Effect of Change in Fiber Link by Using Optical WDM Network

Anushree Dwivedi[1], Dr. Mansih Shrivastava[2], Abhishek Dwivedi[3]
[1]M. Tech. Scholar, [1,2,3]LNCT, Bhopal

Abstract - Fiber-optic technology can be considered for meeting our desired need because of its potentially limitless capabilities, huge bandwidth, low signal attenuation, low signal distortion, low material usage, low power requirement, small space requirement, and low cost. These limitless capabilities can be utilized even using multiplexing technique like wavelength-division multiplexing (WDM) is a technology which tangled a number of optical carrier signals onto a single optical fiber by using various wavelengths (i.e., colors) of laser light. This skill enables bidirectional conveyances over one strand of fiber, as well as multiplication of capability. The main objective is to determine all possible paths from source to destination in WDM optical network. If there is a network connection request from a source node to a destination node, first all possible paths are determined, then a series of practical are performed using a simulation tool. The results are called performance matrices. Then a comparison has been made between these performance matrices and finds best possible paths. So in the proposed work a WDM algorithm for optical network Routing and wavelength assignment (RWA) is applied on different network topologies. In this work different network topologies like bus, mesh, ring and star are analyzed based on different parameters like message propagation delay, network congestion, link utilization and others. The result of the work shows reduction in fiber links in network topology without compromising with the performance and reliability. So the conclusions drawn illustrates that ring topology is better than all when implemented as dual ring. Dual ring is also called self healing ring and its performance is compared with simple ring and other topologies in terms of parameters mentioned.

Keywords - WDM, RWA, Dual ring.

I. INTRODUCTION

Fiber-optic technology can be considered for meeting our above-mentioned need because of its potentially limitless capabilities huge bandwidth (nearly 50 Tbps), low signal attenuation (nearly 0.2 dB/km), low signal distortion, low material usage, low power requirement, small space requirement, and low cost[1,2]. Our challenge is to turn the promise of fiber optics to reality to meet our networking demands of the next 21st century. Thus, the basic principle of the subject on optical wavelength division multiplexing (WDM) networks is that, as multiple users start to use our data networks, and as their usage patterns evolve to include more and more bandwidth-intensive networking applications such as data browsing on the world wide web (WWW), java applications, video conferencing, etc., there emerges an severe need for very high-bandwidth transport network facilities, whose capabilities are much beyond those that current high-speed (ATM) networks can provide[3,4].

In optical conveyance, wavelength division multiplexing (WDM) is a technology which carries a number of optical carrier signals on a single fiber by using various wavelengths of laser light. This allows bidirectional conveyance over one standard fiber with in increased capability. As optical net supports huge bandwidth; WDM net 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 de-multiplexers 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 tunable wavelength. The receiver consists of photodiode detector which converts an optical signal to electrical signal. This new technology allows engineers to increase the capability of net without laying more fiber. [1, 5] It has more security compared to other types of conveyance from tapping and also immune to crosstalk [1, 2]. WDM dramatically expands the total capability of an optical net by enabling a large number of independent wavelength channels to travel within the same net. This core technology allows net capability to be gradually and cost effectively increased while flexibly allowing multiple generations of broadcast technologies to be supported on the same net infrastructure.

II. LITERAURE REVIEW

Due to power considerations [5], it is possible that not all wavelengths available in a fiber can be used at a given time. In his paper, an analytical model is proposed to evaluate the blocking performance of wavelength-routed optical nets with and without wavelength conversion where the usable wavelengths in a fiber is limited to a certain maximum number, referred to as wavelength usage constraint. The effect of the wavelength usage constraint is studied on ring and mesh-torus nets. It is shown that the analytical model closely approximates the simulation results. It is observed that increasing the total number of wavelengths in a fiber is an attractive alternative to wavelength conversion when the number of usable wavelengths in a fiber is maintained the same.

The paper [7] says while optical-broadcast skills have been researched for quite some time, optical "neting" studies have been conducted only over the past dozen years or so. Paper [8] proposed approaches for the traffic grooming problem that consider connection holding-times and bandwidth availability. In paper [9], Existing routing and wavelength assignment (RWA) solutions try to minimize the blocking rate as the main quality of service (QoS) metric. In paper [10], they have presented an efficient RWA protocol for WDM networks. The optimal and sub-optimal light paths are found by the ants (control agents) depending upon the number of free wavelengths available, the length of the lightpath (hop count) and number of conversion required from source to destination. This paper [11] shows that, the impact of Stimulated Raman Scattering (SRS) in Routing and Wavelength Assignment (RWA) is performance analyzed in three different setting in the number of hops in routes using fixed shortest path routing in 8-nodes mesh and 8-nodes ring topologies.

