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Survivability strategies with backup multiplexing in WDM optical networks

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Abstract

In this paper, we have presented four variations of applying the same routing algorithm for primary and backup lightpaths, wavelength assignment strategy for survivability. The simulation results show that although everything is the same, yet how and when they are applied leads to variations in results in terms of number of connections accepted. The backup multiplexing technique has been incorporated to reduce the blocking probability in all the strategies. The results have been calculated both for the systems that require 100% degree of survivability, i.e. critical, and for those that do not. The variation to be used depends upon whether the application is critical or not.

Keywords: WDM; Survivability; Permutation routing; Backup multiplexing; Blocking probability

1. Introduction

Optical networks are very high-speed networks and carry a huge amount of traffic. The service interruption even for a short duration can result in huge data loss and the survivability strategy should try to provide almost continuous service in the case of failure. These networks are also increasingly becoming capable of delivering bandwidth in a flexible manner where and when needed. The reliability of a network is directly affected by the survivability strategy used. A key technology behind optical networks is wavelength-division multiplexing (WDM). While the bandwidth of an optical fiber reaches nearly 50 Tb/s, electronic data rates are in the order of Gb/s. WDM is the same as the frequency-division multiplexing (FDM) technique used in traditional systems and, in addition, allows for bridging the opto-electronic mismatch. In WDM networks, data can be simultaneously transmitted at multiple wavelengths over the same fiber [1]. Each wavelength can be used for a separate connection. So, many connections can simultaneously use the same fiber, thus exploiting the huge bandwidth that a fiber offers.

In case of a failure, a tremendous amount of information can be lost, affecting a huge number of requests. In this scenario, network survivability becomes an important issue. Provisioning and survivability are related issues in WDM optical networks [2]. Provisioning is important due to the fact that it deals with resource allocation with the aim to minimize the resource requirement. The resources required depend upon the resource allocation strategy, i.e. provisioning. Provisioning also greatly affects the number of connections accepted.

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In this paper, we have discussed four survivability strategies. These can be used for critical applications that provide 100% degree of survivability and very low restoration time. The strategies can also work for non-critical applications. This paper is organized as follows. Section 2 introduces the survivability in WDM networks. Section 3 explains the four survivability strategies. In Section 4, we explain about the simulator setup to evaluate the performance of *s* restoration strategies. This section will also focus on the performance evaluation of the strategies in terms of blocking probability. Conclusions are drawn in Section 5.

2. Restoration in optical networks

Providing resilience against failure, i.e. survivability, is an important requirement for high-speed networks. The amount of disruption caused by a network-related outage becomes more significant because these networks carry more and more data. A single outage can disrupt millions of users and results in millions of dollars of lost revenue to users and operators of the networks [3,4]. Survivability is the ability of the network to continue providing service in the presence of failure. It is greatly affected by the provisioning. Lightpath is a connection in all optical networks, which is totally optical except at the end nodes. There are two types of lightpaths: primary lightpaths and backup lightpaths. Primary lightpaths are those lightpaths upon which data transmission takes place under normal conditions. Backup lightpaths are those lightpaths that carry the data when the primary lightpath cannot be used due to failure occurrence. There can be three provisioning approaches for resource allocation for survivable networks [5]:

(i) *Dedicated backup (DB)*: In this, there is a DB lightpath for each source destination pair. The resources, i.e. channels, are not shared. A channel is a wavelength on a link. A channel is reserved at any time for at the most one lightpath.
(ii) *Primary backup (PB) multiplexing-based allocation*: A primary lightpath and one or more backup lightpaths can share a channel. It does not warrant 100% survivability degree.
(iii) *Backup multiplexing (BM)-based allocation*: In this, two or more backup lightpaths can share a channel if the corresponding primary lightpaths do not fail simultaneously, i.e. primary lightpaths need to be link and node disjoint. Two or more paths are said to be link disjoint if there is no common link between any two paths. Two or more lightpaths are said to be node disjoint if the there is no common intermediate node between any two lightpaths.

With the BM-based allocation technique, resources among backup lightpath can be shared and it greatly reduces the resource requirement. Also, as there is resource sharing among backup lightpaths only, it can provide 100% degree of survivability. For the critical applications, we require 100% degree of survivability. A PB multiplexing-based scheme does not warrant 100% survivability degree, so DB and BM-based allocation are the only solutions. Mostly a backup lightpath requires more channels as compared with a primary lightpath. So sharing the channels among multiple backup lightpaths results in very good results in terms of resource utilization.

Many terms are associated with restoration such as blocking probability, degree of survivability, resource utilization and restoration time. Blocking probability is the ratio of the number of connections rejected and the total number of connection requests. Degree of survivability is the ratio of traffic affected that has been restored by the amount of the total traffic affected. Resource utilization gives the ratio of utilized resources and total resources. Restoration time is the time taken by the system for restoration after failure.

3. Proposed fault tolerance strategies

This section covers four different variations of applying the survivability giving four strategies. Centralized control has been assumed, i.e. there is one central controller to manage all the activities such as routing, wavelength assignment, etc. These can work with all the routing algorithms that can be used for finding the routes of primary and backup lightpaths. These can be used when no wavelength converters are considered to observe wavelength continuity constraint and also when wavelength conversion is used to establish a lightpath. These can work for both failure-dependent and failure-independent survivability approaches as well as for link-based and path-based survivability approaches. A static traffic model is assumed. A single failure model is taken. These strategies can work for the systems that require 100% degree of survivability for all the connections accepted as well as for those systems that do not require 100% degree of survivability and backup lightpaths are established if possible. In the first type of systems, a connection is accepted only if both its lightpaths are established, but in the second type of systems a connection is accepted if its primary lightpath is established although an attempt is made to establish the backup lightpath. The strategies can be used with all wavelength assignment strategies.

In all of these strategies, the primary lightpath corresponding to each connection request is established