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Analysis of Dynamic Traffic Patterns on WDM Optical Networks for Different Topologies Using RWA Algorithm

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Abstract: In this technologically advanced world where capabilities of the communicating devices and transmission media is increasing. Fiber optic cable has played an important role. Itutilizesthis, high capability media of transmission by performing multiplexing. Wavelength Division Multiplexing (WDM) is one such technology used in optical networks. Every single link in optical network has the capability to transmit gigabytes of data. Using WDM, data of multiple users is sent simultaneously through the same link by assigning distinct wavelengths. Such algorithm is referred as Routing and Wavelength Assignment Algorithm (RWA). In this paper, all the optical network topologies are simulated using MATPLAN WDM tool based on MATPLAN. All such topologies are analyzed for different dynamic traffic loads. Comparison between all the topologies is performed on the basis of some governing parameters like message propagation delay, channel utilization, traffic handling capacity and others. It is found that mesh topology is better for high traffic but it is costly due to large number of links. So ring topology is found better in all aspects.

Keywords: Wavelength Division Multiplexing (WDM), Routing and Wavelength Assignment Algorithm (RWA), MATPLAN.

1. INTRODUCTION

With the fastest growing technology where speed has most importance, there is strong need to focus on the backbone which is connecting several networks of computers and other devices. In this era of information technology, technology has already grown up to a considerable mark. Information is utilized by the research scholars in various fields like business intelligence and customer behavior tracking. To provide high speed data transfer and communication,Fiber-optic technology has played a crucial role [1]. Fiber-optic technology has immense capabilities like high bandwidth, low attenuation, low power requirement and reasonable cost [2, 3]. The fiber optic cables capacity can be used to provide full duplex communication and single cable can be shared by many senders and receivers by assigning separate wavelengths with the process of multiplexing. Here, WDM is studied for optical networks. To simulate optical network for different topologies, a simulation tool calledMATPLAN WDM is used [7].

With the help of this tool, physical topology ofoptical network is created and traffic which is to be routed in the network is also simulated using the tool [13]. Primary objective of the study is to analyze different physical topologies in respect of optical network for RWA algorithm.

WDM networks deals with two basic types of topologies:

a. **Physical Topology:** It specifies physical interconnection of nodes in the optical network. In optical network, fibre cables are used to connect nodes. This topology can be Bus, Ring, Mesh and Star depending upon how the network is laid down [4].

b. **Virtual Topology:** It deals with the virtual light paths between the nodes of physical optical network which is used to transferring messagebetween nodes without intermediatebetween electronic processing of message [4].

Virtual Topology Design

Virtual topology design problem can be considered to be composed of four sub problems and these are as follows:

a. Determining appropriate virtual topology inform as that which nodes within the physical network should be optically interconnected.
b. Routing of the lightpaths over the physical topology.
c. Wavelength assignment to the lightpaths in an optimal way. Such that number of assigned wavelengths should be less.
d. Routing the traffic on to the virtual topology rather than physical.

The subproblems b and c denotes RWA algorithm.

2. ROUTING AND WAVELENGTH ASSIGNMENT (RWA)

Optical path between any source and destination is established by selected preferably the shortest path between them and by allocating wavelength. This problem is called Routing and Wavelength assignment problem.RWA is a fundamental problem of all-optical networks, and arises in network designing applications,

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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 network[11]. 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 to handles these steps. Another approach isused to combine these steps so that routing is tied to a particular wavelength. This approach starts by assigning with a particular wavelength and reducing the network topology to only those links on which this wavelength is available[12]. RWA difficult problem can be fragmented into two independent sub-problems, the routing sub-problem and the wavelength assignment sub-problem and each of them can be solved independently.

Routing in RWA –There are various routing approaches based on Routing like fixed routing[14], fixed alternate routing and adaptive routing[15].

