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Survivable Sparse Traffic Grooming in Optical WDM Mesh Network Using Genetic Algorithm

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Abstract: Optical communication provides large bandwidth for the transfer of data. This large bandwidth is in Tbps and the requirements of the users are small. To use this large amount of bandwidth availability in an efficient manner one has to use the WDM technique. The optical network provides routing, multiplexing and wavelength assignment for the grooming of traffic. Traffic grooming in optical WDM mesh network is a topic of interest. The traffic grooming is either a full grooming or sparse grooming. Sparse traffic grooming is important to use as it reduces the cost of the network. In sparse traffic grooming most important is grooming node (G-node) selection. The proposed Genetic algorithm is used for the selection of G-nodes. Once the G-nodes are selected then sparse traffic grooming will be performed on the virtual topology created. Also, if any fault occurs on the network then we are providing the survivability model. This model reduces the loss of data. The proposed Genetic algorithm improves the performance for Survivable Sparse Traffic Grooming (SSTG) and shows that the throughput is nearly equal to sparse traffic grooming.

Key words: Optical communication, traffic grooming, survivability, WDM, Genetic algorithm, availability

INTRODUCTION

Optical backbone has moved from ring to mesh. This optical network provides huge bandwidth approximately in Tbps. Each such an optical fiber is divided into small optical channels having different capacity. The capacity of optical fiber is measured in OC-n (Optical Channel-n) where n is variable showing the capacity of the channel. OC-1 is STS-1 (51.4 Mbps), OC-12, OC-48 and OC-192 ($192\times51.4 = 10$ Gbps) are some examples of these varying capacity (Keyao *et al*., 2006). Due to such a high bandwidth channels, it needs to divide these channels into small wavelength bands. Therefore, Wavelength Division Multiplexing (WDM) is used for the multiplexing of wavelengths in the backbone network. This WDM helps us to divide the channel capacity appropriate to user requirements, avoids wastage of bandwidth.

The optical network uses Optical cross Connects (OXC) at the groom0ing node. The use of Add-Drop Multiplexers (ADM) and Optical ADM (OADM) is also important at these nodes. The switching techniques are used at the nodes where connection requests are switched. At these nodes, we need to have traffic grooming capabilities. Traffic grooming means the transfer of multiple low-speed connections onto high-speed channels (Keyao *et al*., 2006). There is a requirement of specific hardware and software at a node to be grooming. The increase in the requirements of such a hardware and software increases the cost. The increased cost of the network may reduce the users of the network. To reduce these requirements a special technique which reduces the use of hardware as well as software is traffic grooming. In the traffic grooming, every node is having grooming devices and in sparse traffic grooming only a few nodes with grooming devices. The node with grooming devices is called Grooming nodes (G-node). Increase in the number of nongrooming nodes in the network decreases the cost of the network. In sparse traffic grooming, the G-node selection must be done on performance criteria. There are various methods for G-node selection.

Random G-node, maximum nodal degree, maximum total traffic and sequential minimize blocking probability. Random G-node is the method in which any node is selected at random and made grooming. This random method selects few nodes as G-node. Random selection of G-node does not guarantee the performance and reduction in blocking probability. The second method is based on graph theory where the number of edges of each vertex will be considered as a measure to select one of the nodes as G-node. The node having a maximum nodal degree will be selected. It will be considered as the best G-node on the assumption that the maximum number

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of the request will arrive at this node. The third method is based on maximum total traffic. The counters are there at every node to count the requests. The node with maximum traffic will be selected as G-node. The last method is based on blocking probability. When G-nodes are selected based on performance of the network then this performance may affect by link or node failures in the network.

Link or node failure leads to loss of connection requests and loss of data. This affects the cost of networks and performance of that network. Survivability is important aspect at the point where any kind of failure has occurred. Service which is affected must be recovered in an instance of time. To recover the system we have fault management schemes. Among the two methods of fault management, protection method gives two solutions. In protection, one can provide dedicated or shared backups. These solutions in the protection method consider the path for data transfer and also the link for data transfer. We can provide either path protection or link protection. The restoration method is also for the path or the link.

To address the problem of traffic grooming many researchers has put their efforts and various methods are brought into literature. This literature has studied in depth in the next section of this study.

