ADAPTATION TO NON-CRITICAL FAILURE AND PERFORMANCE ANALYSIS OF OPTICAL WDM NETWORKS

Dissertation submitted in fulfillment of the requirements for the Degree of

MASTERS OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION

By

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MAY, 2017

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DECLARATION BY THE SCHOLAR

I hereby declare that the work reported in the M-Tech thesis entitled **"ADAPTATION TO NON-CRITICAL FAILURE AND PERFORMANCE ANALYSIS OF OPTICAL WDM NETWORKS"** submitted at **Jaypee University of Information Technology,Waknaghat India,** is an authentic record of my work carried out under the supervision of **Dr. Rajiv Kumar**. I have not submitted this work elsewhere for any other degree or diploma.

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CERTIFICATE

This is to guarantee that the proposal entitled **"ADAPTATION TO NON-CRITICAL FAILURE AND PERFORMANCE ANALYSIS OF OPTICAL WDM NETWORKS"** put together by **Ashit Chander (152008)** in halfway satisfaction of the prerequisites for the honor of Masters of Technology Degree in **Electronics And Communication Engineering at Jaypee University of Information Technology, Waknaghat**, India (173234) is a real work completed by him under my direction. The matter epitomized in the report has not been submitted to whatever other University/Institute for the honor of any degree.

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ACKNOWLEDGEMENT

I might want to offer a profound feeling of gratitude and indebtedness to **Dr. Rajiv Kumar,** Department of ECE, supervisor for this work, for his direction, support, inspiration, and consolation all through the finish of this work. His excitement to listen to the issues, his educative remarks, his suggestions for the convenient and successful completion of this work has been exemplary.

We are appreciative to **Prof. Dr. Sunil Bhooshan,** Professor, and Head, Dept. of ECE for his superb support during our work. I might likewise want to thank all of the professors & other supporting members of the department of Electronics and Communication Engineering for their generous help in different courses for the finish of this work. Last however not the slightest, I might genuinely want to thanks, every one of my companions, Ph.D. researchers and friends for their insightful recommendations for fulfilling this undertaking.

Date : Ashit Chander

ABSTRACT

An optical network which is considered to be the backbone of all the services provided. The networks are able to deliver a bandwidth in a flexible, transparent manner, supports capacity up gradation and backings limit up a degree. The optical system consists of the optical source which acts as a transmitter for the transmission of signal from the optical fiber acting as medium of propagation with cross connects and the photo-transreceivers. There being the confinement of electronic handling of opto-electronic instruments which restrains the full use of transmission capacity.

The primary area of concern for the WDM system is to locate the best feasible and reliable way . In case fault occurs in a network, the network needs to be prepared for such situations by providing a fault tolerant network in case of a failure occurring between the source-destination node and assignment of different matrices such as wavelength, feasible path and availability of resources for data transmission in the network. The best path is selected on the basis of a number of factors like delay, capacity etc which are called as performance matrices. The Quality of Service parameters (QoS) are evaluated from these performance matrices. I have outlined three distinctive system topologies having an alternate number of hubs and connections however with the equivalent limit. The networks are then simulated under different scenario to obtain the performance matrices. Those performance matrices are compared with case of network failure and network which is best is proposed under our project consideration for present scenario.

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LIST OF ACRONYMS AND ABBREVIATIONS

BWDM-Basic Wave Division Multiplexing

CWDM-Coarse Wave Division Multiplexing

CDM – Code Division Multiplexing

D node- Destination Node

DLE-Dynamic Light Path Establishment

DWDM-Dense Wave Division Multiplexing

DWXCs- Dual Wireless Cross-connects

Gb/s- Gigabits per Second

ITU-International Telecommunication Union

QoS- Quality of Services

QoP-Quality of Protection

QORP-Quality Based Routing Protocols

RWA-Routing and Wavelength Assignment

S node- Source Node

SLE-Static Light Path Establishment

WIXCs-Wireless Cross-connect

WDM-Wavelength Division Multiplexing

MILP -Mixed integer linear programming

CHAPTER 1
INTRODUCTION

Introduction

In this modern time where the communication demands has increased from previous ages with the introduction of new communication techniques. In today's world web has become a vital part of our lives. There is a huge increment in customers, so we require immense data transmission and fast systems to convey great nature of administration to customers. The present design has been supporting different dispersed applications and work innovations. The notoriety of the web has itself turned into a tremendous issue considering the parts of unwavering quality and security. With this fast development, the administrations, for example, video sharing, online exchanges, superior quality video on request and system processing, transport systems need to give the high ultra-limit bolster with the enormous web activity. The response to the above issues is fiber optics correspondence which addresses up the above difficulties of the advanced period correspondence. This uses diverse sorts of multiplexing systems to keep up a decent nature of administration without activity, less muddled instruments with great usage of accessible assets. Optical networking, with its almost unlimited bandwidth, is the only technology that can support such demand for bandwidth. The potential limit of single-mode fiber is about 50 Tb/s and is almost four times size higher than electronic information rates of a couple of gigabits for every second (Gb/s). Every effort should be made to tap out this huge potential of this mismatch of data rates between the single mode fiber and optoelectronic devices. The end-user which can be a workstation or gateway that interfaces with lower-speed sub-networks have access to the network which is limited by electronic speed (few Gb/s).The enter in outlining optical correspondence organizes keeping in mind the end goal to misuse the fiber's gigantic data transmission is to decay the transfer speed among numerous client transmissions in the system engineering. In an optical system correspondence, the decay of data transmission should be possible on the premise wavelength or recurrence [wavelength-division multiplexing (WDM)], schedule vacancies [time-division multiplexing (TDM)], state of the flag [code division multiplexing (CDM)].Although very little work have been done to make optical TDM and CDM for a business reason yet both are thought to be future innovations today. The developing best decision for the up and coming era of the system is WDM strategy. Wavelength division multiplexing is a method by which we separate the colossal transfer speed accessible of an optical fiber into numerous non-covering wavelength channels. These optical systems are inclined to segment disappointments at transmitter level, organize level and collector level. The disappointments happening at the transmitter and recipient level are basically because of Trans-associates and transponders and corrected effectively by essentially supplanting these segments. The system disappointments are hard to situate in WDM systems and set aside the opportunity to amend. The disappointments happening in system level are predominantly because of fiber cuts bringing on connection disappointments. Ordinarily, fiber cuts happen at the rate 4.83 cuts for each 1000 sheath miles for every year and it takes more often than not 10-12 hours to settle fiber disappointment. Because of various association connected each other; disappointment at a solitary connection causes different association disappointments. In this manner blame -resilience conveys awesome hugeness in WDM systems.

The fault-tolerant routing techniques are broadly classified as restoration and protection techniques. In restorations techniques, a backup path is initiated upon link failure or node failure. The backup path is computed and a light path is restored based on the availability of resources at the time of failure. Restoration techniques are best efforts services. In protection techniques, the primary and backup paths are computed and resources are reserved for these paths in case of failures before the connection are established. The protection method avoids a long delay. The Protection techniques guarantee that a path being restored as they provide an alternate path for a failure occurring situations totally dedicated to tackling such situations.

WDM

The concept was first published in 1978, and by 1980 WDM systems were being realized in the Bell laboratory. The first WDM systems combined only two signals. In optical communication, WDM [1] is a technology which carries a number of optical carrier signals on a single fiber by using different wavelengths of light. This allows bidirectional communication over one standard fiber within increased capacity. The WDM organize parts this into various little transmission capacities optical channels which permit numerous information streams to be moved in a solitary strand of same fiber in the meantime. The WDM network splits this into a number of small bandwidths optical channels which allow multiple data streams to be transferred in a single strand of same fiber at the same time. A WDM system uses a number of multiplexers at the transmitter end, which multiplexes more than one optical signal onto a single fiber and demultiplexers at the receiver to split them apart. Generally, the transmitter consists of a laser and modulator. The source generates an optical carrier signal at fixed or a tunable wavelength.

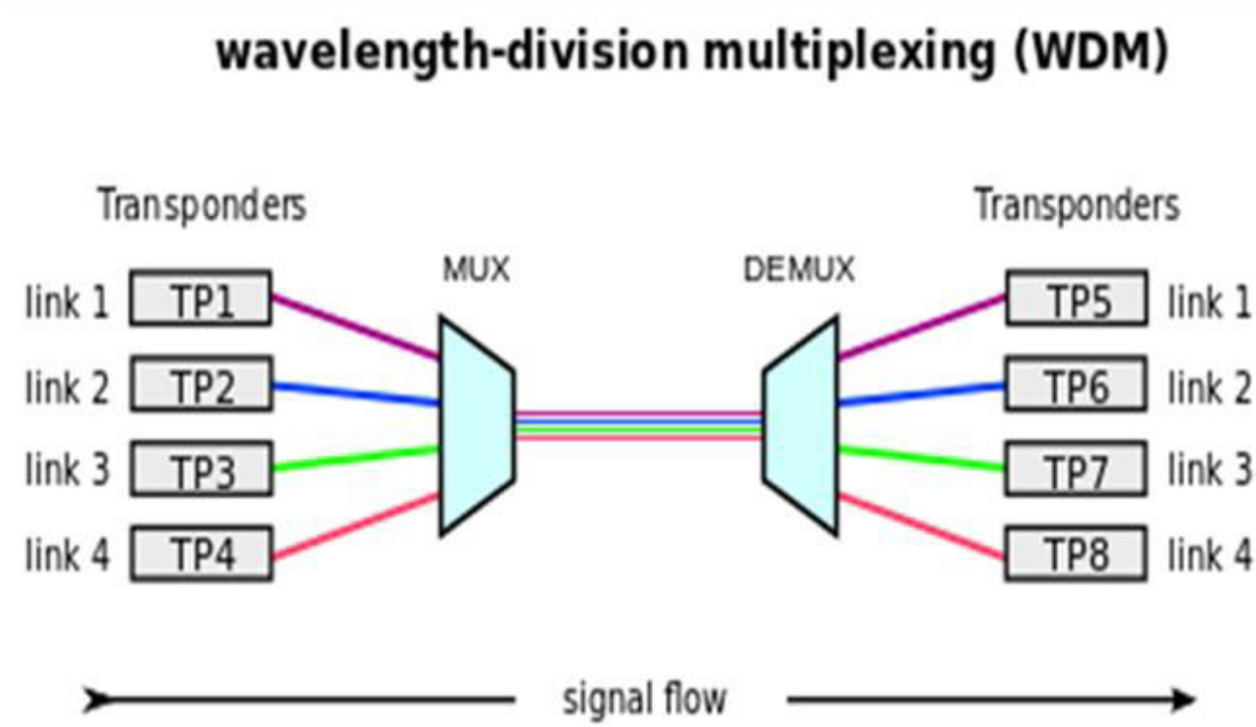

Figure 1 Wavelength Division Multiplexing Working Principle

WDM Network Types

The optical network has the large bandwidth and its capacity can be as high as 1000 times the entire RF spectrum. But this is not the case due to attenuation of signals, which is a function of its wavelength and some other fiber limitation factor like imperfection and refractive index fluctuation. So 1300nm (0.32dB/km)-1550nm (0.2dB/km) window with low attenuation in the fiber is generally used for transmission purposes. On the basis of different lightpath patterns, normal (WDM), coarse (CWDM) and dense (DWDM) is categorized [2]. The Normal WDM which is also called as BWDM uses only two normal wavelengths or lightpaths of usually 1310 nm and 1550 nm on a single fiber. In Coarse WDM, a number of channels available for transmission are up to 16 channels across multiple wavelengths of fibers. The dense wavelength division multiplexing (DWDM) uses the C-Band (1520 nm -1560 nm) range of wavelengths but with denser channel spacing in between them. The channel plans vary for the DWDM system but normally 40 channels at 100 GHz spacing or 80 channels with 50 GHz spacing are used. Some technologies are even capable of 12.5 GHz spacing and are therefore called ultra dense WDM systems. Now the amplification enables the extension of the usable wavelengths to the other bands which more or less doubling these numbers.