Fixed Routing: In fixed routing, connection always established between same fixed routes. This is also known as fixed shortest path routing. A shortest path route between the source and destination pair is always calculated by Dijkstra and Bellman ford's algorithms. This routing approach is very simple but the disadvantage is that, if wavelengths along the path are tied up, it can lead to high blocking probabilities in the dynamic case, or may result in large amount of wavelengths used in the static case[11]. It also, fixed routing unable to handle fault tolerance by which one or more node links in the network fail. To handle with these disadvantages, the routing method must either consider alternative path or must be able to find the route dynamically.

Adaptive routing: It is also known as dynamic routing because the path between the source and destination is chosen dynamically. Adaptive shortest routing is used to find the shortest cost path with the available link load or cost[12]. Adaptive routing dynamically updates the routing tables at each node. An advantage of adaptive routing is lower blocking probability than fixed and fixed-alternate routing

Wavelength Assignment (WA) Problem: It is a sub-problem of Routing and Wavelength assignment problem. In this problem of WA, consider that the light paths are already given and wavelengths should be assigned such that by using minimum number of wavelengths assignment. This problem consists of two types of constraints namely:

Wavelength continuity constraint: Alight path along the path from source to destination must have same wavelength on all the sub links which constitutes the path[12].

Distinct wavelength constraint: All light paths which are using the same link must be allocated distinct wavelengths. That is any twolight paths must be assigned distinct wavelengths on any common link[13].

Three wavelength assignment algorithms are the following:

• **Random-fit algorithm:**This algorithm works on the principle of uniform probability distribution. In th q1is algorithm, for a connection between a source to destination. Set of wavelengths is assigned in which each wavelength is selected randomly from the wavelength set according to principle[9].

• **First-fit algorithm:** In the first-fit, each wavelength is given a unique number. Wavelength is selected to setup a connection according to lowest number. The concept behind the first-fit scheme is to group the usage of the wavelengths that have lower indexes so that high numbered wavelengths can be used in longer paths[9]. This scheme performs better than the random-fit scheme. Due to its simplicity and high performance, this scheme is preferred in practice.

• **Most-used algorithm:** The most-used scheme enhances the idea of the first-fit scheme of packing the usage of wavelengths[8]. In this scheme, all the available wavelengths that can be used most to establish a connection are considered; the wavelength that has been used the most is selected for the connection. The most-used algorithm performs slightly better than the first-fit scheme.

RWA algorithm:

Routing and wavelength assignment algorithm is applied for the given source and destination. The source is the node which wants to transmit data and destination is the node to which data is to be transmitted.

The algorithm is as follows:

```
RWA(Source,destination)
{
   Dijkstra(source, destination);
Wavelength assignment(source,destination,V);
}
```

```
Dijkstra(Source,Destination,V)
{
Dist[Source] ← 0
For all v ϵ V – {S}
   Do dist[v] ← ∞
Source ← φ
Q ←V
While Q ≠ φ
Do u ← min(Q,dist)
 Source ← Source U {u}
 For all v ϵ neighbours[u]
  Do if dist[v] > dist[u] + W(u,v)
    Then d[v] ← d[u] + W(u,v)

Return dist.
}
```

In the Dijkstra algorithm, V is set of all the vertices, Q is the set of the vertices which belongs to the path between the given source and destination. W is the adjacency matrix for the given topology.Dist. matrix will store the shortest distance to all the vertices from the source vertex.

The second phase of the RWA algorithm consists of

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wavelength assignment algorithm which depends on the variant used as discussed.

3. ILLUSTRATING RWA

Consider a network having nodes A,B,C, D,E AND F. let's consider that A wants to send message to F and at the same time C wants to send message to E.

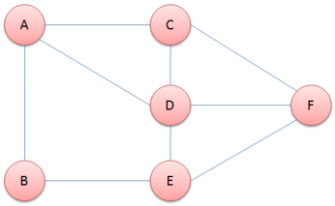

Fig 1: Hybrid network topology for illustrating RWA.

And let's consider routes selected by the Routing algorithm are as shown below.