Study of existing methods: The traffic grooming problem was investigated by Zhu and Mukherjee (2002). Network performance improvement was one of the objectives of this study. Integer Linear Programming (ILP) formulation was done with two new heuristic algorithms. Grooming, Routing and Wavelength Assignment (GRWA) is formulated as ILP formulation by Hu and Leida (2004). They divided GRWA problem into two subproblems. One is GR and other is WA. Different approaches for traffic grooming are proposed by few other researchers (Hu and Leida, 2004; Zhu *et al*., 2003; Yao and Ramamurthy, 2005; Yoon *et al*., 2005; Konda and Chow, 2001). A Genetic algorithm for traffic grooming is proposed by Lee and Park (2002). The cost optimization was the main objective of this study. Mukhopadhyay *et al*. (2004) proposed a Genetic algorithm for traffic grooming. This Genetic algorithm is for unidirectional SONET/ WDM ring network.

A Genetic algorithm for sparse traffic grooming was proposed by Awwad *et al*. (2006). The focus was GRWA problem using a Genetic algorithm. The objective of this paper is to minimize cost and number of equipment for wavelength conversion. Der-Rong (2009) proposed Genetic algorithms to solve minimal cost multicast routing problem. The objective is to find light paths and minimize the cost. To represent the routing path a path oriented encoding chromosome is used. Tanmay *et al*. (2008) proposed traffic grooming technique using a Genetic algorithm based approach. This Genetic algorithm based approach solve the GRWA problem in the optical mesh network. The researchers claim that the network throughput has increased by use of Genetic algorithms. Shinde and Patil (2015) a heuristics algorithm proposed which results in improved network performance and reduced cost. Modified multiobjective metaheuristics proposed by Shinde *et al*. (2015) solve the traffic grooming problem in a different manner.

Most of the work specified focus on sparse traffic grooming either by a Genetic algorithm or by heuristics methods. But when a fault occurs in the given sparse traffic grooming network then the solution is proposed by research by Shinde *et al*. (2016). The fault tolerant network gives good performance with disaster survivability. These failures are addressed using a Genetic algorithm in this study.

Problem formulation: Consider an optical network with N nodes connected by E number of edges forms a directed connected graph, E (N G STG). Each edge is a link between two nodes represented by e€E is bidirectional. Then, the problem of survivable sparse traffic grooming is defined as.

Problem: For any given network topology at any node N if the number of transceivers is known, the capacity of each fiber channel is known. Also a number of the wavelength at fiber link and varying capacity connection request is known. Then, we need to establish a light path with path protection and wavelength multiplexing low-speed traffic connections on high-speed line. For the above problem statement, we are using a Genetic algorithm with the following assumptions:

- Traffic demands known in advance at each node before establishing the path
- G-node has wavelength conversion capability. Nongrooming nodes do not have wavelength conversion capability
- Traffic multiplexing from low to high is possible at G-nodes
- All the channels are having the capacity of OC-192
- Each channel will be divided into varying capacity of wavelengths
- Multiplexing and demultiplexing are allowed at all nodes
- Call switching is dynamic at G-node

MATERIALS AND METHODS

Here we are presenting Genetic algorithm approach to solve traffic grooming problem. First, we are considering an NSFNET topology for simulating the environment. When traffic grooming problem is addressed we need to solve it by virtual topology design. When the G-nodes are selected Genetic algorithm is applied for the selection. Next step is to multiplex/demultiplex the data of low-speed connection to high-speed connection. The virtual link will be created from start node of backbone network to last node. If the G-node is on the way of the above virtual link then the link is a divided into sub links, i.e., from start to G-node and G-node to G-node and/or G-node to last node.

Fitness function and chromosome: The fitness function is useful to decide whether the given node is fit to survive for the next generation traffic. It is important to know the traffic in advance to establish the path and for allocation of resources. We are applying statistical models to determine percentage of the increase in traffic. The analysis shows that the future traffic increases by 22-67%. When we modeled genetic algorithm we also increased traffic gradually in the given range. The node is said to be fit as G-node if the throughput of network increases. As more number of calls is served due to increased throughput of the network there is a decrease in the blocking probability. Chromosomes will be formed by a number of wavelengths at that node, a nodal degree of that node and maximum total traffic at that node. The node will be selected at random with maximum nodal degree is given by:

$$P(G_{nd}) = \frac{P(G_i \text{ and } Max_{nd})}{P(Max_{nd})}$$

Where:

$P(G_i)$ = The Probability of ith node to be grooming

$P(Max_{nd})$ = Total Probability of Maximum nodal degree for that node

The probability of maximum total traffic at given node is:

$$P(G_{mtt}) = \frac{P(G_t \text{ and } Max_{tt})}{P(Max_{tt})}$$

Where:

$P(Max_{tt})$ = The overall Probability of Maximum total traffic

$P(G_t)$ = Total traffic at the given node

If $P(G_{mtt})$ and $P(G_{nd})$ is acceptable for the given node then the node is selected as G-node.

