QoS WDM NETWORK ARCHITECTURE

DESIGN AND SIMULATION

Dissertation submitted in fulfilment of the requirements for the Degree of

MASTERS OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION

By

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MAY-2018

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Declaration By The Scholar

I hereby declare that the work reported in the Mtech. dissertation entitled "**QoS WDM ARCHITECTURE DESIGN AND SIMULATION**", submitted at **JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY, WAKNAGHAT, INDIA** is an authentic record of my work carried out under the guidance of **Dr. Rajiv Kumar** and **Dr. Shweta Pandit**. I have not submitted the work elsewhere for any other degree or diploma.

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CERTIFICATE

This is to certify that the thesis entitled "**QoS WDM ARCHITECTURE DESIGN AND SIMULATION**" submitted by **Aman Sharma (162001)** in Dissertation submitted in fulfilment of the requirements for the Degree of "**MASTERS OF TECHNOLOGY**" in "**ELECTRONICS AND COMMUNICATION**", at "**JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY WAKNAGHAT, SOLAN - 173234, INDIA**", is an authentic work carried out by them under our guidance during session 2016-2018.

The matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any degree.

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ACKNOWLEDGEMENT

I would like to express my deep sense of gratitude and indebtedness to **Dr. Rajiv Kumar and Dr. Shweta Pandit**, Department of ECE, my supervisor's for this work, for there guidance, support, motivation and encouragement throughout the completion of this work. Their eagerness to listen to my problems, their educative comments, their advices for the timely and successful completion of this work has been exemplary.

I am grateful to **Prof. Dr. Samir Dev Gupta,** Director and Head of Dept. of ECE for his excellent support during our work. We would also like to thank all the professors & other supporting members of the department of Electronics and Communication Engineering for their generous help in various ways for the completion of this work.

ABSTRACT

A usual infrastructure above which a diversity of services are able be to conveyed is given by an optical network. This optical network is also efficient of delivering bandwidth in a pliable way, transparency within data transference and capacity of gradation is also handled by these networks. It comprises of transmitter and transmission medium in which optical source (LASER, LED) works like a transmitter and optical fiber like transmission medium, accompanied by photo detector and connectors, receiver set. By using a single high capacity channel or wavelength it is difficult to utilize all the BW of an optical fiber because of restriction in electronic processing speed.

Discovering best feasible path within a source and destination node pair and allocating accessible wavelength to this feasible path for data transference is the main difficulty in designing a WDM network. A sequence of measurements called as Performance Matrices are executed to decide the best path. The quality of service (QOS) parameter is decided with the help of performance matrices. In this we have designed 4 unlike network topologies in which each have same capacity but dissimilar number of nodes. For obtaining performance matrices we have simulated all the 4 networks with distinct frameworks, and contrasted these performance matrices for recommending finest network under the present case.

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List of Abbreviations

‘S’ node-Source node.

‘D’ node- Destination node.

TD-Traffic Demand.

GBPS- Giga Bytes Per. Second.

PON-Passive Optical Network.

WDM-Wavelength Division Multiplexing.

QoS-Quality of Service.

WCC-Wavelength Channel Capacity.

1. INTRODUCTION

In this modern world we all are moving to the era of digital using communication. In this time of life span the INTERNET is one of the most essential part of our lives. Due to the increase in clients, we need high bandwidth and high speed network to deliver good quality of data so as to increase our performance. Currently the techniques that are used support various distributed applications and work technologies. The internet facilities are nowadays themselves becoming a problem considering the aspects of reliability and security. The rapid growth of these services such as video sharing, online transactions, high definition video demands and network computing, the transport networks need to provide high ultra-capacity to support the tremendous internet traffic.

1.1. Network Topology:

When various elements of communication network are arranged to form a larger network it is called network topology. A variety of basis network topologies:

- Bus topology.
- Ring topology.
- Star topology.
- Mesh topology.

Bus - having a backbone network:

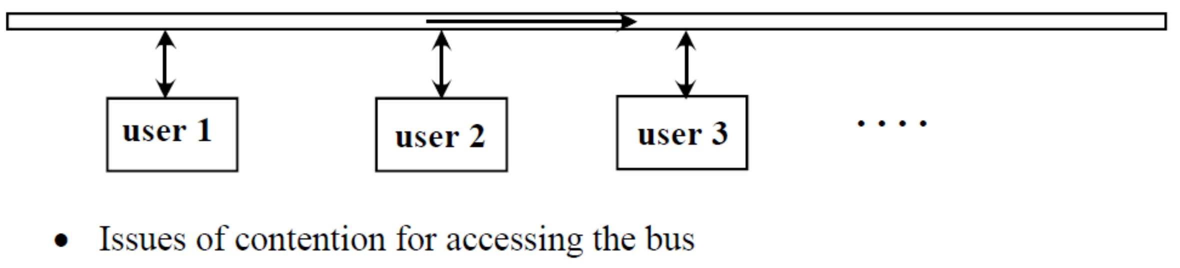


Fig.1.1. Bus Topology

Ring-

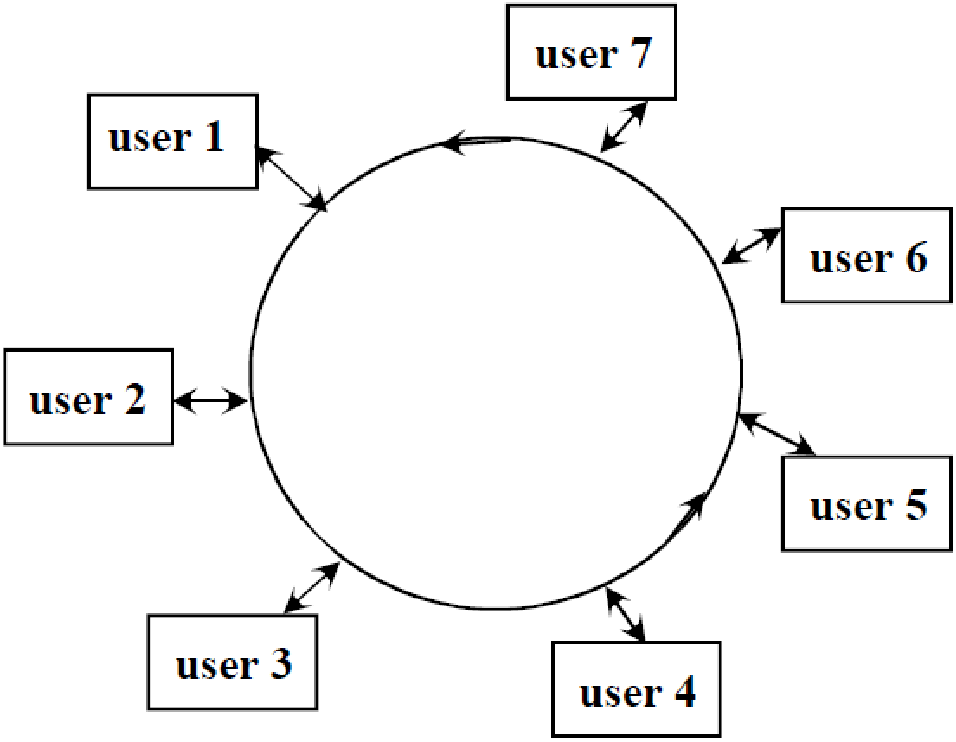


Fig.1.2. Ring Topology

Star-

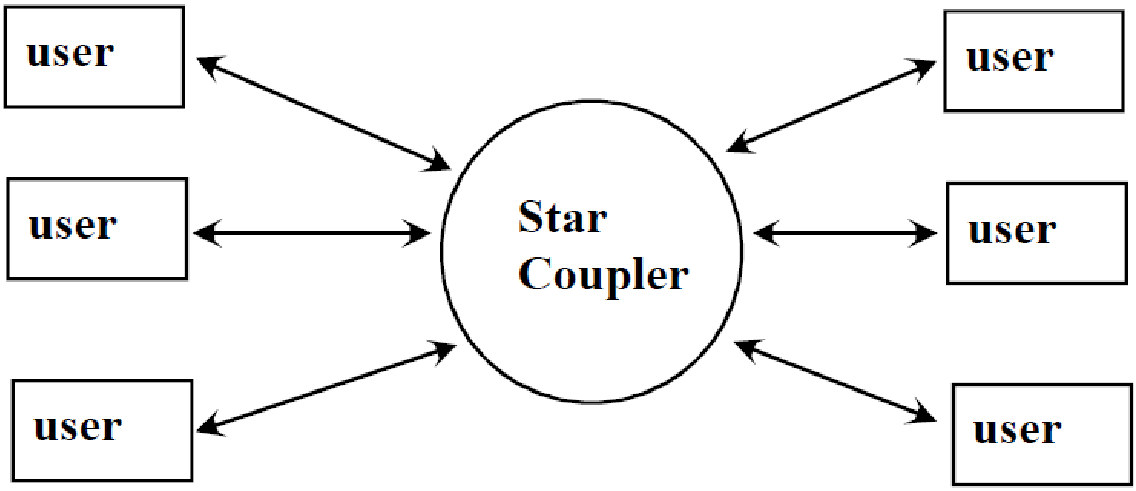


Fig. 1.3 Star Topology

Mesh-

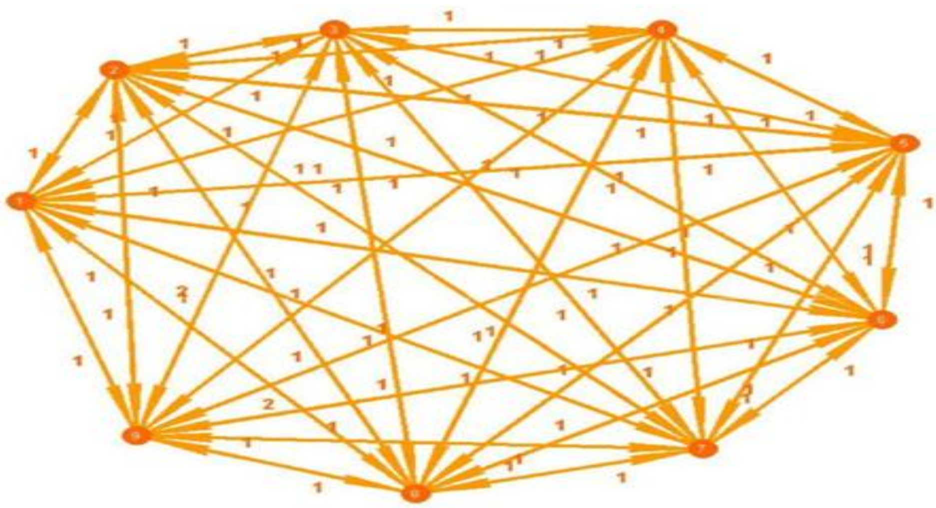
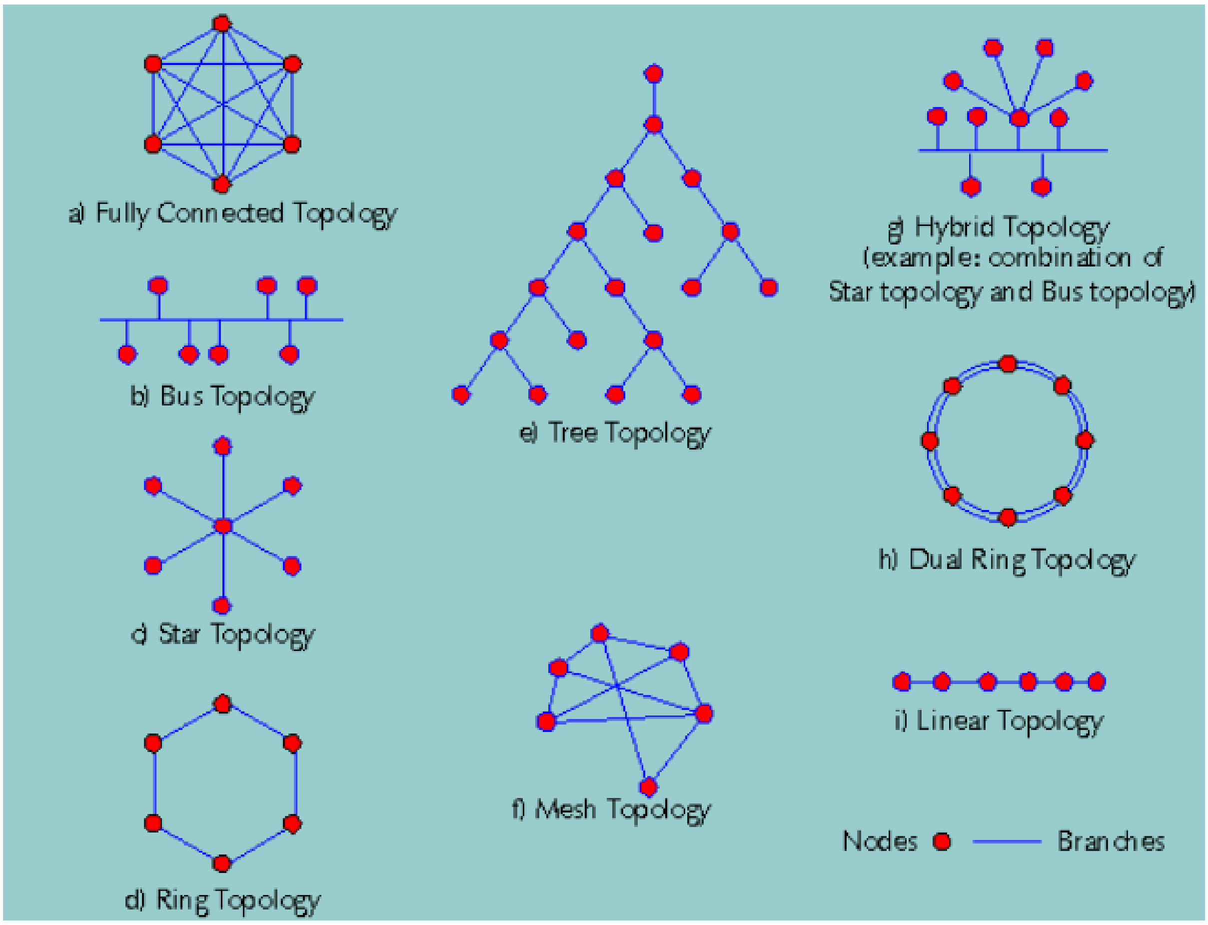


Fig. 1.4. Mesh Topology

Fig. 1.5.Different types of topologies are shown below:



1.2.Optical network terminology:

SONET/SDH- Synchronous Optical Network later called Synchronous Digital Hierarchy- This standard defines a synchronous frame structure for transmitting time division multiplexed signals.

