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An Efficient Fault Restoration Algorithm in Survivable Optical Networks

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ABSTRACT

Background: In optical WDM networks, fault tolerance is an important network management function which has a high impact on survivability of the network. These failures can result in the disruption of communication, and can be difficult to detect, localize and repair. Optical communication networks need a system that performs fault diagnosis from the information given by the network components. In order to protect against the failures, we propose to develop a dynamic fault restoration algorithm for fault tolerance. By the simulation results, we show that our proposed algorithm achieves minimum network blocking ratio with increased channel utilization and throughput.

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INTRODUCTION

Nowadays, network failure is the most probable cause of congestion, packet loss and has notable impact on maintaining high Quality of Services (QoS). Communication networks face intentional interruptions due to wide variety of failures such as natural disasters, wear out and overload software bugs and human errors (Pickavet *et al* 2006) Due to more number of channels involved in a single fault, detecting and isolating faults becomes even more complex. Therefore, network survivability is an important and difficult issue involved in the deployment of QoS scheme in optical networks (Soung Liew *et al* 1994 and Yu Liu *et al* 2005). The optical network is developed and being instigated on existing Synchronous Optical Networking (SONET) architecture, which provides its own restoration and protection schemes. The network management system will able to identify or prevent the possible conflicts.

In optical Wavelength Division Multiplexing (WDM) Networks, the ability to manage and provide new services to customers quickly is crucial (Parthasarathy *et al* 2011). Provisioning of end-to-end services can be difficult, especially when network capacity increases. Service providers need an intelligent network management system to manage the end-to-end wavelength services thereby increasing their bandwidth revenues. As WDM networks carry huge volume of traffic, survivability issue has become a key issue in research and development. In optical networks, it is very important to have a mechanism that guarantees quick detection, isolation and localization of failures and efficient recovery.

After investigating the existing works carefully, we observed that problems addressed above were not been suggested with a proper solution. Thus, our objective is to develop a fault recovery algorithm, which provides a combined solution for the above problems. In this paper, an efficient dynamic algorithm for fault recovery in survivable WDM networks is proposed and simulated. The overall goal of the proposed approach is to improve the restoration efficiency.

The rest of the paper has been organized as follows: Section 2 presents the related study of the work. Section 3 proposes the algorithm for fault restoration. Section 4 analyses the simulation and compares the performances. Section 5 concludes the paper.

Related Study:

An efficient fault location algorithm was presented by Mas *et al* (2005), which points out the elements that could have triggered the received alarms. This algorithm addresses the redundancy and lack of coordination in internetworking at different layers of WDM, Synchronous Digital Hierarchy (SDH) / SONET, Asynchronous

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Transfer Mode (ATM) and Internet Protocol (IP). A single failure can trigger large number of alarms. Some failures are hard to detect resulting in missing or false alarms. Moreover, they addressed the behaviour of network components in transparent WDM networks as a result of failures. The non-polynomial complexity of the algorithm is pre-computed i.e., before a failure occurs in order to improve the efficiency of the multiple failure diagnosis problem which is found to be Nondeterministic Polynomial (NP) hard. The failure diagnosis phase is found to be very fast.

Fault localization is an important research issue in optical WDM networks since the light-path carries the information at high data rate. To overcome the data loss in the network, Mehdi Khani *et al* (2010) developed a fast and robust fault-tolerance mechanism to localize the faulty component in optical networks. This mechanism handles multiple fault situations even with a reasonable amount of false or lost alarms. Results reveal that processing and memory usage of the reported mechanism is lower than the existing mechanisms.

Fault detection and localization become a challenging issue for providing survivability in optical networks since most commercially available all-optical space switches are incapable of detecting the loss of optical signals along the data-path between its input and output port. Jun Zheng *et al* (2006) employed a fault localization technique which identifies the location of a failure by detecting the power loss of optical signals in data and control channels. Based on the reported fault localization technique, they presented a fault advertisement protocol which incorporates the signaling protocol that can be used in the network to facilitate the provisioning of static protection (or) dynamic restoration. They analyzed different metrics such as data loss, fault detection time and connection recovery under different failure scenarios.

