EXISTENCE AND SURVIVABILITY IN FIBER OPTICS NETWORKS

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Abstract: In communication networks, survivability is an important aspect in protection and restoration. The main object of this paper is to develop an integrated model, which describes the design of networks, with node and switch architectures. The proposed model gives a design tool to analyze several partial mesh and hierarchical topologies, and demonstrates that a hierarchical topology provides the most scalable solution for satisfying the design constraints. The design tool is to optimize the design based on the comparison of different network components. Protection and restoration strategies are proposed in order to achieve survivability in multi-layer networks such as physical layer and logical layer networks. The results are computed by using FNUS algorithm.

1. INTRODUCTION

Survivability is a measurement of network recovery capability when a failure occurs in the network. It provides connections from source to destination across many network segments, which may have any type of topology or combinations [linear, ring and mesh], besides the network resource discovery and network management connectivity. It defines the principles of the architecture layers for design and represents the components in each layer. It also describes the applications, bringing together the architecture principles such as wire line, cellular and voice over packet networks. In this, network routing is addressed and network elements (NE’s) and their functions are described.

The work of Song Ho-Wu et.al. Group [1&2] form the strong foundations for the establishment of technologies and strategies related to survivable fiber optic network architecture. Manonnet Singh et.al. [3] discussed the survivability parameters in optical networks, using the Hubbing Span Architecture. From the evaluation of Digital Signal Level 3 (DS3) characteristics, Vande.V et.al. [4] discussed the methods of survivability, which can be provided in single fiber network architecture. Starting from the SONET Characteristics, Frank J.Effen Berger [5&6], discussed the survivability of SONET in hubbing architecture. Nag T.S et.al. [7&8] introduced the problem of ad-hoc fair queuing. The focus was how to resolve the conflicts between fairness and maximal throughput. Lisong XU Group [9&10] depicted the fair channel sharing and limited channel reuse with the generation of Enhanced Maximize -Local-Min Fair Queuing [EMLM-FQ] algorithm. Ju.J Group [11&12] has carried out the problem with location – dependent contention in ad-hoc network design issues.

Optical restoration is one of the missing building blocks in today’s optical network architecture. In network’s survivability, the restoration is not only confined to link but the whole optical segment. To economically utilize the fiber’s high capacity, the network architecture is often organized as a hubbing structure, which is based on a single-homing (SH) concept and/or Dual Homing Concept (DH). Single homing is a centralized demand routing concept that aggregates demands from any office to their destinations through an associated home hub. The fibre-hubbed architecture or single homing architecture is economically attractive, but at the expense of service vulnerability, since a single fiber cut or a hub office failure would isolate a large area served by the Central Office [CO] from communicating with other communities. This can be overcome by Dual Homing [DH] concept which can be evaluated and achieved by Physical Layer and Logical Layer concepts.

Survivability methodologies are further subdivided in to two types. They are Traffic Restoration and Facility Restoration. Traffic restoration is applied to switched networks, where as facility restoration is applied to facility transport networks. At present, high-capacity asynchronous fiber facility networks are commonly used is Digital Signal Level (DS3), which carries 45 Mbps of data, rather than Digital Signal Level 0 (DS0), which carries a voice call of 64kbps. Technological advancements play a crucial role in implementing survivable fiber networks.

Real network contains a mix of protected and unprotected traffic in the network survivability aspect. Some traffic may be protected in other layers. A complete multi-layer and multi-period network optimization has to be considered to yield practical network solutions. An Optical network survivability design cycle starts with a given network topology and traffic forecast. The network design task is to find an appropriate routing, protection, bundling and throughput for all nodes in network.