This paper [12] describe that, a simulation algorithm is proposed to re-evaluate different routing and wavelength assignment (RWA) algorithms with emphases on their robustness to the accumulation of homodyne cross talks. This paper [13], says designed of Mat Plan WDM software for topology design, multi hour analysis, what-if analysis & performance analysis. It is a MATLAB-based publicly available network design and functionality tool for Wavelength-Routing (WR) optical network.

In article [14], discuss the problem of routing and wavelength assignment (RWA) in optical networks with wavelength division multiplexing (WDM). Two variations of the problem are also studied in this paper: static-RWA, whereby the network traffic requirements are recognized in advance, and dynamic-RWA in which network link connection requests arrive in some arbitrary fashion. This paper [15] describe about Optical performance monitoring (OPM) which is essential for managing high capacity optical transmission and switching systems. Paper [16] proposed that the development of communication networks is driven by user demands for new applications and advances in technologies. Paper [17] stated that the problem of routing and wavelength assignment (RWA) is significantly important for increasing the efficiency of wavelength-routed all-optical network.

This paper [18] shows that network performance analysis of four classical topologies (random, star, ring and tree) networks from the perspective of blocking probability, average hop count, average packet delay and link utilization has been carried out depending on wavelength conversion factor. This Paper [19] evaluates the performance of three wavelength allocation algorithms for allocating wavelength to optical WDM (Wavelength Division Multiplexing) networks and they are: first-fit algorithm, least-used algorithm and most-used algorithm.

III. FUNDAMENTAL OF OPTICAL NETWORK TOPOLOGY

1.1 Dual Ring

A network topology in which two concentric rings connect each node on a network instead of one network ring that is used in a ring topology [11]. Typically, the secondary ring in a dual-ring topology is redundant. It is used as a backup in case the primary ring fails. In these configurations, data moves in opposite directions around the rings. Each ring is independent of the other until the primary ring fails and the two rings are connected to continue the flow of data traffic.

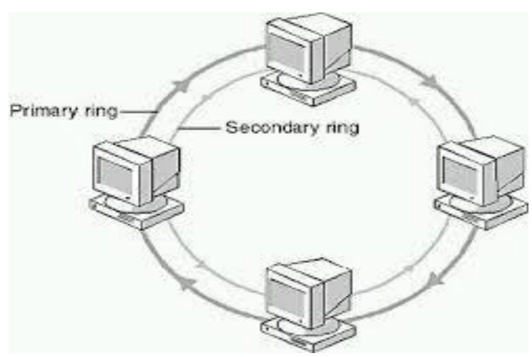

Fig 3.1 Dual Ring

1.2 Self Healing Ring

A self healing ring, or SHR, is a telecommunications term for loop network topology, a common configuration in telecommunications transmission systems [10, 11]. Like roadway and water distribution systems, a loop or ring is used to provide redundancy. SDH, SONET and WDM systems are often configured in self healing rings.

The system consists of a ring of bidirectional links between a set of stations, typically using optical fiber communications. In normal use, traffic is dispatched in the direction of the shortest path towards its destination. In the event of the loss of a link, or of an entire station, the two nearest surviving stations "loop back" their ends of the ring. In this way, traffic can still travel to all surviving parts of the ring, even if it has to travel "the long way round". A second break in the ring may divide it into two sub-rings, but in such a case each sub-ring will remain functional.

1.2.1 Advantages

Self healing rings offer high levels of resilience at low cost, since it is often geographically easy to take multiple paths across the landscape and link them up into a ring with very little extra fiber length. Recent submarine communications cables are typically built in pairs to function as a self healing ring [8, 9]. Very high resilience systems are typically built on interconnected meshes of self healing rings.

Another example of a self healing ring network technology is the FDDI local area network. Resilient Packet Ring is a new technology for packet switched self healing ring networks. These types of rings mainly used for saving high rate traffic flowing in Telecom networks

1.2.2 Dual Ring Topology

Dual ring topology is a network redundant topology where nodes are connected using two concentric rings with four branches. Dual ring topology is ideal for applications with cabling issues or small networks that are not frequently reconfigured [8, 20]. Though more expensive than star or extended star topologies, dual ring is the most cost efficient redundant topology.

Dual ring topology is made up of two rings connected to a network. Each ring works independently until one is disabled when the network fails. When this takes place, the functioning ring automatically wraps around the disabled ring to ensure data flow.

