Trends in Survivability Techniques of Optical Networks

Neeraj Mohan, Amit Wason and Parvinder S. Sandhu

Abstract— The ability of a network to continue functioning even after the occurrence of any failure is very much required in optical networks. As optical networks are capable of transmitting a large amount of data at very high speed, so any failure or breakdown even for small duration can cause significant data and revenue loss. So the survivability of optical networks has become very important issue for research. Many efforts are going on to improve the survivability of optical networks. Most of the failures occur due to the link failures.

Keywords— Network Survivability, Link Failures, Optical Networks

I. Introduction

NETWORK survivability may be defined as network's ability to continue functioning correctly in the presence of failures of any network components. It is an important requirement for any optical networks due to their ultra-high capacity [1]. A single failure can disrupt millions of applications and results in tremendous data and revenue loss to both end users and network operators. The common requirement of the downtime of a leased connection in the industry is less than 5 minutes per year [2]. Although many network components can cause the failure of a connection, such as fibers, switches, transceivers and so on. But the most common network failure is the link failure. In general, there are two ways to provide recovery from failures, namely, protection and restoration. In the protection paradigm, each connection is provisioned and allocated certain amounts of spare resources for protection, which can be used to reroute the transmission upon a failure on the connection. The restoration paradigm does not assign any spare resource for the protection in advance. Upon a failure, network has to search spare resources to reroute each disrupted connection around the failure [1-2].

II. Literature Survey

Ning Zhang et. al. [3] have analyzed the protection principle of WDM optical network. They proposed a protection method for failures in optical networks. These protection schemes can be divided into two categories. One is link protection and other is path protection scheme. Path protection scheme can be further subdivided into two categories i.e. dedicated path protection and shared path protection scheme.

Burak Kantarci et. al. [4] proposed a restoration framework for Wireless Optical Broadband Access Network (WOBAN). The proposed scheme tries to select optimum number of protection clusters for the WDM-PON segments at the back-end of WOBAN. It further considers the optimum deployment of the fibers between the backup ONUs so that the restored traffic propagates with the minimum delay.

Ankitkumar N. Patel et. al [5] addressed the problem of survivable traffic grooming in optical WDM networks in which lightpaths are hop constrained. Survivability is provisioned at the wavelength granularity through either dedicated or shared path protection schemes. An auxiliary-graph-based algorithm was proposed that addresses grooming, protection, and impairment constraints as a single aspect. It also determines the placement of regenerators and grooming equipment in the network with the goal of minimizing equipment cost.

Raghav Yadav et.al [6] introduced intercycle switching (ICS) that reduced the length of the *p*-cycle restoration segment by using an idle *p*-cycle. The effectiveness of the ICS approach can be enhanced by considering the restored path during intercycle switching instead of the p-cycle restoration segment. It is referred as enhanced intercycle switching (EICS).

Burak Kantarci et. al. [7] has proposed a planning heuristic called Locate-ONU-with-Lowest-Availability-Requirement-First (LOWLARF) to compare the coverage capability of three previously proposed survivability policies under the similar constraints. This heuristic can determine the length of the feeder fiber and can locate each ONU on the appropriate location. It will help to meet the availability requirements at the same time not violating the budget limit. The proposed planning heuristic, three different survivability schemes under various budget constraints and split ratios are compared within various square regions.

Siti Nur Fariza binti Halida et. al. [8] has addressed the issue of protection scheme in order to guarantee the survivability of the networks. This protection scheme provides better quality of services (QOS) in terms of network resource usage, connection availability satisfaction ratio (ASR) and blocking probability. Mesh torus network was used to compare several basic connection management processes and dedicated protection scheme. Availability satisfaction Ratio (ASR) is significantly improved when dedicated path protection is utilized in optical networks.

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Elaine Wong et. al. [9] has proposed a simple automatic protection switching scheme. It exploits the use of a highly-sensitive and fast-response protection module which is used to achieve traffic diversion onto the protection path within 12 ms for all customers. The protection module provides an additional flexibility of activating amplifier shutdown within 2 ms of failure detection hence removing the hazard at the fiber break. This model was tested for Long Run Passive Optical Network (LR-PON).

Bayrem Triki et. al. [10] proposed a novel technique for survivable routing in WDM optical Networks. It is able to work with random network topologies and allows to pro-actively generate primary and secondary paths that share a tunable number of nodes specified by the source. It performs on-demand generation and resolution of requests to establish survivable routes. Further it can provide rapid failure recovery.

Wen-De Zhong et. al [11] investigated flow *p*-cycle and optimal path pair based dual-source protection approaches for source failure recovery on top of the combined node and link failure recovery for optical multicast traffic protection. Results show that, the total capacity is increased by up to 14%, if source failure recovery is required on top of the combined node and link failure recovery. It is suggested that source failure recovery is more important than failure recovery of any other node or link on a multicast session.

Uma Rathore Bhatt et. al [12] discussed about the multiclass services in WDM optical networks. Three classes of services (class I, II & III) were considered according to the traffic and resource requirement. A survivable RWA strategy has been proposed and discussed for these classes of services. The proposed strategy aims to provide 100% survivability of connection request for class I, II and III services. The proposed strategy has been tested on various well known network topologies.

Fen Yuan et. al. [13] proposed a Single-Node Failure Algorithm and verified the validity of this algorithm. The main goal of this algorithm is to map the IP topology links into light paths in WDM topology. It ensures that IP topology remains connected even after the failure of any one node in WDM topology. Hence it will assure the survivability of network.

Amir Askarian et. al [14] applied cross layer technique to improve the survivability of all-optical networks, which are facing link failures. Algorithms were proposed to improve the network survivability over non-cross-layer algorithms by decreasing both the blocking probability and the vulnerability of the network to failures. Two new compound novel quality of transmission aware protection schemes were also proposed that exhibit low blocking probability and have a moderate vulnerability ratio and time complexity.

