IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Wavelength Division Multiplexing

Neeraj Jindal[*1], Shweta Lakhara [2]

[*1]Department of Electronics &Communication Engineering, Chartered Institute of Technology, Abu Road , India

[2]Department of Computer Science Engineering, Chartered Institute of Technology, Abu Road , India

er.neerajjindal@yahoo.com

Abstract

In Wavelength Division Multiplexing (WDM) networks, there is huge amount of available bandwidth so each light path can carry a huge amount of traffic and if somehow any failure occurs. It may seriously damage the end-user applications. Hence fault-tolerance becomes an important issue on these types of networks. The light path which carries traffic during normal operation is called as primary path. In case any failure occurs, the same traffic is rerouted on an alternative path that may be called as backup path. This paper mainly presents the routing approach for establishing primary and backup paths. In order to establish the primary path, this approach uses load balancing in which link cost metrics are estimated based on the current load of the links. In backup path setup, the source calculates the blocking probability through the received feedback from the destination by sending a small fraction of probe packets along the existing paths. It then selects the optimal light path with the lowest blocking probability. This approach reduces the blocking probability and latency at the same time increases the throughput and channel utilization.

Keywords- WDM, fault-tolerance, primary path, backup path

Introduction

Wavelength Division Multiplexing (WDM) Network

The term wavelength-division multiplexing is commonly applied to an optical carrier (which is typically described by its wavelength), whereas frequency-division multiplexing (FDM) typically applies to a radio carrier (which is more often described by frequency). Since wavelength and frequency are tied together through a simple relationship, the two terms actually describe the same concept. WDM system uses a multiplexer at the transmitter to join the signals together and a demultiplexer at the receiver to split them apart [1].

With the right type of fiber it is possible to have a device that that does both simultaneously, and can function as an optical add-drop multiplexer (OADM).

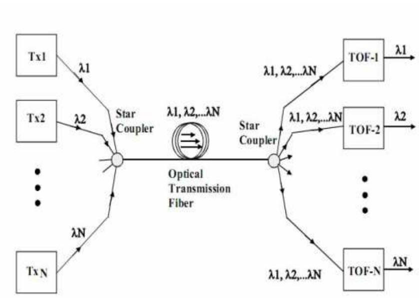

Fig1: Basic point to point communication configuration using mux-demux

WDM multiplexer (MUX) combines N independent data streams, each on a unique wavelength, and sends them on a fibre. Demultiplexer (DEMUX) at the fibre's receiving end separates out these data streams. Fig 2 shows use of star couplers thereby obviating the need of multiplexer and Demultiplexer [2].

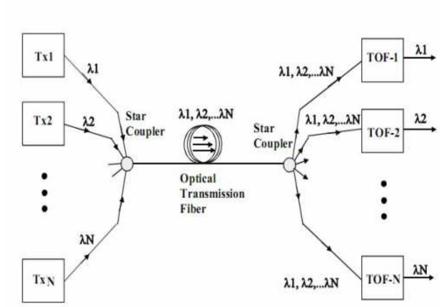

Fig 2: Basic point to point communication using star couplers.

This type of system uses a star coupler to mix signals of different wavelengths and wavelength tunable filters to extract the information. Although the power is decreased by a factor of 1/N, this loss can be offset with the use of an optical amplifier prior to the second star coupler.

WDM systems are popular with telecommunications companies because they allow them to expand the capacity of the network without laying additional optical fiber cable. By using WDM and optical amplifiers, they can accommodate several generations of technology development in their optical infrastructure without overhauling the backbone

Fault Tolerance in WDM Networks

Since each light path can carry a huge mount 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 [3]. One category is a wavelength-level failure which impacts the quality of transmission of each individual light path. The other category is a fiber-level failure which affects all the light paths on an individual fiber. Since each light path is expected to operate at a rate of several gigabytes per second, a failure can lead to a severe data loss. The ability of network to with-stand failures is called as fault-tolerance. Failures arise due to the node failure or link failure. When a link fails all its constituent fibers also fails. All the connections which use these fibers are to be rerouted and a wavelength will be assigned. The light path which carries traffic during normal operation is called as primary path. The traffic is rerouted on a backup path in case of a failure. Optical networks which use the wavelength division multiplexing (WDM) and wavelength routing are subjected to failures. Fault tolerance becomes an important issue because of the large amount of traffic on these networks in contradiction to the conventional copper links.