Table 1 Comparison of WDM, DWDM and CWDM

Parameters	WDM	DWDM	CWDM
Channel Wavelength	1310nm &1550nm	Large,1.6nm-25nm	Small,1.6nm or less
Band Used	C-Band(1521-1560)	C(1521-1560nm), L(1561-1620nm)	C(1521-1560nm), L(1561-1620 nm)
Cost	Low	Low	High
No. of Channels	2	14-16	Hundreds of channels possible

Lightpaths: Lightpath is defined as the optical signal which travels through the fiber. Lightpaths could be Unidirectional and Bidirectional. The path the signal follows to travel from source S to destination D is known as the lightpath. The link between the source and the destination use a particular frequency/wavelength for the transmission. There are more than one lightpaths in a single strand of fiber. The challenge is not the existence of more than one lightpath but their resource allocation and optimization. The lightpaths in the example are as

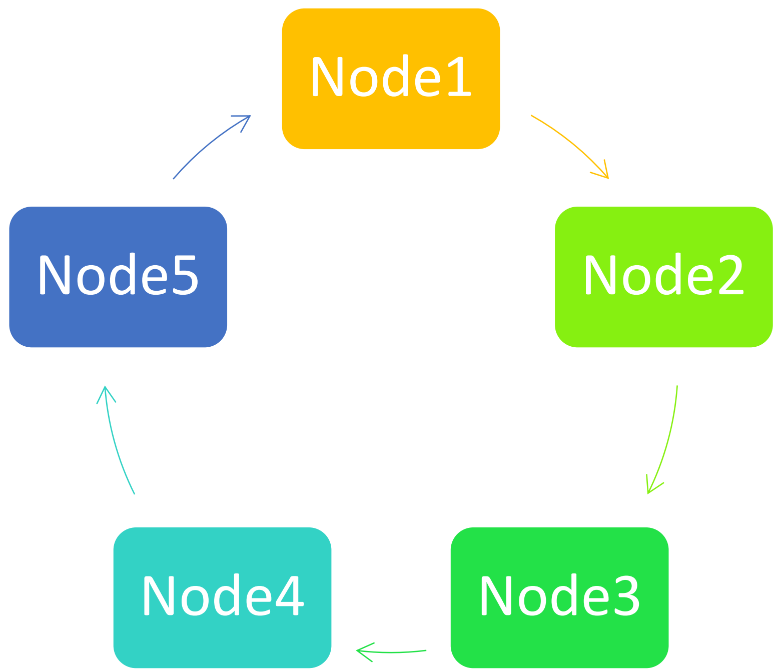

Figure 2 Bidirectional Lightpath with 5 Nodes in a Ring Topology

Lightpath 1: Node1→Node2

Lightpath 2: Node 2→Node3

Lightpath 3: Node3 →Node4

Lightpath 4: Node4→Node5

Lightpath 5: Node5→Node1

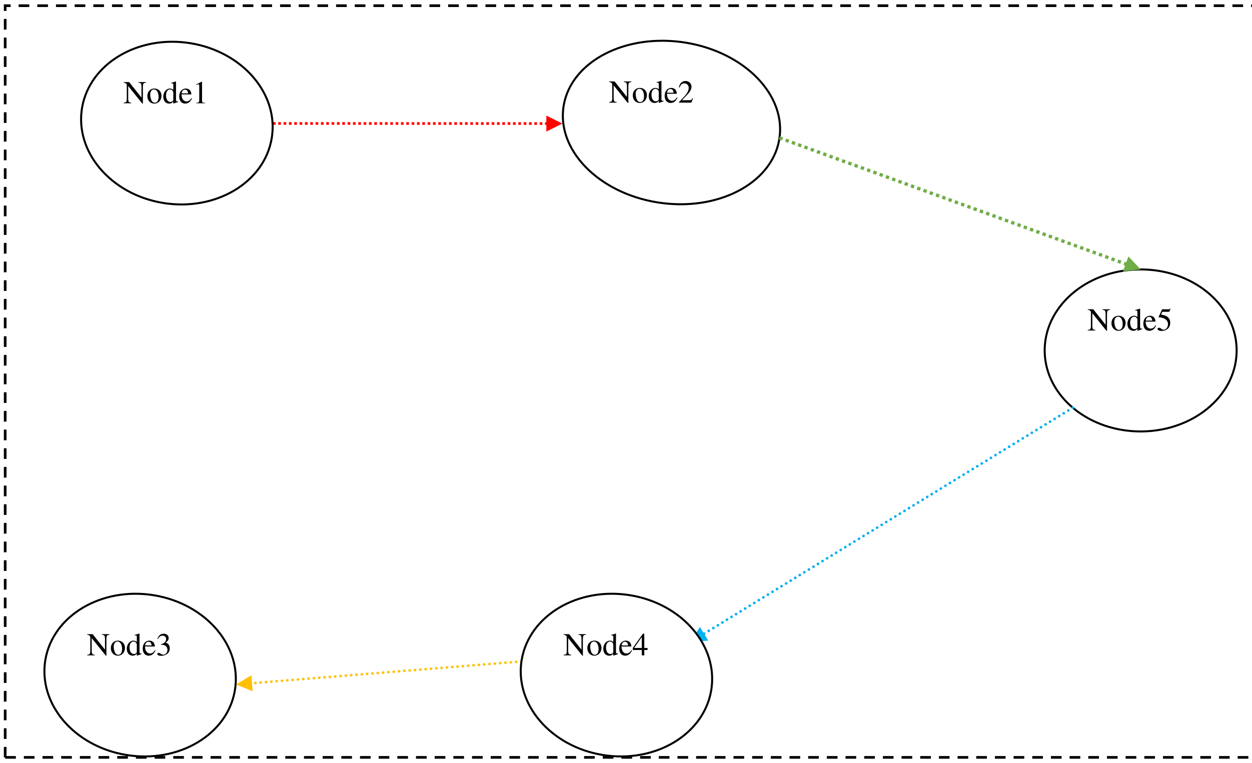

Figure 3 Different Unidirectional Lightpaths Between 5 Nodes

Fault Tolerant Network

All-optical networks that employ WDM technique emerges as the most suitable choice for communication purposes for the future networks. A fiber cut which cause a link failure at an occurrence rate of 5.39 cuts per 1000 sheath miles per year and the time it took to solve the problem is around 12-14 hours. The variety of the associations on a solitary connection, a disappointment of a solitary connection causes loss of different associations which could be not kidding issues if there should arise an occurrence of fiascos. On account of WDM system, the system depends absolutely on the fiber and harm could demonstrate deadly. Hence fault-tolerance carries great significance in optical WDM networks. That's the main reason why the focus is on the fault tolerance of networks is getting significant attention in today's world.

The fault- tolerance is usually employed at the optical layer or at the higher layers like IP layer. In the case of failure at the higher layers of a network, the recovery time is in the order of seconds which due to the high data rate of the channel could cause enormous data loss. The data loss is large when a connection cannot be restored within a given bounded framework of time. Whereas in the case of optical layer, the time for restoration is very much less and is in order of microseconds. The fault -tolerance is provided in the optical layer for the efficient utilization bandwidth and achieving high efficiency. Also, the resources could be better managed and utilized at the optical layer than at the higher layers. This accounts for an active research in the field of fault- tolerance in today's time.

The routing techniques are generally classified as reactive (Restoration) and proactive (Protection) techniques [2] [3] on the basis of fault- tolerance. These techniques are generally employed in fault tolerant networks in case of failures. In reactive techniques; a search starts for the backup path as soon the failure occurs in the link. The availability of resources is checked and the best decision is chosen based on resources utilization before establishing backup lightpath at the time of link failure. The restoration or reactive techniques surfer's long delays in searching and allocate the traffic on to the backup path while providing no assurance that the connection could be restored in case of network failure. The services provided by these techniques are best-effort services. In the case of proactive or protection techniques, the primary and the backup paths are calculated before the connection is established. The resources are reserved for these backup paths long before the actual connection is setup. Whensoever a link failure is occurs in a network so thereafter traffic is instantly rerouted onto the backup path through the backup lightpath established. A protection technique avoids the delay that is created during the setup of backup paths in case of link failures. The small delay helps to provide greater transparency to higher layers. The proactive techniques provide a guarantee that a connection is being restored in case of link failures. The reason that fault tolerance is provided at the optical layer is its simplicity and guarantee for backup path transparency.

Restoration Methods

WDM networks are prone to component failures and a cut in the fiber causes a link failure. When a link fails, all its constituent fibers will also tend to be failed. A node failure may be caused due to the failure of the cross connect or a fiber might fail due to the failure of receiver components. The lightpath that carries traffic during normal operation is known as the primary lightpath. When a primary lightpath fails, traffic is rerouted over a new lightpath known as the backup lightpath. Failure detection, correlation, and root cause analysis are a difficult problem in WDM optical networks. The nodes adjacent to the failed link can detect the failure by monitoring the power levels of signals on the links. The restoration schemes [4] differ in their assumption about the functionality of cross-connects, traffic demand, performance metric, and network control. Networks with WIXCs do not impose any wavelength continuity constraint. As a result, the wavelength channel utilization is higher in wavelength convertible networks than in wavelength selective networks. The traffic demand can be either is static or dynamic. In static traffic demand, the set of demands is given a priority. The objective is to assign lightpaths with restoration capability to all the demands to maximize resources utilization. This problem is related for the capacity planning phase to determine the capacity needed in the near future based on current and future demands. Instead, the objective could be to satisfy as many demands as possible for a fixed amount of network resources. This problem is valid in a situation where there are new demands, and the objective is to route as many demands as possible using the available capacity on a network. In a dynamic traffic environment, the demands arrive at a network one by one in a random manner. Once a demand is honored, it is held for a random finite time before being terminated. Here, the objective is to increase the acceptance ratio demands. Dynamic traffic demand results in several situations in transport networks. First, it may become necessary to reconfigure the network in response to changing traffic demand patterns. Second, with the rise in broadband traffic it is expected that the leased line rates for private virtual networks and Internet service provider links will grow higher and higher. The demand for such services will change with time. A restoration scheme may assume either centralized or distributed control. For large networks, distributed control is preferred over centralized control. A distributed control protocol requires several control messages to be exchanged between nodes. Also, there is a possibility of reservation conflicts between two simultaneous attempts to find paths. The restorations techniques can be classified as reactive and proactive methods. The reactive method is the simplest way of recovering from failures. In the reactive method, when an existing lightpath fails to communicate with the destination node. A search is started to find a new lightpath which does not use the failed components and is available for the use. This has an advantage of low overhead in the absence of failures. However, the guarantee of successful recovery is not 100 percent sure as it might fail to establish a new lightpath may due to unavailability and absence of resources shortage required at the time of failure recovery. Also, in case of contention among simultaneous recovery attempts for different failed lightpaths may require several retries to succeed resulting in increased network traffic and restoration time.