Fault management has a huge impact on other network management functions such as configuration management and performance management. Chung-Sheng Li and Rajiv Ramaswami (1997) examined the fault management mechanisms for a transparent optical network. Data is transmitted without passing through Optical-to-Electrical (O/E) or vice-versa conversion. They presented several mechanisms to detect and isolate the faults, which allow the non-intrusive device monitoring without requiring any prior knowledge of the actual protocols being used in the data transmission.

Hongqing Zeng *et al* (2004) showed the feasibility of a fault detection scheme for All-Optical Networks (AONs) based on their decomposition into monitoring-cycles (m-cycles). They also formulated an *m*-cycle construction for fault detection as a cycle cover problem with certain constraints. A heuristic spanning-tree based cycle construction algorithm is developed. The results showed that the formulated technique achieves nearly optimal performance.

Based on a detailed study of survivability issues, Hongqing Zeng *et al* (2005) presented an end-to-end light-path fault detection and notification scheme in the data and control planes respectively. In this scheme, the source node sends the hello packets to the destination node along the light-path for data traffic. When the destination node misses a certain number of hello packets consecutively during a predetermined period of time, it notifies the network management unit by means of an alarm. This unit collects all the alarms and locates the faulty source. After locating the faults, the network management unit sends fault notification messages through control plane either to the source node or all upstream nodes along the light-path. The performance evaluation showed that the reported algorithm achieves fast fault detection. However, sending hello packets to the destination node brings high overhead cost to the user data, which creates significant impact.

Fault Restoration Algorithm For Fault Recovery:

In Optical network, Quick detection and isolation of faults is essential for the robustness and reliability of both the network and the services carried over it. For network failure recovery mechanism, dynamic restoration algorithm has been implemented and presented in this section. The algorithm for the restoration approach is explained below:

Path Assignment:

Step 1: For (every link $l_i \sum L$) ,

$$CF = NB + T_L ;$$

where, *NB* is the network blocking ratio, T_L is the current traffic load of l_i and *CF* is the link cost function.

Step 2: $NB = P_{lost} / P_{sent}$

where, *NB* - Network blocking ratio, P_{lost} - Number of packets lost and P_{sent} - Number of packets sent in the network.

Step 3: Let $s_1, s_2, \ldots, s_k$ be the set of nodes along the route from the source node s1 to the destination node sk

3.1: The source node s_1 sends data packets in fixed time interval.

3.2: The destination node s_k checks the packet sequence number.

3.3: When a *k/2* number of consecutive packets are missed within a given time threshold, the destination detects a fault on the light path.

3.4: If destination node n_k does not receive the data within the time interval, quick detection and isolation of faults is essential for the robustness and reliability of both the network and the services carried over it. An intelligent agent based on neural network was developed to predict the failures and to guarantee proactive fast re-routing in the network by Arunachalam *et al* (2011).

Path Re-assignment after fault detection:

Step 1: At time t_i, let LP={P_1,P_2,…..Pn} be the set of light-paths with $L_i = L_{max}$, where L_i is the total traffic load of {LP} at t_i and L_{max} is the maximum load in the network.

Step 2: Find a pair of backup and primary light-path for re-assigning the traffic.

2.1: Let {LP} contains a sorted list of all the light-paths such that the light-paths are arranged with minimum load and blocking probability.

while {LP} is not empty
Remove the first element P_1 of {LP};
Reroute the traffic again at time t_j ;
if $Load_j = Load_i$, then
Restore the path P_1 ;
else
Repeat the step 2.1;
end if.
end while.

Step 3: Among the list {LP}, choose the first light-path as primary light-path for routing. If any failures occur, choose the next successful path as backup light-path for re-routing the traffic.

Simulation:

In this section, the performance of the proposed dynamic fault recovery algorithm is examined with the help of ns-2 simulator by patching Optical WDM network simulator (Owns). A mesh topology with 14-nodes is shown in Figure 1.

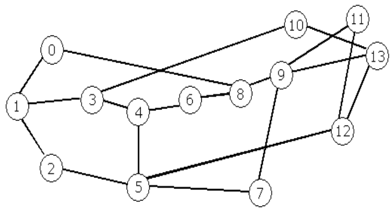

Fig. 1: NSF network with 14 nodes.