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2. PROPOSED METHODOLOGIES

The Physical Layer is classified into four methodologies. They are

(i) Fiber Span Layout and its Demand Distribution, in which Digital Cross Connectivity (DCS) factor is measured. (ii) Fiber Network User Service Survivability in which the restoration mechanism is presented, with different types of protection schemes such as 1:1, 1+1, Automatic Protection Switching (APS) and Diverse Protection (DP) is presented [13]. (iii) Optical Network Demand Bundling Using DS3 Forming, in which point-to-point connections to appropriate DS3 level demands in direct and indirect paths are represented [14]. (iv) SONET (Integrated approach), proposes Multi-period Synchronous Optical Network Survivability (MSONS) which overcomes the limitations of Hubbing Span Architecture. It assures satisfactory survivability parameter estimations for multi-node-to-node connectivity and multiperiod planning of complex networks [15].

The Physical Layer is enhanced to Logical Layer in which Optical Ad-Hoc network connectivity in terms of Global Fairness model and Maximum Channel Reutilization is presented. It is classified in to three methodologies such as the Two-Tier, Bounded Fair Maximize – Local – Min – Fair Queuing (BFMLM-FQ) and Hybrid Algorithms. The Two-Tier algorithm determines the connectivity for multiperiod fair queuing which achieves the global fairness. It is further extended to BFMLM-FQ algorithm to determine the fairness model by using spatial channel mobility and scalability procedures [16&17]. Further the Hybrid algorithm describes an integrated model of both Two-Tier and BFMLM-FQ models [18]. These network architectures are compared with different parameters like Network Size and Traffic Patterns like Optical Channel Capacity [OCC], Optical Channel Resource Sharing [OCR], Spatial Locality [SL], Scalability and Node mobility Fairness [SNF & MNF], Multi-hop Optical Network [MOP], and Maximized the Channel Utilization [MCU] in the QoS environment.

3. RESULT ANALYSIS

Results are presented by various techniques for 9 X 9 node configuration which can easily be extended to any node configuration (N X N). Also the veracity of the results obtained in the work is verified by comparing the results with those obtained for the limited case of 1 X 5 node connectivity in Fig. 1 (extendable to 1 X N) reported earlier. Also results are obtained for a general case (9 X 9 node connectivity) by using all the techniques which will be useful inorder to enhance the performance of survivable fiber optic networks presented in the paper.

In Physical Layer Fiber Span Layout Demand Distribution, computer results for multilayer survivability parameters are obtained and the result for 1 X 5 node connectivity are compared with results available in the literature for Hubbing Span Architecture as shown in Table 1.1. Numerical results for 9 X 9 shown in Table 1.2 through Point-to-Point Architecture in Fig. 1.1 are presented. It is obvious that this method can be easily extended to N X N node connectivity. The DCS Factor by this method for 1 X 5 node connectivity is 80%, where as 20% in the work reported earlier.

<table>
<thead>
<tr>
<th>Span#</th>
<th>Link#</th>
<th>Link(s)</th>
<th>Miles</th>
<th>Traffic (Mb/s)</th>
<th>Hubbing Span Architecture</th>
<th>Point-to-Point Span Architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>(1,2)</td>
<td>14</td>
<td>6</td>
<td>DCS Factor (%) = 20</td>
<td>LUF=(5-1)/5 DCS Factor (%) =80</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>(1,3)</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>(1,4)</td>
<td>11</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>(1,5)</td>
<td>7</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.1. A 5-Node Sub network

Table 1DCS – Fiber Span Layout Demand Distribution for 1 X 5 Node Connectivity

Fig.2 Fiber Span Layout
The Fiber Network User Service Survivability (FNUSS) simulates multi restoration parameters and with multiple failures. Results are obtained and compared with those of Hubbing Span Architecture having 1 X 5 node connectivity.