OC-xx Optical Carrier; STM-xx Synchronous Transfer Module – each bit rate is a multiple of the lowest level OC-1 or STM-1 bit rate.

Fiber optical communication network is one of the major communication system that is used in the modern lifespan, which meets with the above challenges. This utilizes different types of multiplexing techniques that are used to maintain good quality of service without traffic introduced, less complicated instruments with good utilization of available resources. Fiber optical networking, with its almost unlimited bandwidth, is the only technology that can support such demand for bandwidth.

A single-mode fiber as we know has a potential bandwidth of nearly 50 Tb/s, which is nearly four orders of magnitude higher than as electronic data rates of a few gigabits per second (Gb/s), every effort should be made to tap into this huge opto-electronic bandwidth mismatch. Realizing that the maximum rate at which an end-user, which can be a workstation or a gateway that interfaces with lower-speed sub-networks can access the network is limited by electronic speed (to a few Gb/s), the key in designing optical communication networks in order to exploit the optical fiber’s huge bandwidth is to introduce con-currency among multiple user transmissions into the network architectures and protocols. In an optical communication network, this concurrency may be provided according these accepts, wavelength or frequency [wavelength-division multiplexing (WDM)], time slots [time-division multiplexing (TDM)], or wave shape [spread spectrum, code-division multiplexing (CDM)].

1.3. Layout of fiber optic network

Long Haul Network: Signal transmission link among far-away areas like countries, country and continents are provided . (BUS)

Wide Area Network: Country's important part is connected (hundreds of kilo-meters). (STAR)

Metropolitan Area Network: Cities outline region users are connected with users of city. (RING)

Local Area Network: Minute no of customers are connected in few kilo-meters. (RING)

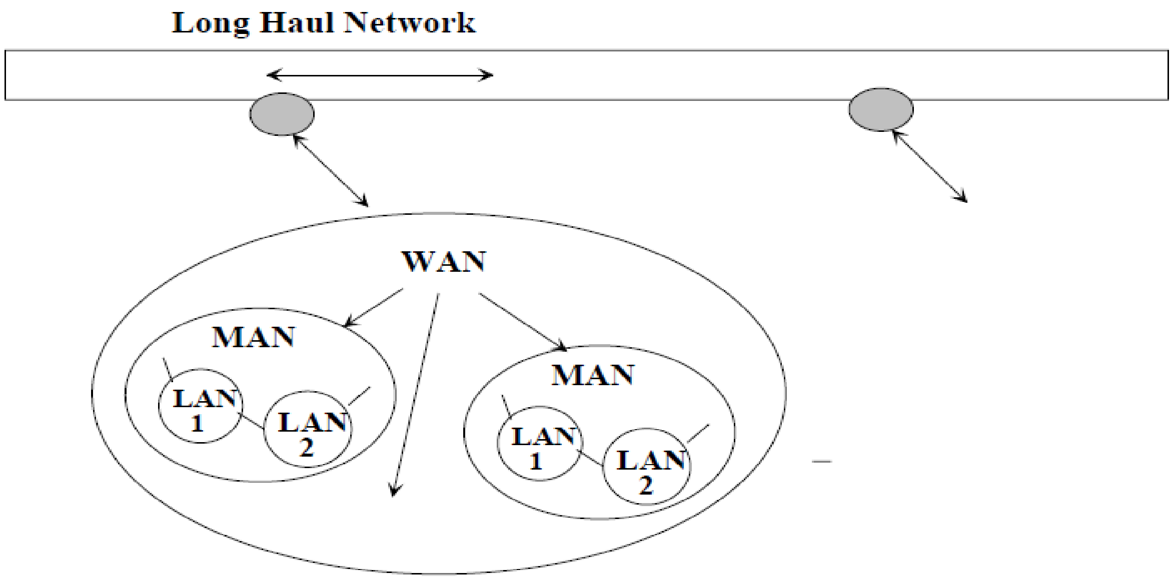


Fig. 1.6. Local Area Network-Connection

Optical TDM and CDM are one of the prior techniques used today. The emerging best known technique for the next generation of network is the WDM technique. Wavelength division multiplexing is a technique by which we divide the tremendous bandwidth available of an optical fiber into many non overlapping wavelength channels. These optical networks are prone to component failures at transmitter level, network level and receiver level. The failures occurring at transmitter and receiver level are due to trans-connects and transponders and these are rectified easily by simply replacing these components. In WDM the network failures are difficult to locate and its takes time to resolve them. The failures in the network level are mainly due to fiber cuts causing link failures. Usually fiber cuts occur at the rate 4.83 cuts per 1000 sheath miles per year and it takes usually 10-12 hours to fix fiber failure. Due to different connection linked to each other; failure at a single link causes multiple connection failures. Therefore fault-tolerance carries great role in WDM networks.

These 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, one best in its services. In this techniques the primary and backup paths are computed and resources are reserved for these paths in case of failures before the connection are established. This method of protection avoids long delay. The protection techniques guarantee that a path being restored as they provide an alternate path for failure occurring situations, totally dedicated to tackle such situations.

1.4.WAVELENGTH DIVISION MULTIPLEXING(WDM):

In optical communication, wavelength division multiplexing (WDM) is a technology which carries a number of optical carrier signals on a single fibre by using different wavelengths of laser light. This allows bidirectional communication over one standard fibre with in increased capacity. As optical network supports huge bandwidth; WDM network splits this into a number of small bandwidths optical channels. It allows multiple data stream to be transferred along a same fibre 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 fibre and demultiplexers at the receiver to split them apart. Generally the transmitter consists of a laser and modulator. The light source generates an optical carrier signal at either fixed or a tuneable wavelength. The receiver consists of photodiode detector which converts an optical signal to electrical signal [1]. This new technology allows engineers to increase the capacity of network without laying more fibre. It has more security compared to other types of communication from tapping and also immune to crosstalk [2].

The most gifted concepts for high capacity communication systems is wavelength division multiplexing (WDM).

- Each communication channel is billed to a dissimilar frequency and multiplexed onto a single fiber. At the end wavelengths are spatially removed to different receiver locations.

- In this configuration the elevated carrier bandwidth is exploited to a greater extent to transmit several optical signals throughout a single optical fiber.

- In this configuration the elevated carrier bandwidth is exploited to a greater extent to transmit multiple optical signals throughout a single optical fiber.

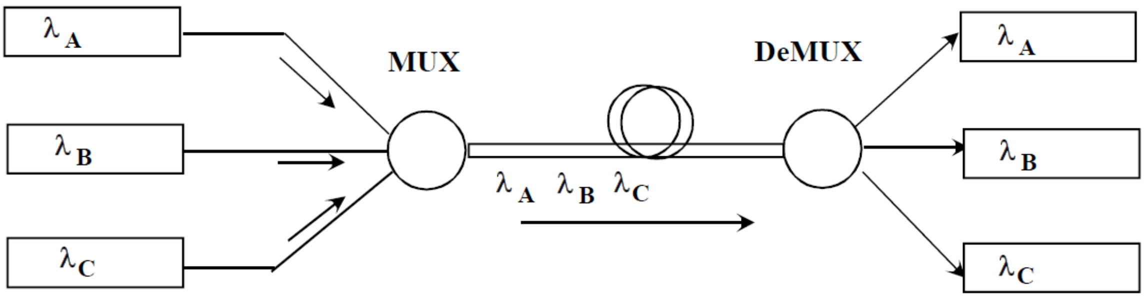


Fig.1.7. Wavelength Division Multiplexing

1.5. WAVELENGHT DIVISION MULTIPLEXING SYSTEM

1) The crucial point-point communication is revealed below:

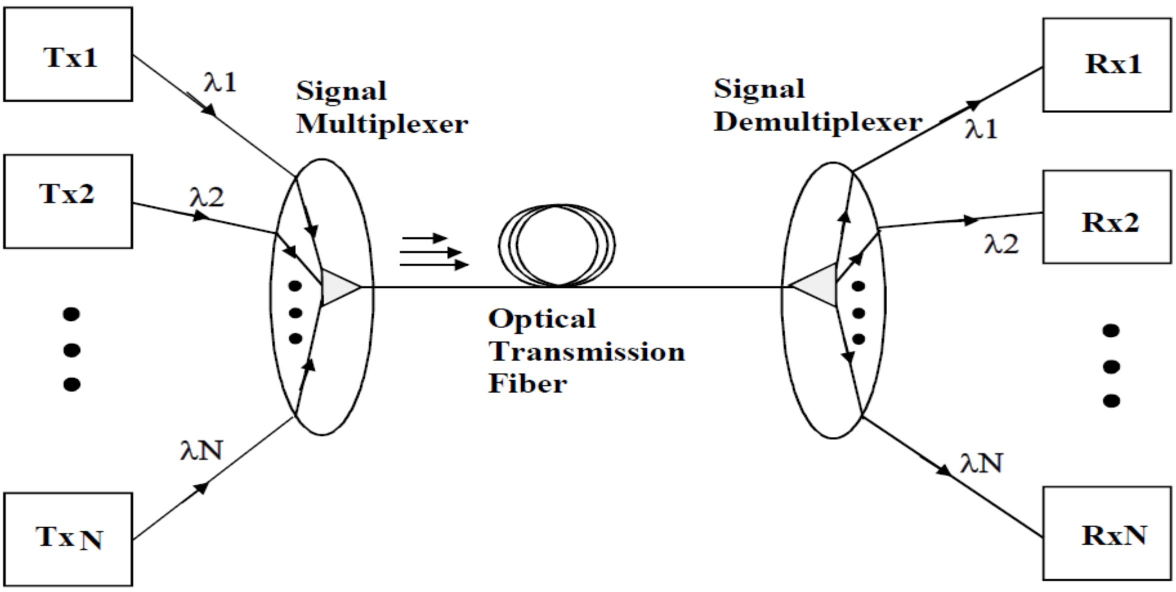


Fig.1.8. WDM- Point To Point Comm.

- The bit rate is partial-100GBPS to dispersion in single frequency and so that is under the means of optical carrier frequency.
- This WDM increases the pace of point to point communication.

2) A new form of transmitting network is shown below, that indicates the channel using star coupler.

A star coupler is used to mix signals with different wavelength and tuneable wavelength filters.

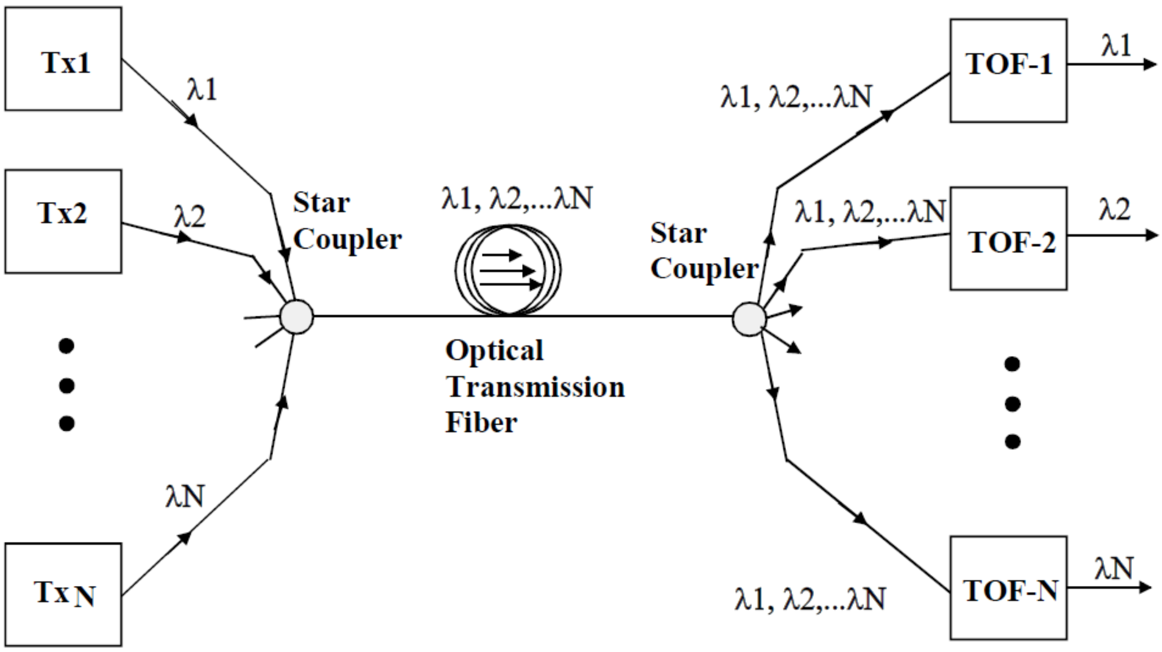
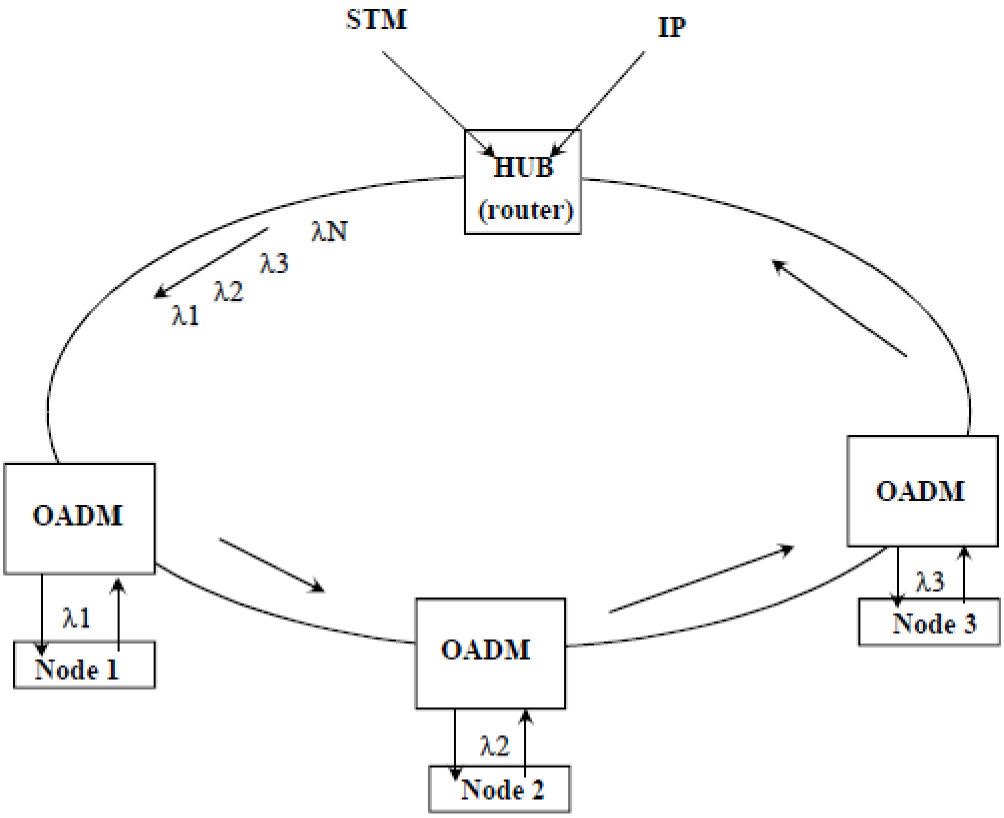


Fig.1.9. WDM- Using Star Coupler

From some years now we have been using the WDM (densed) systems and they are been researched on. The wavelength division is of order 0.3-0.8nm.

