# SURVIVABILITY PROTECTION SCHEMES FOR ALL OPTICAL NETWORKS

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# SURVIVABILITY PROTECTION SCHEMES FOR ALL OPTICAL NETWORKS

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*Dedicated in thankful appreciation for prayers, support, warmth and encouragement to my beloved mother, father, family and beautiful princess, Insyirah. Special dedicated to my husband who spent so much time and supported me each step of the way.*

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# ABSTRACT

The general idea of optical fibre is to function as high bandwidth transport infrastructure in Telecommunication Company. Any failure of the fiber may affect service interruption for customer. As a consequence, service provider unable to fulfill Service Level Agreement (SLA) with their customers. In addition, loss of traffic will lead in decreasing revenue for service provider. Thus, network survivability is required in communication services including voice, video and data especially High Speed Broadband (HSBB). Dedicated Path Protection (DPP) and Shared Path Protection (SPP) have been implemented in ensuring the survivability of the network. Furthermore, the schemes are significantly devotes to provide better Quality of Services (QoS) based on several benchmarks in terms of connection Availability Satisfaction Ratio (ASR), Blocking Probability (BP), Resource Utilization Ratio (RUR) and Protection Recovery Time (PRT). South Africa Network topology was carried out to analyze basic protection scheme to prevent traffic from failure. Quick Heuristic Routing (QHR) algorithm was proposed to analyze the network. One of the contributions of this research is to enhance the solutions in preventing optical networks from network failure. The results show that by implementing protection schemes, ASR of the network was found to be guaranteed more than 99.90%. This research proved that Blocking Probability of the traffic can be reduced less than 15%. Next, the analysis on Resource Utilization Ratio which provides a cost optimal way for network operator can be improved until 17.71% from previous work. Finally, the results show acceptable time to recover from failure which is below than 4ms.

# ABSTRAK

Idea umum mengenai fiber optik adalah untuk berfungsi sebagai jalur lebar tinggi infrastruktur transpor dalam syarikat telekomunikasi. Apa-apa kegagalan fiber mungkin menyebabkan gangguan perkhidmatan kepada pelanggan. Akibatnya penyedia perkhidmatan tidak dapat memenuhi Perjanjian Tahap Perkhidmatan (SLA) dengan para pelanggan mereka. Disamping itu, kehilangan trafik akan menyebabkan kurang pendapatan bagi penyedia perkhidmatan. Maka, kelangsungan rangkaian diperlukan dalam perkhidmatan komunikasi termasuk suara, video dan data terutamanya Jalur Lebar Berkelajuan Tinggi (HSBB). Perlindungan Laluan Didedikasikan (DPP) dan Perlindungan Laluan Dikongsi (SPP) telah dilaksanakan untuk menjamin kelangsungan rangkaian. Tambahan pula, skim-skim tersebut secara signifikannya menumpukan usaha bagi menyediakan Perkhidmatan Berkualiti (QoS) yang lebih baik berdasarkan kepada beberapa tanda aras dalam bentuk perhubungan Nisbah Kepuasan Diperolehi (ASR), Kemungkinan Halangan (BP), Nisbah Penggunaan Sumber (RUR) dan Masa Pemulihan Perlindungan (PRT). Topologi Rangkaian Afrika Selatan telah dibuat untuk menganalisa skim perlindungan asas untuk mengelakkan kegagalan trafik. Algoritma Laluan Heuristik Segera (QHR) telah dicadangkan bagi menganalisa rangkaian tersebut. Satu daripada sumbangan kajian ini ialah untuk meningkatkan penyelesaian dalam mengelakkan rangkaian-rangkaian optik daripada kegagalan rangkaian. Keputusan menunjukkan bahawa dengan melaksanakan skim-skim perlindungan, rangkaian ASR didapati dijamin lebih daripada 99.90%. Kajian ini telah membuktikan yang Kemungkinan Halangan trafik boleh diturunkan kurang daripada 15%. Seterusnya, analisa ke atas nisbah penggunaan sumber yang menyediakan satu kos optima bagi operator rangkaian boleh diperbaiki sehingga 17.71% berbanding kajian lepas. Akhirnya, keputusan menunjukkan masa yang diterima untuk pulih daripada kegagalan adalah kurang daripada 4ms.

