections of conversions between different transmission systems or layers within the same system. Major advantages of traffic grooming are reduced network cost improved network performance. Different multiplexing techniques can be used for traffic grooming in different domains of optical WDM networks [1].

• Space Division Multiplexing (SDM): It partitions the physical space to increase transport bandwidth, e.g. bundling a set of fibers into a single cable or using several cables within a network link.

• Frequency Division Multiplexing (FDM): It partitions the available frequency spectrum into a set of independent channels. The use of FDM within an optical network is termed (dense) wavelength-division multiplexing (DWDM or WDM) which enables a given fiber to carry traffic on many distinct wavelengths. WDM divides the optical spectrum into coarser units called wavebands, which are further divided into wavelength channels [2].

• Time Division Multiplexing (TDM): It divides the bandwidth’s time domain into repeated time-slots of fixed length. Using TDM, multiple signals can share a given wavelength if they are non-overlapping in time.

• Dynamic Statistical Multiplexing: It is also called packet-division multiplexing (PDM) and provides virtual circuit service in an IP/MPLS over WDM network architecture. The bandwidth of a WDM channel is shared between multiple IP traffic streams i.e. virtual circuits [2].

II. LITERATURE SURVEY

T.K Ramesh et. al. [3] presented an RWA protocol for WDM networks. The optimal and sub-optimal lightpaths were found by the control agents depending upon the number of free wavelengths available, the length of the lightpath (hop count) and number of conversion required from source to destination. When a connection request arrives at a node, the high speed data are routed through the readily available optimal lightpath thereby reducing the processing time. The low speed data are first tried to groom over the existing low speed data, else routed through the readily available lightpath. This proposed protocol proactively updates the changes in the network status using the concept of ant colony optimization. A backup lightpath was also suggested and maintained for survivability.

YANG Peng et. al. [4] have proposed Wavelength decomposition approach to compute blocking probability of fixed routing in wavelength-routed optical networks (WRONs) without wavelength conversions. In this approach, a WRON was treated as a set of different layers (colors), in which blocked traffic in one layer is overflowed to another layer. This is an analytical scheme that may be used to compute the Blocking Probability.

Amit Wason et.al. [5] have developed a low complexity mathematical model to calculate the blocking probability of network. This paper has suggested an optimum path as a solution to routing problem and the appropriate number of wavelengths have also been suggested which should be free in a network to have the least blocking probability. The implementation of the model has less complexity and it is very efficient in calculation of the blocking probability. This model can be used to evaluate the blocking performance of NSFNet and EUPAN Network topology and hence used to improve its performance on the basis of the blocking probability.

Rajneesh Randhawa et. al. [6] have proposed a new algorithm for wavelength assignment and its performance was evaluated in terms of blocking probability and fairness. The blocking performance of wavelength division multiplexing (WDM) network has been analyzed for the network having 10 nodes and for varying loads. Results have shown that blocking probability was increased as the load per link was increased.
The proposed algorithm was given the name best-fit sparse-wavelength conversion algorithm. In this algorithm the best-fit wavelength assignment algorithm is followed until the path is blocked. When the path is blocked, the wavelength $W_i$ is converted to a fixed other wavelength $W_j$.

Amit Wason et. al. [7] have proposed an efficient wavelength assignment algorithm for dynamic provisioning of lightpath. This proposed algorithm was based on most-used wavelength assignment algorithm. This study have also suggested a mathematical model for WDM optical networks for minimization of blocking probability. The results of proposed algorithm and suggested model were compared with the conventional wavelength assignment algorithms such as first-fit, best-fit, random and most-used wavelength assignment algorithms.

Xingwei Wang et. al. [8] have proposed a technique called Waveband Switching (WBS) to reduce the number of switching ports for reducing the network costs. High speed and ultra-large capacity requirements in optical network have increased the cost of networks. At the same time, the survivability for optical networks was also considered as failures may lead to a lot of traffic blockage. WBS technique have been combined the survivability in optical networks. Anuj Singal et. al. [9] have calculated the blocking probability of the network with respect to total number of wavelengths available in the eight node ring network. Number of available wavelengths were varied and blocking probability was calculated accordingly. Blocking probability varied from 0.8 to 0.2, 0.7 to 0.1 as number of available wavelength changed from 1 to 9 for most used and wavelength conversion algorithm, respectively. So as the number of available wavelength was increased, the blocking probability was decreased accordingly in ring network.

Amit Wason et. al. [10] have proposed a mathematical model to reduce the blocking probability of the WDM optical network. The proposed model had a closed-form expression and it did not require simulated statistics. This model suggested to choose the best path and appropriate number of free wavelengths in the network. It suggested that a compromise is required between the path length and number of free wavelength. The model was also used to evaluate the blocking performance of NSFNet topology.

Spyridon Antonakopoulos et. al. [11] have analyzed traffic grooming in optical network design, where the goal was to aggregate low bandwidth traffic streams to utilize efficiently high-bandwidth media such as wavelength channels. The suggested design defined a collection of light paths so that each traffic demand can follow a sequence of consecutive light paths. Two objectives were addressed: one was to minimize the total cost of equipment necessary to support the light paths and second was to minimize the number of light paths.

Jingjing Wua et. al. [12] have proposed multi-granularity grooming to save the cost and reduce the number of switching ports in Optical-Cross Connects (OXCs). Three heuristic algorithms were proposed: Multi-granularity Dedicated Protection Grooming (MDPG), Multi-granularity Shared Protection Grooming (MSPG) and Multi-granularity Mixed Protection Grooming (MMPG). Numerical results were compared for these algorithms for average port-cost, resource utilization ratio and the blocking probability.