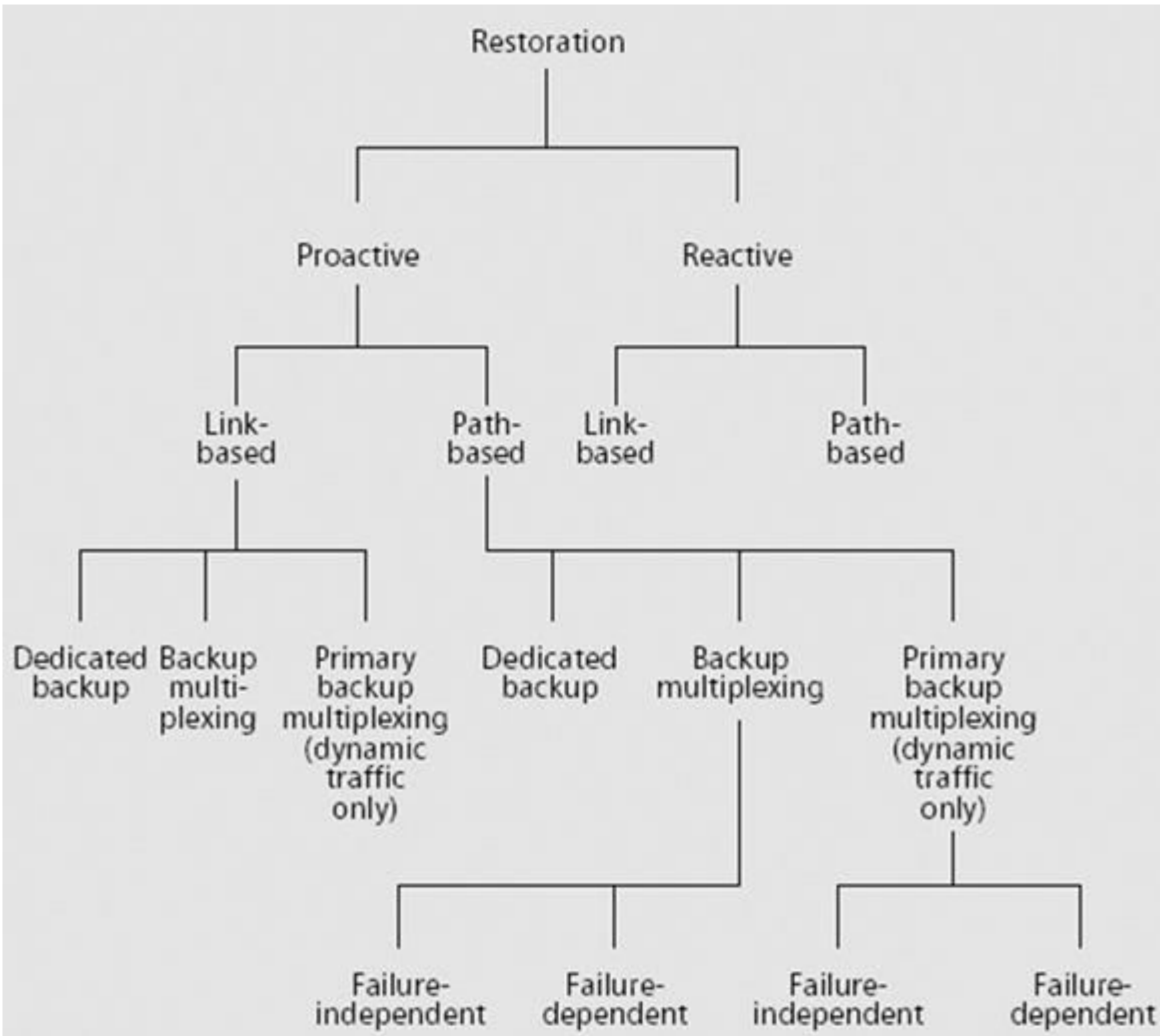

Figure 4 Restoration Techniques

The deficiencies of receptive strategies are overcome in proactive techniques. In a proactive strategy, reinforcement lightpaths are distinguished, and assets are held along the reinforcement lightpaths at the season of setting up the essential lightpath itself. The technique yields a 100 percent reclamation ensure for setting up a reinforcement way. This ensures a fizzled way discovers its reinforcement way promptly accessible upon disappointment. The reinforcement lightpath assumes control over the part of the essential lightpath when it comes up short. Since the reinforcement lightpath is built up before a disappointment really happens, one can utilize it promptly upon the event of a disappointment on the essential, without conjuring the tedious association restoration prepare. Thus, the rebuilding time of a proactive strategy is much lower, prompting quick recuperation. The procedure that utilizations preassigned ability to guarantee survivability is alluded to as security and the method that reroutes the influenced movement after disappointment event by utilizing accessible limit is alluded to as reclamation in **ITU-T RecommendationG.872** [5]. The terms, for example, reclamation arrange, rebuilding strategy, and rebuilding ensure have been utilized to allude to security with a say that the assets are pre-relegated. The term proactive is utilized to allude to the assurance and the term receptive to allude to reclamation.

A proactive or responsive strategy is either interface based or way based. The connection based technique reroutes movement around the fizzled segment. At the point when a connection comes up short, another way is chosen between the end hubs of the fizzled interface. This way, alongside the working fragment of the essential way, will be utilized as the reinforcement way. This strategy is ugly for a few reasons. The decision of reinforcement ways is restricted; additionally, the reinforcement ways are normally more. The wavelength of specific systems of the reinforcement way should utilize an indistinguishable wavelength from that of the essential way as a result of the working fragment being utilized is same. Moreover, taking care of hub disappointments along these lines is extremely troublesome. In connection based reclamation technique essential lightpath p1, and two reinforcement lightpaths, b11 and b12, on a wavelength. At the point when interface 0→1fails, reinforcement way b11 is utilized. It can be watched that b11 is directed around connection 0→1 while holding the working portion of p1.

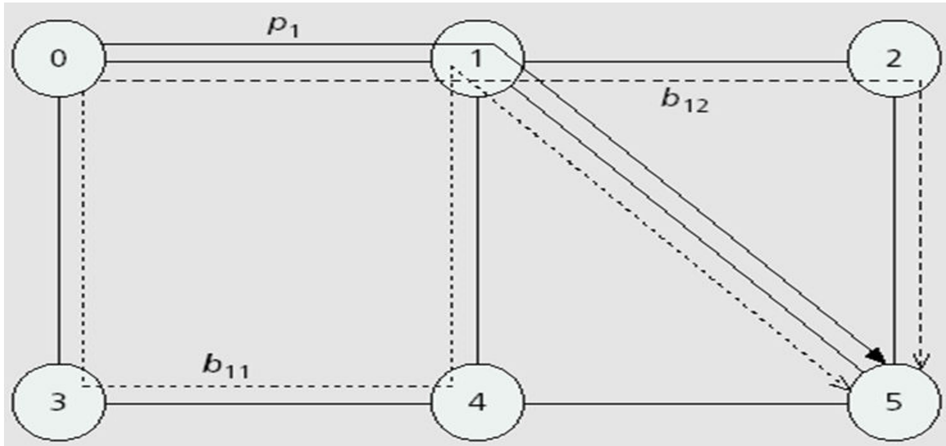

Figure 5 Link And Path Based Restoration

In way based rebuilding strategy when essential lightpath flops between 2 hubs. Not at all like in the connection based technique, in the way based strategy, has a reinforcement lightpath required not hold the working section of the essential lightpath. The technique demonstrates preferable asset use over the connection based strategy. The reinforcement way can utilize any wavelength free of the one utilized by the relating essential lightpath. It demonstrates an essential lightpath, p1, and its reinforcement lightpath, b1, on a wavelength. The b1 is set up between the end hubs of p1, and the working fragment of p1 is not held by b1.

A proactive reclamation strategy may utilize a committed reinforcement way for an essential lightpath. This is known as the committed reinforcement reservation technique. This strategy is represented in Fig.6.The figure demonstrates two essential lightpaths, p1 and p2, and their separate reinforcement lightpaths, b1 and b2, on a wavelength. It can be watched that b1 and b2 don't share any wavelength channel. The committed reinforcement reservation strategy has a favorable position of shorter reclamation time since the WXCs are designed for the reinforcement way while building up the essential way itself. However in this strategy assets are unreasonably held for the reinforcement rebuilding ways. In path based restoration method when primary lightpath fails between 2 nodes. Unlike in the link-based method, in the path-based method, a backup lightpath need not retain the working segment of the primary lightpath. The method shows better resource utilization than the link-based method. The backup path can use any wavelength independent of the one used by the corresponding primary lightpath. It shows a primary lightpath, p1, and its backup lightpath, b1, on a wavelength. The b1 is established between the end nodes of p1, and the working segment of p1 is not retained by b1.

A proactive restoration technique might use a dedicated backup path for a primary lightpath. This is known as the dedicated backup reservation method. This method is illustrated in Fig.6.The figure shows two primary lightpaths, p1 and p2, and their respective backup lightpaths, b1 and b2, on a wavelength. It can be observed that b1 and b2 do not share any wavelength channel. The dedicated backup reservation method has an advantage of shorter restoration time since the WXCs are configured for the backup path when establishing the primary path itself. However in this method resources are excessively reserved for the backup restoration paths.

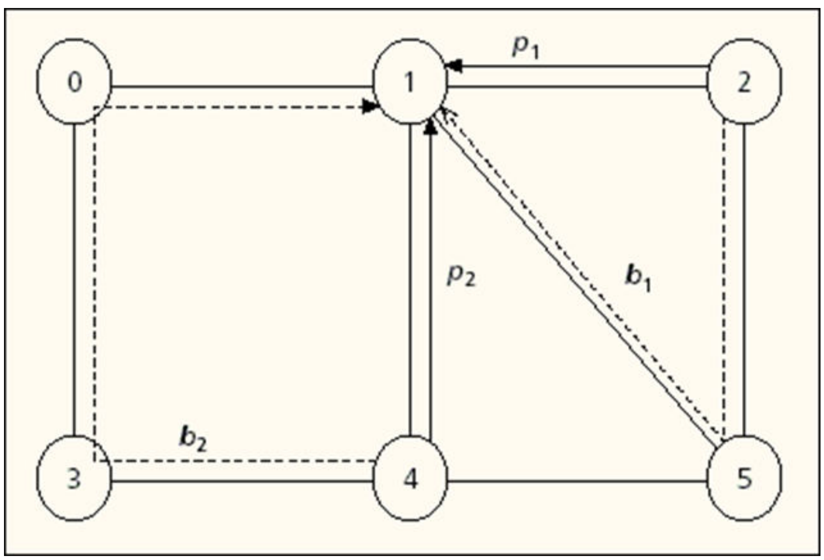

Figure 6 Dedicated Backup Path Reservation

For better resource utilization, multiplexing techniques can be employed. If two primary lightpaths do not fail simultaneously, their backup lightpaths can share a wavelength channel. This technique is known as backup multiplexing. The resource utilization can be further improved in case of dynamic traffic using a proactive method by using primary backup multiplexing. This technique allows a wavelength channel to be shared by a primary and one or more backup paths. This leads to the decrease in blocking probability of demands at the cost of reduced restoration guarantee.

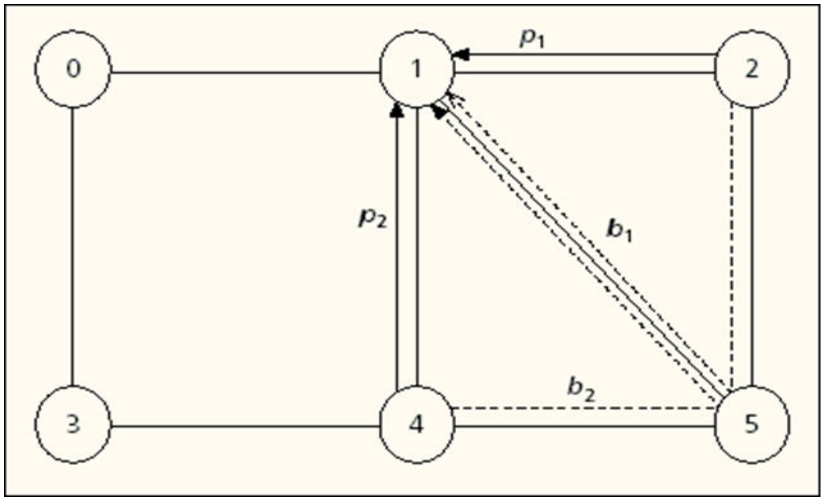

Figure 7 Backup Multiplexing

A path-based restoration method is either **failure-dependent** or **failure-independent**. In a failure-dependent method, associated with the failure of every link used by a primary lightpath, there is a backup lightpath. When a primary lightpath fails, the backup lightpath that corresponds to the failed link will be used. A backup lightpath can use any link, including those used by the failed primary lightpath, except the failed link. Different backup lightpaths of a primary lightpath can share channels since they do not fail simultaneously in a single-link failure model. The failure-independent model applies a backup lightpath to link-disjoint with the primary lightpath. This backup path is used upon link failure, irrespective of which of its links has failed. When this method is employed, a source node of a failed primary lightpath need not know the identity of the failed component. However, this method does not allow a backup path to use the channels used by the failed primary lightpaths. This will result in poorer resource utilization.

CHAPTER 2
OBJECTIVE AND PROBLEM STATEMENT

Objective of Work

The key objective of the work is to develop reliable network algorithm for WDM network. The network should be able to deliver maximum performance at the cost of reduced failures. This work proposes a fault-tolerant network design having following features:

- Optimum cost
- Scalability
- Availability
- Low delay
- Low blocking probability
- Resource efficiency

Problem Statement

In WDM innovation to be sent, there is need of a physical topology. At the point when the topology is planned, there is a requirement for steering and wavelength task to make it work. The two issue explanations outlined are as:

- Design a 60 Gbps network topology and find out performance parameters.
- Design a 100 Gbps network topology and compare the performance parameters.
- Compare 60Gbps and 100 Gbps network topologies performance parameters
- Design a network topology with link failure and find out performance parameters.

