A Global RWA Protocol for WDM networks

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ABSTRACT

In this paper we present the design of a global RWA protocol (GRP) consisting of 'N' sector networks, each with a centralized management system (CMS) and sectors acts as a node of a distributed system. As per the connection request it uses centralized or hybrid method (centralized and distributed) to identify the primary and backup lightpaths. In addition an extra backup CMS is maintained to takeover if any of the sector CMS fails. It also involves in the data transmission between two sector CMS when the optimal primary lightpath fails. In this protocol lightpaths with least blocking probabilities are used for primary and backup lightpaths. Data is transmitted through the primary lightpath and if primary lightpath fails, the data will be routed through the backup lightpath and the lightpath with next least blocking probability is used as new backup lightpath. Global network overcomes the performance bottleneck of a large network with single CMS. In addition, grooming is also used to improve the blocking probability of connection request.

Keywords - **Blocking probability; CMS; global WDM network; grooming.**

I. INTRODUCTION

Wavelength division multiplexing (WDM) and wavelength routing are rapidly becoming the technologies-of-choice in network infrastructure to meet ever increasing bandwidth demand. [1]. In a wavelength routed WDM network, end users communicate with one another via all-optical WDM channels, which are referred to as lightpaths [2].A lightpath is used to support a connection in a wavelength routed WDM network, and it may span multiple fiber links. In WDM optical networks, there are three main constraints related with wavelength assignment: wavelength continuity constraint (WCC), distinct wavelength assignment constraint (DWAC), and non wavelength continuity constraint (NWCC) [3].In WCC, the same wavelength should be used on all the links along the selected route. In DWAC, two lightpaths cannot be assigned the same wavelength on any fiber and in NWCC, different wavelengths can be used on the links along the selected route but the nodes should have wavelength conversion capability. Since each lightpath can carry a huge amount of traffic, failures in such networks may seriously damage end-user applications. According to the scale of their effect, failures in all-optical WDM networks can be classified into two categories [4]. One category is a wavelength-level failure which impacts the quality of transmission of each individual lightpath. The other category is a fiber-level failure which affects all the lightpaths on an individual fiber. Since each lightpath is expected to operate at a rate of several gigabytes per second, a failure can lead to a severe data loss. Therefore, it is very important to have networks that are capable of preventing such failures; these are known as survivable networks [5]. In survivable WDM networks, the lightpath known as primary lightpath carries traffic during normal operations. In case a primary lightpath fails, the traffic is rerouted over a new lightpath known as the backup lightpath. Survivable network architectures are based either on dedicated resources or on dynamic restoration. In dedicated-resource protection the network resources may be dedicated for each failure scenario, or the network resources may be shared among different failure scenarios. In dynamic restoration, the spare capacity available within the network is utilized for restoring services affected by a failure. Generally, dynamic restoration schemes are more efficient in utilizing capacity due to the multiplexing of the spare-capacity requirements and provide resilience against different kinds of failures, while dedicated-resource protection schemes have a faster restoration time and provide guarantees on the restoration ability. In wavelength routed WDM networks a connection is realized by a lightpath. An algorithm used for selecting routes and wavelengths to establish lightpaths is known as a routing and wavelength assignment (RWA) algorithm. Many problems in wavelength routed WDM networks have RWA as a sub problem [1].Therefore, it is mandatory to use a good routing and wavelength assignment algorithm to establish lightpaths in an efficient manner i.e. it is critically important to improve network performance in terms of blocking probability of connections. The connection request may be either static or dynamic. In case of a static traffic demand, connection requests are known a priori and in case of a dynamic traffic demand, connection requests arrive to and depart from a network one by one in a random manner. Lightpath establishment in WDM networks can use either distributed or centralized control. In distributed control, no central controller is assumed to be present. The global state information of the network, which includes the details of wavelength usage and existing lightpaths, is not known to any node in the network. It is the responsibility of the source node to identify and to establish the optimal lightpath with the limited information available with it. In centralized scenario, when a demand arrives at the source node, the node sends the demand information to a central management system (CMS), which runs a centralized routing algorithm to compute a primary/backup path pair for the demand. The CMS then sends the computed routes back to the source node and the source node performs a signaling procedure to set up the primary lightpath and reserve backup channels along the backup path [6]. The advantage of this approach is that wavelength channels can be utilized in an efficient way, as the central node keeps the up-to-date network state information. As the traffic load increases, the control traffic to and from the controller increases substantially and the central controller requires sufficient buffer and processing power to handle the request. Also, in a large network, the central controller becomes the performance bottleneck; hence centralized algorithms are useful for small networks and are not scalable to large networks. In our protocol we have overcome this by dividing the larger networks into sectors of smaller networks called global networks. It is also a case of single-point failure, which is not desirable, i.e. the failure of the CMS can bring down the entire network [7].We has overcome this by maintaining a backup CMS. We also added grooming in our algorithm to improve network performance in terms of blocking probability of connections.