1.3 Topology

Net topology is the arrangement of the various elements (links, nodes, etc.) of a computer net. Essentially, it is the topological structure of a net and may be depicted physically or logically. Physical topology is the placement of the various components of a net, including device location and cable installation, while logical topology illustrates how data flows within a net, regardless of its physical design. Distances between nodes, physical interconnections, broadcast rates, or signal types may differ between two nets, yet their topologies may be identical [11].

There are two basic categories of net topologies:

- Physical topologies.
- Logical topologies.

The cabling layout used to link devices is the physical topology of the net. This refers to the layout of cabling, the locations of nodes, and the interconnections between the nodes and the cabling.

a. Physical Topology : The physical topology of a net is determined by the capabilities of the net access devices and media, the level of control or fault tolerance desired, and the cost associated with cabling or tele-conveyances circuits.

b. Logical Topology: The logical topology in contrast, is the way that the signals act on the net media, or the way that the data passes through the net from one device to the next without regard to the physical interconnection of the devices. A net's logical topology is not necessarily the same as its physical topology. For example, the original twisted pair Ethernet using repeater hubs was a logical bus topology with a physical star topology layout. Token Ring is a logical ring topology, but is wired a physical star from the Media Access Unit.

1.3.1 Bus Topology

In local area nets where bus topology is used, each node is connected to a single cable. Each computer or server is connected to the single bus cable. A signal from the source travels in both directions to all machines connected on the bus cable until it finds the intended recipient. If the machine address does not match the intended address for the data, the machine ignores the data [10]. Alternatively, if the data matches the machine address, the data is accepted. Because the bus topology consists of only one wire, it is rather inexpensive to implement when compared to other topologies. However, the low cost of implementing the technology is offset by the high cost of managing the net. Additionally, because only one cable is utilized, it can be the single point of failure.

- Advantages
  - It is easy to set up, handle, and implement.
  - It is best-suited for small nets.
  - It costs very less.

- Disadvantages

- The cable length is limited. This limits the number of net nodes that can be connected.
- This net topology can perform well only for a limited number of nodes. When the number of devices connected to the bus increases, the efficiency decreases. It is suitable for nets with low traffic. High traffic increases load on the bus and the net efficiency drops.
- It is heavily dependent on the central bus. A fault in the bus leads to net failure.
- It is not easy to isolate faults in the net nodes.

1.3.2 Star net Topology

In local area nets with a star topology, each net host is connected to a central hub with a point-to-point connection. In Star topology every node (computer workstation or any other peripheral) is connected to central node called hub or switch. The switch is the server and the peripherals are the clients. The net does not necessarily have to resemble a star to be classified as a star net, but all of the nodes on the net must be connected to one central device. All traffic that traverses the net passes through the central hub. The hub acts as signal repeater. The star topology is considered the easiest topology to design and implement. An advantage of the star topology is the simplicity of adding additional nodes. The primary disadvantage of the star topology is that the hub represents a single point of failure.

➢ Advantages
- Due to its centralized nature, the topology offers simplicity of operation.
- It also achieves isolation of each device in the net.
- Adding or removing net nodes is easy, and can be done without affecting the entire net.
- Due to the centralized nature, it is easy to detect faults in the net devices.
- As the analysis of traffic is easy, the topology poses lesser security risk.
- Data packets do not have to pass through many nodes, like in the case of a ring net. Thus, with the use of a high-capability central hub, traffic load can be handled at fairly decent speeds.

➢ Disadvantages
- Net operation depends on the functioning of the central hub. Hence, central hub failure leads to failure of the entire net.
- Also, the number of nodes that can be added, depends on the capability of the central hub.
- The setup cost is quite high.

1.3.3 Ring net Topology

A net topology that is set up in a circular fashion in which data travels around the ring in one direction and each device on the ring acts as a repeater to keep the signal strong as it travels. Each device incorporates a receiver for the incoming signal and a transmitter to send the data on to the next device in the ring. The net is dependent on the ability of the signal to travel around the ring. When a device sends data, it must travel through each device on the ring until it reaches its destination. Every node is a critical link. In a ring topology, there is no server computer present; all nodes work as a server and repeat the signal. The disadvantage of this topology is that if one node stops working, the entire net is affected or stops working.

➢ Advantages
- The data being transmitted between two nodes passes through all the intermediate nodes. A central server is not required for the management of this topology.
- The traffic is unidirectional and the data broadcastis high-speed.
- In comparison to a bus, a ring is better at handling load.
- The adding or removing of net nodes is easy, as the process requires changing only two connections.
- The configuration makes it easy to identify faults in net nodes.
- In this topology, each node has the opportunity to transmit data. Thus, it is a very organized net topology.
- It is less costly than a star topology.