CHAPTER 3
LITERATURE REVIEW

Literature Review

The paper [6] examines distinctive rebuilding strategies that are utilized in WDM systems. The proposed organize utilizes less rebuilding time than the standard other system topologies that are utilized. The topology is exceptionally valuable in helping high movement through the system. In the accompanying papers [7][8][9][10] creators have proposed distinctive calculations plans which upgrade the speed of steering by legitimate asset usage. The diverse calculations process distinctive courses in a topology by which the deferral could be lessened in a system. With the developing interest in the system data transfer capacity, optical WDM systems are rising as the most fitting decision for cutting edge systems. Giving adaptation to internal failure to these rapid systems is a noteworthy QoS issue. In this review [11] [12], a complete characterization of the blame tolerant insurance directing methods is displayed. A dynamic dividing subway security steering strategy with way substitution is proposed. A wavelength task plan to essential and reinforcement ways is talked about. Broad recreations on a specimen organize topology have demonstrated that as opposed to settled parceling uniform sub-way insurance procedures and dynamic apportioning strategy executes and in addition way assurance method, as far as blocking likelihood. The system-wide normal downtime is littler than that of way insurance strategy. The system-wide most extreme downtime of the dynamic parceling method is much better than way insurance strategy. By permitting dynamism in parceling the essential way, great system wide most extreme and normal downtime can be accomplished without giving up a significant part of the blocking execution of the system. The paper [13] talks about various sorts of difficulties that are confronted in a WDM system and channels working. The paper likewise concentrates on the diverse sorts of segments that are utilized as a part of a WDM framework and how they function out and out. The paper is to give the outline of the exploration and advancements going in the field of optical systems administration. The papers examine fundamental optical-systems administration approaches provided details regarding the WDM. Then the physical-layer weaknesses which unequivocally impact organize outline. Ultimately the paper gives the illustrated of ebb and flow inquire about improvement patterns going in the field of WDM optical systems. The articles [14] [15] [16] talk about the routing and wavelength assignment (RWA) issue in optical systems utilizing WDM innovation. The two variations of the issue are considered as static RWA, whereby the movement prerequisites are known in beforehand known and other is dynamic RWA in which association demands touch base aimlessly way. Both sorts of requests are contemplated i.e. indicate point and multicast activity.

Input information for correspondence organize plan streamlining issues including multi-hour or dubious movement can comprise of a biggest of activity networks [17]. The networks are plainly considered in while figuring an issue for connection measurement. Nonetheless, a hefty portion of these grids are generally overwhelmed by others so just a moderately little subset of lattices would be adequate to get legitimate connection limit reservations, supporting all unique activity frameworks. Along these lines, disposal of the overwhelmed networks prompts considerably littler enhancement issues, making them treatable by contemporary solvers. In their paper, they examined the issues behind recognizing control of one movement lattice over another. They consider two fundamental instances of control: (i) add up to mastery when a similar movement steering must be utilized for both grids and (ii) standard mastery when activity subordinate directing can be utilized. The paper depends on our unique outcomes and sums up the control come about known for completely associated systems. Because of energy considerations [18] [19], it is believed that not all wavelengths accessible in a fiber can be utilized at a given time. The paper considers a systematic model to assess the blocking execution of wavelength-directed optical systems with and without wavelength transformation where the usable wavelengths in a fiber are restricted to a wavelength use requirement. The impact of the wavelength utilization imperative is examined on the ring and work torus systems. It is demonstrated that the expository model nearly approximates the reproduction comes about. The creators have demonstrated that expanding the aggregate number of wavelengths in a fiber is a superior other option to wavelength transformation when usable wavelengths in a fiber are kept up the same.

In proposed paper [20] [21] [22] a dispersed quality-based convention for directing, setting up, and bringing down and keeping up the condition of associations in wavelength steered every optical system. QORP represents physical impedances and limits the blocking likelihood of all-optical wavelength directed systems. The data about the nature of the optical flag is made accessible promptly with the assistance of an optical correlator. The QORP course is chosen with a quality corruption that has an edge settled. Subsequently, the convention wipes out associations with low quality though different conventions, which don't represent quality, set up calls that are of unsatisfactory quality.

In paper [23] the authors recommend that while optical transmission strategies have been looked into for a long time yet inquire about in the field of optical systems administration is still new.

In paper [24], the author proposed a paradigm for quantifying the grade of protection service in a generic way. Protection resources can be dedicated and shared. The first scheme shows 100% recovery and is it warranted by dedicated protection. The second scheme is associated with a measure based on recovery probability, which indicates the grade of connecting users with shared resources. Basically, in this work the recovery probability concept is proposed to be used in order to define different grade of conflicts which conform set of QoP levels. The algorithm proposed considered for unicast flow under pre-defined QoP protocols.

The paper [25] talks about the wavelength steered channels considering diverse imperatives and wavelength. The paper characterizes a calculation to deal with multi-bounce static movement preparing in light of coterie apportioning approach. Reproduction is done and the approach is contrasted on standard topologies and standard calculations.

The insect province calculation has been talked about and its usage is delineated in [26] [27] [28] [29].The focal points of the calculations are expressed and comparison with standard calculations are finished. The difficulties confronted because of the notoriety of the web are examined and dynamic activity designs.

The paper [30] examines how the information is utilized as a part of for stimulation also for the instructive reason.

The paper [31] gives a review of the MatplanWDM device and territory where it can be beneficial. It gives the outline of the reproduction apparatus.

In [32] NS3 reenactment device and change over other reproduction instruments are discussed. It tells about the unlimited extent of NS3 recreation apparatus and its application alongside beginning with NS3.

CHAPTER 4
NETWORK DESIGN

Network Topology Designing

A mesh topology is designed for 6, 9 and 12 nodes with bidirectional network. The node information is measured by the X and Y coordinates. The separation between hubs is measured in kilometers in a Euclidean plane. The quantity of E/O transmitter, O/E recipients, hub populace, hub sort, the quantity of hubs and the name of every hub are appointed in the plane.

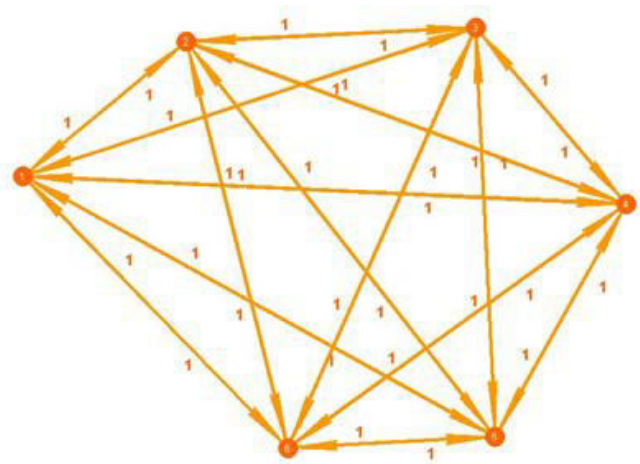

Figure 8 6-Node Fully Connected Mesh Topology

Table 2 Physical Information for 6-node network

Nodes	6
Links	30
Limit of channel	60 Gbps
Accessibility of wavelengths	40
Kind of Connection	Bidirectional

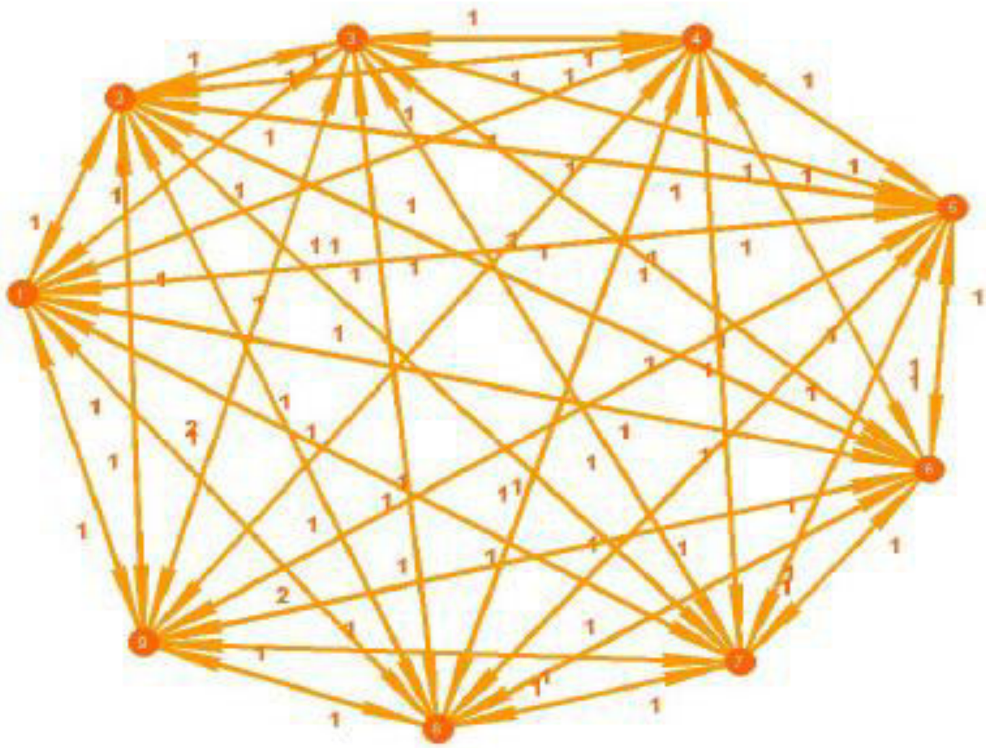

Figure 9 9 Node Mesh Topology

Table 3 Physical Information Of 9 Node Mesh Topology

Number Of Nodes	9
Total Number Of Links	72
Total offered capacity	60Gbps
Number of available wavelengths	40
Type of Connection	Bidirectional

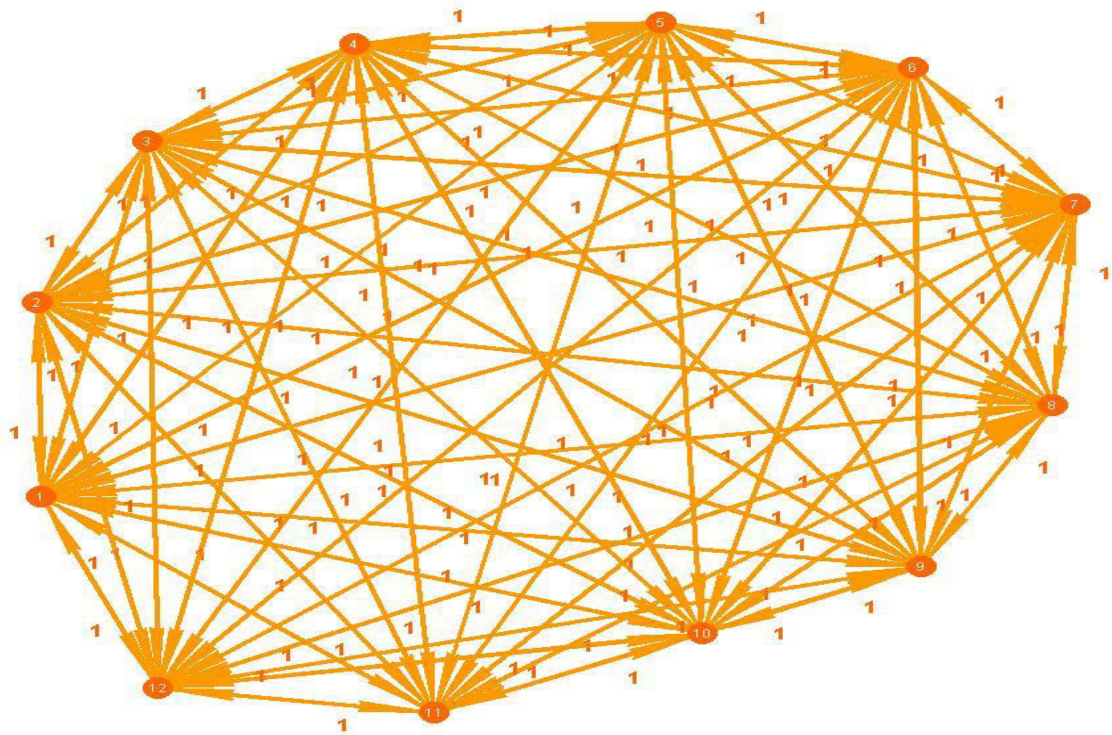

Figure 10 12-Node Mesh Topology

Table 4 Physical Information for 12-node network

Nodes	12
Links	132
Capacity of channel	100 Gbps
Availability of wavelengths	40
Type of Connection	Bidirectional