Genetic operators: The Genetic algorithm performs following steps.

Initial population: All the nodes in the network will be considered as an initial population to find few best fittest as G-node. In every generation one node whose probability to be selected are less than all other will be rejected. Also, the node whose probability is high as to become G-node is duplicated in the population.

Selection: We need to select best to fit in the next generation. We are selecting based on the fitness function. One more parameter which is important is a number of wavelengths when maximum total traffic will be calculated the available wavelengths will be counted at each node. Initially, WDM divides wavelengths in equal capacity till G-node selection will not be done. At the service time, WDM has a varying division of band. The node with maximum wavelength availability is selected. This selection is from the nodes with the highest probability.

Crossover: When the wavelength counts are considered in chromosomes then at a node with maximum probability of fitness the small wavelength requests are combined on one large and more wavelengths are made available. This crossover is giving us the node with maximum wavelength availability so that we can serve a number of requests.

Mutation: Due to randomness and wavelength multiplexing sometimes it may happen that node with maximum fitness has less number of wavelengths available and will be removed from the population. This type of nodes will be converted to be fit population by mutation. This selection of G-node is based on reduced blocking probability and the network performance. The selected G-node with given topology is used for SSTG. The system architecture is as shown in Fig. 1.

Sparse traffic grooming: With the selected number of G-nodes poisson traffic is generated at every node. Each such a request will give us the source-destination pair in advance. Based on the routing table information shortest route is selected to serve that request. The Dijkstra's shortest path routing algorithm is used. The WDM method divides the channel into unequal wavelength bands equals to some OC-n. When a G-node falls on the route R then divide route R into R1and R2. Here, R1 and R2 are the routes from the source node to G-node on the path and G-node to that destination. Both R1 and R2 hold the principle of optimality. The route R2 may also divide into two or more routes in a similar manner if there is more than one G-node on the shortest path. This route also follows the principle of optimality.

At each G-node requests are groomed, routed and wavelength assignment is done. When a request is not served due to unavailability of wavelength band then the

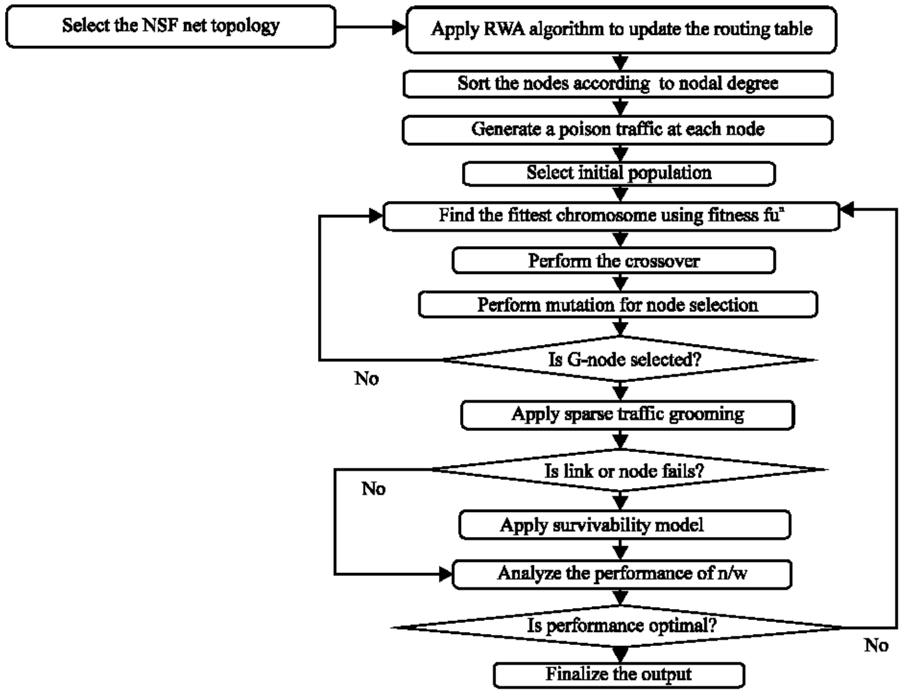

Fig. 1: Architecture of SSTG using Genetic algorithm

request is counted as blocked request. The blocking probability is calculated. After blocking probability the throughput of the network is measured and also the network performance is calculated. If there is any fault in the network may be of node failure or link failure we apply survivability principles on the sparse traffic grooming network.