DWDM Ring Topology:



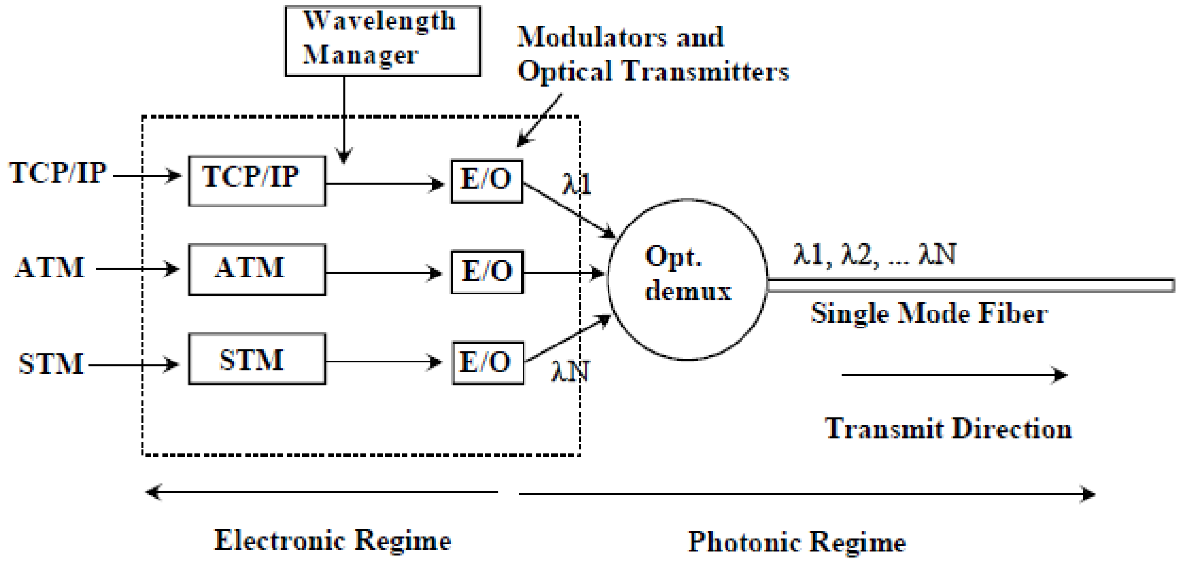
STM – Synchronous Transport Module

IP – Internet Protocol

OADM – Optical ADD-Drop Multiplexers

Fig.1.10.DWDM Ring Topology

Fig.1.11. Routing the information over the network is controlled by the HUB(act as controller).



TCP/IP – Transmission control protocol/internet protocol

ATM – asynchronous transfer mode

STM – synchronous transfer mode

1.6. Development components for DWDM:

From the previous overview a number of critical components are required for the realization of DWDM communication systems. These include:

- Sources with stable narrow band emission wavelengths.
- Tunable optical filters.
- ADD-Drop Filters.
- Broadband Optical Amplifiers.
- Optical Cross Connects.

In addition there are a number of important support components that also must be developed. These include:

- Optical Directional Couplers
- Wavelength Filters

- Optical isolators
- Optical Equalizers
- Polarizer's, rotators, circulators
- Wavelength Interleaver's

System and component growth is focused on act inside two low loss wavelength bands during silica fibers. These include the C- and L- bands.

1) S-Band: (1480-1520 nm)
2) C-Band: (1521-1560 nm)
3) L-Band: (1561-1620 nm)

1.7. DWDM Optical Technologies:

- Thin Film Filters.
- Micro Electro Mechanical Systems – switches and cross connects.
- Passive Optical Elements (POE): waveguides, arrayed waveguide gratings AWGs, star couplers, grating devices.
- Acousto-Optic devices – Bragg cells, tunable optical filters.
- Micro-resonator structures – resonant grating filters, ring filters.
- Functional Fiber Components – Bragg gratings and Doped Fibers.
- High speed optical modulators – Mach Zehnder interferometers.
- Liquid Crystal Devices.
- Temperature Tunable Integrated Waveguide Devices.

1.8. Different types WDM network

The optical network has huge bandwidth and 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 fibre limitation factor like imperfection and refractive index fluctuation. So 1300nm (0.32dB/km)-1550nm (0.2dB/km) window with low attenuation is generally used.

According to different wavelength pattern there are 3 existing types as:-

- WDM (Wavelength Channel Multiplexing)
- CWDM (Coarse Wavelength Division Multiplexing)
- DWDM (Dense Wavelength Division Multiplexing)

TABEL 1.1. Parameters Of Various WDM

Parameters	WDM	CWDM	DWDM
Channel Spacing	1310nm & 1550nm	Large,1.6nm-25nm	Small,1.6nm or less
No of base bands used	C(1521-1560 nm)	S(1480-1520 nm)C(1521-1560 nm),L(1561-1620 nm)	C(1521-1560 nm),L(1561-1620 nm)
Cost per Channel	Low	Low	High
No of Channels Delivered	2	17-18 most	hundreds of channel possible
Best application	PON	Short haul, Metro	Long Haul

1.9. Benefits of WDM

Wavelength Channel Multiplexing (WDM) is important technology used in today's telecommunication systems. It has better features than other types of communication with client satisfaction. It has several benefits that make famous among clients such as:

1.9.1. Capacity Upgrade

Communication using optical fibre provides very large bandwidth. Here the carrier for the data stream is light. Generally a single light beam is used as the carries. But in WDM, lights having different wavelengths are multiplexed into a single optical fibre. So in the same fibre now more data is transmitted. This increases the capacity of the network considerably.

1.9.2. Transparency

WDM networks supports data to be transmitted at different bit rates. It also supports a number of protocols. So there is not much constraint in how we want to send the data. So it can be used for various very high speed data transmission applications.

1.9.3. Wavelength Reuse

WDM networks allows for wavelength routing. So in different fibre links the same wavelength can be used again and again. This allows for wavelength reuse which in turn helps in increasing capacity [5].

1.9.4. Scalability

WDM networks are also very flexible in nature. As per requirement we can make changes to the network. Extra processing units can be added to both transmitter and receiver ends. By this infrastructure can redevelop to serve more number of people.

1.9.5. Reliability

WDM networks are extremely reliable and secure. Here chance of trapping the data and crosstalk is very low. It also can recover from network failure in a very efficient manner. There is provision for rerouting a path between a source-destination node pair. So in case of link failure we will not lose any data [19].

1.10. QoS in WDM Network

Quality of Service (QoS) parameters refers to certain parameters which are used to determine performance of a WDM network. To determine QoS first all the possible light paths are found out. Then a number of measurements are performed on these light paths using simulation software, whose results are called performance matrices. From these performance matrices QoS is determined. Few QoS parameters are Delay, Network Congestion, and Single Hop Traffic/Offered Traffic [7]. For better performance, delay should be low, Network Congestion should be less and Single Hop Traffic/Offered Traffic should be more. So while designing the network, these conditions should be taken into account.

2. LITERATURE REVIEW

The topology is creatively valuable in helping for the high communication through the system. In the papers [1][2][3][4] authors 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 entire interest in the system on 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 an QoS issue.

In the fallowing review [5] [6], 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 also talked about. Broad recreations on a specimen organize topology have demonstrated that as opposed to settled packaging 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 packaging method is much better than way insurance strategy. By permitting dynamism in packaging 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.

In the fallowing [7] [8] [9] we talk about the routing and wavelength assignment (RWA) issue in optical systems utilizing WDM innovation. The two variations of this issue are considered as static RWA, whereby the movement for necessary conditions are known in beforehand and other is dynamic RWA in which association demands touches base in 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 [10].

In fallowing paper [12] [13] [14] 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 research [15], 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 QORP levels. The algorithm proposed considered for uni-cast flow under pre-defined QORP protocols.

The research [16], 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 [17] the author 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 [18] [19] [20] [21].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. In [22] we examines how the information is utilized as a part of for stimulation also for the instructive reason. [23]This gives a review of the MatPlanWDM device and territory where it can be beneficial. It gives the outline of the reproduction apparatus. In [24] NS3 re-enactment 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.

The research [25] talks about various sorts of difficulties that are confronted in a WDM system and channels working. The author 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.

3. Problem Statement & Network Design

In WDM technology to be deployed we need a physical topology. After topology design we need routing and wavelength assignment to make it fully functional. Here we have taken three problem statements as:

- To design 60 Gbps capacity topology and compare performance matrices.
- To design 100 Gbps capacity topology and compare the performance matrices with 60 Gbps topology.
- To design a network to study the case of link failure and check the performance matrices.

3.1 Existing Wavelength Assignment Algorithms

There are different types of wavelength assignment algorithms are used in WDM network. It is important task after designing a physical topology upon which whole network quality depends. So the existing wavelength algorithms are follows as:

3.1.1. Random Wavelength Assignment

In this algorithm, first all possible routes between a source-destination node pair is determined. Then all the free wavelengths (which are currently not being used) are found out. Then randomly a wavelength is assigned for data transmission to take place[16].

3.1.2. First-fit Wavelength Assignment

Here, each and every wavelength is numbered. When a connection request is made, the wavelength which is having the lowest assigned number is selected from the available wavelength set.

3.1.3. Most-used Wavelength Assignment

The wavelength that is used by the highest number of links in the network is the most used wavelength. The most used wavelength is selected by the most used algorithm from the available wavelength on the path.

3.2 Routing and Wavelength Assignment

A connection needs to be established in the optical layer in order to carry the information between the clients of the network. The optical connection that is maintained between a source node, s and destination node, d is known as an optical path or light path. The problem of finding a route for a light path and assigning a wavelength to the light path is referred to as the routing and wavelength assignment problem (RWA) [11]. The problem of RWA is divided into two parts:-

- Routing
- Wavelength Assignment

Static Light path Establishment (SLE): The idea is to reduce the number of wavelengths needed to accommodate the given connection set.

Dynamic Light path Establishment (DLE): The idea is to reduce the blocking probability.

3.3. Constraints

The two fundamental constraints to be followed for the purpose of wavelength assignment are as follows:

3.3.1. Wavelength Continuity Constraint

Along the path from the source to destination nodes, a light path must use the same wavelength on all the links.

3.3.2. Distinct Wavelength Constraint

Within a link all the light paths must be assigned different wavelengths

3.4. Performance Analysis

The objective is to determine all possible paths from source to destination in WDM optical network. If there is a connection request from a source node to a destination node, first all possible paths are determined, then a series of measurements are performed using a simulation tool. The results are called performance matrices. Then comparing these performance matrices best possible paths is determined.

Here we have designed four different network topologies having different number of nodes, but each having equal capacity. Then we have simulated them with different scenarios to obtain the performance matrices. Then we have compared those to suggest which network is best for the present case.

3.5. Network Design

We have designed four different mesh network topologies (fully connected) having 6, 9, 12 and15 nodes. Also we have further designed two 9-nodes networks to analyse the link failure case. We have designed an .xml code to design each network. The .xml contains the list of nodes and fibre links in the network. Per node information is composed by the X and Y coordinates of the node measured in kilometres over a Euclidean plane, number of E/O transmitters, O/E receivers, node population, node type (or node level), number of nodes and the name of each node. Per link information is the maximum number of wavelengths per link and the number of optical fibres.