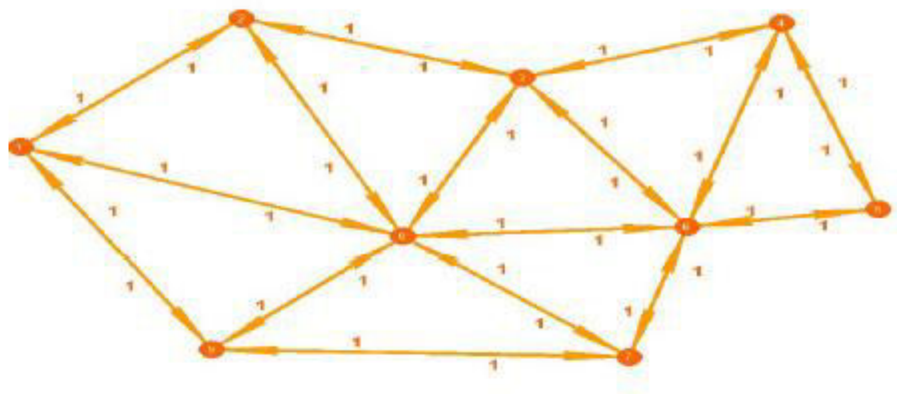

Figure 11 9Node Topology Before Link failure

One link has been removed from S-node to D node from mesh topology of 9.This link act as a failed link in the network. In our case we have removed the link from 8-6 node pair

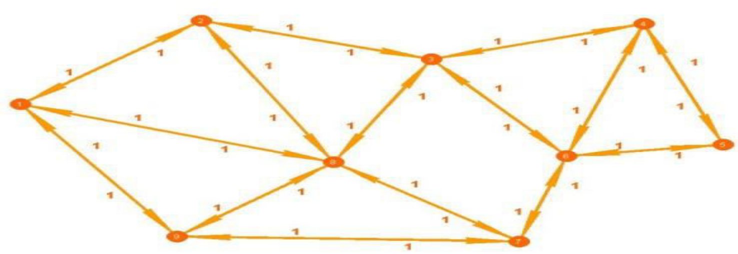

Figure 12 9- Node Topology After Link Failure

Table 5 Physical Information for 9-Node networks

Parameters	Without Link Failure	With Link Failure
Nodes	9	9
Links	32	32
Accessibility of Wavelengths	40	40
Limit of channel	60Gbps	60Gbps
Sort of channel	Bidirectional	Bidirectional

Algorithms

The Matplan WDM is the software used to study the characteristics of the network. The main menu opens as listed below

1. Design Virtual and Flow Routing
2. What if Analysis
3. Multi – Hour Analysis
4. Dynamic Analysis
5. Topology Designer

The different options which MatPlanWDM provides help in designing the topology and assigning parameters to network. The First four options which are preferably used for the planning of WDM networks and analysis in different environmental constraints by varying the parameters. These different network strategies apply different algorithms.

Flowchart for Lightpath Computational Algorithm

Algorithms are important in transfer of information from one node to another. The lightpaths used to transfer data are calculated by lightpath computational algorithm which contains most of the other algorithms as its sub-algorithms. These sub-algorithms are used to calculate the shortest path, delay, Input/output traffic at nodes, bandwidth utilization and lightpath utilization. As per the demands, the information needs to be transferred in minimum amount of time which is done by applying shortest path algorithms for data transfer from source to destination node. Dijkstra's, Bellman Ford and MILP algorithm are used as sub-algorithms of lightpath algorithm at various stages of the work to evaluate different matrices required. The flowchart for the finding the optimal lightpath is given below.

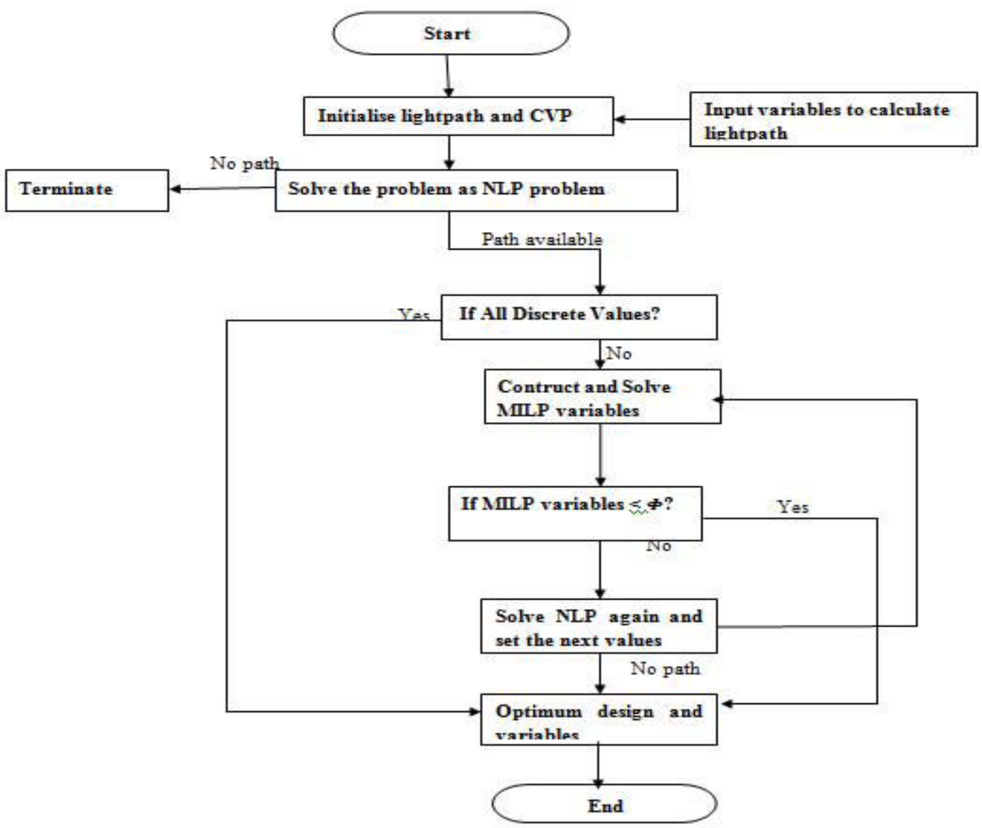

Figure 13 Flowchart for Lightpath Selection Algorithm

Pseudo Code for Sub-Algorithms

Systems are extremely perplexing and have progressive structure. The switches don't get the full data about the system complexities and topology. Most brief ways are computed by the areas for hundred of switches. However, these days' huge datacenters are made with level topologies to diminish the weight. In such systems, SSP (Source Shortest Path) must be turned out to be quick and dependable. The node vertices are given as N= (v, e)

Where V is set of Vertices with the end goal that v_i= {V_j|j= 0, 1, 2, 3… … , n-1}

E is set of edges with the end goal that e_i= {E_j|1, 2, 3… … , m-1}

Edge is characterized as the connection between hubs V_J, V_k, E= (V_J, V_k, W_i)

V_J is forerunner hub to V_k and W_i is weight appointed to the hub.

Pseudo Code for Bellman Ford

The Bellman-Ford calculation processes the briefest way from the source hub to the goal hub with weights appointed to every hub. The calculation is thought to be a flexible calculation as its ability to deal with the negative weights too. At first, the Vertex separations are set to maximal qualities (INF) and the antecedent to Null. Be that as it may, separation of source hub is kept 0.The edge relaxations are performed for all hubs (n-1 times to most extreme). In the event that the whole is little then the separation of the terminal vertex is changed to forerunner vertex distance and weight additionally gets refreshed. The Pseudo code for Bellman-Ford calculation is as

```
BELLMAN FOR D (P, s)
  for each vertex V€ P.v
        V.D =INF
        V.P =Null
S.D =0
 for i=1 to |G.v|-1
      for each edge (U, V, W) € N.e
         if V.D>U.D +W
```

```
        V.D =U.D +W
        V.P =U
for each Edge (U, V ,W) € N.e
      If V.D> U.D+W
        Return False
Return True
```

Pseudo Code for Dijkstra's Algorithm

Dijkstra's Algorithm is one of the best algorithms which are used in commonly in computing path in most of the IoT applications and SDN networks. The algorithm is used to find the shortest path between one node to other or from source node to all other nodes. The initialization is done in similar manner as in Bellman Ford algorithm. But the Dijkstra's algorithm iterates in a predefined manner. At every emphasis, a vertex with least cycle is separation is found among those which have not been prepared beforehand. So as to discover such vertices a need lines are set up. The vertex with smallest distance from priority queue is selected and edges are relaxed. The minimum priority queue is arranged after the procedure. The pseudo Code for Dijkstra's Algorithm as

```
DIJKSTRA (P, s)
  for each vertex V€ P.v
      V.D =INF
      V.P =Null
S.D =0
Q =N.v
while Q  ≠ θ
    U' =min (Q)
    Q = Q \ {U'}
For each edge (U, V, W) € N.e such that U = U'
    If V.D> U.D+W
     V.D = U.D +W
     V.P = U
```

Rearrange (Q, V)

Mixed-Integer Linear Programming Algorithm (MILP)

A mixed-integer linear program is a problem with which different matrices are reduced to the form of integers. This algorithm is used for the simplification of large linear matrices.

- Linear objective function, $f^T x$, where *f* is a column vector of constants, and *x* is the column vector of unknowns
- Bounds and linear constraints, but no nonlinear constraints ()
- Restrictions on some components of *x* to have integer values

In mathematical terms, given vectors *f*, *lb*, and *ub*, matrices *A* and *Aeq*, corresponding vectors *b* and *beq*, and a set of indices intcon, find a vector *x* to

{

$x(\text{intcon})$ are integers

$A \cdot x \leq b$

$Aeq \cdot x = beq$

$lb \leq x \leq ub$

}

CHAPTER 5
SIMULATION RESULTS

Simulation results for Testing Topology

MatPlanWDM (0.61) [25] and Net2plan are utilized as the test systems instrument. It takes physical topology and activity information for various system topologies. Here execution examination of the topologies has been done utilizing the MatPlanWDM0.61 test system. The topologies are given in .xml and movement record as .traff. The briefest way calculation is utilized for the testing topology. From that point onward, the parameters with lower and furthest breaking point are being settled. The number range focuses are chosen for which the yield is required. Right off the bat, the outcome for a straightforward is represented. The source is chosen as Node 1 and diverse parameters are evaluated for the testing topology.

