INTERNATIONAL JOURNAL OF MICROWAVE AND OPTICAL TECHNOLOGY

VOL.4, NO.1,JANUARY 2009

High-performance Optical Networks – An Overview

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Abstract - Due to the distributed administration, large geographic coverage, and expensive resource cost, communication networks are one of the most vulnerable parts in the current information infrastructure. Both failures and malicious attacks are difficult to eliminate in such systems recent advances in fiber transmission and switching/routing techniques have dramatically increased the communication capacity of links. Moreover, merging large amount and multiple classes of services over the same communication links is also common now a days. An adverse consequence of these advances is increasing network vulnerability since a small network failure or network attack can significantly reduce the capability to deliver services in large-scale information systems. Hence, this paper describes about the greater focus on spare capacity design and network restoration techniques to mitigate the impact of failures and attacks, providing network survivability for circuit switched networks.

Index Terms - Optical communication networks, Switchinhg/Routing, Spare capacity, Bandwidth allocation, Restoration Techniques & High Performance.

I. INTRODUCTION

A network that supports high capacity traffic, for telecommunications or power distribution, must be designed in a way that makes it robust to the potential damage from unforeseen events like a cut in a link or a breakdown of some network equipment. A network having survivability is capable of satisfying the demand for the point-to-point services expected of it, despite the potential for such disruptive events. This is achieved when the network is planned with sufficient extra capacity, is multi-connected, and has the ability to immediately re-route traffic, if necessary, to avoid any failed network locations [1]. In these networks, when a cable or equipment failure is detected, the (pre-designed) plan for restoring service is automatically and quickly implemented by using Internet and Layered Service Techniques in order to improve the high performance optical networks [2].

II. OPTICAL NETWORK ARCHITECTURES (ONA) AND PAPRAMETERS

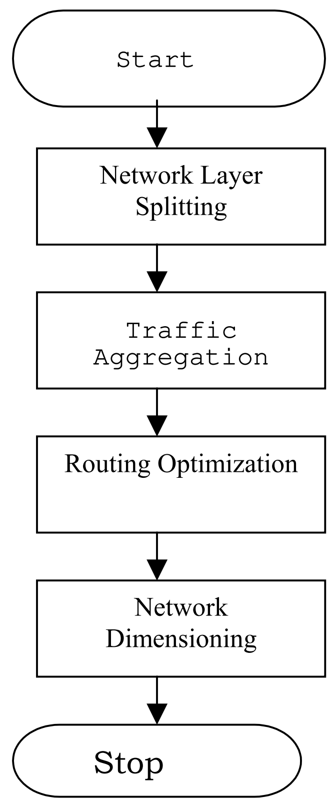

Fig. 1. Optimization Process

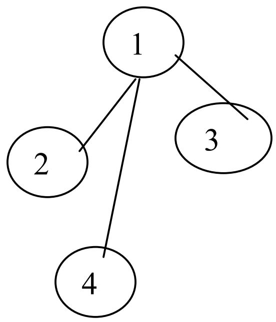

Fig.2. Optical Network Connectivity

These architectures are well defined by the optimization process as shown in the Fig. 1, which are categorized into four steps i.e. Network Layer Splitting, Traffic Aggregation, Routing Optimization and Network Dimensioning. These elements are more economical parts of high performance networks where they are well connected to the drop ports of each OXC, pack lower rate digital signals into higher rate optical signals to increase the optical network efficiency. Traffic aggregation interconnects between one node to another node, to the intermediate node and also multiple nodes as shown in the Fig.2. Network is also designed in view of scalability and mobility to restore the network from single failure and multiple failures[3].

Since the network is decoupled into multiple trees, a scheduler is needed by each of them to coordinate the medium access of the transmitters for collision avoidance and bandwidth allocation. The schedulers can be located either centralized or distributed[4,5]:

• *Centralized*: all the schedulers are put together in a single node. This facilitates network management and algorithm upgrade, but it brings the drawback that the scheduling node must have high reliability and strong computation ability. The node is critical and its failure disrupts the whole network; usually a backup scheduler is highly necessary for this solution.

• *Distributed*: the scheduler for each tree is geographically distributed, usually located in its root node. In this case, each scheduler has low complexity and its failure does not affect other trees.