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## LIST OF SYMBOLS

| | | |
|---|---|---|
| $l$ | - | Fiber link in the network |
| $C_l$ | - | Cost of link, $_l$; it is determined by the current state of network |
| $F_l$ | - | Numbers of free wavelengths on link $_{,l}$ |
| $p_l$ | - | Numbers of primary wavelengths on link, $_l$ |
| $B_n$ | - | Numbers of backup wavelengths on link, $_l$ |
| *Crn* | - | Connection request |
| $p_n$ | - | Primary path for Crn |
| $b_l$ | - | Numbers of backup wavelengths on link, $_l$ |
| β | - | Connection arrival rate |
| $1/\mu$ | - | Mean holding time |

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| QOS | - | Quality of Service |
| SPs | - | Service Providers |
| WWW | - | Worldwide web |
| TDM-PON | - | Time Division Multiplexing –Passive Optical Network |
| WDM | - | Wavelength Division Multiplexing |
| ONUs | - | Optical Network Units |
| RWA | - | Routing and Wavelength Assignment |
| PPP | - | Partial Path Protection |
| DPP | - | Dedicated Path Protection |
| SPP | - | Shared Path Protection |
| QHR | - | Quick Heuristic Routing |
| ASR | - | Availability Satisfaction Ratio |
| BP | - | Blocking Probability |
| RUR | - | Resource Utilization Ratio |
| PRT | - | Protection Recovery Time |
| CapEX | - | Capital expenditures |
| OpEx | - | Operational costs |
| FM | - | Fault Management |
| CM | - | Configuration Management |
| SONET | - | Synchronous Optical Networks |
| SDH | - | Synchronous Digital Hierarchy |
| OTDM | - | Optical Time Division |
| ITU | - | International Telecommunications Union |
| CWDM | - | Coarse Wavelength Division Multiplexing |

| | | |
|---|---|---|
| DWDM | - | Dense Wavelength Division Multiplexing |
| NSFNET | - | National Science Foundation Network |
| NJLATA | - | New Jersey Local Access and Transport Area |
| ARPANET | - | Advanced Research Projects Agency Network |
| PMW | - | Preventive Maintenance Work |
| MTTR | - | Mean Time to Repair |
| MTBF | - | The Mean Time Between Failure |
| BERs | - | Bit error rates |
| MPLS | - | Multi Protocol Label Switching |
| ATM | - | Asynchronous Transfer Mode |
| LP | - | Link Ptotection |
| PP | - | Partial Protection |
| PPP | - | Partial Path Protection |
| EBS | - | Essential Backup Survivability |
| MBS | - | Minimal Backup Survivability |
| GBS | - | Global Backup Survivability |
| IETF | - | Internet Engineering Task Force |
| ITU-T | - | ITU Telecommunication Standardization Sector |
| SLA | - | Service Level Agreement |
| MATLAB | - | Matrix Laboratory |
| HEGONS | - | Heterogeneous Grooming Optical Network Simulator |
| OPNET | - | Optimized Engineering Tools |
| FORTRAN | - | Formula Translating System |
| IP | - | Internet Provider |

# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

Nowadays, optical fibre is the media of choice for the transmission of telecommunication services throughout the world due to the intrinsic capability of optical fibre in carrying high capacity and high quality traffic. Since optical network is a promising technology to accommodate the explosive growth of telecommunication traffic in worldwide, failure that occur must be conducted in the most efficient and effective manner. Thus, this research comes out to improve network performance in handling network failure so that the quality of services (QoS) can be maintained in good level in order to give satisfaction for both service providers and also subscribers.

### 1.1.1 Service Perspectives: Increasing Demand

Optical networks are undergoing significant growth, fueled by the exponential growth of traffic due to variety of services. The rapid growth continues to be ever increasing demand for bandwidth, to the point where, just as 10 Gb/s technology has reached maturity, service providers (SPs) have already installed higher bit rates. Nowadays, optical network technology can be considered as our savior technology because of its potential for limitless capabilities (B. Mukherjee, 1997), huge bandwidth of nearly 50 Tb/s, low signal attenuation as low as 0.2 dB/km, low signal distortion, low power requirement and small space requirement. Thus, more telecom network providers start to use optical fibre as their usage patterns evolve to include more bandwidth and capacity intensive networking applications such as voice traffic as well as data browsing on the worldwide web (WWW), video conferencing, IPTV and others.