BIDIRECTIONAL MESH TOPOPLOGY, NODE-6

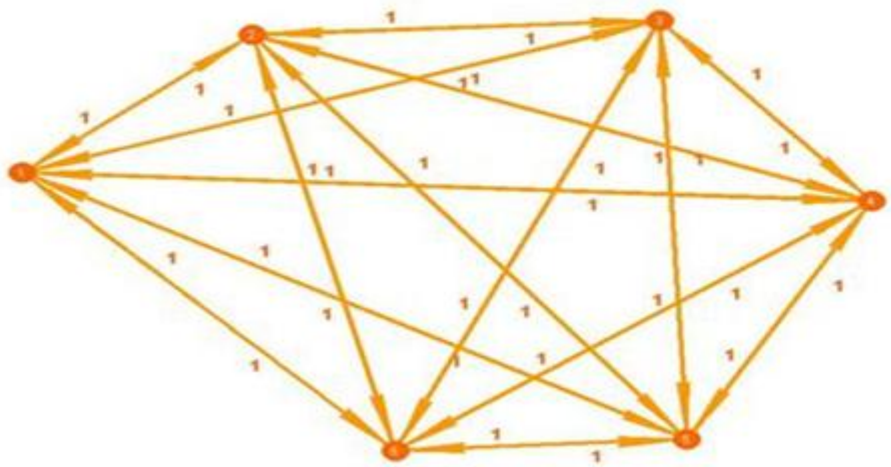


Fig.3.1. Mesh Topology, Node-6

Table 3.1.Materialin order, Node-6 Network

Number Of Nodes	6
Total Number Of Links	30
Total offered capacity	60Gbps
Number of available wavelengths	40
Type of Connection	Bidirectional

MESH BIDIRECTIONAL TOPOLOGY, NODE-9:

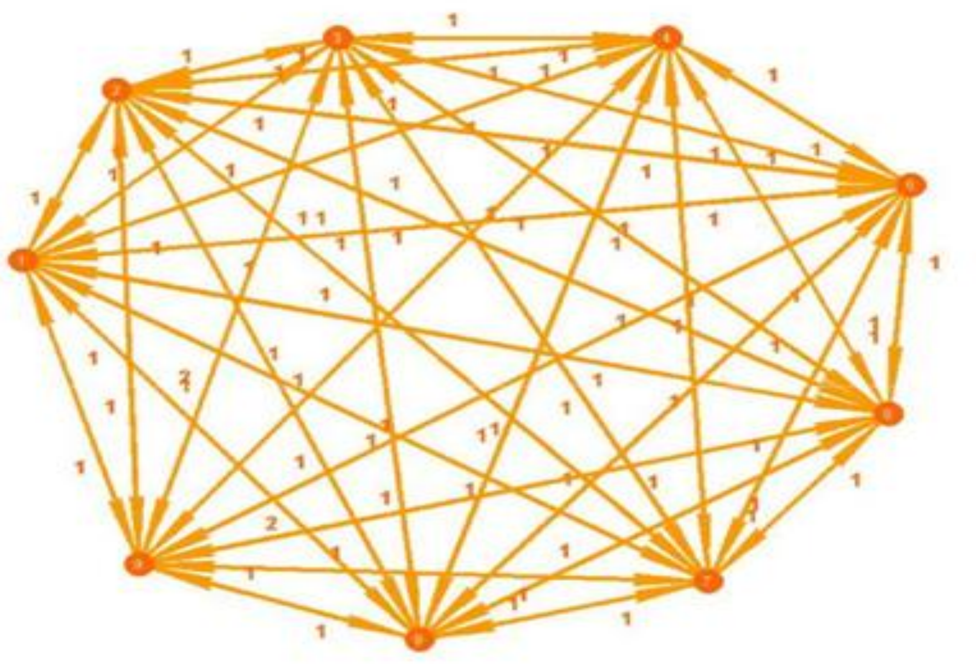


Fig.3.2.Mesh Topology, Node-9

Table.3.2.Material in order, Node-9 Network

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

NODE-12 MESHBIDIRECTIONAL TOPOLOGY:

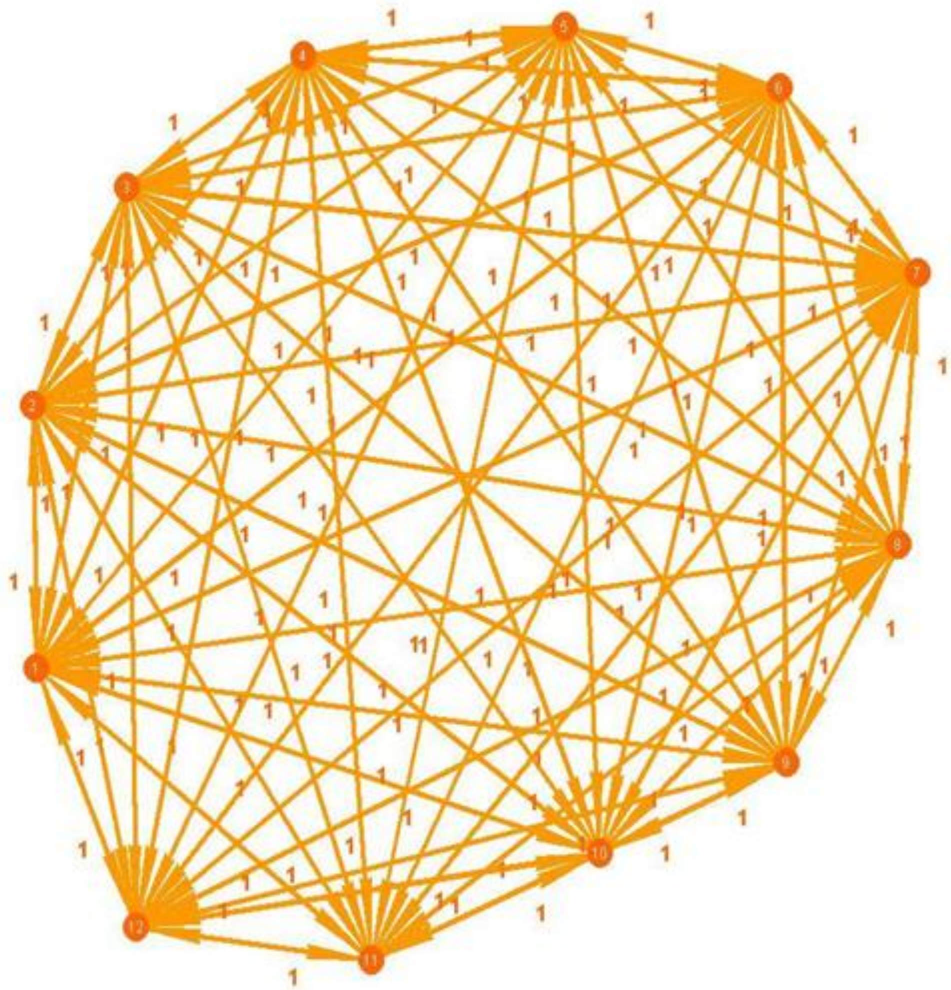


Fig.3.3.Mesh Topology, Node-12

Table 3.3.Material in order, Node-12 Network

Number Of Nodes	12
Total Number Of Links	132
Total offered capacity	60Gbps
Number of available wavelengths	40
Type of Connection	Bidirectional

15- NODE BIDIRECTIONAL FULLY CONNECTED MESH TOPOLOGY

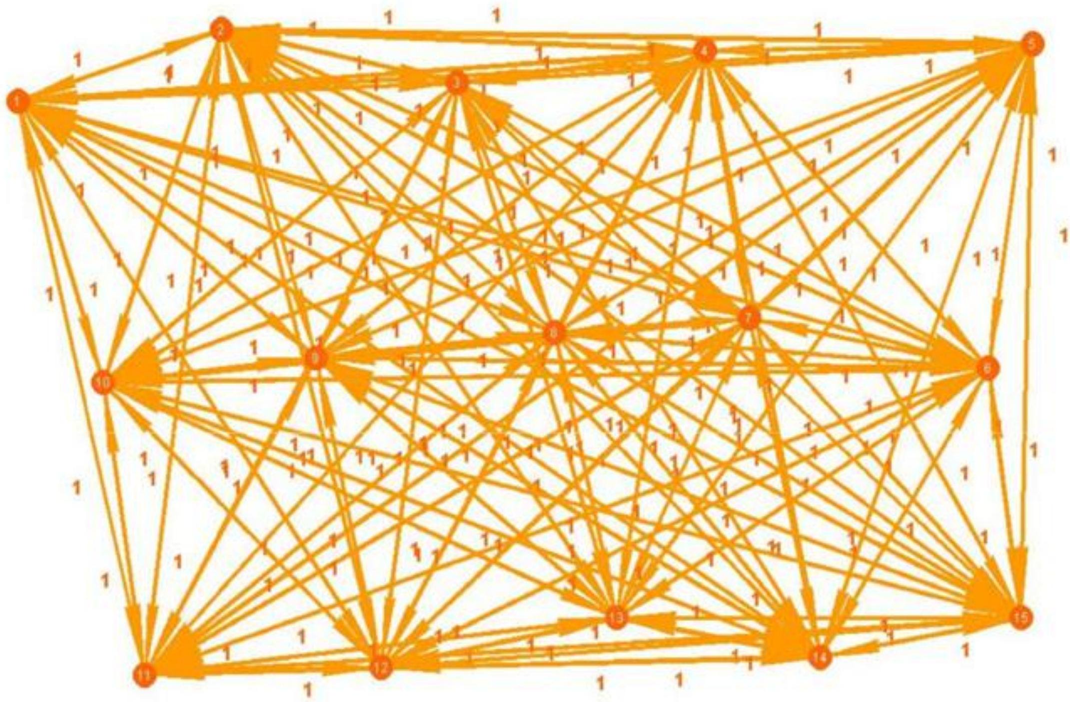


Fig.3.4.Mesh Topology, Node-15

Table 3.4.Material in order, Node-15 Network

Number Of Nodes	15
Total Number Of Links	210
Total offered capacity	60Gbps
Number of available wavelengths	40
Type of Connection	Bidirectional

Cases Of Link Failures:

- **9-Node Topology Used To Study Link Failure Case**

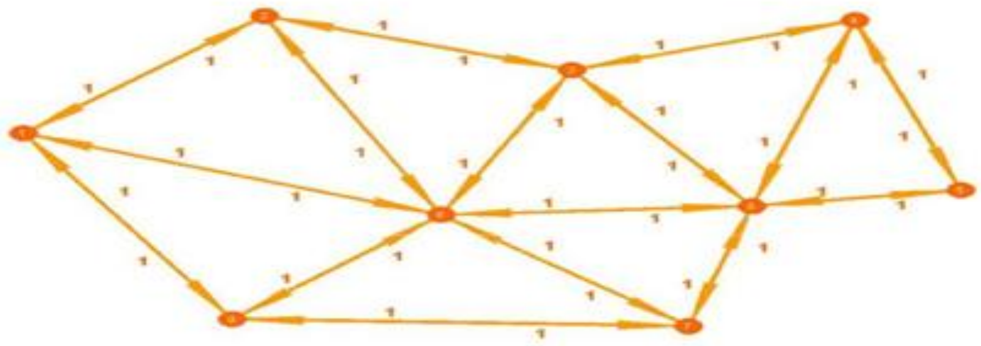


Fig.3.5.Using Topology, Node-9

- **After the error is introduced within the topology:**

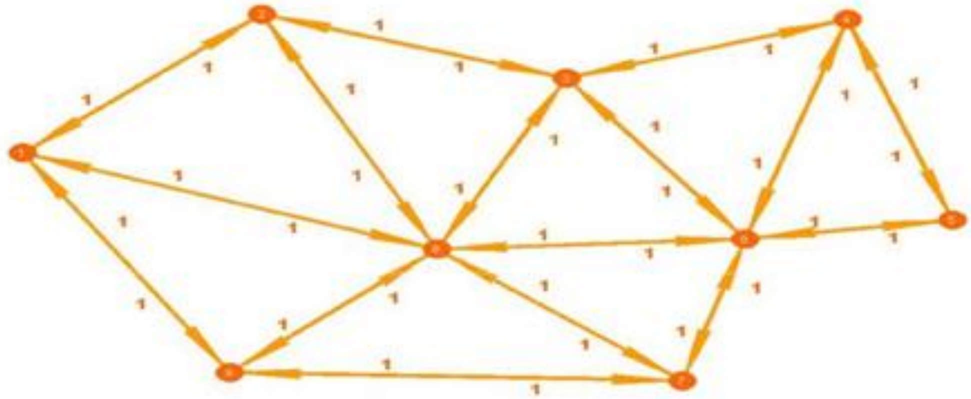


Fig.3.6.Link Failure Introduced

In the above two networks, to analyse the link failure case, we have removed one link. The link removed is between 6-8 node pair. Accordingly the traffic matrix is changed to analyse the link failure case.

Table 3.5.Material in order, Node-9 Network

Parameters	Before Link Failure	After Link Failure
Number Of Nodes	9	9
Total Number Of Links	32	30
Total offered capacity	60Gbps	60Gbps
Number of available wavelengths	40	40
Type of Connection	Bidirectional	Bidirectional

4. Result and Simulation

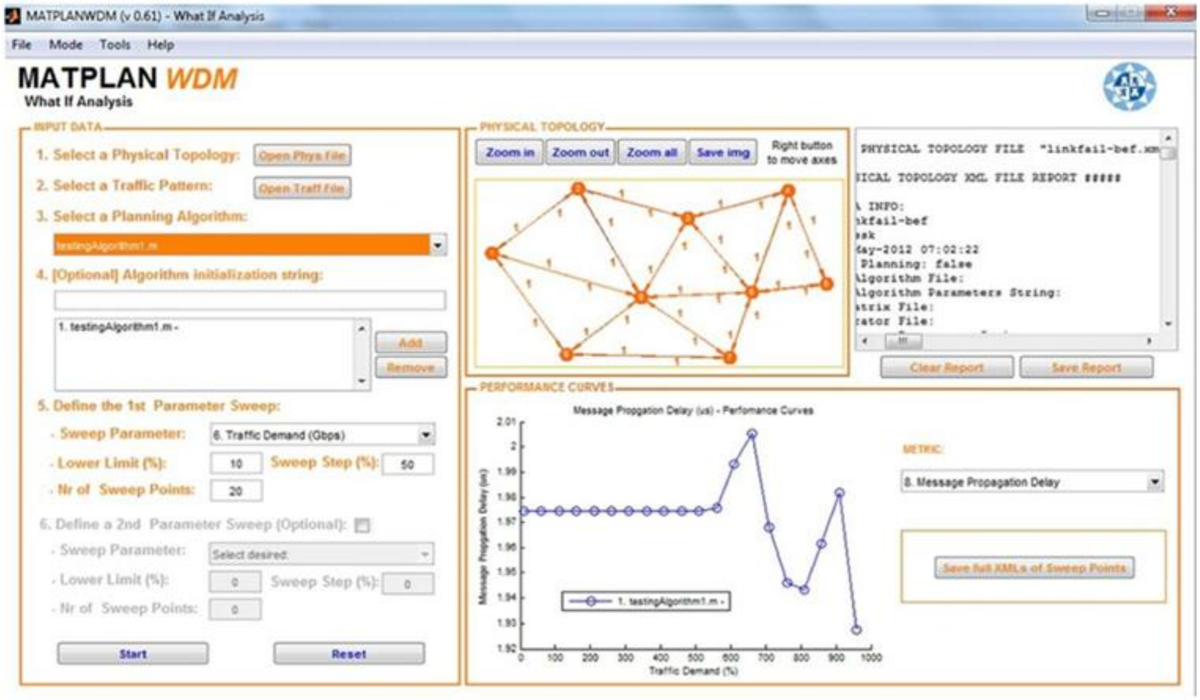


Fig.4.1. Shows MatPlanWDM (v.o61) Simulator.

Theory

Here we have used MatPlanWDM (0.61) as the simulation tool to simulate our topologies. It takes physical topology and traffic data for different network topologies. Here performance analysis of the four topologies has been done using MatPlanWDM0.61 simulator. We have to give topologies in .xml & traffic file in .traff format. The algorithm we used here is a shortest path algorithm. After that we have selected sweep parameters with lower & upper limits and number of sweep points to start simulation.