➢ Disadvantages
- The failure of a single node in the net can cause the entire net to fail.
- The movement or changes made to net nodes affect the entire net's performance.
- Data sent from one node to another has to pass through all the intermediate nodes. This makes the broadcasts lower in comparison to that in a star topology. The broadcast speed drops with an increase in the number of nodes.
- There is heavy dependency on the wire connecting the net nodes in the ring.

1.3.4 Mesh net Topology

The value of fully meshed nets is proportional to the exponent of the number of subscribers, assuming that communicating groups of any two endpoints, up to and including all the endpoints, is approximated by Reed's Law. Fully connected mesh topology a fully connected net is a communication network in which each node is connected to each other. in graph theory it known complete graph. A fully connected net doesn't need to use switching or broadcasting However, its vital disadvantage is that the number of connections grows quadratically with the number of nodes.

- Advantages
  - The arrangement of the net nodes is such that it is possible to transmit data from one node to many other nodes at the same time.
  - The failure of a single node does not cause the entire net to fail as there are alternate paths for data transmission.
  - It can handle heavy traffic, as there are dedicated paths between any two net nodes.

  Point-to-point contact between every pair of nodes makes it easy to identify faults.

- Disadvantages
  - The arrangement wherein every net node is connected to every other node of the net, many connections serve no vital purpose. This leads to redundancy of many net connections.
  - A lot of cabling is required. Thus, the costs incurred in setup and maintenance are high.
  - Owing to its complexity, the administration of a mesh net is difficult.

1.3.5 Tree net Topology

Tree topology is essentially a combination of bus topology and star topology. The nodes of bus topology are replaced with standalone star topology nets. These result in both disadvantages of bus topology and advantages of star topology. For example, if the connection between two groups of nets is broken down due to breaking of the connection on the central linear core, then those two groups cannot communicate, much like nodes of a bus topology. However, the star topology nodes will effectively communicate with each other. It has a root node, intermediate nodes, and ultimate nodes. This structure is arranged in a hierarchical form and any intermediate node can have any number of the child nodes. But the tree topology is practically impossible to construct, because the node in the net is nothing, but the computing device can have maximum one or two connections, so we cannot attach more than 2 child nodes to the computing device (or parent node).

- Advantages
  - The tree topology is useful in cases where a star or bus cannot be implemented individually. It is most-suited in neting multiple departments of a university or corporation, where each unit (star segment) functions separately, and is also connected with the main node (root node).
  - The advantages of centralization that are achieved in a star topology are inherited by the individual star segments in a tree net.
  - Each star segment gets a dedicated link from the central bus. Thus, failing of one segment does not affect the rest of the net.
  - Fault identification is easy.
  - The net can be expanded by the addition of secondary nodes. Thus, scalability is achieved.

- Disadvantages
  - As multiple segments are connected to a central bus, the net depends heavily on the bus. Its failure affects the entire net.
  - Owing to its size and complexity, maintenance is not easy and costs are high. Also, configuration is difficult in comparison to that in other topologies.

  Though it is scalable, the number of nodes that can be added depends on the capability of the central bus and on the cable type.

1.3.6 Hybrid net Topology

Hybrid nets use a combination of any two or more topologies, in such a way that the resulting net does not exhibit one of the standard topologies (e.g., bus, star, ring, etc.). For example a tree net connected to a tree net is still a tree net topology. A hybrid topology is always produced when two various basic net topologies are connected. Two common examples for Hybrid net are: star- ring net and star bus net.

- A Star-ring net consists of two or more star topologies connected using a multi -station access unit (MAU) as a centralized hub.
- A Star Bus net consists of two or more star topologies connected using a bus trunk (the bus trunk serves as the net's backbone).

Some of the resulting layouts are nearly incomprehensible, although they function quite well. A Snowflake topology is really a "Star of Stars" net, so it exhibits characteristics of a hybrid net topology but is not composed of two various basic net topologies being connected.

1.4 Routing and Wavelength Assignment

To establish an optical path between source and destination pair is necessary to allocate or route a wavelength. This problem is known as the Routing and Wavelength Assigning (RWA) problem. RWA is a fundamental problem of all-optical networks, and arises in network designing applications, including traffic grooming, survivability network design, and traffic scheduling. Internet is formed by collection of network topologies. Different topologies show different performance parameters like packet loss, network congestion, delay and cost. Network congestion is an important parameter which must has to be reduced for optical. RWA problem can be static and dynamic. RWA of light paths in optical networks is usually done in two steps. First tries to find a route between the pair of nodes, and the then second assigns wavelengths for links of the route. The simulation suggests different solutions and handles these steps. Another approach is to combine these steps so that routing is tied to a particular wavelength. This approach is typically accomplished by starting with a particular wavelength and reducing the network topology to only those links on which this wavelength is available. RWA difficult problem can be divided into two separate sub-problems, the routing sub-problem and the wavelength assignment sub-problem and solve them individually [21, 22].