Amit Wason et. al. [13] have proposed an efficient wavelength rerouting algorithm for dynamic provisioning of lightpaths. Rerouting of lightpaths was used to improve throughput and to reduce blocking probability in wavelength-division multiplexed (WDM) networks. Lightpath Rerouting Algorithm (LRRA) was proposed for dynamic traffic in WDM optical networks. LRRA can improve blocking performance of the network. A low complexity algorithm has also been developed which is used for the calculation of blocking probability of network. The proposed algorithm was applied on the realistic network such as NSFnet for calculation and optimization of blocking probability of the network. The proposed algorithm may also be implemented to huge networks.

Ilker Akgun et. al. [14] has addressed virtual topology reconfiguration (VTR) problem of optical WDM networks by taking the traffic grooming factor into consideration. Virtual topology reconfiguration (VTR) problem was divided into two independent sub-problems. Network resource utilization and network disruption are examined in terms of measurable parameters. A new multi-objective VTR algorithm called integrated reconfiguration (IR) algorithm was proposed to provide better overall VTR performance. The proposed VTR algorithm combines three main factors i.e. traffic load, traffic grooming ratio and route length of lightpaths into one single objective and considers them all while reconfiguration.

Weigang Hou et. al. [15] have addressed the issue of saving energy followed by the traffic grooming. Multicast grooming policies and auxiliary graph were proposed to support the multicast routing in green optical network. Based on these, a Multicast Green Grooming (MGG) approach was proposed by using the energy efficient optical bypass technology by reducing the use of energy-consuming equipments that mainly include the core router ports, optical transceivers and amplifiers etc.

Amit Wason et. al. [16] addressed that blocking probability can be affected by many factors such as network topology, traffic load, number of links, algorithms employed and whether wavelength conversion is available or not. A mathematical model has been proposed to reduce the blocking probability of the WDM optical network for wavelength convertible networks and wavelength non-convertible networks.

Wei Huo et. al. [17] have proposed to protect multi-granular optical networks against near-simultaneous dual-failures using capacity re-provisioning and the performance of re-provisioning was studied under different protection frameworks such as lightpath level and connection level protection.

Girish V. Chowdhary et. al. [18] addressed the problem of survivable multicast traffic grooming in WDM bidirectional ring networks related to multicast applications such as video conferencing, distance learning, and online auction etc. A node architecture was proposed based on Bidirectional Add Drop Multiplexers (BADM) to support bidirectional add/drop functionality along with traffic duplication at each node. Two traffic grooming algorithms, namely Survivable Grooming...
with Maximum Overlap of Sessions (SGMOS) and Survivable Grooming with Rerouting of Sessions (SGRS) were also proposed.

Richard S. Barr et. al. [1] addressed that network grooming is an active area of research which can be spanned to multiple disciplines and technologies. Telecommunication specific grooming has been addressed. The term grooming can be defined in a number of methods in the telecommunications industry. A new taxonomy called PACER is developed to capture five key aspects of telecommunication network grooming problems: Packing, Assigning, Converting, extracting/inserting, and Routing. Various problems of Traffic Grooming has been analyzed using PACER.

Chunsheng Xin [19] has developed an analytical model for dynamic traffic grooming in WDM optical networks. The performance of a specific network can be evaluated using this model. The model can be further used to analyze the blocking performance of the dynamic calls under mixed static and dynamic traffic. This can be implemented using two methods. Firstly remove all wave links that have been used to aggregate static calls and secondly treat each lightpath used to aggregate static calls as a single-link waverooute to support the g-link containing this lightpath.

Bensong Chen et. al. [20] has studied the traffic grooming problem on WDM networks with the physical topology of a star. Several nodes are connected to a single hub directly through a bi-directional optical fiber and these are not connected to each other in a star network. Line Terminating Equipment (LTE) constitutes a dominant cost among optical devices, so they consider to minimize the number of LTE,s to reduce network cost. A heuristic algorithm was proposed for the same.

Ding Zhenmin et. al. [21] has studied the problem of traffic grooming in mesh networks. An ILP formulation was presented to minimize the network cost. This formulation is achieved using clustering technique called Blocking Island. A new heuristic for traffic grooming in mesh networks was proposed.

Gangxiang Shen et. al. [22] studied sub-wavelength traffic grooming in a translucent optical network. A virtual nodal degree ranked algorithm was proposed for opaque node placement and the novel mixed-integer linear programming (MILP) based models for sub-wavelength traffic grooming for translucent optical networks. This model maximizes served sub-wavelength traffic demand and minimizes the required wavelength capacity.

Orman Gerstel et. al. [23] proposed network design for optical add–drop wavelength-division-multiplexed (OADM) rings. It minimizes overall network cost and the number of wavelengths required. The network cost includes the cost of the transceivers required at the nodes as well as the number of wavelengths. The transceiver cost may be further divided into two categories i.e. cost of terminating equipment and cost of higher-layer electronic processing equipment. A simple OADM ring is the point-to-point ring, where traffic is transported on WDM links optically, but switched through nodes electronically. Although the network is efficient in using link bandwidth, it has high electronic and opto-electronic processing costs.

Chunming Qiao et. al. [24] have proposed a paradigm called optical burst switching (OBS) as a method to support the burst data transfer. Two major types of OBS protocols were discussed and both of them use an out-of-band control packet to set up the optical switches for the following data burst. One protocol is based on tell-and-go (TAG). The other is based on Just-Enough-Time (JET).

III. CONCLUSION

Traffic grooming has become a very important issue in optical networks. Optical networks are generally used to provide a very high speed of data transmission for huge amount of data. So the performance optimization of optical network is very much required. The performance of any optical network can be measured on various parameters such as blocking probability, speed, cost, failure rate etc. Various algorithms and techniques have been proposed to measure, control and improve all these parameters. But still lot of improvements can be done on these techniques to achieve desired results.

REFERENCES