4.1 Networks For 60 GBPS:

- As observed from the figures below, delay is increasing with increase in traffic demand, but decreasing with increase in WCC. Also average delay of network is more for 6-node network, whereas least for 15-node network. So more number of nodes is preferable.

- Delay VS Traffic Demands, Delay VS Wavelength Channel Capacity:

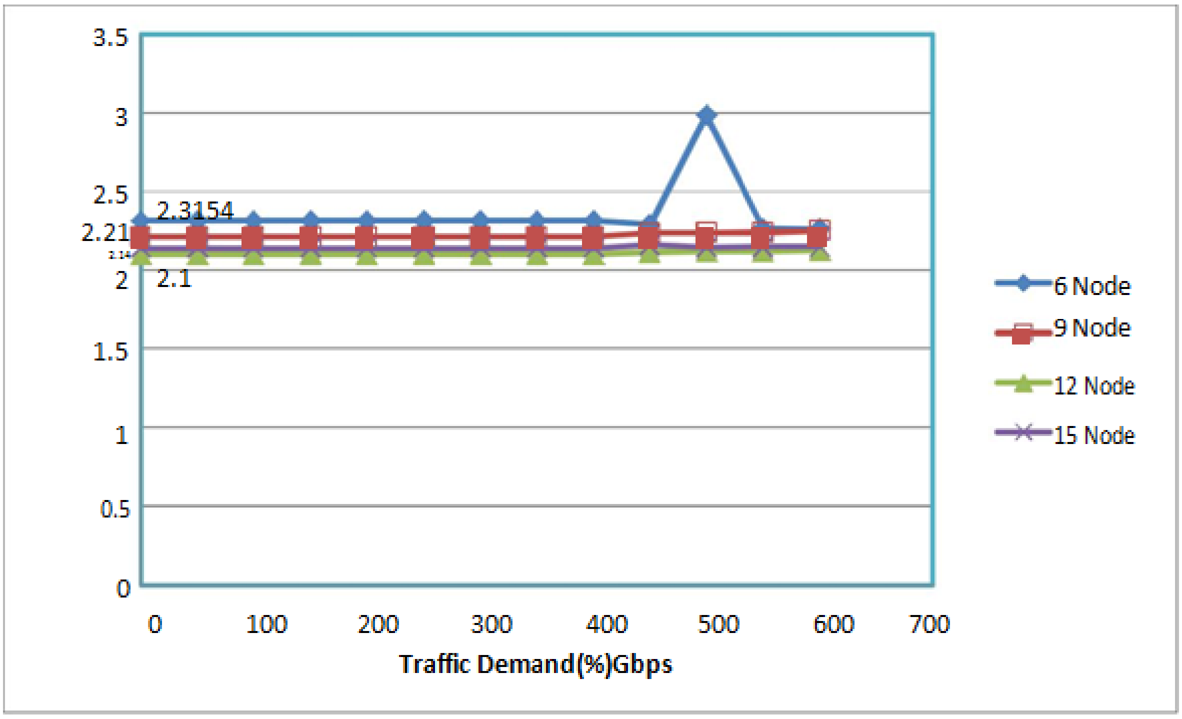


Fig.4.2.Case-1, Traffic Demand vs Delay

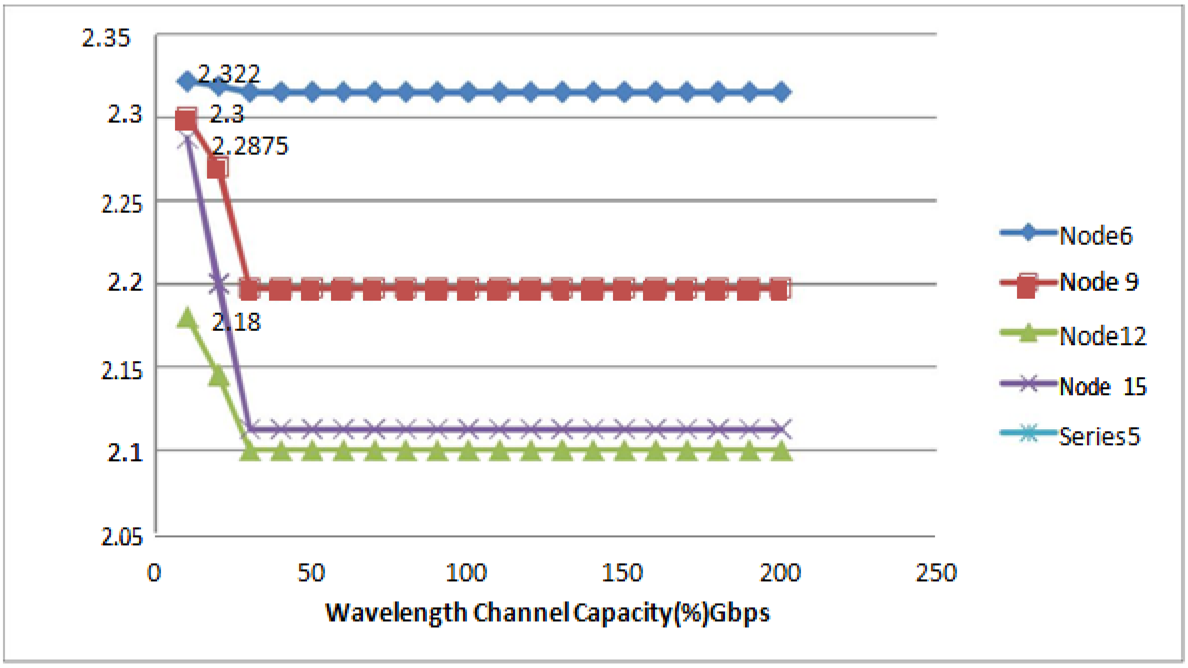


Fig.4.3.Case-1, WCC vs Delay

- From the figures below we observe that network congestion increase with both increase in traffic demand and WCC. Also network congestion is more for networks having more number of nodes. So network having less number of nodes is preferable.

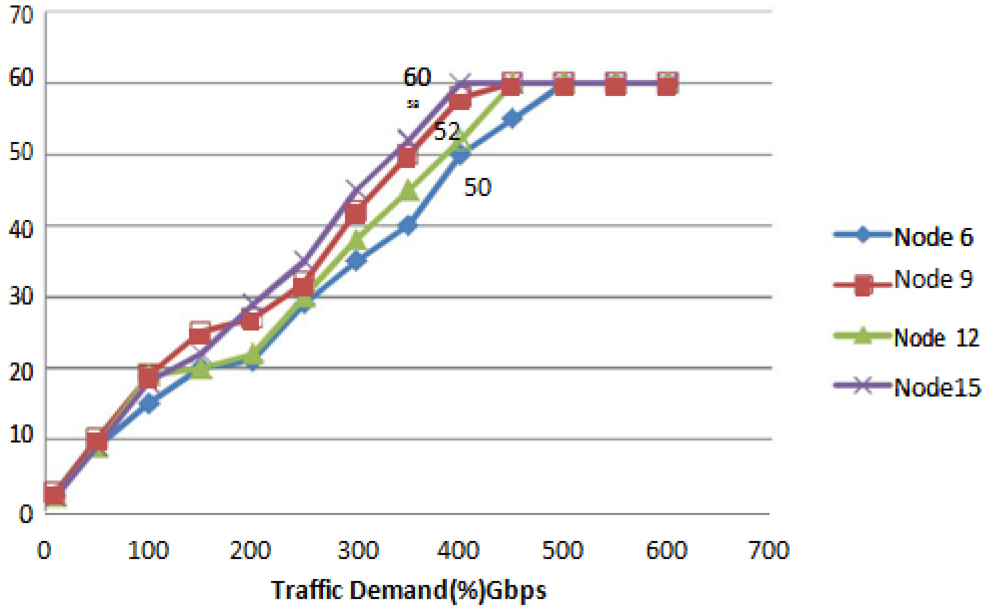


Fig.4.4. Case-1, Traffic Demand vs Network Congestion

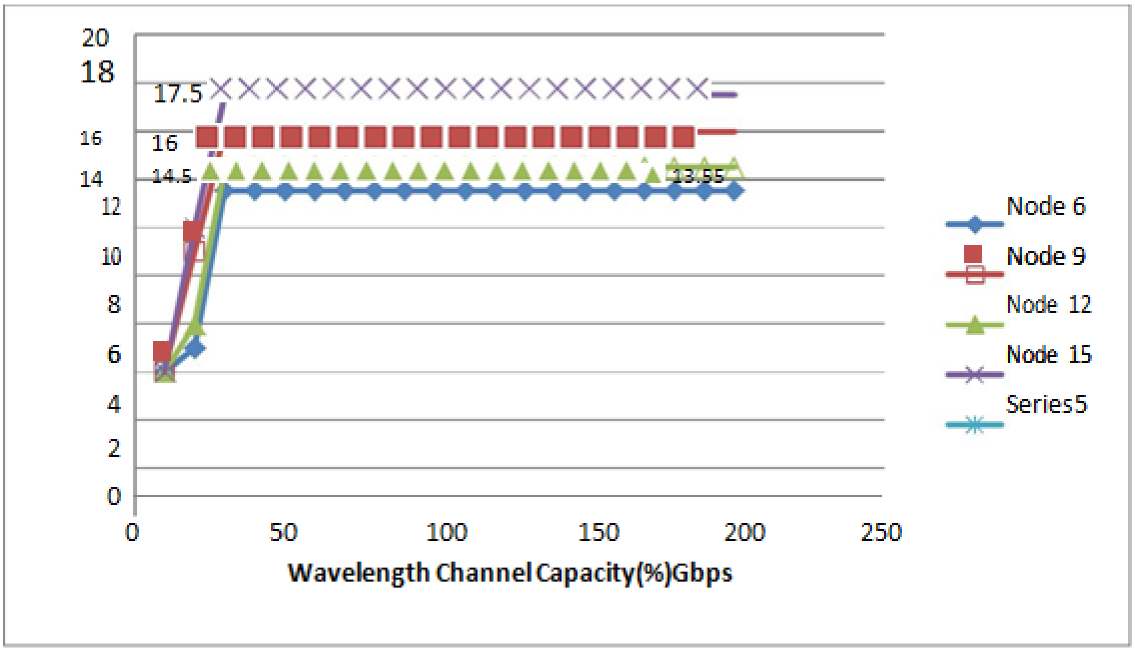


Fig.4.5.Case-1, WCC vs Network Congestion

Number of light path increases with increase in traffic demand as light paths are created as per demand. It decreases with increase in WCC, because as the capacity for each channel increases, the number of light path will decrease to maintain the total offered traffic. More number of light paths are desirable for better routing. Therefore network having more number of nodes is preferable.

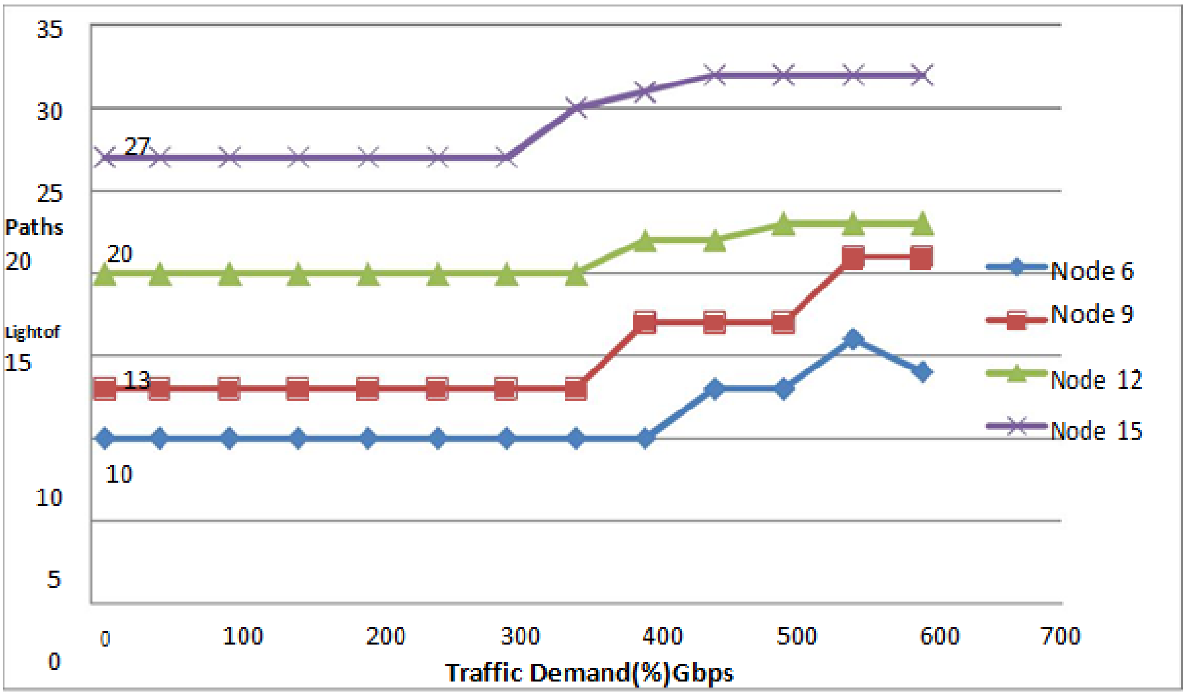


Fig.4.6.Case-1 Traffic Demand vs Number Of Light Paths

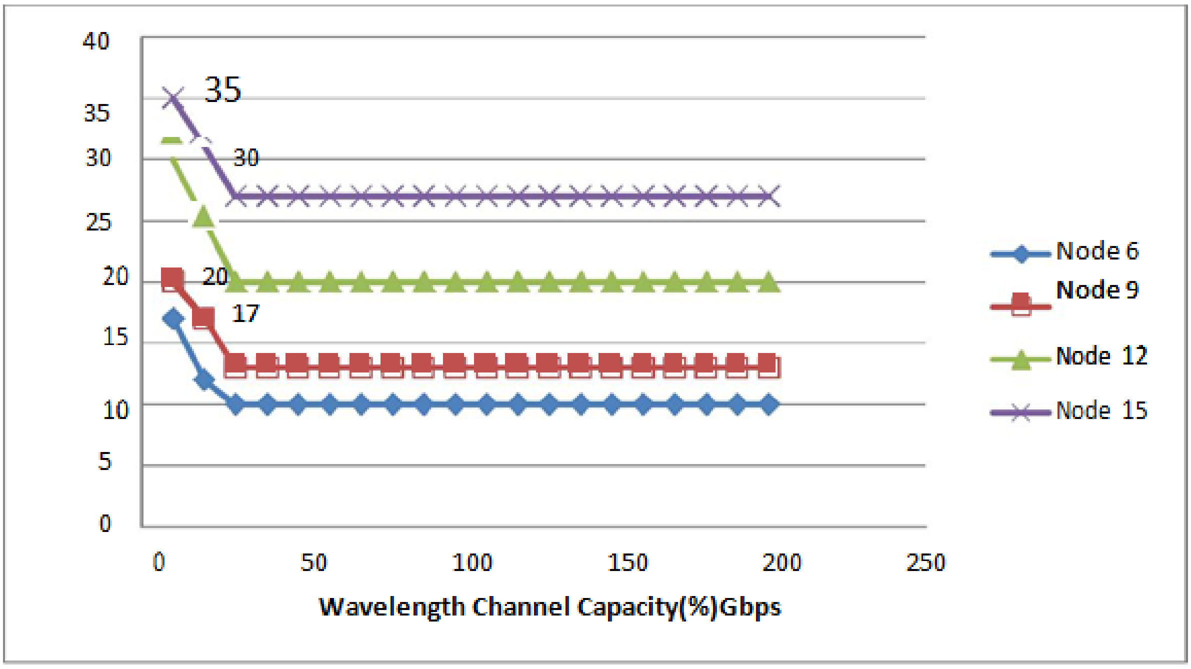


Fig.4.7.Case-1, WCC vs Number of Light Paths

Single Hop Traffic/Offered Traffic is more for 6-node network as it has least number of hops. This is desirable. As number of nodes increases Single Hop Traffic/Offered Traffic decreases. So network having less number of nodes is preferable.