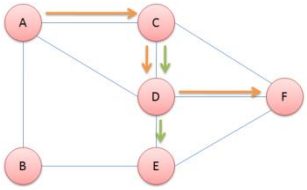

Fig 2: Data path from A to F in orange and C to E in green.

Now as one edge in these paths is common that is C-D. This condition is called conflict. This conflict can be resolved using two approaches.

a. Alternate selection of Path using Routing algorithm: According to this approach, different path can be selected between source and destination. So that conflict is not there.

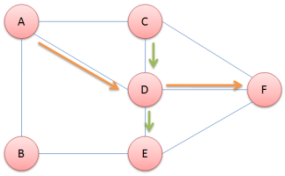

Fig 3: Alternate path for A to F to remove conflict.

Using different path will make both paths having no edge in common. So, same wavelengths can be used for communication.

b. Distinct wavelength for all edges in common: If routing can't resolve common edge problem. Then only solution is to use distinct wavelengths for such edges.

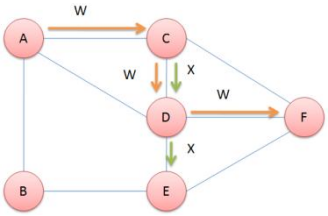

Fig 4: Wavelength assignment for light paths from A to F and C to E.

This RWA problem is NP-Hard problem and thus many heuristic algorithms are also applied. But the objective of this paper is to analyze the topologies for different traffic.

4. LITERATURE SURVEY

In [1], performance analysis of RWA algorithm is done for different topologies so that we can use topologies for specific application. Existing research demonstrated that Routing and Wavelength Assignment (RWA) algorithm and wavelength conversion are two primary parts for improving the blocking performance which are analyzed in this paper. In [2], it 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. The objective of this experiment was to simulate the performance of wavelength allocation algorithms with different aspects: throughput and blocking probability.
In [3], they have conducted a broad comparison of a state–of– the–art WDM ring network with a state–of–the–art WDM star network. With respect to node structure, ring networks come in different formats.
In [4],it sorts out the problem of Routing and Wavelength Assignment (RWA) in optical networks by 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.

5. COMPARATIVE ANALYSIS AND RESULTS

What –If Analysis -
In what if analysis we have analysed our topologies in interns of following parameters:

- Carried / offered traffic v/s Traffic demand.
- Message propagation delay v/s. Traffic demand %.
- No. of used wavelength channels v/s. Traffic demand %.
- No. of used wavelength channels v/s. Wavelength channel capacity.
- No. of light paths per fibre links Vs. No. of wavelengths per fibre.

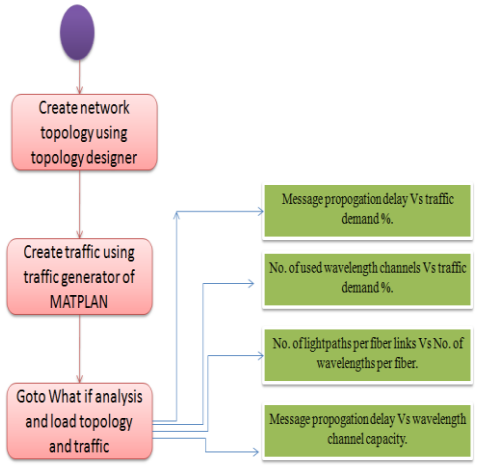

Fig 5: Figure showing flow chart of WDM topology analysis.

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Analysis of optical WDM topologies in terms of above parameters :

Carried / offered traffic Vs Traffic demand

This analysis is done in order to check the traffic handling capacity of the network topologies. For a given network topology with fixed bandwidth and available wavelengths as the traffic demand increases packets are dropped and some data loss occurs. So this analysis is important to check for a given bandwidth how different network topologies behave for different traffic demand. So higher the curve of the topology the better it handles the network traffic. From the graph shown below it is clear that Mesh topology handles the traffic better than other topologies.