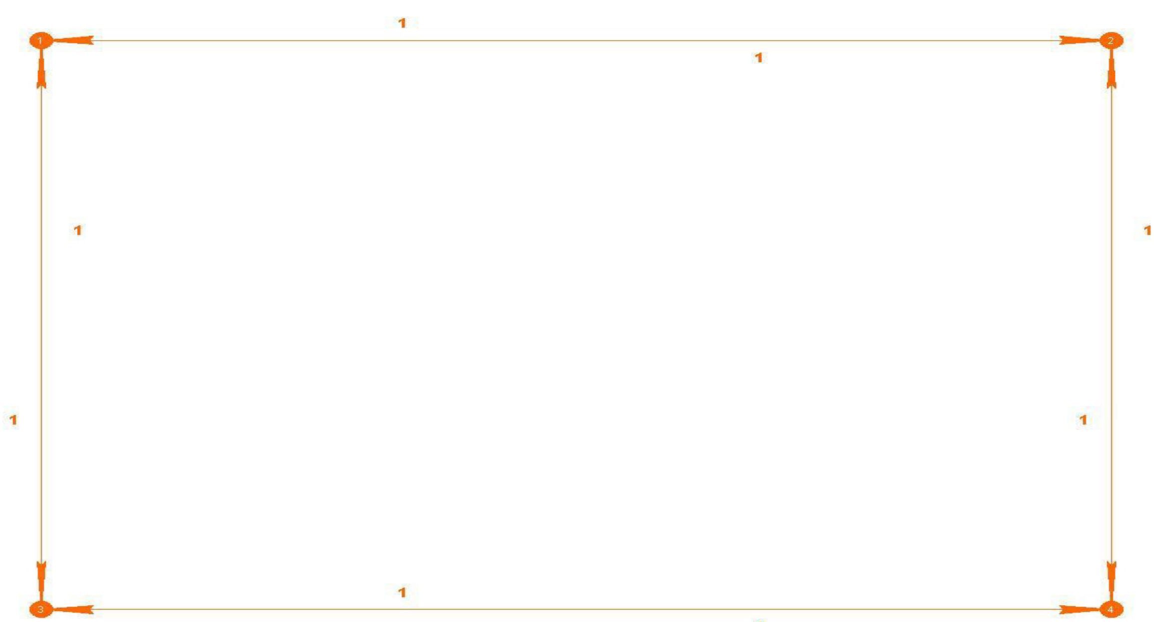

Figure 14 Simple 4 Nodes Topology with Lightpaths

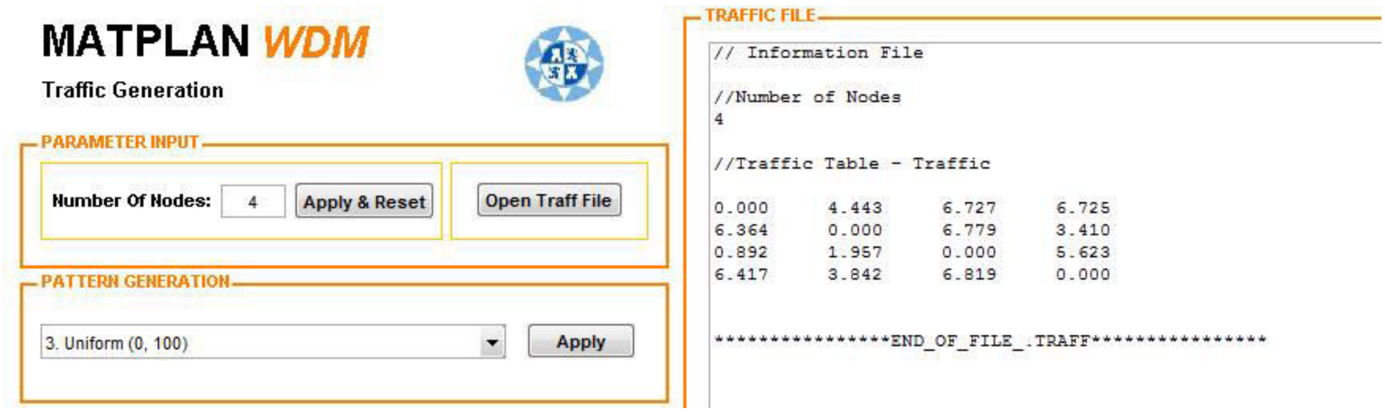

Figure 15 Traffic File for 4 Nodes Network

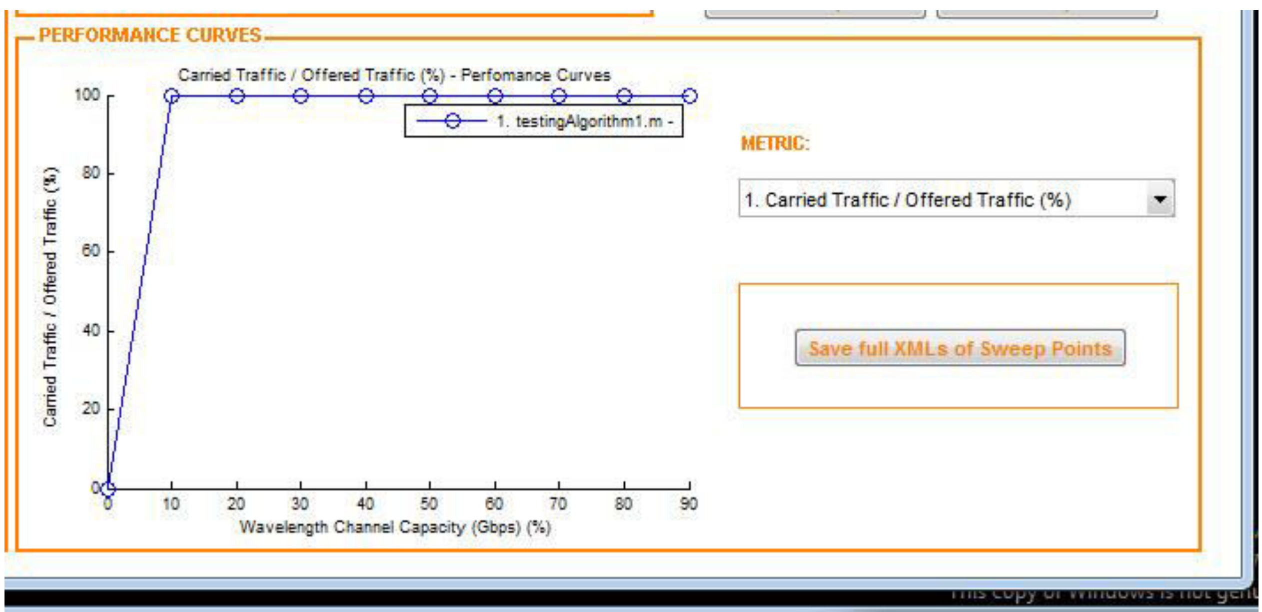

Figure 16 Carried Traffic/Offered Traffic V/s Wavelength Channel Capacity

It can be seen that the channel capacity increase with the increase in offered traffic .It attains a maximum capacity. In this testing topology, it is considered to be ideal conditions which propose that the maximum capacity could be attained.

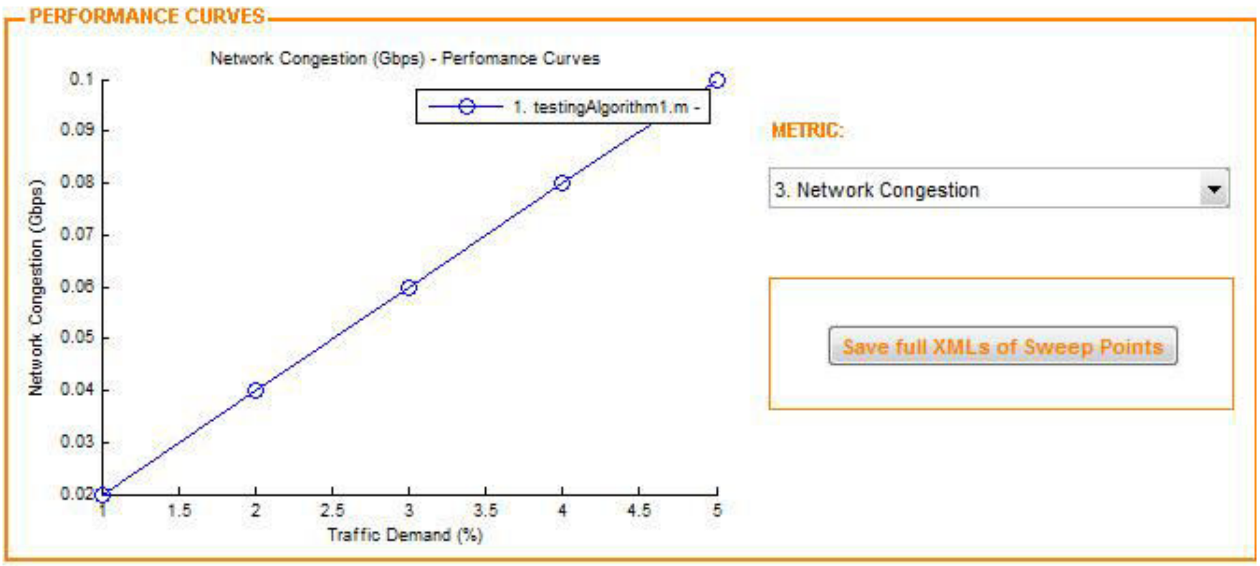

Figure 17 Network Congestion V/s Traffic Demands (%)

The results show that the network congestion increase with increase in traffic demands. It is clear that more traffic leads to more congestion in the network as more users.

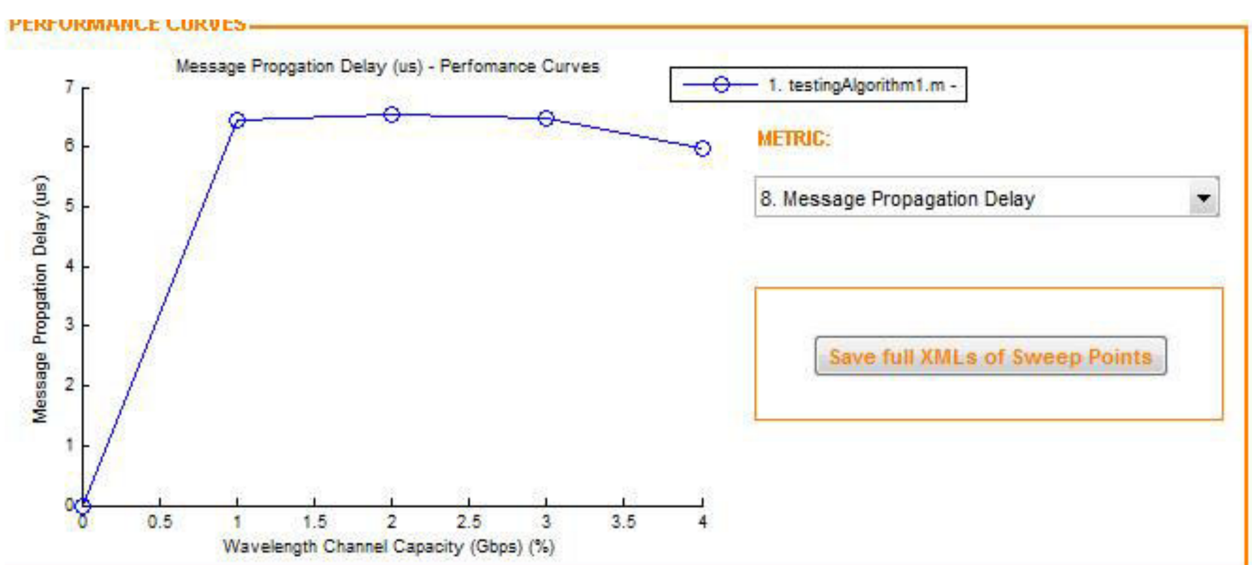

Figure 18 Message Propagation Delay V/s Performance Curves

Simulation results for 6, 9 and 12 nodes topology

The table below shows means values of the delay, network congestion, number of lightpaths and single node traffic for 6, 9 and 12 node topology. The comparison is done among the three topologies for the traffic file generated in MatplanWDM simulator.

Table 6 Comparison of Results for 60 Gbps Network Topology with Traffic Demands

Nodes	Mean Delay(us)	Mean network Congestion in Gbps	Mean Number of light paths	Single Node Traffic offered (%)
6	2.218	54.4	11	84
9	2.144	58	18	68
12	1.816	62.8	25	70.8

The network is desired to have a minimum delay, low network congestion, maximum number of possible lightpaths and high single node traffic and offered traffic. The delay is supposed to increase as the number of nodes increase but from performance analysis table, it is seen that as there is an increase in nodes leading to decreases in delay (2.218us to 1.816us) in the bidirectional network. This happens as there is increase in the number of nodes leading to increase lightpaths. As there are more lightpaths available tending decreases in queuing delay leading to decrease in the overall delay. The network congestion, number of lightpaths, single hop traffic/offered traffic increases with increase in number of nodes in an optical bidirectional network.