Fault tolerance schemes can be broadly classified into

Path Protection

Path

Restoration

1) Path protection: In path protection, backup resources are reserved during connection setup and both primary and backup light path are computed before a failure occurs. There are two types of protection schemes: Dedicated and Shared protection.

Dedicated-path protection: In dedicated-path protection (also called 1:1 protection); the resources along a backup path are dedicated for only one connection and are not shared with the backup paths for other connections.

Shared-path protection: In shared-path protection, the resources along a backup path may be shared with other backup paths. As a result, backup channels are multiplexed among different failure scenarios, and therefore, shared-path protection is more capacity efficient when compared with dedicated-path protection.

2) Path Restoration: In path restoration, the source and destination nodes of each connection traversing the failed link participate in a distributed algorithm to dynamically discover an end-to-end backup route. If no routes are available for a broken connection, then the connection is dropped.

Related Work

Lei Guo [4] has studied the problem of multiple failures in WDM networks. In order to improve the survivable performance he proposed a heuristic algorithm called Shared Multi-sub backup paths Reprovisioning (SMR). The survivable performance of SMR in multiple failures was considerably improved when compared with the previous algorithm.

Guido Maier, Achille Pattavina, Luigi Barbato, Francesca Cecini and Mario Martinelli [5] have investigated the issue of dynamic connections in WDM networks. It is also loaded with the high-priority protected static connections. They have compared various routing strategies by discrete event simulation in terms of blocking probability. Based on the occupancy cost function they have proposed a heuristic algorithm which takes several possible causes of blocking into account. The behavior of their algorithm was tested in well known case study of mesh networks, with and without wavelength conversion.

A.Rajkumar and N.S.Murthy Sharma [6] have proposed a distributed priority based routing algorithm. In order to establish the primary and backup light paths they have proposed a variety of traffic classes which uses the concept of load balancing. Based on the load on the links, their algorithm estimates the cost metric. The routing of high priority traffic was performed over the lightly loaded links. Therefore while routing the primary and backup paths, the lightly loaded links are chosen instead of choosing the links with heavier loads. The load balancing will not reflect the dynamic load changes because it is used in the routing metric. Michael T. Frederick and Arun K. Somani [7] have presented an L+1 fault tolerance which is used for the recovery of optical networks from single link failures without the allocation of valuable system resources. While the approach in its simplest form performs well against the existing schemes, the flexibility of L+1 leave many options to examine possible ways to further increase performance.

Muriel M'edard [8] has described that the protection routes are pre-computed at a single location and thus it is centralized. Before the restoration of the traffic, some distributed reconfiguration of optical switches is essential. On the other hand, restoration techniques depend upon distributed signaling between nodes or on the allocation of a new path by a central manager.

Hongsik Choi, Suresh Subramaniam and Hyeong-Ah Choi [9] have considered the network survivability which is a critical requirement in the high-speed optical networks. A failure model is considered so that any two links in the network may fail in an random order. They have presented three loop back methods of recovering from double-link failures. Only the first two methods require the identification of the failed links. But pre-computing the backup paths for the third method is more complex than the first two methods. The double link failures are tolerated by the heuristic algorithm which pre- computes the backup paths for links.

Dong–won shin, Edwin K.P.Chong and Howard Jay Siegel [10] have developed two heuristic multipath routing schemes for survivable multipath problem called CPMR (Conditional Penalization Multipath Routing)and SPMR (Successive Penalization Multipath Routing).

Their schemes use "link penalization" methods to control (but not prohibit) link-sharing to deal with the difficulties caused by the link sharing. When compared with the routing scheme that searches for disjoint paths, their methods have considerably higher routing success rates which are shown through the simulation results.