II. LITERATURE SURVEY

Lu Ruan, Haibo Luo and Chang Liu [6] have presented a distributed dynamic routing algorithm for restorable connections that uses load balancing heuristics in both primary and backup path computations to achieve low demand blocking. The key idea was to assign costs to links so that heavily loaded links will be avoided in the routing of the primary and backup paths and links with a high chance of including a sharable backup channel will be included in the backup path. Simulation results showed that the algorithm performs significantly better than a simple distributed algorithm and achieves comparable performance as a centralized algorithm. Since the paths with minimum number of free wavelengths only considered for identifying the optimal paths leads to increase in the blocking probability of connections.

A.Rajkumar and Dr.N.S.Murthy Sharma [7] have proposed a distributed priority based routing algorithm intended for a variety of traffic classes, which employs the concept of load balancing to establish the primary and backup light paths. Their algorithm calculates the cost metric on the basis of the load on the links. The routing of high priority traffic was performed over the lightly loaded links, in such a manner that the links with lighter loads are chosen instead of links with heavier-loads whilst routing the primary and backup paths. Since the load balancing is employed in routing metric, it will not reflect the dynamic load changes. So route discovery has to be done repeatedly, there by increasing the overhead.

Alvaro L.Barradas and Maria do Carmo R. Medeiros [8] have presented a traffic engineering approach for path selection with the objective of minimizing contention using only topological information. The main idea was to balance the traffic across the network to reduce congestion without incurring link state dissemination protocol penalties. This protocol also does not consider the dynamic traffic load into consideration and hence not adaptive.

Lei Guo [9] have studied the problem of multiple failures in WDM networks and proposed a heuristic algorithm called Shared Multi-sub backup paths Reprovisioning (SMR) to improve the survivable performance. Compared with previous algorithms, the survivable performance of SMR in multiple failures was significantly improved, but the algorithm is not suitable for larger networks.

Jianping Wang, Xiangtong Qi, and Biao Chen [10] have studied wavelength assignment for WDM multicast network to cover the maximum number of destinations for minimizing the network cost. The computational complexity of the problem was also studied. Three heuristic algorithms were proposed and the worst-case approximation ratios for some heuristic algorithms were given. They also derive a lower bound of the minimum total wavelength cost and an upper bound of the maximum number of reached destinations. The efficiency of the proposed heuristic algorithms and the effectiveness of the derived bounds were verified by the simulation results.

Yu Dong and Jian Wang [11] have presented a failure aware routing algorithm and enhanced fault tolerance in large-scale optical switches through innovations in architecture and control logic design. A large-scale switch is constructed from a network of 2 × 2 optical Switch Elements (SEs). There were three major contributions: (1) they developed an analytical method to calculate the average connection blocking probability in a faulty switch network referred to as the probability accumulation method; (2) they provided a failure- aware routing algorithm to effectively circumvent connections from defected SEs in a dilated Benes switch and (3) they improved the connectivity pattern of the Benes network to further reduce the blocking probability, especially when the SE failure rate is low.