Nowadays, services have evolved significantly to the growth of global traffic flows. For example, Figure 1.1 below shows how the Internet has evolved from predominantly web, email, and file sharing in 2008 to a predominance of video today. This is a situation which is expected to continue into the future (Cisco, 2011). Thus, due to increasing demand of services, survivability of the network is very important to ensure the information able to deliver by the customer or user. Survivability of a network refers to a network's ability to continue providing service in the presence of failures even though this might mean a momentary minimal degradation in quality of service. It refers to the capability of a system to fulfill its mission, in a timely manner, in the presence of attacks, failures, or accidents. A survivable optical path has a primary path, which carries traffic during normal operation, and a backup path, which carries traffic when the primary path fails (B. Mukherjee, 1997). In order to save network cost and to improve network performance, it is very important for the network operator to optimize of capacity utilization in transport systems.

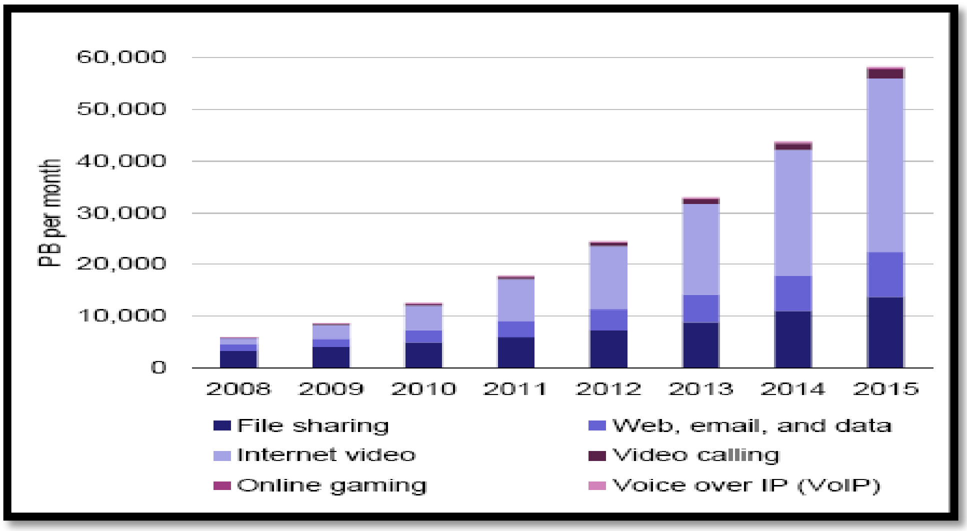


**Figure 1.1** Worldwide traffic generated by different consumer services (Cisco, 2011)

### 1.1.2 Research Challenge in Survivable WDM Optical Networks

In order to guarantee traffic grooming, the technology should be able to meet the requirement on our networking demands. Failures may result in a large disruption in the network traffic and data streams since it carries huge capacities. One of the challenges is Telecom network operators face fiber cuts occurring consecutively in the order of weeks or even days. It is clear that providing 100% flexibility guarantee to all types of traffic supported by the network would be ideally desirable. In simple ways, network survivability enhancement is very important.

Nowadays network survivability becomes a challenge in network design and operation to manage frequent occurrence of the traffic loss due to failure. Many works have been done to arrange smart strategy to the problems associated with planning and protection of optical networks. The network survivability has been extensively studied. Yang Qiu and Chun Kit Chan (2013) have proposed and experimentally investigated a novel survivable WDM/TDM PON architecture. By using TDM rings for ONUs, the survivable protection architecture can simultaneously protect against the distribution fiber failures. On the other hand, there are several approaches to ensure fiber network survivability such as Anil Kumar *et al.* (2013) proposed algorithm to determine shortest route in order to improve cost effectiveness of optical fibre by minimizing the required capacity. Stefanos Mylonakis (2012) used difference equations to calculate traffic and the available network capacity of the WDM mesh networks. Then, Rodrigo *et al.* (2012) compared the performance of three different restoration schemes for all-optical networks involving link, sub path and path. From the research, path restoration is the best reactive scheme for all optical networks without wavelength conversion.