The parameters used for simulations are shown in Table 1:

Table 1: Simulation parameters.

Topology	Mesh
Wavelength Assignment	First Fit Algorithm
Wavelength Routing	Dijkstra's Algorithm
Total no. of nodes	14
Link Wavelength Number	8
Link Delay	10ms
Link Utilization sample Interval	0.5s
Traffic Arrival Rate	0.5Mb
Traffic Holding Time	0.2s
Packet Size	500 bytes
No. of Session-traffics	5
Max Requests Number	50

RESULTS AND DISCUSSION

Here, we present the simulation results for the proposed dynamic fault tolerance algorithm compared with existing static fault tolerance algorithm. In all the simulations, traffic load of the network is compared with various metrics viz., network blocking ratio, packets received and channel utilization. In our initial experiment, we vary the load as 2, 4, 6, 8 … 14MB.

Figure 2 shows the network blocking ratio obtained with the proposed algorithm. It is observed from the figure 2 that the blocking ratio for the proposed algorithm is significantly less than the existing static algorithm. This improvement is due to the selection of backup paths with least blocking probability and load. For example, when the load is 8 MB, the blocking probability with dynamic algorithm is only 0.2, whereas for static fault tolerance scheme, the blocking ratio is 0.41.

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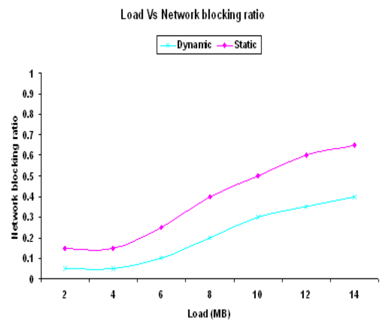

Fig. 2: Variation of network blocking ratio with load.

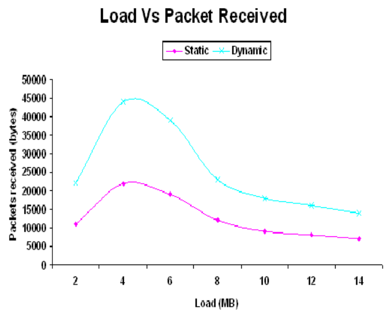

Fig. 3: Variation of packets received with load

Figure 3 shows the number of packets received by the proposed algorithm for various loading conditions. For a network load of 8 MB, it is observed that the number of packets received by the dynamic algorithm is 22495 bytes, whereas static scheme receives only 12490 bytes respectively. Since the proposed algorithm selects the primary and backup paths with least load, this higher packet receiving capacity.

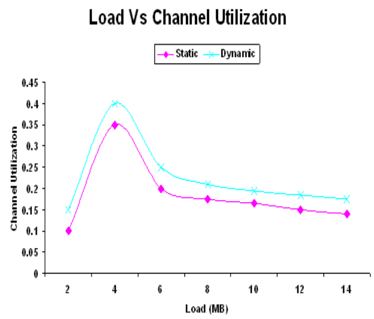

Fig. 4: Variation of channel utilization with traffic load.

The variation of channel utilization with various traffic loads viz., 2,4,6,8 … 14 MB is depicted in figure 4. It is seen from the figure 5 that the channel utilization by the proposed dynamic algorithm is significantly better than the existing algorithm. This significance is due to the minimum network blocking ratio achieved by dynamic restoration algorithm. For example, when the load is 8 MB, the channel utilization with dynamic algorithm is only 0.23Mbps, whereas for static fault tolerance algorithm, channel utilization is 0.189 Mbps.

Conclusion:

In this paper, we have proposed a dynamic fault restoration algorithm for fault recovery in survivable WDM networks. In this algorithm, multiple shortest light paths are established based on the current load and blocking probability. The first successful path is selected for routing the primary light path. Then, the remaining alternate light paths, the first successful path are selected for routing the backup light path. When a link-failure occurs, backup path which is computed previously is selected by the source node and wavelengths are reserved for the backup path. If it cannot be reserved for that path, the next available path from the list is selected as a backup path. By the simulation results, we have shown that our proposed dynamic algorithm achieves reduced blocking ratio with increased bandwidth utilization and throughput.

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