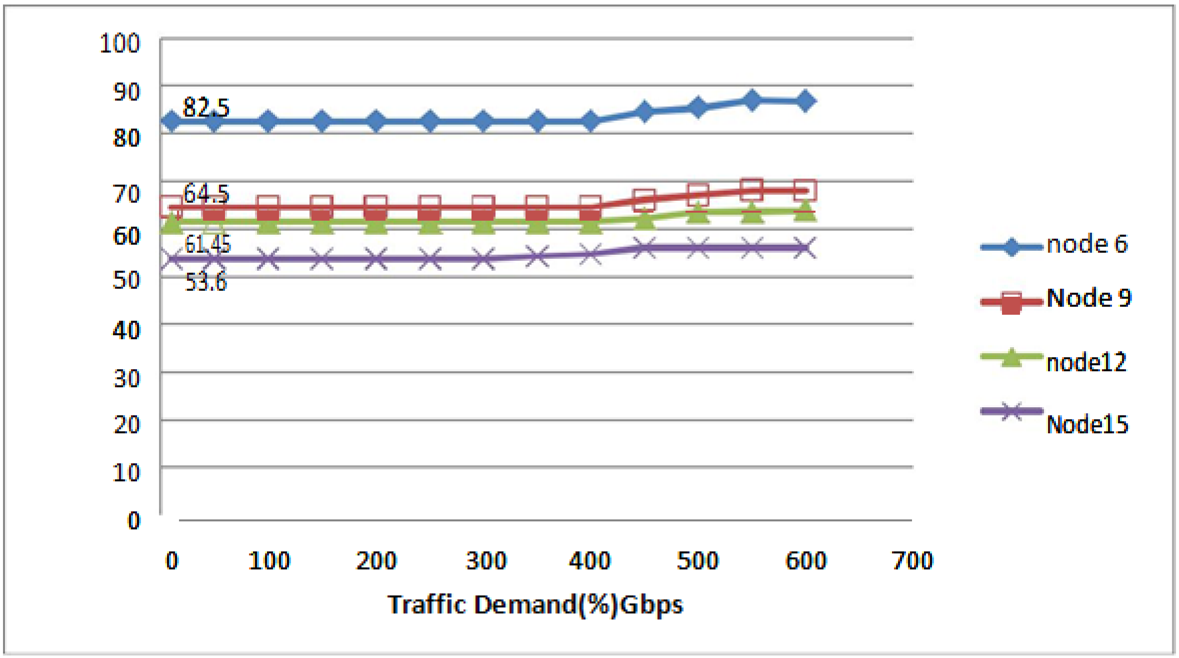


Fig.4.8.Case-1, Traffic Demand vs Single Hop Traffic/Offered Traffic

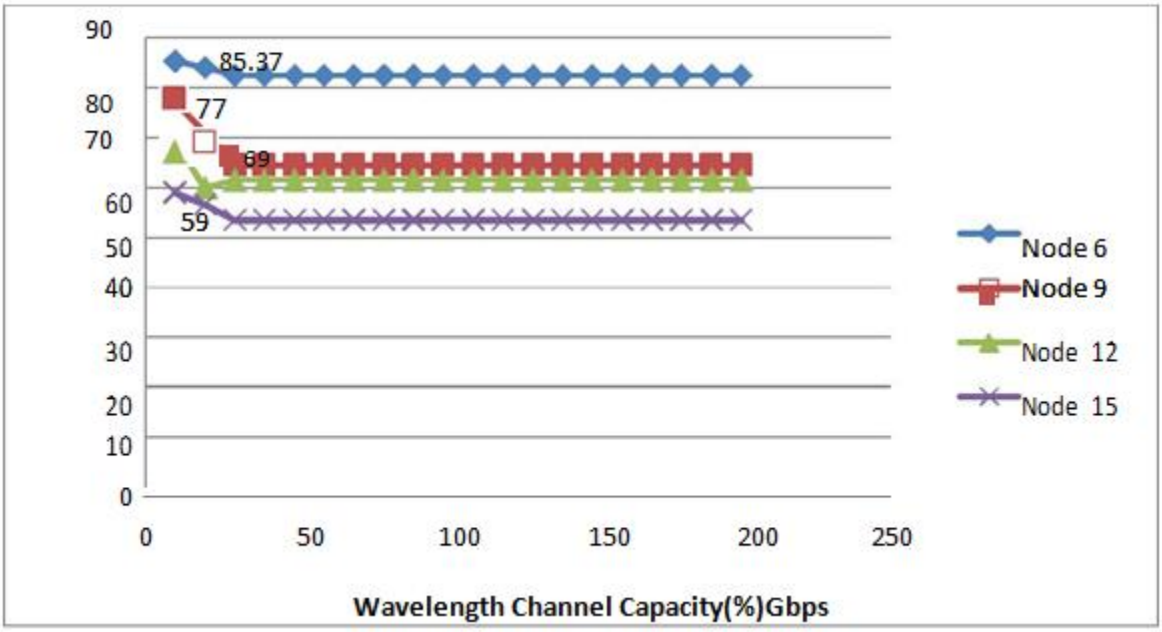


Fig.4.9.Case-1, WCC vs Single Hop Traffic/Offered Traffic

4.2 Networks For 100 GBPS :

- From the fallowing graphs we can observe that with increase in capacity delay is also increasing with traffic demand, but decreasing with increase with WCC. So it is preferable not to have a very high capacity network. Otherwise QoS will decrease.

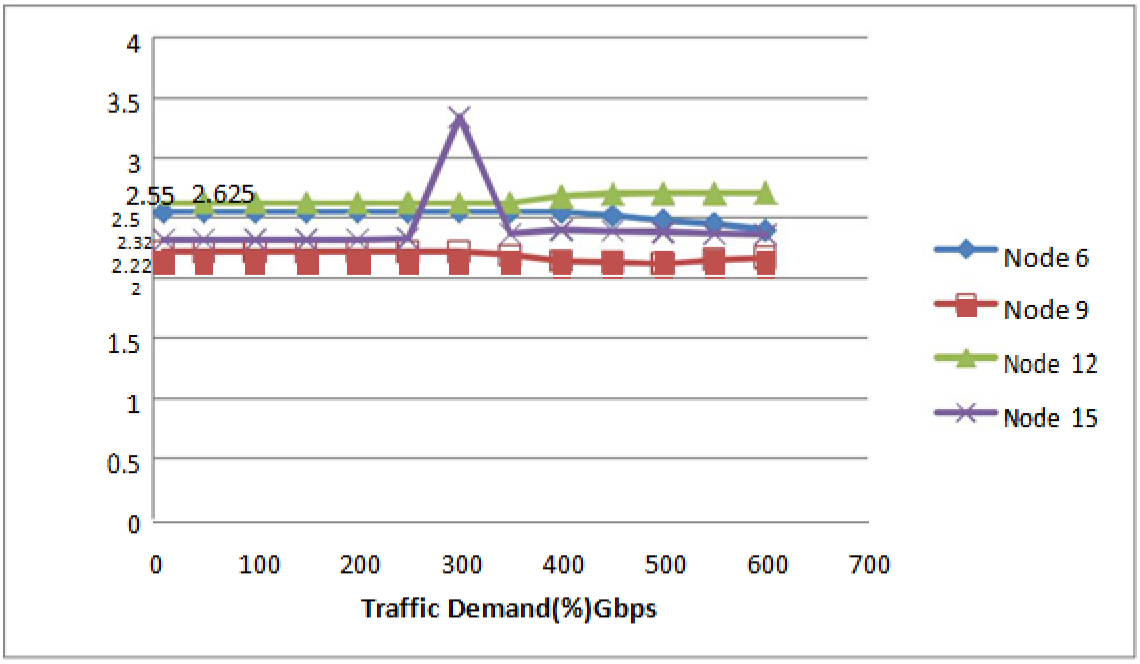


Fig.4.10.Case-2, Traffic demand vs Delay

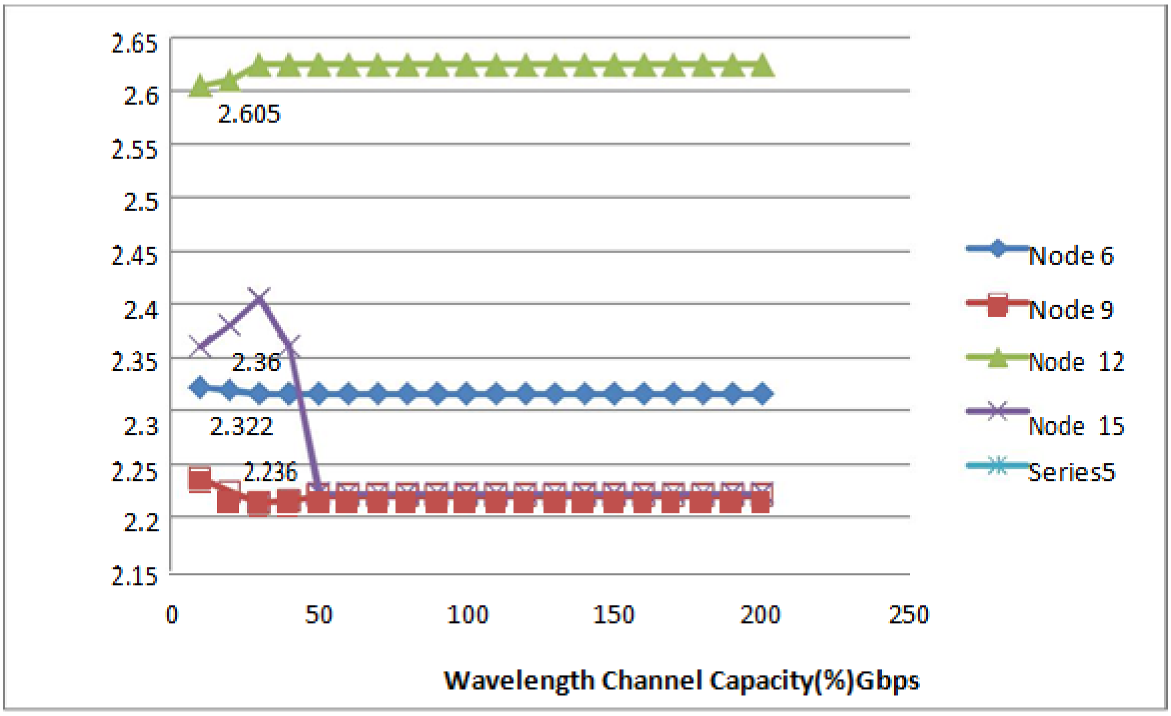


Fig.4.11.CASE-2, WCC vs Delay

We can observe from the graphs below that network congestion is increasing with increase in overall capacity of the network. So capacity should be as low as possible maintaining the QoS.