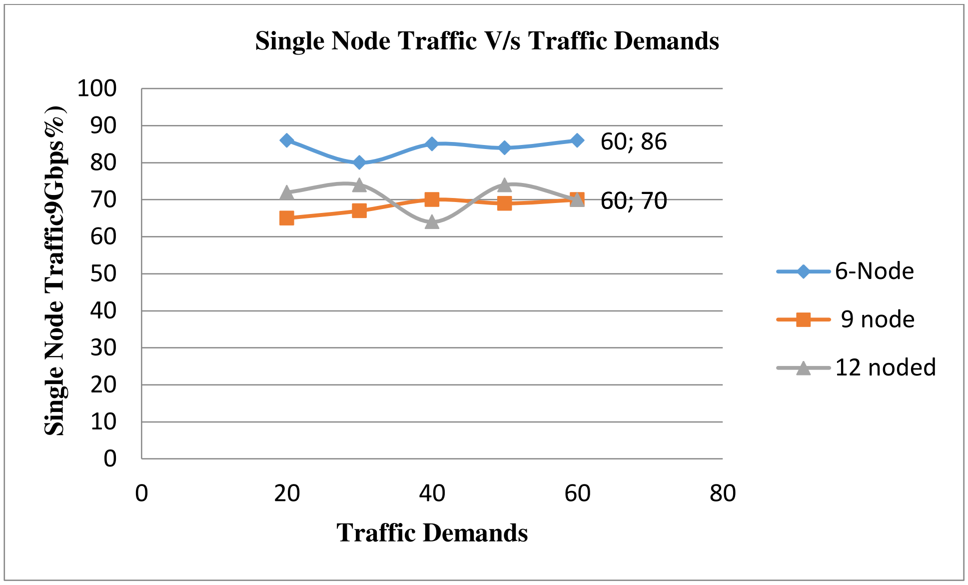

Figure 19 Single Node Traffic V/s Traffic Demands

The above figure shows that there is gradual decrease in the node traffic with increase in traffic demands. The traffic handled by single node decrease as the number of nodes in a network increase.

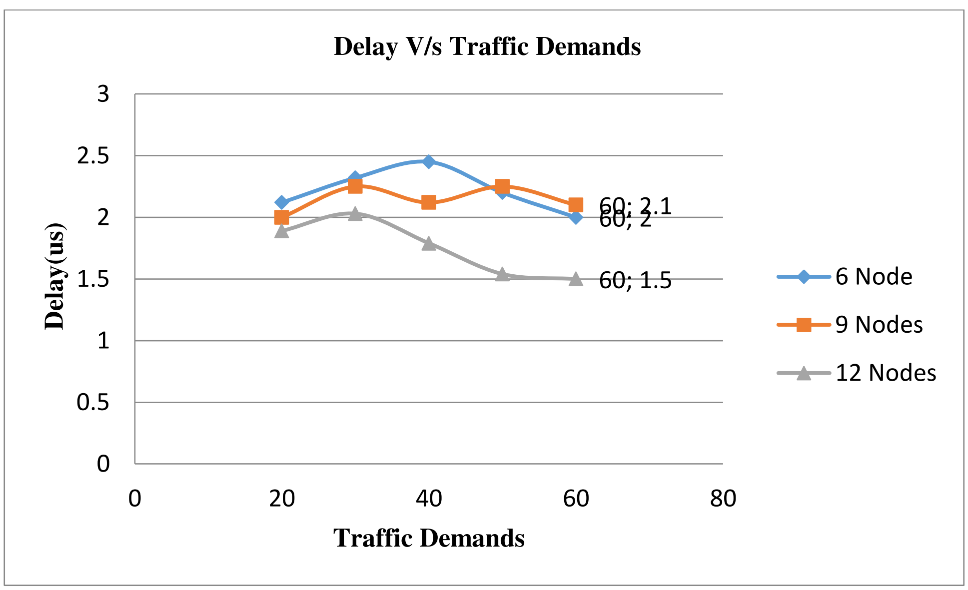

Figure 20 Delay V/s Traffic Demands

The graph shows that the delay decrease with the increase in traffic demands. There is a decrease in delay instead of increase is due to the fact as there is more lightpaths available for communication.

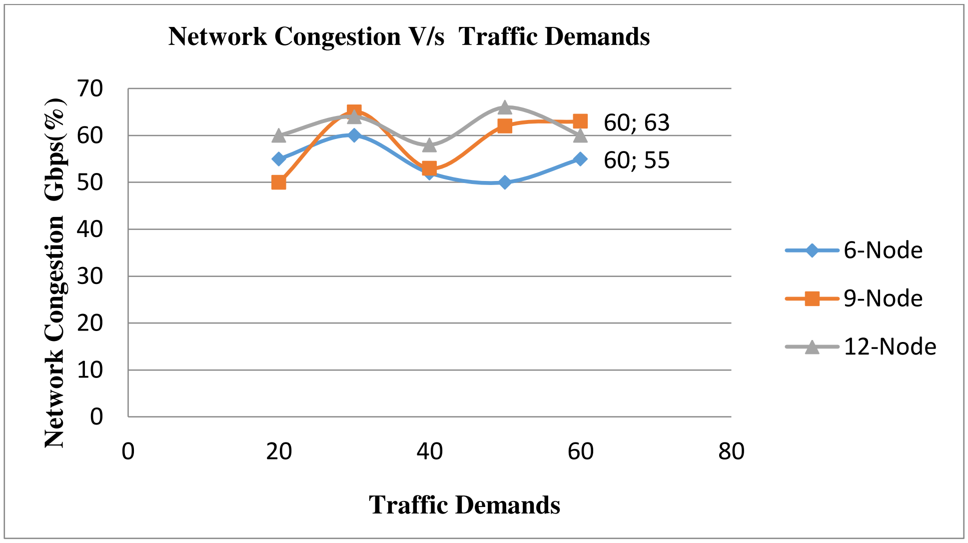

Figure 21 Network Congestion V/s Traffic Demands

The network congestion decrease with increase in the number of nodes as there is more lightpaths available leading to less congestion of traffic through the network.

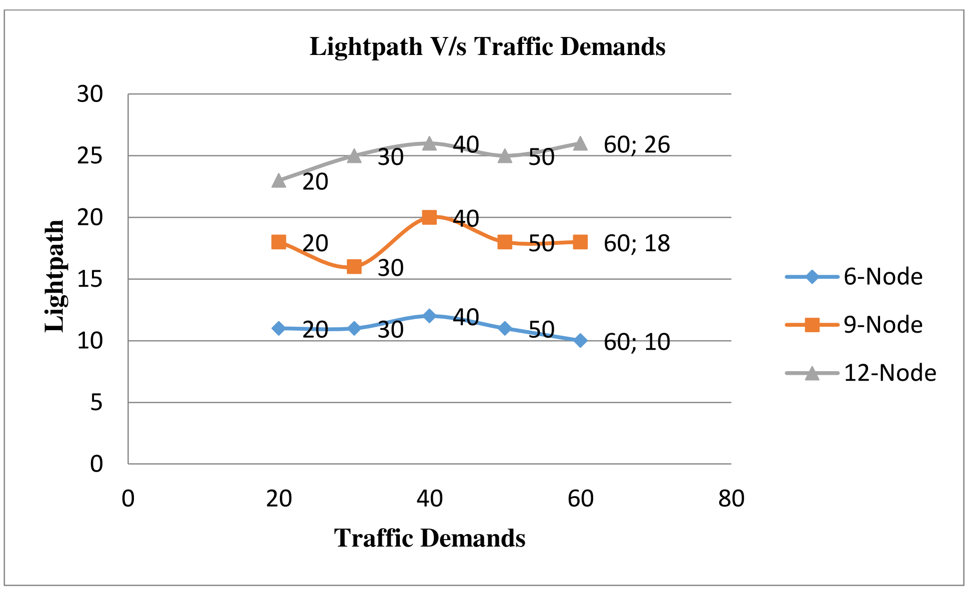

Figure 22 Mean Lightpath V/s Traffic Demands

The lightpaths increase with the increase in the number of nodes in the bidirectional network as there are more paths available for communication.

Table 7Comparison of Results for 60 Gbps Network Topology with Wavelength Utilization

Nodes	**Mean Delay(us)**	**Mean network Congestion in Gbps**	**Mean Number of light paths**	**Single Node Traffic offered (%)**
6	3.32	23	19	85.5
9	3.31	26	24	79.2
12	3.11	27.5	30	70.25

The above table shows the same trends as the trends shown by the 6, 9 and 12 nodes for the traffic parameter. Similarly there is decrease in delay as the number of nodes increases (from3.32 to 3.11).Mean congestion also decreases with increase in the number of nodes as the number of lightpath and network congestion also increase.

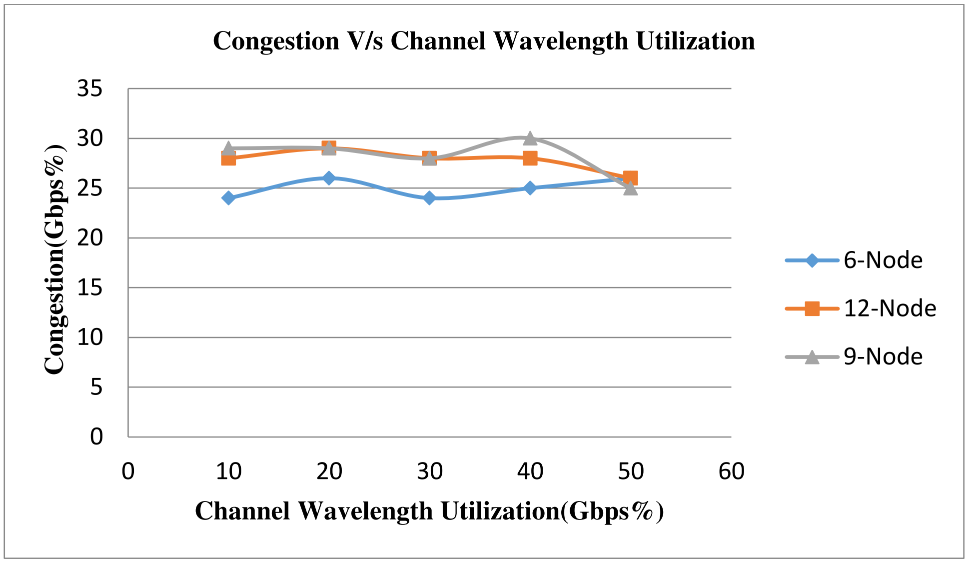

Figure 23 Congestion V/s Channel Wavelength Utilization

The congestion decrease as there is increase in the number of nodes as there is more number of lightpaths available leading to decrease in congestion as the channel wavelength utilization increases.

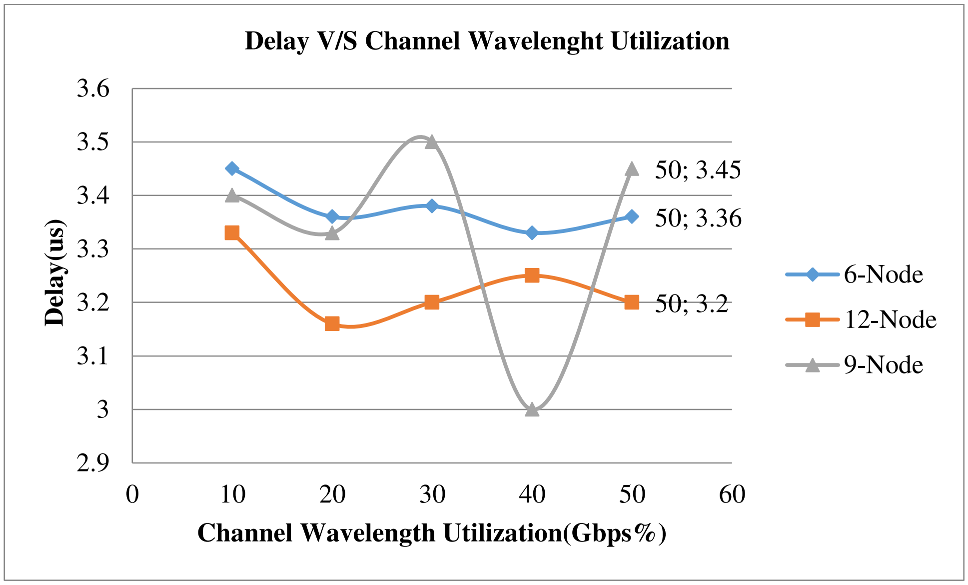

Figure 24 Delay V/s Channel Wavelength Utilization

The delay decreases with increase in the number of nodes as there are more lightpaths available for communication. More lightpaths leads to less delay as there has to be no waiting for communication establishment from source node to destination node.