Survivability model: Survivability is applied only if there is either a link failure type of fault, path failure fault or node failure has occurred. When a link or path fails the route of the request broke down and the probability of data loss increases. To avoid this path protection and path restoration mechanism is recommended. We have provided path protection mechanism. Shared path protection mechanism is provided. This will avoid the loss of data. If the node failure occurs then restoration mechanism is applied for survivability. After the survivability methods, the performance of the network is evaluated (Fig. 1).

RESULTS AND DISCUSSION

The NSFNET topology is used for experimental work. The simulation for 14 node network uses OC-192. Initially to update the routing table and count the maximum total traffic static WDM technique is used. Static WDM gives each wavelength is of equal capacity. Once the maximum total traffic is calculated at each node the vectors for maximum total traffic, maximum nodal degree and wavelength counts available according to traffic at each node is created. These parameters are used to form the chromosomes.

According to the fitness function, the fittest nodes are selected. The selected best fittest nodes will be considered as G-nodes. Other than these G-nodes all other nodes are nongrooming node in the network. This will help to create the virtual topology design. To evaluate the performance of the network Poisson traffic is generated at all nodes. The generated request randomly defines the destination for that request. At each node, dynamic WDM is used so that varying size wavelength is available for service of varying sized requests. When traffic grooming is performed at G-nodes the numbers of wavelengths are made available for the usage. A virtual path through the virtual link on the given physical topology is created from start node to the last node. This link is optimal path for that call. Due to sparse grooming route may get divided into n links. The wavelength assignment is based on best fit method.

When the experimentation is performed then we created an instance, so that, a link failure will occur. For this type of failure, we have monitored the network. The observations are that performance has not degraded due to path protection mechanism. The throughput of the network has decreased a bit but the loss of data has

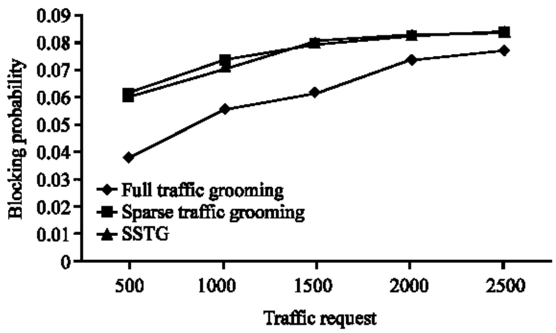

Fig. 2: Blocking probability vs. traffic requests

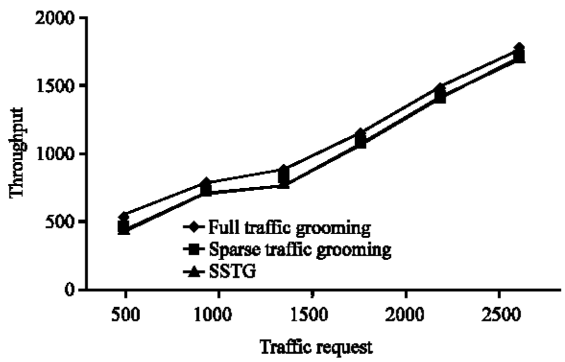

Fig. 3: Throughput vs. traffic requests

avoided and the decrease in the performance in not measurable. So, we can say the system is robust for link failure.

We have compared the blocking probability when we have used full grooming with regular sparse traffic grooming and Survivable Sparse Traffic Grooming using GA (SSTG). These comparative results are as shown in Fig. 2. This graph shows that there is no variation in the blocking probability when used STG and SSTG using GA.

The throughput is shown in Fig. 3 for all the three methods. In full grooming, all the requests will get served. STG and SSTG using GA throughput are compared. There is a small deviation in the throughput of these two methods.

CONCLUSION

Survivability is the major problem in any network. This study gives direction about the use of fault tolerant mechanism for failures if any occurred in the sparse traffic grooming problems. The Genetic algorithm gives best G-nodes and the performance of the network improved in considerable amount. Also, there is considerable improvement in the throughput of the network by use of the proposed methodology. Blocking of requests is reduced due to the selection of best G-node. The comparison of blocking probability in all methods proves the variation.