Bayrem Triki *et al.* (2011) suggested novel technique for survivable routing in WDM optical networks. The finding in their work is random network topologies which allow generating primary and secondary paths that share a variety number of nodes specified by the source in advance. The results perform on demand generation and decision of requests to establish survivable routes. Nirmala L Devi *et al.* (2011) consider both alternate path routing and partial placement of wavelength converters to analysis the trends for reduction of blocking probability. Uma Rathore Bhatt and Sanjiv Tokekar (2011) discussed about the multiclass services in WDM optical networks. Three classes of services (class I, II & III) were used according to the traffic and utilization requirement. A survivable RWA strategy has been proposed and discussed for these classes of services. The proposed strategy has been tested and its aims to provide 100% survivability of connection request for class I, II and III services.

Amir Askarian *et al.* (2010) implemented cross layer techniques for improving the survivability of all optical networks. The process had been done by decreasing both blocking probability and the susceptibility of the network to failures. Ning Zhang and Jiazhu Xu (2010) have analyzed the protection principle of WDM optical network. They proposed a protection method to manage failures in optical networks. These protection schemes can be divided into two categories which is link protection and other is path protection scheme. Path protection scheme can be further subdivided into two categories. First category is dedicated path protection and the other one is shared path protection scheme. Another research is done by Ankitkumar

N. Patel and Jason P. Jue (2010). They addressed the problem of survivable traffic grooming in optical WDM networks using hop constrained. Survivability technique is provisioned at the wavelength granularity through either dedicated or shared path protection schemes. An auxiliary graph based on algorithm was proposed that addresses grooming, protection, and impairment constraints as a single aspect. They propose to replace the regenerators and grooming equipment in the network with the goal of minimizing equipment cost.

Meanwhile investigation done by Arunita Jaekel *et al.* (2010) have introduced a method for survivable topology design and traffic grooming of low-speed and also scheduled traffic demands. For these traffic demands, the setup and breakdown times must be known. 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. Guo liang Xue *et al.* (2007) who introduced partial path protection (PPP) scheme where one active path is protected by a collection of backup paths with each backup path protecting one or more links on active path. Research carried out by Sunil Gowda *et al.* (2003) show in reduction in blocking probability. Besides, number of converters required at each node to achieve a given blocking probability. These results were based on few algorithms like CFPR (conversionfree primary routing), converter multiplexing technique in backup paths and backup path relocation scheme.

In this research, protection for survivable optical network use an algorithm called Quick Heuristic Routing (QHR) to protect traffic from failure. QHR proposed for each connection request will have one primary path and multiple segment backup paths. Thus, QHR can contribute significant improvements in blocking probability, protection recovery time, and resource usage (Lei Guo, 2006).

## 1.2 Objectives of Research

The research intends to study on survivability in optical networks. The main objectives of this research are:

1. To investigate and implement two protection scheme; Dedicated Path Protection (DPP) and Shared Path Protection (SPP).

2. To analyze the proposed schemes which are DPP and SPP by using Quick Heuristic Routing (QHR) for South Africa Network Topology.

3. To enhance the performance of Quality of Service (QOS) by using several benchmarks which are availability satisfaction ratio (ASR), Blocking Probability (BP), Resource Utilization Ratio (RUR), and Protection Recovery time (PRT).

## 1.3 Scope of Research

In order to achieve the objectives, thorough study and research have been conducted to get relevant information. Several scopes of research are listed to ensure the research is conducted within its intended time frame:

1. This research is intended to analyze the performance of protection scheme applied on South African Network topology. This topology had been chosen as it is quite similar with the Malaysia Network topology compared to other network which will be discussed in the next chapter (Telekom Malaysia, 2008).

2. The simulation is based on the long haul optical WDM network domain as it carries the most traffic compared to access and metro networks and thus requires more efficient protection mechanism.

3. The proposed protection schemes are based on quick heuristic (QHR) routing algorithm. Heuristics routing chosen due to its simple process that generates accurate results in acceptable amount of time.