James Yiming Zhang, Oliver W. W. Yang, Jing Wu and Michel Savoie [12] have studied RWA problem in a semi-dynamic scenario where rearrangements were conducted in a series of sessions after variation in traffic demands. Unlike pure static RWA problems each rearrangement scheme must consider established lightpaths in the previous session. A novel formulation of the WDM network rearrangement problem was used to minimize rejected demands and rerouted lightpaths. This was done by coordinating the re-routing of existing lightpaths with the adaptation to varying demands.

T.K. Ramesh and P.R.Vaya [13] have presented an adaptive reliable multipath routing (ARMR) protocol. In this protocol, few probe packets is sent by the source along all the paths. By the monitored results from the probe packets on each path, the source estimates the blocking probability and identifies the primary and backup path. By simulation results, the protocol concludes low blocking probability and delay with high bandwidth utilization. But probe packets are used to identify optimal paths, the setup time increases and also as rerouting is done after periodical time intervals the burden on the network increases.

T.K Ramesh, Sandeep kumar konda, Swaraj teja, Harshadeep and P.R Vaya [14] have presented an adaptive reliable multipath centralized RWA algorithm; in which source gets all the possible paths from a particular source and destination pair. It selects optimal primary and backup paths on the basis of number of available free wavelengths. If the number of used wavelengths on optimal primary path reaches the threshold value it will be automatically switched to the new optimal path. It shows an improved performance in the selection of the path by considering the number available free channels for the dynamic traffic models in all-optical WDM networks but it will not give better performance when compared with blocking probability.

III. A GLOBAL RWA PROTOCOL (GRP)

Global network is a network with 'N' number of sectors. In our study we considered N=4, sectors A,B,C,D with 10 nodes respectively. The block schematic is as follows.

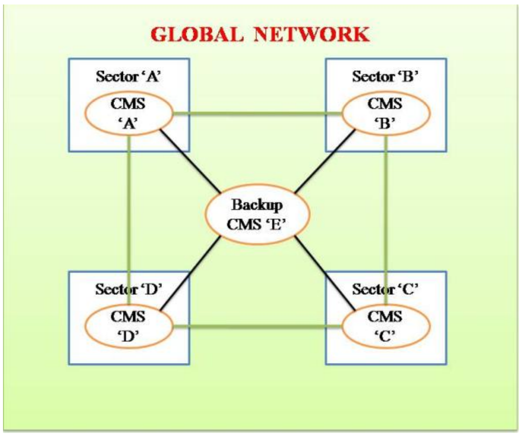

Figure 1: Global Network with 4 sectors

The additional CMS ('E') is acts as a backup for sector CMSs, i.e., if any of the sector CMS fails CMS 'E' will takeover, and also it act as backup lightpath between the sector CMS.

3.1 Data transmission:

The data transmission in the global networks is of two types.

I. The data transmission with in the sector (INTRA) is centralized.

II. The data transmission between two sectors (INTER) is distributed. The sector CMS of the corresponding source and destination nodes acts as source and destination nodes in a distributed manner.

3.2 Algorithm:

Step1: When a request comes to a source node it will inform request details to the sector CMS.

Step2: The sector CMS identifies INTRA or INTER transmission.

Step3:

(a) INTRA transmission of data

For INTRA sector CMS identifies the optimal primary and backup lightpath using blocking probability technique as follows

(i) It calculates blocking probability as:

Blocking probability [i] = 1 – Number of free wavelengths [i] / Total number of wavelengths[i] ; $0<i\leq n$

Where i is the lightpath, n is the number of possible lightpaths.

(ii) Path with least blocking probability is selected as primary path and very next path acts as backup path.

(iii) If the primary path fails, the data will be rerouted through the backup lightpath and very next lightlightpath is considered as new backup lightpath.

(b) For INTER transmission of data

(i) Source node transfer the request to the sector CMS.

(ii) The sector CMS finds the destination sector.