IV. PROBLEM STATEMENT AND RESULT ANALYSIS

1.5 Problem Statement

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

- In this Paper we have developed dual ring topology and compared its features with other topologies. It is illustrated in the paper that dual ring posses self healing characteristics and is fault tolerant than other topologies.

1.6 Proposed Work

In this paper we have studied dual ring behavior on different parameters. Our study proves that the fully connected dual ring and partially connected dual ring performs same under different parameters.

Here we have configured 12 nodes completely connected dual ring topology and a 12 nodes dual ring in which some nodes are not connected. The generated traffic consist of (0, 10) uniform pattern normalization.

We have considered an .xml code file to design each network. The .xml includes the list of nodes and fiber 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 fibers.

The simulation tool used in this dissertation is MATPLAN WDM 0.61. This tool runs using MATLAB. MATPLAN WDM is used for analysis of optical network for different traffic and topologies.

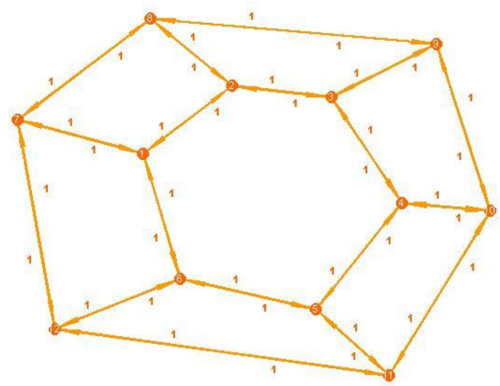

Fig 4.1 12-node Dual ring with all connected nodes

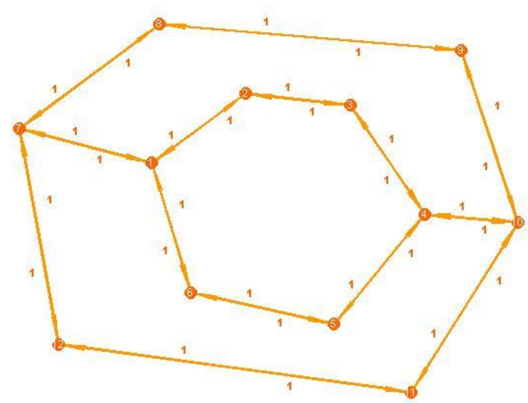

Fig 4.2 12-node Dual ring with some connected nodes

1.7 Result Analysis

In what if analysis we have analysed our topologies in terms of following parameters :

- Message propogation delay Vs traffic demand %.
- No. of used wavelength channels Vs traffic demand %.
- No. of lightpaths per fiber links Vs No. of wavelengths per fiber.
- Message propogation delay Vs wavelength channel capacity.

1.7.1 Message propagation Delay Vs Traffic Demand

In this part we have plot graph between traffic demand % and message propogation delay.

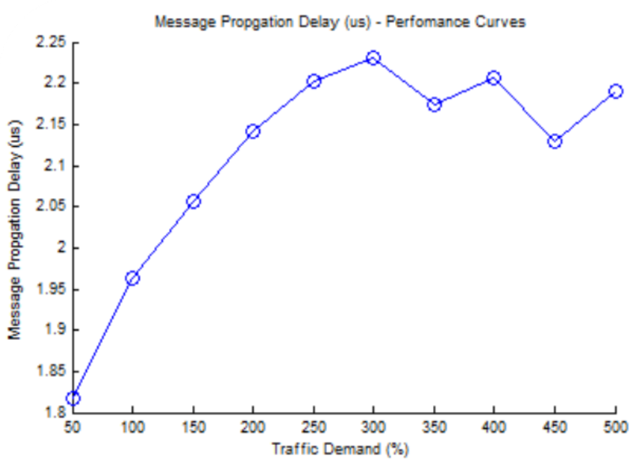

Fig 4.3 12-Node Dual ring with all connected nodes

In above graph delay is increasing as traffic demand is increasing as it should be. The above graph is for fully connected dual ring of 12 nodes. The average delay here is 2.1.

