Survivable Traffic Grooming in Optical Networks

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**Abstract**—As high capacity all-optical networks and WDM technologies advance and merge together, aggregating low speed traffic streams onto high-speed wavelengths becomes more critical. Efficient aggregation techniques, known as traffic grooming, allow higher bandwidth utilization and can reduce request blocking probability. Traffic grooming in optical networks refers to the process of multiplexing, switching and de-multiplexing of wavelengths in efficient ways for improving network performance, throughput and bandwidth utilization while reducing the network cost and blocking ratio. The ability of an optical network to survive after the occurrence of failures is known as optical network survivability. Blocking Probability is the statistical probability that a telephone connection cannot be established due to insufficient transmission resources in the network. Usually expressed as the percentage or decimal equivalent of calls blocked by network congestion during the busy hour.

**Keywords**— WDM optical networks, RWA -Routing and Wavelength Assignment, GRWA - Traffic Grooming RWA, ILP - Integer Linear Programming, Blocking Probability.

**I. INTRODUCTION**

Optical fibre communication is firmly entrenched as part of the global information infrastructure”, that is high performance optical networks are essential for economic growth and well-being of communities. The attraction of transmission over an optical fibre is mainly in its much larger capacity compared to copper counterparts and immunity to electromagnetic interference and other external influence. At present, optical fibre transmission is seen as a dominant technology for both long-haul and short-haul broadband transmission[1]. Traffic grooming in optical networks refers to the process of multiplexing, switching and de-multiplexing of wavelengths in efficient ways for improving network performance, throughput and bandwidth utilization while reducing the network cost and blocking ratio. Satisfying a given set of traffic requests by minimizing the network cost and maximizing the network throughput, have been the major focus areas of traffic grooming. Some of the important factors that affect traffic grooming are the traffic load, link and wavelength capacities, placement of grooming devices, number of grooming devices and wavelength granularities. The ability of an optical network to survive after the occurrence of failures is known as optical network survivability. For survivability of such networks, protection and restoration become integral parts of network design. Restoration is carried out after a failure occurs and involves restoring the affected capacity by provisioning network resources. Protection, on the other hand, is a proactive approach in which backup capacity is provisioned for a potential failure before the fact. Based on the efficiency of network resource utilization, protection can be divided into dedicated protection and shared protection. Dedicated protection, which assigns dedicated backup resources to each working connection, is more effective for time critical applications because of its fast switching time. On the other hand, shared protection, which allows multiple working connections to share backup resources as long as they do not fail simultaneously, provides a more efficient way to utilize the network resource [2].

**II. LITERATURE SURVEY**

Chunsheng Xin et. al[3] have analyzed the performance of grooming dynamic client traffic in WDM optical networks. They have developed two multiservice link blocking models for traffic grooming, an exact solution and an approximation solution based on the continuous time Markov chain (CTMC). The analytical model is accurate compared with numerical results from simulation.

Anna Tzanakaki et. al[4] have focused on survivable optical networks and studied in detail the network performance improvement that can be achieved when jointly considering network resilience and physical layer constraints. They proposed a solution routing and wavelength assignment for both primary and protection paths which were jointly performed considering their physical performance. Simulations comparing the proposed solution with alternative schemes aiming at maximizing sharing of protection resources have shown substantial network performance improvement in terms of blocking probability reduction when jointly addressing resilience and physical layer performance requirement.

Wang Yao et. al[5] have studied the STG problem in WDM mesh optical networks employing path protection at the connection level. They have considered both dedicated protection and shared protection. The objective of STG problem is to maximize network throughput. In this the authors have presented two ILP formulations for the survivable...
traffic grooming problem one for dedicated path protection and the other for shared path protection. They have also proposed three efficient heuristic grooming algorithms namely SSGA, ISGA and TSGA. With numerical results they have showed that the computational complexity of the ILP approach is too large even for networks of small sizes. On the other hand ISGA performs much better than SSGA with an average of 50% and 15% improvement in network throughput. The result implies that the integrated routing approach is superior to the overlay routing approach in terms of resource efficiency.