REFERENCES

Awwad, O., A.I. Al-Fuqaha and M. Guizani, 2006. Genetic approach for traffic grooming, routing and wavelength assignment in WDM optical networks with sparse grooming resources. Proceedings of the IEEE International Conference on Communications ICC'06. Vol. 6, June 11-15, 2006, IEEE, Istanbul, Turkey, ISBN:1-4244-0355-3, pp: 2447-2452.

Der-Rong, D., 2009. Genetic algorithm for finding minimal cost light-forest of multicast routing on WDM networks. Artif. Intell. Rev., 2008: 195-222.

Hu, J.Q. and B. Leida, 2004. Traffic grooming, routing and wavelength assignment in optical WDM mesh networks. Proceedings of the 23th IEEE Annual Joint Conference INFOCOM Computer and Communications Societies Vol. 1, March 7-11, 2004, IEEE, Hong Kong, China, ISBN:0-7803-8355-9, pp: 495-501.

Keyao, Z., H. Zhu and B. Mukherjee, 2006. Traffic Grooming in Optical WDM Mesh Networks. Springer, Berlin, Germany, ISBN:978-0387-25432-6, Pages: 173.

Konda, V.R. and T.Y. Chow, 2001. Algorithm for traffic grooming in optical networks to minimize the number of transceivers. Proceedings of the 2001 IEEE International Workshop on High Performance Switching and Routing, May 29-31, 2001, IEEE, Dallas, Texas, USA., ISBN:0-7803-6711-1, pp: 218-221.

Lee, C. and E.K. Park, 2002. A genetic algorithm for traffic grooming in all-optical mesh networks. Proceedings of the 2002 IEEE International Conference on Systems, Man and Cybernetics Vol. 7, October 6-9, 2002, IEEE, Yasmine Hammamet, Tunisia, ISBN:0-7803-7437-1, pp: 1-6.

Mukhopadhyay, M., U. Biswas and M.K. Naskar, 2004. A genetic algorithm for traffic grooming in unidirectional SONET-WDM rings. Proceedings of the IEEE 1st India Annual Conference on INDICON, December 20-22, 2004, IEEE, Kharagpur, India, ISBN:0-7803-8909-3, pp: 252-255.

Shinde, S., S.H. Patil and M. Gulwani, 2015. Modified multiobjective metaheuristics for sparse traffic grooming in optical WDM mesh networks. Procedia Comput. Sci., 57: 980-987.

Shinde, S.R. and S.H. Patil, 2015. Heuristics for sparse traffic grooming in dynamic WDM optical mesh networks. Proceedings of the 2015 International Conference on Computing Communication Control and Automation (ICCUBEA), February 26-27, 2015, IEEE, Pune, India, ISBN:978-1-4799-6892-3, pp: 159-163.

Shinde, S.R., S.H. Patil, S.E. Roslin and A.S. Shinde, 2016. Fault tolerant system for sparse traffic grooming in optical WDM mesh networks using combiner queue. Intl. J. Adv. Comput. Sci. Appl., 7: 176-180.

Tanmay, D., J. Puneet, P. Ajit and S. Indranil, 2008. A gene tic algorithm based approach for traffic grooming, routing and wavelength assignment in optical WDM mesh networks. Proceedings of the 16th IEEE International Conference on Networks ICON, December 12-14, 2008, IEEE, New Delhi, India, ISBN:978-1-4244-3805-1, pp: 1-6.

Yao, W. and B. Ramamurthy, 2005. A link bundled auxiliary graph model for constrained dynamic traffic grooming in WDM mesh networks. IEEE. J. Sel. Areas Commun., 23: 1542-1555.

Yoon, Y.R., T.J. Lee, M.Y. Chung and H. Choo, 2005. Traffic Grooming Based on Shortest Path in Optical WDM Mesh Networks. In: Computational Science, Sunderam,V.S., D.V.A. Geert, M.A.S. Peter and D. Jack (Eds.). Springer, Berlin, Germany, pp: 1120-1124.

Zhu, H., H. Zang, K. Zhu and B. Mukherjee, 2003. A novel generic graph model for traffic grooming in heterogeneous WDM mesh networks. IEEE. ACM. Trans. Networking, 11: 285-299.

Zhu, K. and B. Mukherjee, 2002. Traffic grooming in an optical WDM mesh network. IEEE. J. Sel. Areas Commun., 20: 122-133.