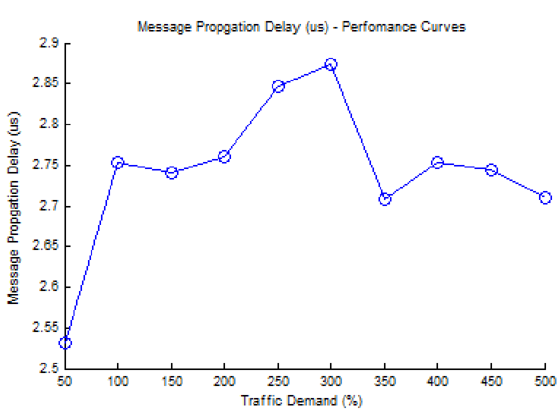

Fig 4.4 12-Node Dual ring with some connected nodes

In the above graph of dual ring of 12 nodes in which only some nodes are connected. The above graph also shows same curve having average delay of 2.4. So it can be depicted from above 2 graphs that both rings perform same in case of same traffic.

1.7.2 No. of used wavelength channels Vs traffic demand %

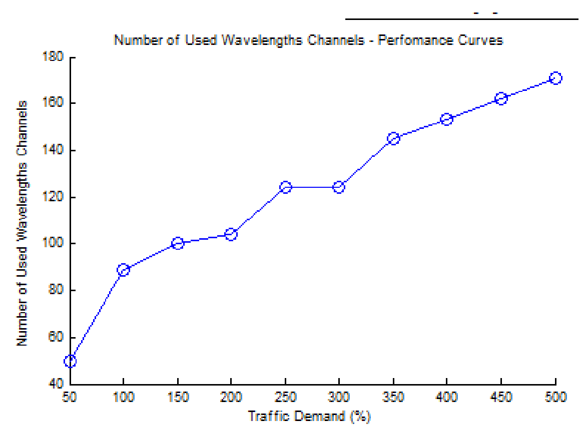

Fig 4.5 12-Node Dual ring with all connected nodes

12 Node Dual ring with all connected nodes no of used wavelength channels has increased as traffic demand increases.

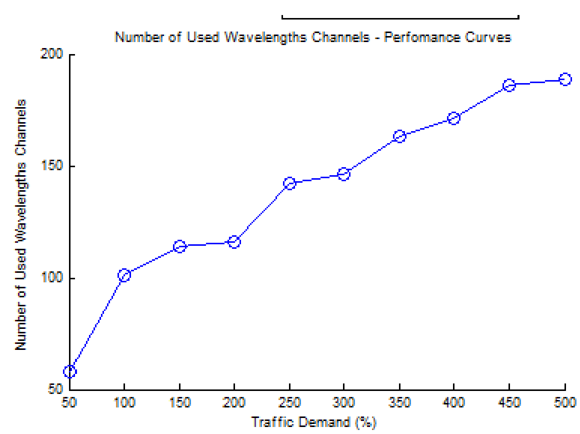

Fig 4.6 12-Node Dual ring with some connected nodes

12 Node Dual ring with some connected nodes no of used wavelength channels has increased as traffic demand increases.

1.7.3 Message propogation delay Vs wavelength channel capacity

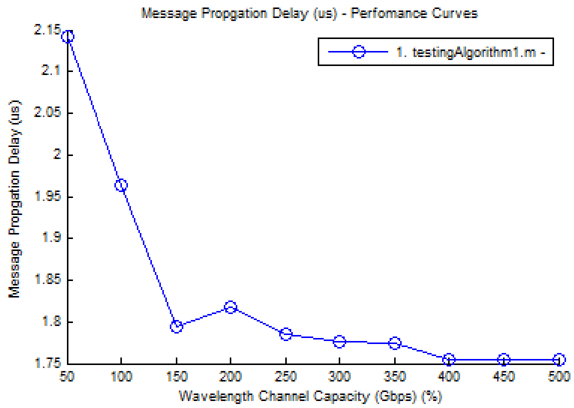

Fig 4.7 12-Node Dual ring with all connected nodes

12 Node Dual ring with all connected nodes message propogation delay is decreasing as wavelength capacity is increased.

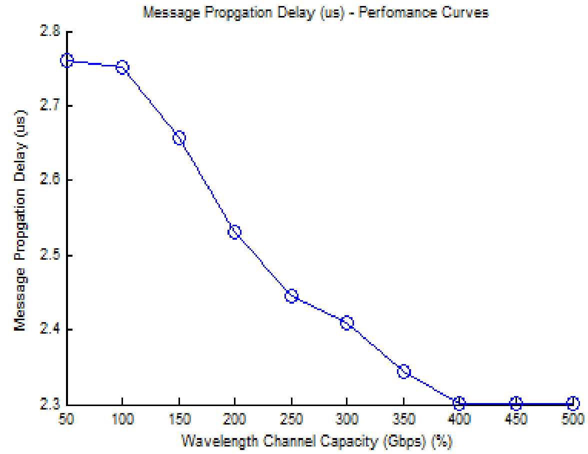

Fig 4.8 12-Node Dual ring with some connected nodes

12 Node Dual ring with some connected nodes message propogation delay is decreasing as wavelength capacity is increased.

1.7.4 No. of lightpaths per fiber links Vs No. of wavelengths per fiber

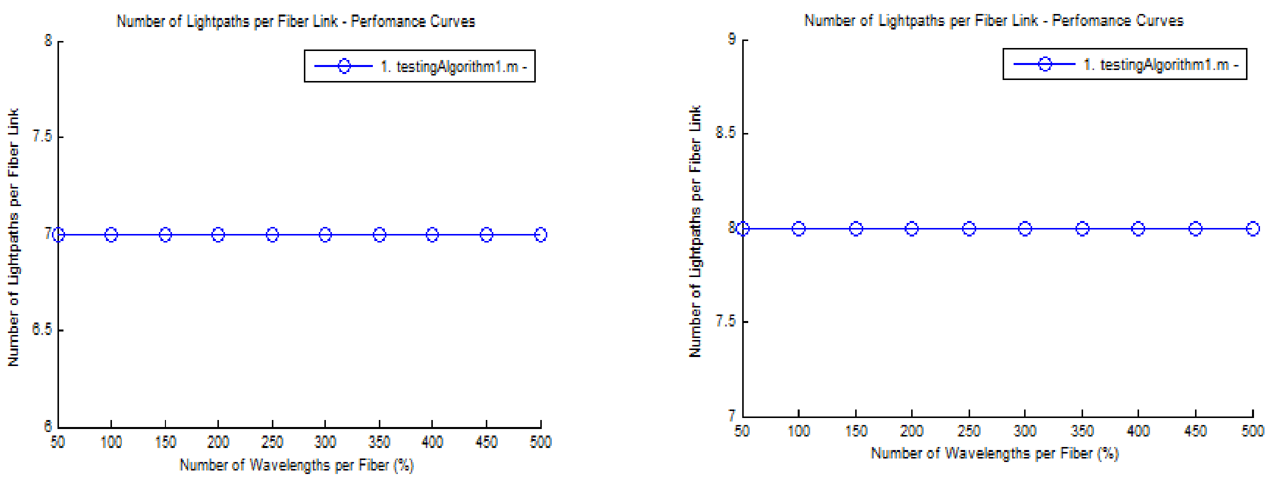

Fig 4.9 12-Node Dual ring with all connected nodes and some connected nodes

V. CONCLUSION AND FUTURE WORK

Recent advances in the field of optical conveyance have opened the way for the practical implementation of WDM nets. After going through several papers it has been observed that for determining Quality of Service the effect of net architecture is not taken into account. So we have proposed 12 Node Dual Ring Topology