**Table 2** User Service Survivability (USSR), FNUSS and Survivability Ratio for 1 X 5 Node Connectivity

<table>
<thead>
<tr>
<th>Demand Pair</th>
<th>Demand Hubbing Span Architecture</th>
<th>Point-to-Point Span Architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1,2)</td>
<td>2</td>
<td>Restoration Mechanism = 1:2DP</td>
</tr>
<tr>
<td>(1,3)</td>
<td>4</td>
<td>Survivability Ratio = 12/14 = 85.7%</td>
</tr>
<tr>
<td>(1,4)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>(1,5)</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

The numerical results with single link failure and multiple failures are obtained for 1 X 5 node connectivity in Fiber Network User Service Survivability restoration method. The Survivability Ratio is 20% in Hubbing Span Architecture where as the same is 86% in Point –to –Point Span Architecture as shown in Table 2. The 9 X 9 node connectivity is also measured by using restoration technique and obtained SR 76.9% is represented in Table 3 and 4. The different types of multi node-to-node connectivities like 3 X 3, 4 X 4, 5 X 5 and 8 X 8 are also simulated which can be extended to N X N connectivity.

**Table 3** FNUSS – 9 X 9 Node Connectivity

<table>
<thead>
<tr>
<th>Demand Pair</th>
<th>Demand</th>
<th>PPSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1,2)</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>(Cu, C6)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>(Cu, C9)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>(6,7)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>(4,6)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>(2,4)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>(5,8)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>(8,6)</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

The different parameters like Bandwidth, Routing Protocols, Max Node Size, Max Flow Size, Throughput Ratio, Special Reuse Gain, Location Dependent, Location independent and Global Fairness are computed.

In Optical Network Demand Bundling using Digital Signal 3 Forming in Table 5 and the user connectivity direct path procedure with maximum network traffic propagation connectivity is achieved as depicted in Table 6. The indirect path distributes the demands into different parcel lists through which maximum restoration facility propagation connectivity and as well direct connectivity is obtained.

**Table 5** Input Table for Connectivity pattern and values

<table>
<thead>
<tr>
<th>S.NO</th>
<th>DIRECT DS1s &amp; DS3s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(1, 2) → 13,15</td>
</tr>
<tr>
<td>2</td>
<td>(1, 3) → 17,21</td>
</tr>
<tr>
<td>3</td>
<td>(2, 3) → 18,25</td>
</tr>
<tr>
<td>4</td>
<td>(3, 7) → 16,30</td>
</tr>
</tbody>
</table>

In Synchronous Optical Network (SONET), the Multi period Service Optical Network Survivability (MSONS) algorithm results in different survivability planning periods. The candidate survivable architecture is achieved for N X N node connectivity and is implemented for different architectures like Fiber Hubbed Span with Diverse Protection (DP) and Point-to-Point Span with DP. The past work results were depicted in Physical Layer Network as shown Table 6. Hence maximum and minimum performance of planning period model computation is also achieved in the present work as compared to the previous results.

**Table 6** Physical Layer Network

<table>
<thead>
<tr>
<th>Span No.</th>
<th>Source Destination</th>
<th>Working Path</th>
<th>Protection Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(1,2)</td>
<td>1-2</td>
<td>1-3-2</td>
</tr>
<tr>
<td>2</td>
<td>(1,3)</td>
<td>1-3</td>
<td>1-4-3</td>
</tr>
<tr>
<td>3</td>
<td>(1,4)</td>
<td>1-4</td>
<td>1-3-4</td>
</tr>
</tbody>
</table>

In Logical Layer, the HSA simulation results were obtained in terms of Lower Bandwidth comprises of packet size and the throughput rate between max and min flow. This work got enhanced by using three techniques viz Two-Tier, BFMLM-FQ and Hybrid models and the different parameters like Bandwidth, Routing Protocols, Max Node Size, Max Flow Size, Throughput Ratio, Special Reuse Gain, Location Dependent, Location independent and Global Fairness are computed.
4. CONCLUSION

The entire research work mainly consists of top-down investigations of the benefits of optical layer services and the requirements for the optical layer. A reconfigurable optical network provides faster user connections over the optical network. Automation of such provisioning can be done ultimately where user’s equipment and optical network equipment cooperate with each other.

The point-to-point approach to enhance the performance of survivable optic networks integration yields better result in physical and logical layer from various simulation models. Correlation of these results corroborates the validity of the algorithms. These architectures are also presented in the context of incremental changes towards the existing networks in order to improve survivability throughput in optical Networks.

5. REFERENCES