Vladica Tintor et. al [6] have proposed a new routing and wavelength assignment scheme that improves the blocking probability of WDM networks and offers a very good utilization of the network resources. This heuristic results in high quality of service, prioritization of the LAN networks and lower installation costs compared with traditional RWA algorithms applied in WDM networks. It is based on the distributed Dijkstra sparse placement routing algorithm, first-fit wavelength reservation and traffic multiplexing. Load is applied for balancing and a sparse electronic switch placement algorithm during the process of finding the optimal light-path in order to reduce the number of dropped light-path sessions to zero, minimize the number of opaque nodes and maximize the utilization of the network. The simulation results showed that the proposed heuristic has no blocking sessions compared with other best algorithms. Our results further showed that network performances can be improved by increasing the number of wavelengths. Accordingly, they have shown through simulation that the proposed algorithm gives very good results for small and medium sized networks. Since the complexity of the problem is relatively high for large networks (more than 30 nodes), we need to apply additional relaxations.

Shuqiang Zhang et. al [7] have investigated both static and dynamic traffic grooming problems in a wavelength routing network, so as to minimize the total energy consumption of the core network, with the additional consideration of the holding times of the light-paths and connection requests. In the static case, all connection requests with their setup and tear-down times are known in advance. They have formulated an integer linear programming to minimize the energy consumption. In the dynamic case, the adopted a layered graph model called grooming graph and proposed a new traffic grooming heuristics called time-aware traffic grooming, which took the holding time of a new arrival connection request and the remaining holding time of existing light-paths into consideration. The results provided implications to select the most energy-efficient traffic grooming policies under various scenarios. According to the simulation results, TATG can achieve the least energy consumption when traffic load is relatively low, and Min-Hops can achieve the least when traffic load is relatively high.

Fsrouk E. El-Khamy et. al [8] have studied wavelength converters relax the wavelength continuity constrain in wavelength routed WDM all optical networks. Since wavelength converter is an expensive component with respect to other components in optical network researches are constrained in minimizing this cost keeping the blocking performance as optimum as we can. In this paper blocking performance optimization for convertible routers in WDM optical networks are examined using simulation. Simulation results show that full wavelength converters for large paths give significant enhancement in blocking performance than the non-wavelength converter router path of the same number of nodes. Results have shown that significant improvement in the blocking performance of the network is achieved when 50% of the nodes are equipped with wavelength converters using the same traffic load.

Chengyi Gao et. al [2] have addressed the problem of survivable traffic grooming and regenerator placement in optical wavelength division multiplexing (WDM) networks with impairment constraints. The working connections are protected end to end by provisioning bandwidth along a sequence of light-paths through either a dedicated or a shared connection-level protection scheme. They have proposed an auxiliary-graph-based approach to address the placement of regenerators and grooming equipment for both working and backup connections in the network in order to minimize the total equipment cost. Simulation results have shown that the proposed algorithms outperform light-path level protection algorithms, in which each light-path is protected separately. They have also shown the performance of connection-level protection under both dedicated and shared protection schemes in terms of the network cost, along with the effect of different cost models on equipment placement and performance for networks with different line rates. They have also investigated the restoration time of dedicated and shared connection-level protection. The simulation results show that our approach outperforms a light path-level protection approach in terms of network cost, and our adaptive placement of regenerators and grooming equipment can always find a good solution under different equipment cost models. Also, our approach can find a solution for any topology and traffic pattern. If the traffic changes or the topology changes, then the algorithm can be run again to re-optimize if desired. We also show that a network with higher line rate and longer optical reach can reduce the network cost when the traffic load increases. Connection-level and light path-level protection schemes have an interesting trade-off between equipment and signaling costs. Shared connection-level protection achieves lower cost than dedicated connection-level protection by sacrificing longer restoration time due to the longer distance of the connections. More practical results that consider physical distances as the optical reach abilities show similar performances of the different protection schemes and under different line rates.

Shuqiang Zhang et. al [9] have proposed a multi-layer auxiliary graph to jointly solve the electrical-layer routing and optical-layer RSA. Various traffic-grooming policies (objectives) can be achieved by properly adjusting the edge weights in the auxiliary graph. Also, they have proposed a spectrum reservation scheme that can efficiently utilize the
Canhui (Sam) Ou et al[10] have investigated the survivable traffic-grooming problem for optical mesh networks employing wavelength-division multiplexing (WDM) and dedicated protection. They have considered the dynamic-provisioning environment where a connection arrives at random, holds for a random amount of time, and then departs. A typical connection request may require bandwidth less than that of a wavelength, and it may also require protection from network failures, typically fiber cuts. Based on a generic grooming-node architecture, they have proposed two approaches—protection at light path (PAL) level and protection-at-connection (PAC) level—for grooming a connection request. They have investigated dedicated protection. In a companion paper (Ou et al. 2003), they investigated shared protection which leads to a substantially different treatment.