with fully & partially connected nodes and simulated them with various scenarios to determine the performance matrices, which are called QoS (Quality Of Service) parameters. In this work, the simulation tool MatPlanWDM0.61 has been used to study WDM nets and their performance analysis, which is freely available. It is an excellent framework for designing & development of topology with various features.

During Experiments, it has been found that if there is less number of nodes with high capability, then delay will be more. If number of nodes is more as well as high capability then net congestion will be more. So a minimized output has to be selected so that a better QoS is maintained. Therefore after simulation it has been found out that 12-node dual ring net is the best for present case. It can be generalize that for very high capability nets number of nodes in net should be moderate. In case of link failure, it has been found that the delay will be more after link failure in nets and also the single hop traffic/offered traffic. So for survivability of WDM net, it is important to find the optimal routes through the net in case of link failure to maintain minimum delay and desired traffic. So it assures a good QoS. So after simulation results shows that dual ring is better than other topology, it is very helpful for reduction of fibre link. In future more efficient topologies or improved dual ring topology can be proposed in order to assure the good QoS with limited fibre links.

REFERENCES

[1] Vitthal J. Gond and Aditya Goel, "Performance Evaluation of Algorithms for Wavelength Assignment in optical WDM Networks",*JournalOf Telecommunication*, vol. 2, Issue 1, April 2010.

[2] Y.Chen, C. Qiao and X. Yu, "An Optical Burst Switching: A New Area in Optical Networking Research", IEEE Networks, vol. 18, pp. 16-23, May-June 2004.