(iii) Sector CMS establishes optimal primary and backup lightpath with lesser number of links.

(iv) CMS checks for the possibility of grooming if the arrived request is equal to or less than 5Gbps else no

IV. SIMULATION RESULTS

We have studied the performance of our GRP protocol using MATLAB 7.10.0(R2010a) simulator. For the analysis, we used west part of ARPANET in each sector, which is of 10 nodes and 13 links as shown in figure 2. Various simulation parameters of west part of ARPANET are as given in table1.

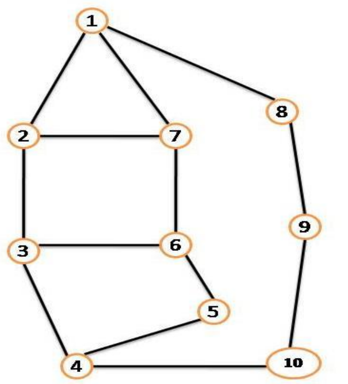

Figure 2: West part of ARPANET

Table1 Simulation Parameters

Sector Topology	ARPANET
Total No.of nodes	10
No of links	13
Link wavelength number	40
Channel capacity	10 Gbps
Arrival rate	100

Table:2 Blocking Performance

Request	Request type Inter / Intra	PL	Optimal Lightlightpath	Backup Lightlightpath	Blocking performance	Requests processed Without grooming	Requests processed with Grooming
A4-C6	Inter	2	4-A-B-C-6	4-A-D-C-6	44	28	30
C4-D10	Inter	2	4-C-D-10	4-C-B-A-D-10	58	21	34
A1-C9	Inter	2	4-A-B-C-9	4-A-D-C-9	50	25	50
B5-C3	Inter	2	5-B-C-3	5-B-A-D-C-3	94	3	6
A5-D4	Inter	2	5-A-D-4	5-A-B-C-D-4	42	29	41
C4-C7	Intra	9	4-5-6-3-2 -1	4-5-6-3-2-7	54	23	35
D5-D3	Intra	10	5-6-7-2-3	5-4-3	96	2	4
B2-D6	Inter	2	2-B-C-D-6	2-B-A-D-6	64	18	28
B4-D5	Inter	2	4-B-C-D-5	4-B-A-D-5	96	2	2
C5-C8	Intra	12	5-6-7-2-3 -4-10-9-8	5-4-3-6-7 -1-8	78	11	13

*PL - Number of Possible lightlightpaths

Blocking performance = (1 – Number of calls accepted / Total number of calls)*100
For case 1:
BP= (1 – 28/50)*100 = 44

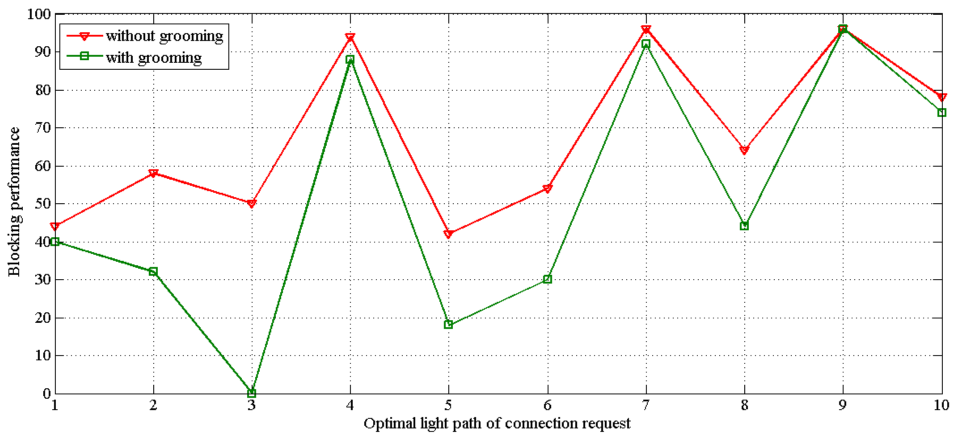

Figure 3: Lightlightpaths Vs Blocking performance

Figure 3 shows the Blocking Performance of GRP with and without grooming as per the simulation results recorded in table 2. Traffic grooming concept is used to improve the bandwidth utilization, i.e. we can send more than one request in a single wavelength at the same time. There by efficiently utilizing the bandwidth.