For dedicated protection, they proved that the problem of provisioning a connection under PAC is NP-complete, proposed effective heuristics for both schemes, and define comprehensive performance metrics to compare PAL with PAC with respect to wavelength/grooming-port efficiency.

Osama Awwad et. al[11] While a single fiber strand in wavelength division multiplexing (WDM) has over a terabit-per-second bandwidth and a wavelength channel has over a gigabit-per-second transmission speed, the network may still be required to support traffic requests at rates that are lower than the full wavelength capacity. To avoid assigning an entire light path to a small request, many researchers have looked at adding traffic grooming to the routing and wavelength assignment (RWA) problem. In this work, they have considered the RWA problem with traffic grooming (GRWA) for mesh networks under static and dynamic light path connection requests. The GRWA problem is NP-Complete since it is a generalization of the RWA problem which is known to be NP-Complete. They have proposed an integer linear programming (ILP) model that accurately depicts the GRWA problem. Because it is very hard to find a solution for large networks using ILP, they have solved the GRWA problem by proposing two novel heuristics. The strength of the proposed heuristics stems from their simplicity, efficiency and applicability to large-scale networks. Simulation results demonstrated that deploying traffic grooming resources on the edge of optical networks is more cost effective and results in a similar blocking performance to that obtained when distributing the grooming resources throughout the optical network domain. The results demonstrated that the proposed heuristics reduce the total number of traffic grooming and wavelength conversion resources without hindering the blocking performance of the network. Moreover, The results also showed that the blocking performance does not always improve as the traffic grooming and wavelength conversion devices are placed throughout the optical network. This implies that a network designer can reduce the network cost without affecting the network performance by carefully deploying a limited number of traffic grooming and wavelength conversion resources in the network.

Rajneesh Randhawa et. al[12] have proposed a new wavelength assignment and evaluated its performance in terms of blocking probability and fairness. They have shown that the proposed algorithm offers the least blocking probability. The blocking performance of wavelength division multiplexing (WDM) network has been analyzed for the network having 10 nodes and for varying loads. As the load per links (in Erlangs) increases, the blocking probability increases. The results have shown that the performance of first-fit algorithm is better than random algorithm where as the proposed algorithm offers the least blocking.

Amit Wason et. al[13] has proposed analyses of the wavelength assignment problem. The first-fit wavelength assignment algorithm is compared with the random wavelength assignment algorithm. These algorithms are compared on the basis of blocking probability; number of channels and number of links are kept constant whereas the response of the algorithms is calculated by varying the load per link (in Erlangs). The blocking probability is also calculated for the network with wavelength conversion and without wavelength conversion. The results showed that the response of first-fit is better than random algorithm where as the response of wavelength conversion is much better than without conversion i.e. with first-fit and random algorithm.

Farid Farahmand et. al[14] has developed several grooming algorithms and studied them under various network objectives. They also compared their performance with previously proposed light-path based grooming algorithms. Through extensive simulation results they have showed that their proposed approaches lead to lower request blocking probability and lower average number of logical hops when the number of transceivers per node is limited.

Canhui (Sam) Ou et. al[15] have proposed three approaches—protection-at-light-path (PAL) level, mixed-protection-at-connection (MPAC) level and separate protection-at-connection (SPAC) level for grooming a connection request with shared protection against single-fiber failures.

Jintao et. al[16] have proposed rational approximation to perform the blocking analysis of circuit switched all optical networks. This algorithm can be applied to large networks with various topologies and routing and wavelength assignment algorithms. It can be applied to either full, sparse or no wavelength conversion. They also proposed fixed path
wavelength assignment algorithm for networks with balanced and unbalanced traffic.

III. CONCLUSION

Traffic grooming has become an important issue in optical networks. Survivability in another terms which is associated with optical networks. A network can be groomed for optimized utilization. Traffic grooming has its own impact on the survivability of the optical networks. In this paper we have studied and analyzed a number of traffic grooming techniques and survivability techniques

REFERENCES