Yufeng Xin, Jing Teng, Gigi Karmous-Edwards, George N.Rouskas and Daniel [11] have studied the important fault management issue which concentrates on the fast restoration mechanisms for Optical Burst Switched (OBS) networks. The OBS network operates under the JIT signaling protocol. The basic routing mechanism is similar to the IP networks, where every OBS node maintains a local forwarding table. The entries in the forwarding table consist of the next hop information for the bursts per destination and per FEC (Forward Equivalent Class). Based on looking up the next-hop information in their forwarding tables, OBS nodes forwards the coming burst control packets and set up the connections. The connection set up process is signified by the burst forwarding or burst routing.

Jian Wang, Laxman Sahasrabuddhe and Biswanath Mukherjee [12] have considered the fault-monitoring functions which are usually provided by the optical-transmission systems. In order to measure the bit error rate in the wavelength channels using SONET framing, the B1 bit in the SONET overhead can be used. Moreover, to detect certain failures like fiber cut in other formatted optical channels, the optical power loss can be used. Optical-Electrical-Optical (OEO) conversion is used before each OXC port because most of the OXCs use electronic switching fabric. Therefore, faults can be detected on link-by-link basis. Both the end nodes of the failed link can detect the fibre cut for all-optical switches. S

Routing Approach

In order to establish the primary path, this approach uses the concept of load balancing. Given a physical network with the link costs and the traffic requirements between every source-destination pair, then finding a route of the light paths for the network with least congestion, is called as .load balancing. In this approach, based on the load of the links the cost metric is estimated. The traffic is routed over the lightly loaded links. Therefore when routing the primary path, the links with the lighter loads are selected instead of links with the heavier loads. Using path restoration backup paths are established. In backup path setup, the source sends a small fraction of probe packets along the existing paths. For a higher burst arrival rate, the fraction of traffic probing will be lower. For a slow changing traffic, the period of update will be higher resulting in an even smaller fraction. The source edge can monitor and identify the requests that are rejected at the network based on receiving the PACKS/NACKS from the destinations [13]. Thus the source can easily calculate the blocking probability through the monitored results from the probe packets. The ingress edge node selects the optimal light path with the lowest blocking probability based on the measured blocking probabilities and forwards the data through this optimal light path. On the other hand, it keeps probing the sub-optimal path for their current blocking probability.

Computing Primary Path

The link cost function for primary path computation is designed based on the following steps:

- For each link L_j, j = 1, 2, 3… calculate the load index of the link L_j as

  Load (LI) = C_f / C_n (1)

Where C_f gives the number of free channels in that link and C_n is the total no. of channels in that link.

- The link cost function Cost (L_j) is then defined as

Cost (L_j) = 1- Load (LI), if Load (LI) >LT

= 1+ Load (LI), if Load (LI) > 0 And Load (LI) < = LT

=∞, if Load (LI) = 0 (2)

Where LT shows the load threshold.

After we assign each link a cost using the above formula, Dijkstra's shortest path algorithm is then used to compute the least-cost path as the primary path. If the least-cost path has a cost of infinity, then the demand is blocked; otherwise a backup path is computed using the method given in the next subsection.

Computing Backup Path

Let the number of paths between source S and destination D are n. In this approach, small fractions of probe packets are sent by the non-optimal paths such that these paths are selected very rarely. The probe packets contain sequence numbers to identify the packets.

1) Let P_j, j=1, 2….k be the set of probe packets sent on the paths R_j, j=1, 2…k.

2) On receiving the probes packets, the destination D for the path R_j, send an PACK packet to the source, for each packet correctly received. The missing or dropped packets can be identified using the sequence numbers of the received packets. For each dropped packet, it sends a NACK packet to the source.

3) For the path R_j, the source calculates the blocking probability BP_j such that

$$BP_j = P_{lost} / P_{sent} \quad (3)$$

P_{lost} is the number of packets dropped and P_{sent} is the number of packets sent.