III. SINGLE HOP ARCHTECTURE

1.Link Sequence (LS)

2.Link Distance (LD)

3.Link Connectivity (LC)

4.Digital Cross-connectivity Factor (DCSF)

1. Link Sequence (LS) It is defined as the number of edges(links) (E) to the number of vertices(nodes) (V).

$$LS = E/V \quad - (1)$$

2. Link Distance (LD) It is defined as a measure of the demand. It determines a particular traffic flow along the link sequence to the span (joint). It is measured in miles.

$$LD = V/S\# \quad - (2)$$

3. Link Connectivity (LC) It is defined as the product of determining of the establishment of a network with a LS and LD.

$$LC = LS \text{ X } LD \quad - (3)$$

4. Digital Cross-connectivity Factor (DCSF) It is defined as the connectivity factor, which results the establishment of network connectivity in an isolated condition. If the traffic requirement s between node pairs is 1 X 5 such as minimum number of node connectivity (m) to the maximum number of node connectivity (n).

$$DCSF (\%) = m/n \quad - (4)$$

IV MULTI-HOP ARCHITECTURE

Link Connectivity (LC)
Network Connectivity (NC)
Demand Connectivity (DC)
Link Utilization Factor (LUF)
Restoration Factor (RF)
DCS Factor (DCSF)

1. Link Connectivity (LC) It is defined as the product of determining the establishment of a network with a LS and LD using the Eq 1 and 2.

$$LC = LS \times LD \quad - (5)$$

2. Network Connectivity (NC) The node connectivity of a network is usually defined as some value that indicates how easy it is to disconnect the network through node removal. It represents the nodal stability of the network in terms of the anticipated number of nodes in a given network configuration. It is given by the number of nodes and also the decomposition of nodes in order to maintain in the form of standalone configuration.

$$NC = NjP(Nj) \quad - (6)$$

3. Demand connectivity (DC) The Demand Connectivity quantifies the connectivity for the overall network configuration. It determines the individual value assigned to each node and link, which determines the best network structure. These individual node and link importances are quantified through the Node Decomposition and Link Connectivity[6].

$$DC = ND(N) \times LC \quad - (7)$$

4. Link Utilization Factor (LUF) LUF indicates the contribution of the network's communication links to maintain connectivity between network elements. It computes the relative weights to each individual node and link network structure is important when designing survivable network topologies. It is the ratio of Network Connectivity to number of nodes. It also represents the difference between max allowable link flow to the link flow available in a given network[7].

$$LUF = (\text{Max allowable link flow} - \text{Link flow}) \quad -(8)$$

5. Restoration Factor (RF) The most survivable network topologies are
those in which link restoration is essential. It quantifies the impact on network connectivity caused by the loss (failure) of a link. The RF determines the best choice for relocation between those nodes selected by network topology.

$$RF = \text{Max allowable link flow} \quad - (9)$$

$$RF = \frac{LUF}{V(N)} \quad - (10)$$

6. Digital Cross connectivity System Factor(DCSF) The DCSF gives the survivable performance in which the difference between LUF and RF is considered. It represents the Fiber Span Layout Demand Distribution performance.

$$DCSF\ (\%) = \frac{(LUF - RF)}{N} \quad - (11)$$

Table 1 & 2. Traffic requirements between Node Pairs &
Optical Network Connectivity Table

Mixed Span Layout (Link Sequence)		
Span#	Link#	Link(s)
1	1	(1,2)
2	2	(1,3)
3	3	(1,4)
4	4	(1,5)

Link Distance (Miles)		
Link	#	Miles
(1,2)	1	14
(1,3)	2	4
(1,4)	3	11
(1,5)	4	7

Table 3 Determination of Optical Cross Connectivity Pattern

Criterion	Value
Link Connectivity	1 X 5
DCS Factor %	20

Table 4. Traffic requirements between Node Pairs &
Optical Network Connectivity Table

Source	Destination	Traffic (Mb/s)
1	2	6
2	3	5
3	4	8
4	5	10

Table 5. Determination of Optical Cross Connectivity Pattern

Criterion	Value
Link Connectivity	1 X 5
Network Connectivity	N X N
Demand Connectivity	N
DCS Factor %	80
Link Utilization and Restoration factor	(Max allowable link flow-Link flow)/(Max allowable link flow)

Table 6. DCS

LUF&RF	(5-1)/5
DCS Factor (%)	80

Table 7. Traffic requirements between Node Pairs &
Optical Network Connectivity Table