V. CONCLUSION

In this paper we proposed Global RWA protocol (GRP) for WDM networks which gives better performance compared to the large centralized networks. Our approach is more reliable as if any of the sector CMS fails the backup CMS takeover the entire process. In addition grooming is applied to reduce the request rejections.

References

[1] C.Siva Ram Murthy and Mohan Gurusamy, WDM Optical Networks, Prentice hall of India , Private Ltd, New delhi-2004.

[2] I. Chlamtac, A. Ganz, and G. Karmi, " Lightlightpath Communications, vol.40,no.7,pp.1171-1182, July1992

[3] Paramjeet Singh, Ajay K. Sharma, and Shaveta Rani, "Routing and wavelength assignment strategies in optical networks" Optical Fiber Technology 13 (2007) 191–197. Elsevier publications.

[4] S. Ramamurthy, Laxman Sahasrabuddhe, and Biswanath Mukherjee, "Survivable WDM Mesh Networks", Journal of light wave technology, vol.21, no.4, April 2003.

[5] Laxman Sahasrabuddhe, S. Ramamurthy, and Biswanath Mukherjee, "Fault Management in IP-Over-WDM Networks: WDM Protection Versus IP Restoration", IEEE journal on selected areas in communications, vol. 20, no. 1, pp: 21- 23, January 2002.

[6] Lu Ruan, Haibo Luo and Chang Liu, "A Dynamic Routing Algorithm With Load Balancing Heuristics for Restorable Connections in WDM Networks", IEEE Journal on Selected Areas in Communications, vol. 22, no. 9, November 2004.

[7] A.Rajkumar and Dr.N.S.Murthy Sharma, "A Distributed Priority Based Routing Algorithm for Dynamic Traffic in Survivable WDM Networks", International Journal of Computer Science and Network Security, vol.8, no.11, November 2008.

[8] Alvaro L.Barradas and MAria do Carmo R. Medeiros, "Edge- Node Deployed Routing Strategies for Load Balancing in Optical Burst Switched Networks", ETRI Journal, vol.31, no.1, pp: 31-41, Feb. 2009.

[9] Lei Guo, "Heuristic Survivable Routing Algorithm for Multiple Failures in WDM Networks", in proc. of 2nd IEEE/IFIP International Workshop on Broadband Convergence Networks, pp: 1-5, 21 May 2007.

[10] Jianping Wang, Xiangtong Qi, and Biao Chen, "Wavelength Assignment for Multicast in All- Optical WDM Networks With Splitting Constraints," *IEEE/ACM Transactions on Networking*, vol. 14, no. 1, pp. 169-182, February 2006.

[11] Yu Dong, Jian Wang, "Fault tolerance design for large-scale optical switches," *Optical Switching and Networking*, vol. 5, pp. 51–58, 2008.

[12] James Yiming Zhang, Oliver W. W. Yang, Jing Wu and Michel Savoie, "Optimization of Semi-Dynamic Lightpath Rearrangements in a WDM Network," *IEEE Journal on Selected Areas in Communications*, vol. 25, no. 9, pp. 3-17, December 2007.

[13] T.K Ramesh and P.R. Vaya, "An Adaptive Reliable Multipath Routing Protocol for WDM Networks", International Journal of Computer Sciences and Engineering Systems (IJCES), vol. 4, No. 3, July 2010.

[14] T.K Ramesh, Sandeep kumar konda, Swaraj teja, harshadeep and P.R Vaya, "An adaptive reliable multipath centralized RWA algorithm for all-optical WDM networks", CIIT International Journal of Computer Sciences and Engineering Systems, April.