## 1.4 Research Methodology

Figure 1.2 shows the overall research methodology in this research. Literature review also includes telecommunication network overview, network topology, and fault management including protection schemes involved which are Dedicated Path Protection (DPP) and Shared Path Protection (SPP). Then, network setup for South African Network Topology is created using Matlab. Next, Quick Heuristic Routing (QHR) have been used in the simulation to analysis on investigates parameter is determine based on several benchmark for Quality of Service (QoS) for both DPP and SPP. This parameters investigated in this research are Availability Satisfaction Ratio (ASR), Blocking Probability (BP), Resource Utilization Ratio (RUR), and Protection Recovery time (PRT). In short, this research focuses more on QHR simulation where the goal is to develop simple process that generates accurate results in acceptable amount of time.

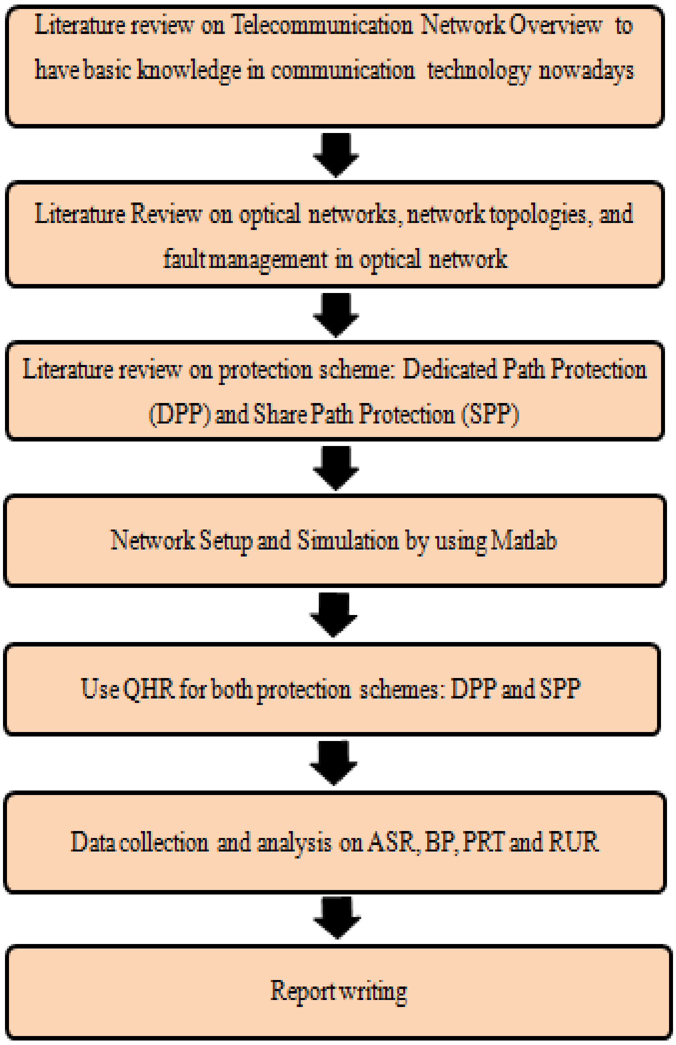


**Figure 1.2** Flow Chart of Research Methodology

## 1.5 Thesis Outline

This thesis is organized into five chapters providing a simple understanding of the overview of the research. Each of the following paragraphs generally emphasizes the content of each chapter. Chapter 1 describes the thesis basics and foundation including the research objective, scope and methodology. Chapter 2 discuss about all the literature review involved in this study such as the basic knowledge of optical network. Besides that Chapter 2 also presents the network topology, routing procedure and protection schemes to tolerate the path failure in order to guarantee network survivability.

Chapter 3 conveys QHR methodology using Matlab simulation. The chapter focuses to compare both protection schemes: DPP and SPP. The chapter also describes the flow chart and parameter used such as ASR, BP, RUR and PRT to analyze the Quality of Service.

The results, analysis and performance evaluation of the simulated results are presented in Chapter 4. This chapter involves analysis on how improvement of Quality of Service can be achieved using same QHR. Finally, the conclusion and recommendations for future works are explained in Chapter 5.

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