Source	Destination	Traffic(Mb/s)
1	3	10
2	5	5
3	4	8
4	1	6
5	2	5

Table 8. Determination of Optical Cross Connectivity Pattern

Criterion	Value
Link Connectivity	5 X 5
Network Connectivity	N X N
Demand Connectivity	N
DCS Factor %	80
Link Utilization and Restoration factor	(Max allowable link flow-Link flow)/(Max allowable link flow)

Table 9. DCS

LUF&RF	(5-1)/5	(5-2)/5	(5-3)/5	(5-4)/5
DCS Factor(%)	80	66.6	40	20

Table 10. Traffic requirements between Node Pairs &
Optical Network Connectivity Table

Source	Destination	Traffic(Mb/s)
1	2	2
2	3	5
3	4	8
4	5	0
5	6	17
6	7	6
7	8	9

Table 11. Determination of Optical Cross Connectivity Pattern

Criterion	Value
Link Connectivity	9 X 9
Network Connectivity	N X N

Demand Connectivity	N
DCS Factor %	77.7
Link Utilization and Restoration factor	(Max allowable link flow-Link flow)/(Max allowable link flow)

Table 12. DCS

LUF&RF	(9-2)/9	(9-3)/9	(9-4)/9	(9-5)/9
DCS Factor(%)	77.7%	66.6%	55.5%	44.4%

Table 13. Optical User Node Connectivity

Demand Pair	Demand
(1,2)	2
(1,3)	4
(1,4)	3
(1,5)	5

Table 14. - Optical User Node Connectivity

Demand Pair	Demand
(1,2)	2
(1,3)	4
(1,4)	3
(1,5)	5

Table 15. Optical Network Connectivity Parameters

Link Connectivity	1 X 5
Node Connectivity	N X N
Network Connectivity	N
Restoration Mechanism	1:2 DP
USSR %	Restoration Link / Demands 12/14 = 85.7

Table 16. Optical Network Connectivity Parameters

Link Connectivity	4 X 4
Node Connectivity	N X N
Network Connectivity	N
Restoration Mechanism	1:2 DP, APS, 1+1
USSR %	Restoration Link / Demands 24/28 = 87.5

Table 17. Optical User Connectivity Parameters

Demand Pair	Demand
(D, C1)	6
(E, C2)	3
(F, C3)	4
(6,7)	1
(4,6)	2
(2,4)	2
(5.8)	3
(8,6)	2

Table 18. Optical Network Connectivity Parameters

Link Connectivity	8 X 8
Node Connectivity	N X N
Network Connectivity	N
Restoration Mechanism	1:2 DP, APS, 1+1
USSR %	Restoration Link / Demands 10/13 = 76.9

The network simulations are presented as shown in the tables above regarding the Single Hop Architecture and Multihop Architecture optical networks [8]. Ring networks have been widely used in optical networks. Initially, SONET rings were made of multiple nodes as shown in. linked together by pairs of optical fibers, one for each direction, transporting a single high-speed optical transport signal. Two main ring network variations were usually implemented: the UPSR and the BLSR. In a UPSR network, information is transported, from the source node to the destination node, in a predetermined direction, as shown in, i.e. clockwise or counter-clockwise, along the ring [9]. The information transport resources in the opposite direction are kept for network protection purposes.

V. CONCLUSION

An Optical Network Architecture (ONA) is proposed for low-cost and high-performance metropolitan area networks. ONA architecture avoids the use of expensive routers by providing single-hop transportation between node pairs; at the same time, it can be combined with a mesh physical topology to achieve high survivability under multiple failures. Based on the ONA architecture, there are several interesting issues to investigate in our future work. One such issue is to improve the efficiency by considering the multi-hop extension of the architecture with traffic grooming, such that when a node does not have much incoming traffic, its wavelength tree can be used to relay traffic to other nodes.

VI. APPENDIX

NOTATIONS AND SYMBOLS

Number of edges (links)
E
Number of vertices (nodes)
V(N)
Number of nodes removed for decomposition sequence Nj
Probability of decomposition sequence j
P(Nj)
Total number of decomposition sequences formed in network Di
Node decomposition index for node N
ND(N)
Link Sequence
LS
Link Distance
LD
Link Connectivity
LC
Network Connectivity
NC
Demand Connectivity
DC
Link Utilization Factor
LUF
Restoration Factor
RF
Digital Cross-connectivity Factor
DCSF
Minimum number of node connectivity
m
Maximum number of node connectivity
n

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