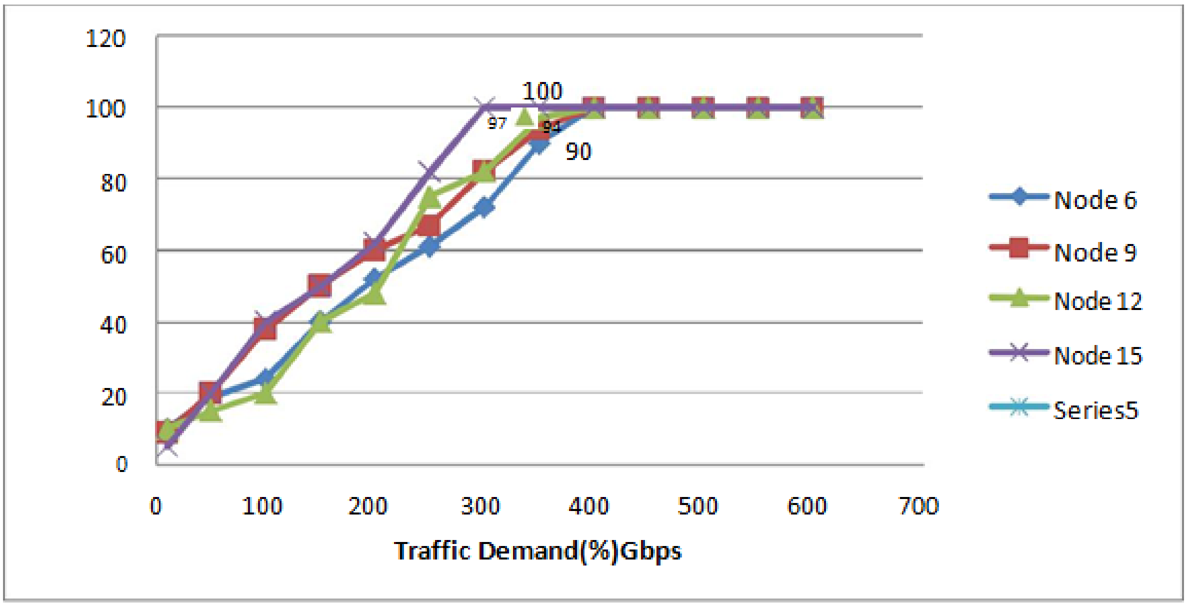


Fig.4.12.Case-2, Traffic Demand vs Network Congestion

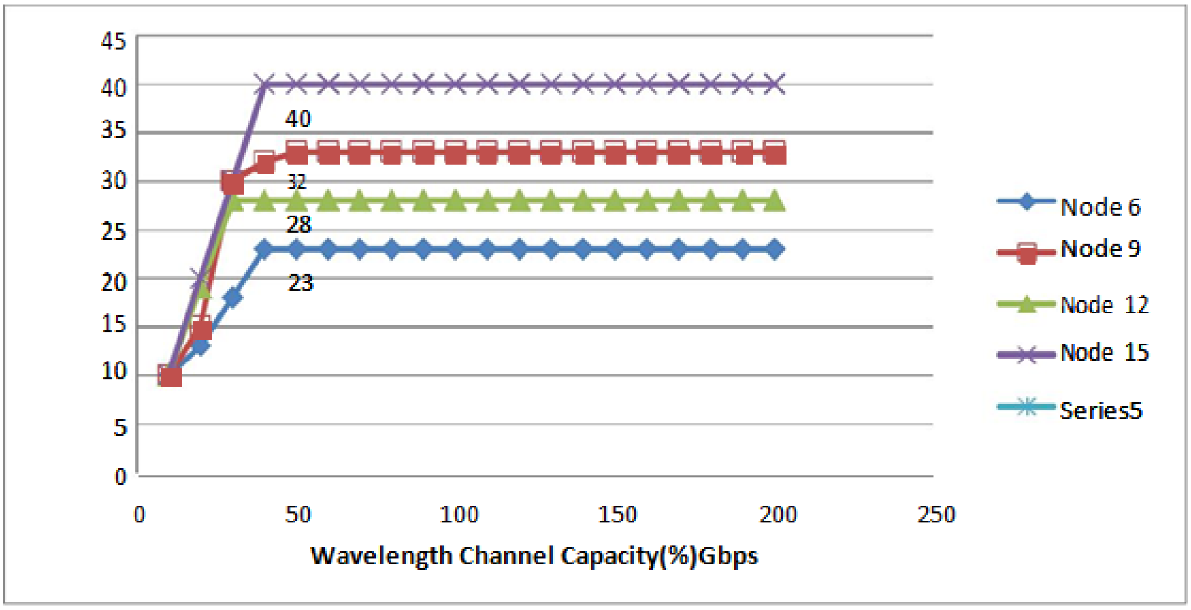


Fig.4.13.Case-2, WCC vs Network Congestion

- The number of light paths is increasing with increase in overall capacity of the network. This is because, as the capacity increases to maintain it, more number of light paths are created.

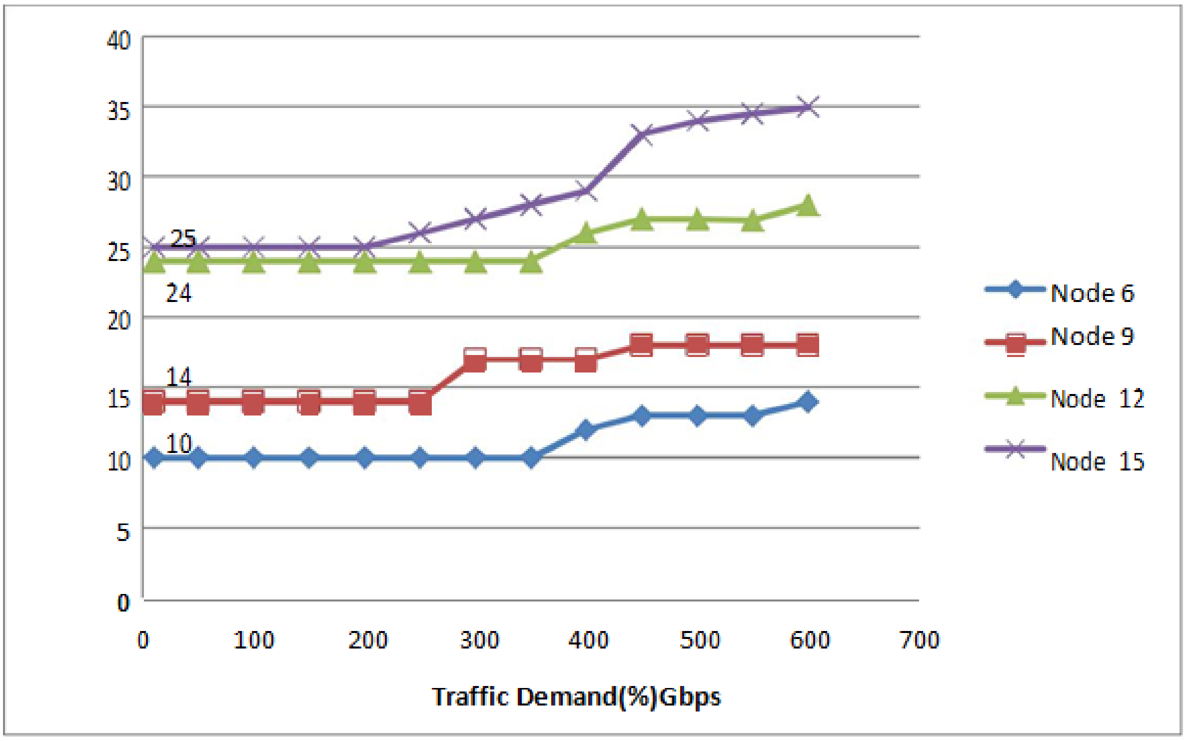


Fig.4.14.Case-2 Traffic Demand vs Number Of Light Paths.

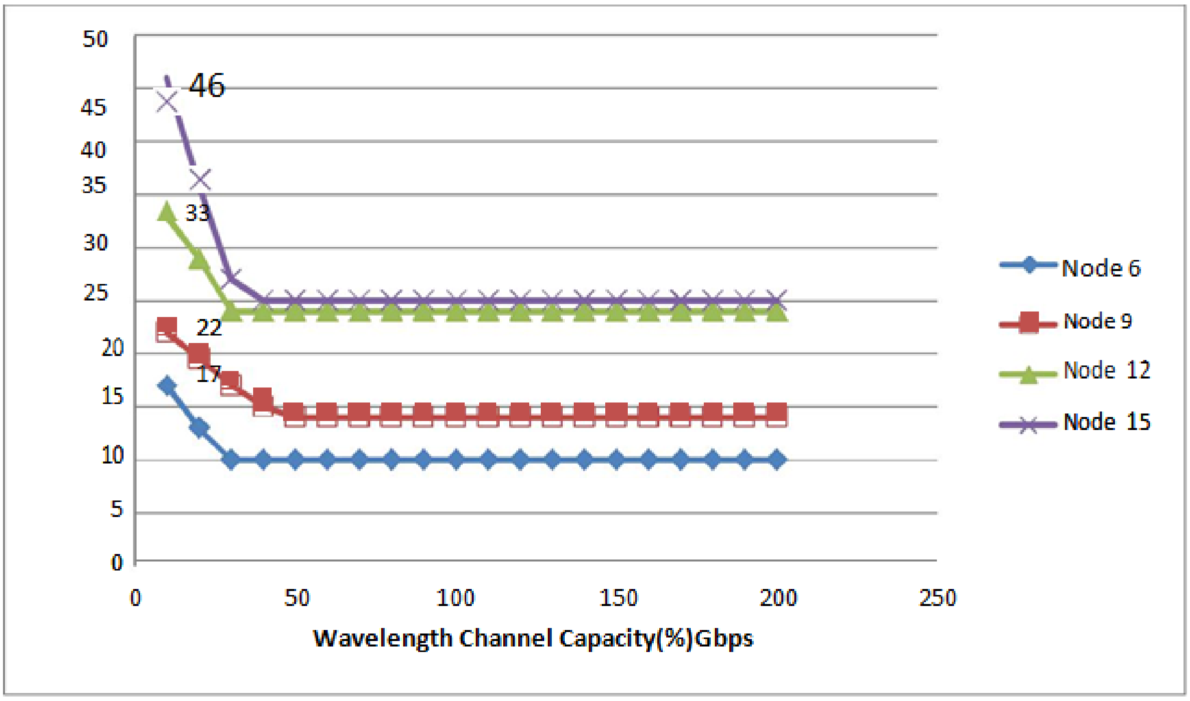


Fig.4.15.Case-2, WCC vs Number Of Light Paths.

As the number of nodes in a network increases in a network as does the number of single hops. So single hop traffic/offered traffic will decrease if the capacity remain constant. If two networks have same architecture, but different capacities, then the network having higher capacity will have higher value of single hop traffic/offered traffic. This is observed from the above figures.

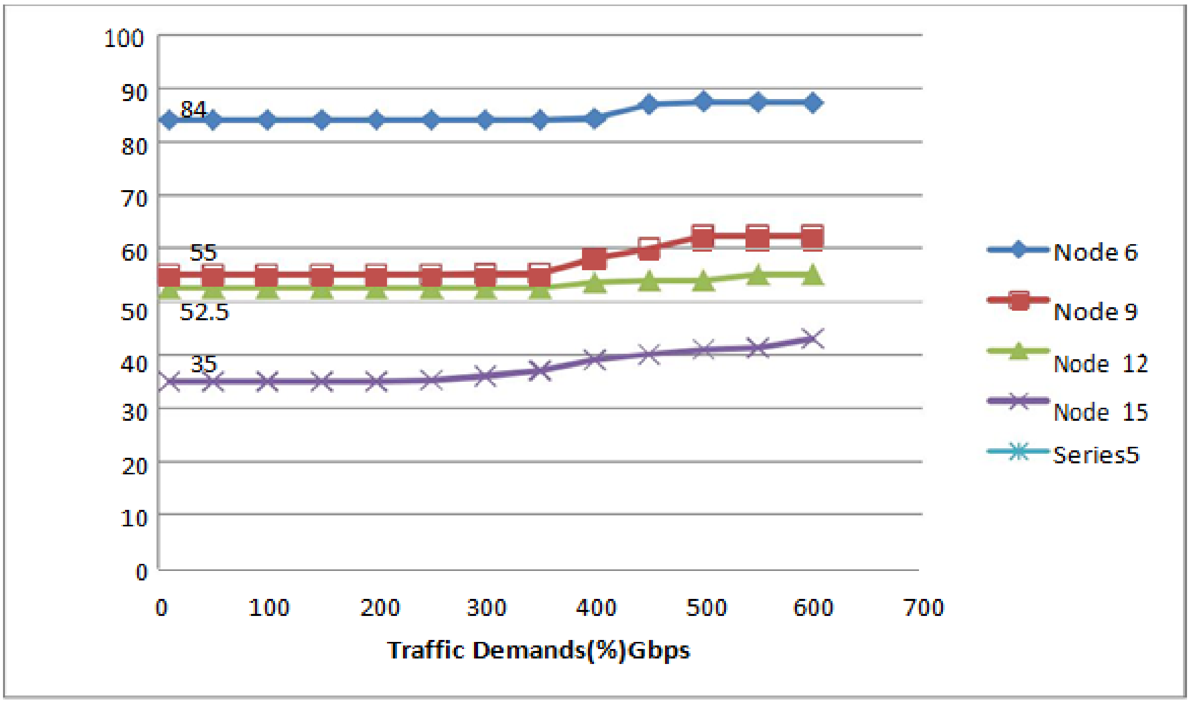


Fig.4.16.Case-2, Traffic Demand vs Single Hop Traffic/Offered Traffic

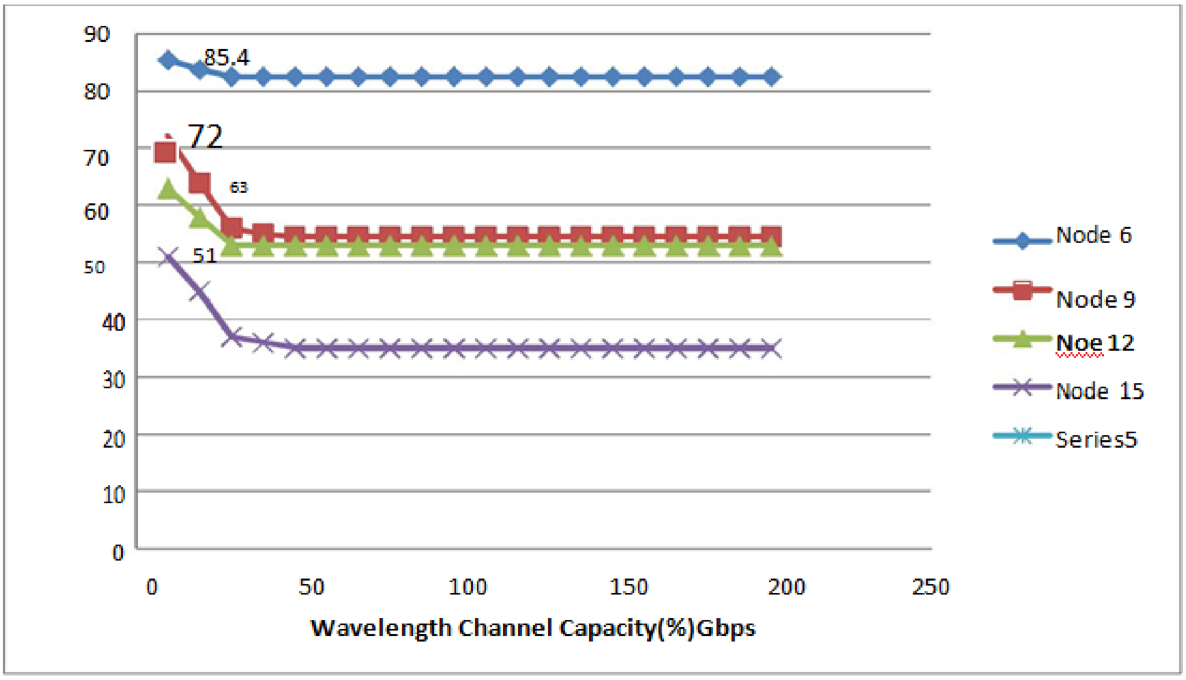


Fig.4.17.Case-2, WCC vs Single Hop Traffic/Offered Traffic

4.3 Link Failure Cases:

To Study the case of link failure, we have designed a two 9-node network topologies. In the second network we have removed one connection from the first network. Then we have simulated them with different scenarios to obtain the performance matrices and observe the difference.