Arunita Jaekel et. al. [15] have introduced a method for survivable topology design and traffic grooming of low-speed, scheduled traffic demands. The setup and teardown times are already known in advance for these traffic demands. A design is proposed of a stable logical topology which is capable of supporting the specified demand set and sharing resources allocated to non overlapping demands. The networks with and without wavelength converters were considered and survivability was implemented using shared and dedicated path protection.

Anteneh Beshir et. al [16] have studied the survivable impairment-aware traffic grooming problem. The problem to minimize the total number of transceivers required for assigning link disjoint primary and backup lightpaths for each request was addressed. A heuristic approach was provided for solving this NP-hard problem. Minimizing the number of transceivers will lead to a significant reduction in the capital expenditure. It will also results in a reduced operational expenditure because of the significant decrease in power consumption and heat dissipation. In addition, the reduced number of wavelengths decreases the operating cost (OPEX) associated with each wavelength.

Chengyi Gao et.al. [17] considered the problem of finding two domain-disjoint paths with minimum total cost. A Cycle Based Minimum Cost Domain Disjoint Paths Algorithm (CMCDP) algorithm was proposed which applies Suurballe's algorithm directly on a multi-domain network with introduced cyclic structures. The CMCDP algorithm outperforms a simple heuristic in terms of total costs of two paths. J.S. Li et. al. [18] proposed a novel quality-based survivability in the dual failure network. A method is provided to achieve the required protection ratio for the two-level protected traffic. This method considers the efficiency in the use of spare capacity for survivable WDM optical networks.

Wei Li [19] has studied survivability and survivability mechanism of military optical fiber communication transmission network. Author has discussed three protection modes in detail and channel/link based restoration mechanisms were compared. Finally, a harmonization strategy including the lower layer principle, fault type based restoration and selective protecting idle capacity design, was proposed to improve the network survivability.

Khaled M. Maamoun et. al. [20] investigated Radio over Fiber Passive Optical Network RoF-PON/PON systems. The authors focused on novel millimeter-waveband (mm-WB) radio over fiber (RoF) system architecture for wireless services with the use of dense wavelength division multiplexing (DWDM). Some models were proposed for PON/ RoF-PON. The proposed models were compared using Expected Survivability Function. Expected Survivability Function is a simple and intelligent tool to provide the measure of network survivability.

David. C et. al. [21] have discussed multiple link failure models, such as shared risk link groups (SRLG), shared risk node groups (SRNG), and more generally shared risk resource groups (SRRG). These models are becoming more critical in survivable network design. These shared risk models have been unified through the notion of colored graphs. The proposed work provides an efficient MILP formulation for the minimum color path problem that is related to finding a path of maximum reliability in a multi-layer network.

Purohit, N. et. al. [22] studied and analyzed GPRS network. The Survivability Index (SI) is proposed which takes into account important features of a GPRS network. Some of these features are success probability in uplink contention, average wait time to get a dedicated slots, throughput and availability.

A weighted sum form is proposed and Genetic Algorithm (GA) is used to find optimum values of weights.

Baibaswata Mohapatra et. al. [23] have proposed a new simple integer linear program (ILP) formulations to allocate working and spare capacity in WDM mesh networks. Shortest path routing (SPR) algorithm and link utilization (LU) algorithm were used for primary and backup lightpath allocation. Routing and wavelength assignment (RWA) is solved by wavelength continuity constraint. Multiple traffic patterns are generated using Poissons distribution.

Yoshiyuki Yamada et. al. [24] has proposed a new network design algorithm for survivable hierarchical optical path networks that offer wavelength path protection. The proposed algorithm adopts the concept of the s-d Cartesian product space, which can efficiently aggregate closely located traffic demands and so substantially reduce network cost. It can be verified that the cost gap between waveband protection and wavelength path protection was found to be marginal over a large demand region.

Sheng Huang et. al [25] presented the differential-delay-constrained disjoint paths (DDCKDP) algorithm, a novel adaptive routing used to calculate differential-delay-constrained link-disjoint paths between any source to destination node pair. It was applied to a telecom mesh network employing optical wavelength-division multiplexing (WDM). It has been observed that DDC significantly impacts network performance if not properly addressed. DDCKDP outperforms KDP, and the improvement is substantial when the DDC is small.

Navid Ghazisaidi et. al. [26] have analyzed the survivability problem of Next Generation Passive Optical Networks (NG-PONs) and emerging hybrid Fiber Wireless (FiWi) networks in terms of failure-free connections. All optical and mixed optical-wireless networks were analyzed. The performances of various schemes to select optical network units (ONUs) were compared and interconnect them wirelessly through a wireless mesh network (WMN). Various network topologies and a wide range of fiber link failure were also considered. It is found that the choice of the right selection scheme has a significant impact on the survivability of NG-PONs and FiWi networks.

Taiming Feng et. al [27] has analyzed that wireless-optical broadband-access network (WOBAN) is a promising architecture for access networks. The front-end wireless mesh networks in a WOBAN are self-healing but the back-end passive optical networks do not have survivability due to their tree topology used. A cost effective protection method is proposed for WOBAN which deals with network element failures in the optical part of WOBAN. An integer linear programming (ILP) model is also presented for the minimum cost and maximum flow (MCMF) problem

III. Conclusion

Survivability has become a very important issue in optical networks. It has gained significant importance due to very high speed and transmission capacity provided by optical networks.

A lot of research work has been done on survivability of different types of networks. Basically two methods are used for survivability i.e. protection and restoration. Each of these methods has certain advantages and disadvantages which have been discussed in literature survey. A number of survivability techniques have been discussed in literature survey.

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