[3] Garcıa-Dorado, J. L., JE Lopez de Vergara, and J. Aracil, "Analysis of OBS burst scheduling algorithms with stochastic burst size and offset time." Proc. 10th Conf. Optical Networks Design and Modelling, 2006.

[4] Md. Shamim Reza, Md. Maruf Hossain, Satya Prasad Majumder, "Contention Problem in Optical Burst Switching Network," *2010 International Conference on Computational Intelligence and Communication Networks*, cicn, pp.239-242, 2010.

[5] Yuanyuan Yang, Jianchao Wang, "WDM Optical Switching Networks Using Sparse Crossbars", *IEEE INFOCOM 2004*, vol 3, pp. 1841 – 1852, March 2004.

[6] Rajalakshmi P, Ashok Jhunjhunwala, "Routing Wavelength and Timeslot Reassignment Algorithms for TDM based Optical WDM Networks - Multi rate traffic demands", Networks, ICON '06. 14th IEEE International Conference, 2006.

[7] C.Murthy and M.Gurusamy, "WDM optical networks, concepts, design and algorithms", Prentice Hall, pp.67-69, 85-90, 2001.

[8] JulianadeSanti,AndréC.Drummond,NelsonL.S.daFonseca"Holding-time-aware dynamic traffic grooming algorithms based on multipath routing for WDM optical networks" in Optical Switching and Networking 16(2015)21–35.

[9] Amin Ebrahimzadeh, Akbar Ghaffarpour Rahbar, Behrooz Alizadeh "Request differentiation in dynamic light-path establishment for WDM routed all optical networks of data centers" in Optical Fiber Technology 21 (2015) 73–80.

[10] T.K Ramesh, Sandeep Kumar Konda, Dr. P.R Vaya "Survivable Traffic Grooming RWA Protocol for WDM Networks" in International Conference on Communication Technology and System Design 2011.

[11] S.C. Tan, F.M. Abbou "The effect of Stimulated Raman Scattering (SRS) in Routing and Wavelength Assignment (RWA) in WDM mesh and ring topologies" in Optik 123 (2012) 1934– 1937.

[12] Tongyu Song,Hanyi Zhang, Yili Guo "Statistical study of crosstalk accumulation in WDM optical network using different RWA" in Optics Communications 202 (2002) 131–138.

[13] R. Ramaswami, K.N. Sivarajan, "Optical Networks-A Practical Perspective, Second Edition, Morgan Kaufmann-Publishers An Imprint Of Elsevier, New Delhi, India, 2004.

[14] George N. Rouskas, "Routing and wavelength assignment in optical WDM network" journal, 2007.

[15] D. C. Kilper, R. Bach, D. J. Blumenthal, D. Einstein, T. Landolsi, L. Ostar, M. Preiss, and A. E. Willner, "Optical Performance Monitoring" IEEE, Journal Of Lightwave Technology, vol. 22, no. 1, January 2004.

[16] Vitthal J. Gond and Aditya Goel, "Performance Evaluation of Wavelength Routed Optical Network with Wavelength Conversion", Journal of Telecommunications, Vol 2, Issue 1, April 2010.

[17] Santhosh Kumar C, Piruthiviraj.P , Dr. Preeta Sharan, "Performance Analysis for All- Optical Networks Using Wavelength Routing Methods in Different Topologies", International Journal of Innovative Research in Computer and Communication Engineering, Vol. 2, Issue 5, May 2014.

[18] Chunyong Yang, Shaoping Chen, "Performance analysis of topologies for optical wavelength convertible networks", College of Electronics Information Engineering, South-Central University for Nationalities, Wuhan 430074, China.

[19] Paulo H. G. Bezerra, Afonso J. F. Cardoso, and Carlos R. L. Francês, "Performance Evaluation of Algorithms for Wavelength Assignment in Optical WDM Networks", IJCSNS International Journal of Computer Science and Network Security, Vol.10 No.1, January 2010.

[20] Der-RongDin "Genetic algorithm for virtual topology design on MLR WDM networks" in Optical Switching and Networking18 (2015)20–34.

[21] Ali Norouzi , A.Halim Zaim, Berk Burak Ustundag, "An integrated survey in Optical Networks: Concepts, Components and Problems", IJCSNS International Journal of Computer Science and Network Security, Vol.11 No.1, January 2011.

[22] Santhosh Kumar C, Piruthiviraj.P , Dr. Preeta Sharan, "Performance Analysis for All- Optical Networks Using Wavelength Routing Methods", International Journal of Innovative Research in Computer and Communication Engineering, Vol. 2, Issue 5, May 2014.