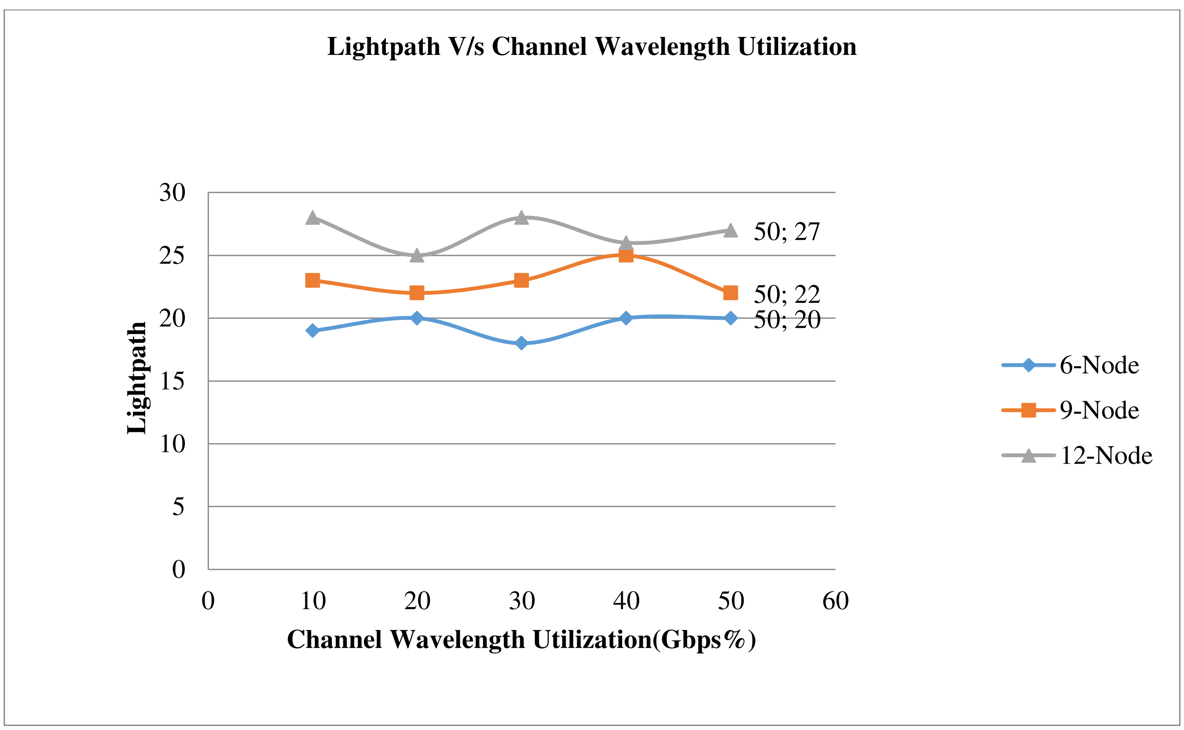

Figure 25 Lightpath V/s Channel Wavelength Utilization

The number of lightpaths increases with increase in the number of nodes. More lightpaths leads to better channel utilization.

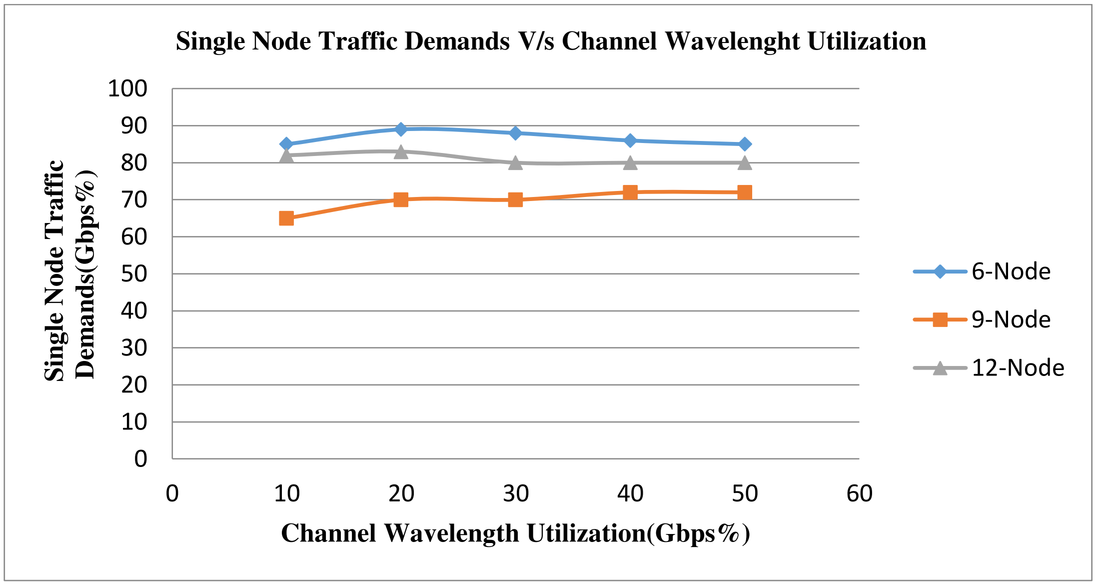

Figure 26 Single Node Traffic Demands V/s Channel Wavelength Utilization

The increase in the number of nodes leads to less number of traffic with single node .It remains constant for 6, 9 and 12 nodes as the channel utilization.

9 Node Topology with link failure

The time delay for the 9 node topology is calculated with and without link failure and the observation are tabled below. The delay is more in case of link failure. The delay tends to slow the network by increasing network congestion.

Table 8 Delay in Case with Link Failure and without Link Failure

Chanel Traffic Demands (Gbps %)	Delay(us)
Link Failure	2.300
Without Link Failure	2.054
Chanel Wavelength Capacity (Gbps %)	
Link Failure	2.675
Without Link Failure	2.454

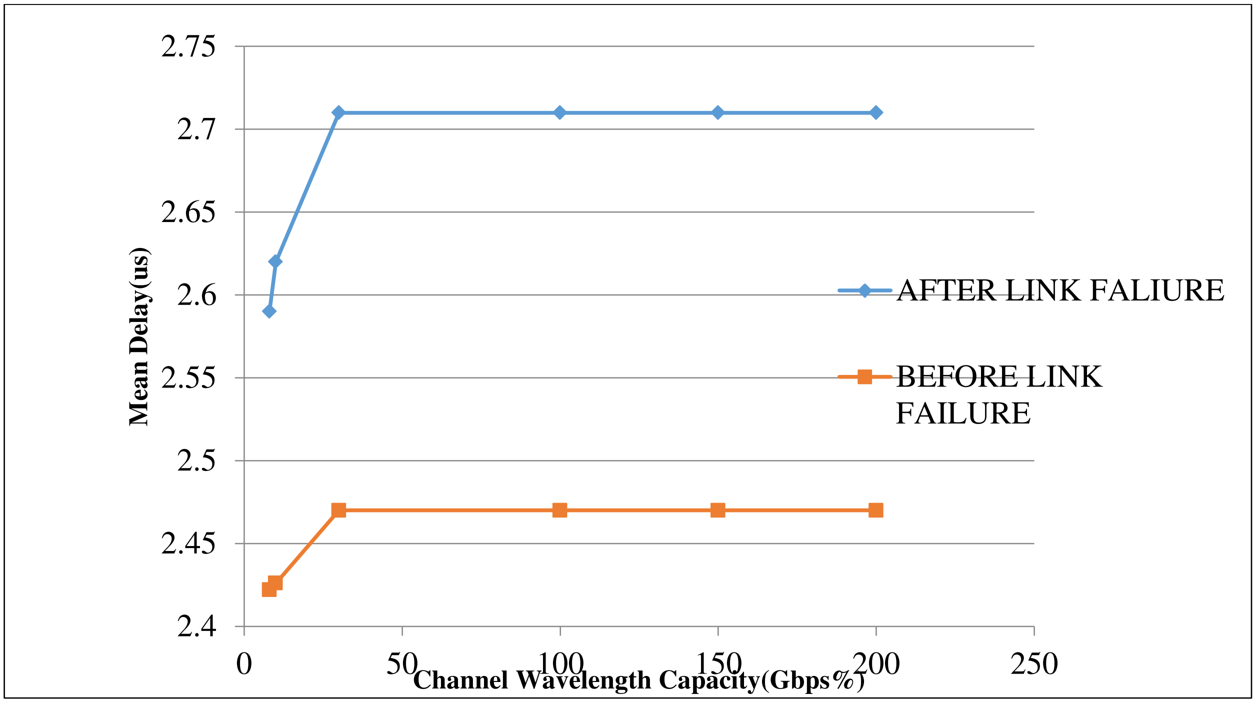

Figure 27 Mean Delay V/s Channel Wavelength Demand

The delay increase in case of link failure as rerouting of traffic is done through another lightpath which is not the best lightpath. The delay remains constant over variation with channel wavelength demand. The demand has very small effect on the delay after a certain value and remains constant.

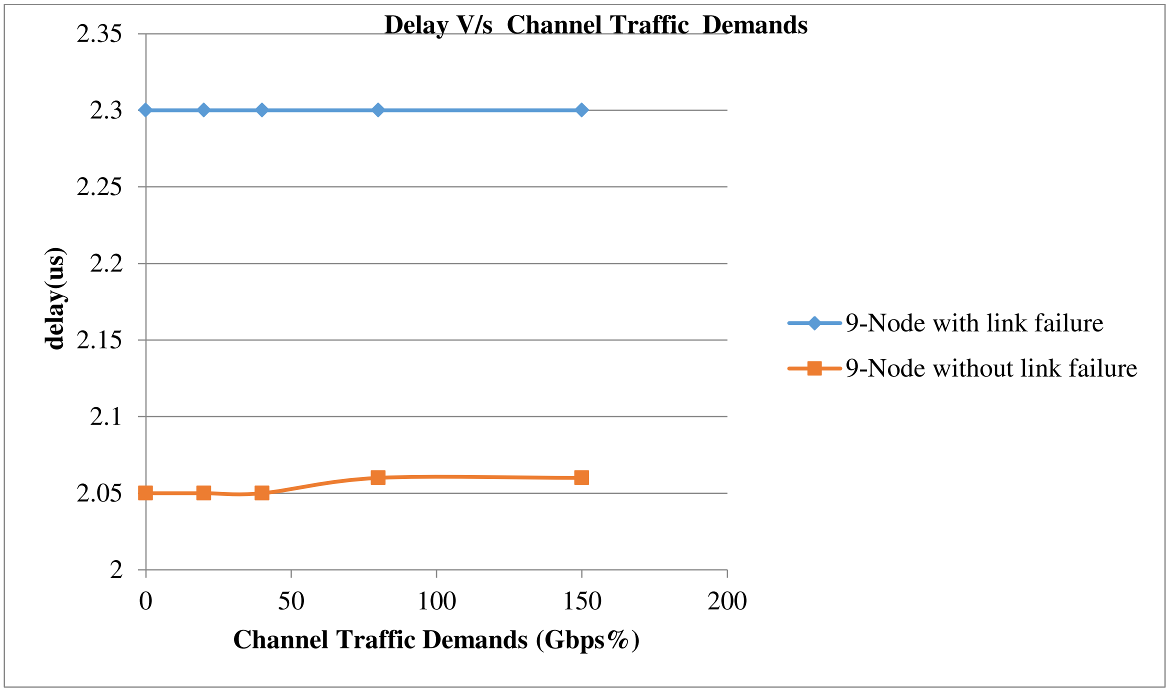

Figure 28 Delay V/s Channel Traffic Demands

CHAPTER 6
CONCLUSION

Conclusion

MatplanWDM is the tool that is used for studying network characteristics and parameters. The tool is designed specifically dedicated for the study for optical network communication. The tool is open source software available and is easily available for WDM network analysis.

After the analysis, it is observed that with the increase in traffic demands there is decrease in delay as there is more lightpaths available. Slightly the mean traffic congestion also increases but the offered traffic from single hop decreases. And when the results are analyzed in respect to channel wavelength utilization follows the same trend.

The best topology found after MatplanWDM simulation among 6, 9 and 12 node topology is 9node topology. The topology has best mean delay, congestion and number of lightpaths for channel wavelength utilization and traffic demands .

Finally the delay is calculated for 9 node topology in case of link failure which is found out to be more than in case without failure.The delay in case have to be minimum so as to maintain good quality of services. Large delay in case of failure might cause the loss of important information.

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