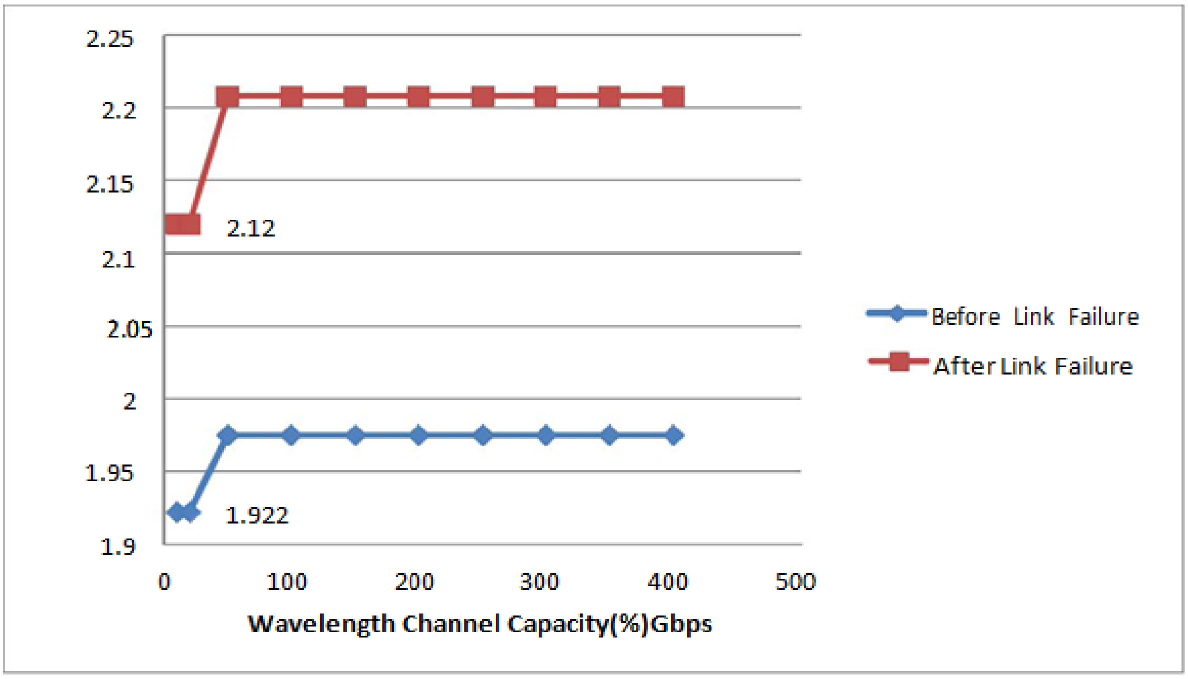


Fig.4.18.Case-3, WCC vs Delay.

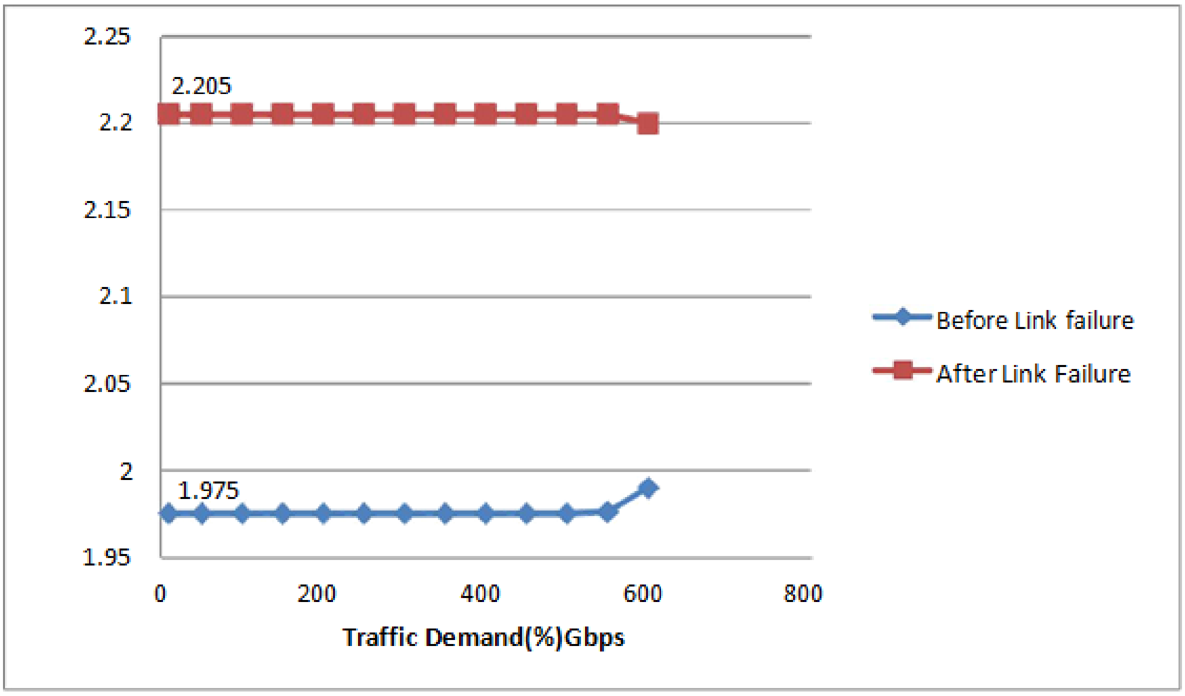


Fig.4.19.Case-3, Traffic Demand vs Delay.

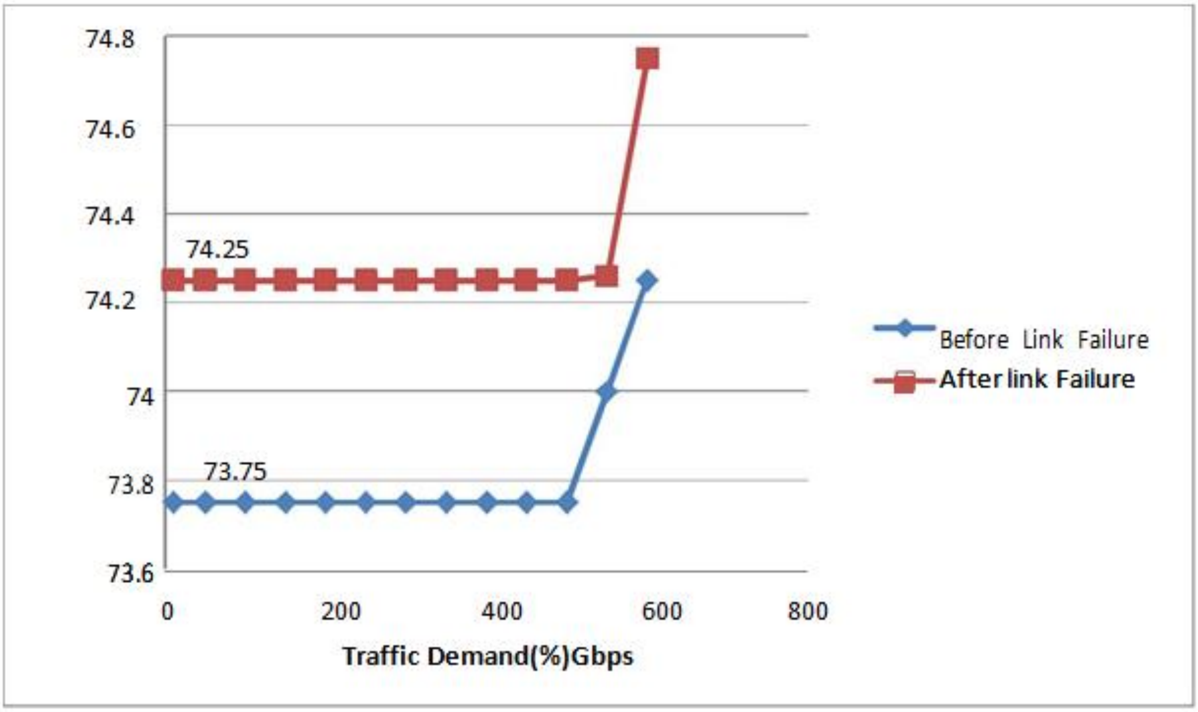


Fig.4.20.Case-3, Traffic Demand vs Single Hop/Offered Traffic

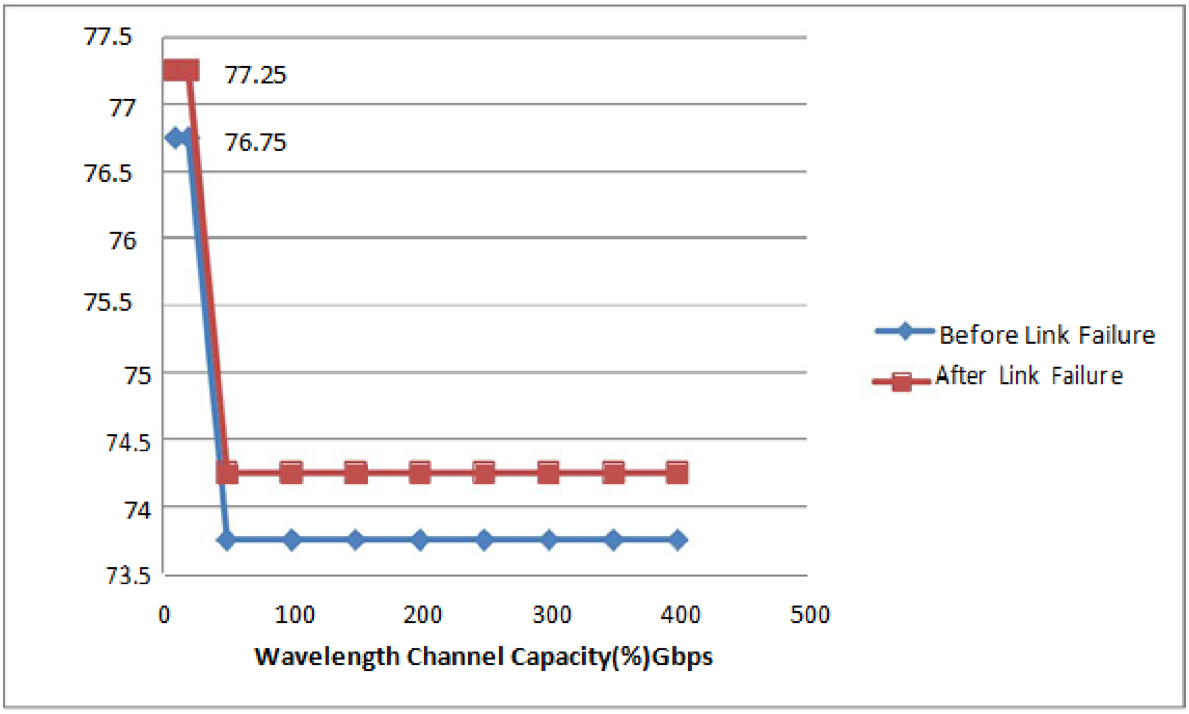


Fig.4.21.Case-3, WCC vs Single Hop/Offered Traffic

Table 4.1. Link Failure, results comparison.

Parameters	Delay(us)	Single Hop Traffic/Offered Traffic (%)
Traffic Demand(TD)		
Before Link Failure	1.975	73.75
After Link failure	2.205	74.25
Wavelength Channel Capacity(WWC)		
Before Link Failure	1.922	76.75
After Link Failure	2.12	77.25

From above table, we can see that the delay increases after link failure. Due to link failure we lose a path from source to destination in shortest path algorithm. Hence distance from 's' to 'd' node increases and to maintain minimal previous data rate the delay increases. In case of single hop traffic/Offered traffic, it also increases after link failure to maintain minimal traffic to avoid congestion.

Table 4.2.Different Node Topology Results, 60 GBPS

Number of Nodes	Average Delay (us)	Average Network Congestion (Gbps)	Average Number of Light paths	Single Hop Traffic/Offered Traffic (%)
6-node				
TD	2.3154	50	10	82.5
WWC	2.322	13.55	17	85.37
9-node				
TD	2.21	52	13	64.5
WWC	2.3	14.5	20	77
12-node				
TD	2.14	58	20	61.45
WWC	2.2875	16	30	69
15-node				
TD	2.1	60	27	53.6
WWC	2.18	17.5	35	59

In real life, to implement the topology application it should have, low network congestion rate, delay should be minimum, light paths should be maximum and high single hop traffic/offered traffic.

In normal we can assume that delay will increase with increase in number of nodes but as observed above when we increase the number of nodes the delay also decreases (i.e. 2.315us to 2.10 us).

It totally rely on number of light paths, there for if we increase the number of nodes, the number of light path also increases from the source node to the destination node.

The queuing delay decrease, hence decreasing the overall delay. As we increase the number of nodes the light paths also increase hence the delay decreases.

Now we observe that with increase in number of nodes network congestion, number of light paths, single hop/offered traffic increases.

5. CONCLUSION

Recent advances in the field of optical communication have opened the way for the practical implementation of WDM networks. After going through several papers we have found out that for determining Quality of Service the effect of network architecture is not taken into account. So we have designed four different networks and simulated them with different scenario to determine the performance matrices, which are called QoS (Quality Of Service) parameters.

In this work, we have used the simulation tool MatPlanWDM0.61, to study WDM networks and their performance analysis, which is freely available. It is an excellent framework for designing & development of topology with various features. We have concluded that if there is less number of nodes with high capacity, then delay will be more. If number of nodes is more as well as high capacity then network congestion will be more. So we have to choose a minimized output so that a better QoS is maintained, so after simulation we have found out that 12-node network is the best for present case. We can generalize this to suggest that for very high capacity networks number of nodes in network should be moderate.

In case of link failure, we found that the delay will be more after link failure in networks and also the single hop traffic/offered traffic. So for survivability of WDM network, it is important to find the optimal routes through the network in case of link failure to maintain minimum delay and desired traffic. So it assures a god QoS.

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