4) Similarly for all the paths R_j, the source S calculates their blocking probabilities BP_j based on the PACK and NACK feedback received from the destination D.

5) Now sort the paths {R_j, j=1, 2…k} in ascending order of BP_j values.

6) The paths which are having less blocking probabilities BP_1, BP_2, BP_3 … are selected as backup paths. If there is any sudden or unexpected failure occurs in the primary path, traffic can be rerouted through these backup paths.

At the same time, for their blocking probability it keeps searching the sub optimal paths. Because of this, we can able to jump quickly to a new path when blocking probability of the current path increases. This occurrence is quite obvious in IP networks where the traffic patterns may vary significantly.

By sending a small fraction of traffic for probing, the aggregated throughput is reduced. However by finding a new optimal path quickly this reduction is compensated. The value of small fraction depends upon the sample size for accurately calculating the blocking probability. For a higher burst arrival rate the fraction of traffic for probing is very low.

Conclusion

In this paper reliable routing approach for establishing primary and backup paths in optical WDM networks has been studied. In order to establish the primary path, this approach uses load balancing in which link cost metrics are estimated based on the current load of the links. The traffic is routed over the lightly loaded links. Therefore the links with the lighter loads are selected instead of links with the heavier loads. In backup path setup, the source sends a small fraction of probe packets along the existing paths. It can monitor and identify the requests that are rejected at the network based on the received positive and negative feedback from the destinations. The source then calculates the blocking probability from the received feedback and selects the optimal light path with the lowest blocking probability.

References

[1] L. Kazovsky, S. Benedetto, and A. Wilner, Optical Fiber Communication Systems, Artech House, ISBN 0-89006-756-2
[2] A. Ghatak, and K. Thyagarajan, Introduction to Fiber Optics, Cambridge Press, ISBN 0-521-57785-3
[3] S.Ramamurthy, Laxman Sahasrabuddhe, and Biswanath Mukherjee, "Survivable WDM Mesh Networks", Journal of light wave technology, vol. 21, no. 4, April 2003.
[4] 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, Doi: 10.1109/BCN.2007.372750.
[5] Guido Maier, Achille Pattavina, Luigi Barbato, Francesca Cecini and Mario Martinelli, "Routing Algorithms in WDM Networks under Mixed Static and Dynamic Lambda-Traffic", Journal on Photonic Network Communications, vol. 8, no. 1, pp: 69- 87, June2004,Doi:10.1023/B:PNET.0000031619.18955.4
[6] 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.
[7] Michael T. Frederick and Arun K. Somani, “A single-fault recovery strategy for optical Networks using sub graph routing”, The International Journal of Computer and Telecommunications Networking, Volume 50, Issue 2 (February 2006)
[8] MurielM´edard, “Network Reliability and Fault Tolerance”, IEEE Transactions on Volume 50, Issue 1, Page(s):85 – 91, Mar 2001
[9] Hongsik Choi, Suresh Subramaniam, and Hyeong-Ah Choi, “On Double-Link Failure Recovery in WDM Optical Networks”, INFOCOM Volume: 2, on page(s): 808- 816 vol.2, 2002
[10] Dong-won Shin, Edwin K.P.Chong and Howard Jay Siegel, “Survivable Multipath Routing Using Link Penalization”, Computing and Communications, 2004 IEEE International Conference.
[11] Yufeng Xin, Jing Teng Gigi Karmous-Edwards,GeorgeN.Rouskas and Daniel Stevenson, “Fault Management with Fast Restoration for Optical Burst Switched Networks”, IEEE,2004
[12] Jian Wang,Laxman Sahasrabuddhe and Biswanath Mukherjee, “Fault Monitoring and Restoration in Optical WDM Networks”, National Fiber Optic Engineers Conference NFOEC 2002
[13] G.Ramesh S.SundaraVadivelu,” A Reliable and Fault- Tolerant Routing for Optical WDM Networks” (IJCSIS) International Journal of Computer Science and Information Security, Vol 6, No 2, 2009