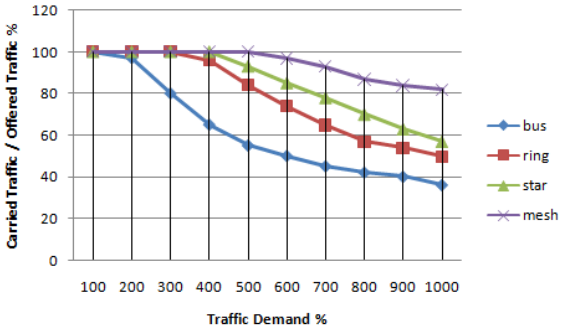

Fig 6: Carried / offered traffic v/s Traffic demand

Message propagation delay v/s Traffic demand %

This analysis is done to check some of the problems that come with the merits of topologies. Like in start topology initialization and scalability are merits but whole network traffic passes through the central connecting device. So it creates a bottleneck and results are poor for star topology. While for bus they are good as whole traffic is through a single cable which efficiently takes advantages of multiplexing and optical fibre cable capacity.

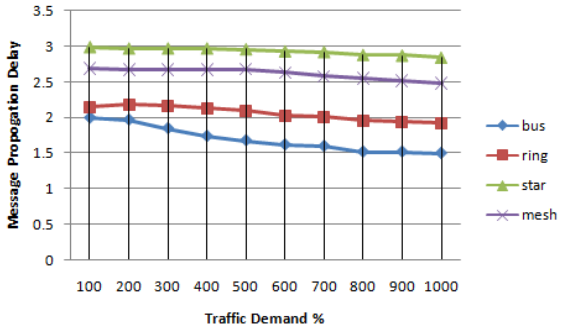

Fig 7:Message propagation delay v/s traffic demand %
No. of used wavelength channels v/s traffic demand %

From this analysis it is concluded that variable nature is shown by every topology which depends on the traffic demand. No. of used wavelength channels should be less according to RWA. So Star topology is the one in which no of used channel are minimum of all. In star topology, common links are less as compared to other topology. On an average in bus topology number of used wavelength channels is more.

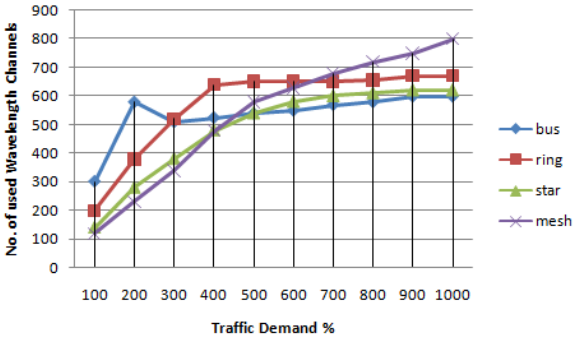

Fig 8: No. of used wavelength channels v/s traffic demand %

No. of used wavelength channels v/s Wavelength channel capacity

As the, wavelength channel capacity increases no. of used wavelength channels will decrease as more bandwidth will be available. But in bus topology it will be more. Which is similar to what is concluded from previous graph? Mesh topology is better in this scenario.

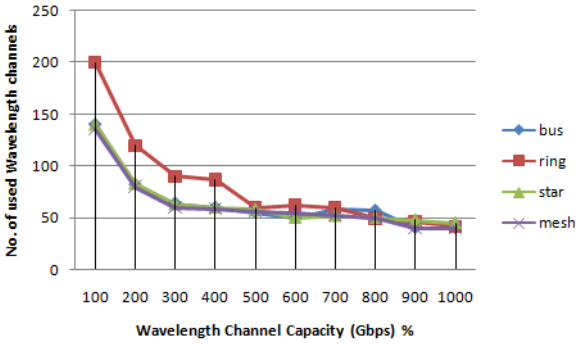

Fig 9: No. of used wavelength channels Vs. Wavelength channel capacity.

No. of light paths per fibre links Vs. No. of wavelengths per fibre

It is clear from the analysis that for all topologies no. of lightpaths per fibre link are independent of no. of wavelengths per fibre. But it is highest for bus topology as single cable is shared among all the nodes.

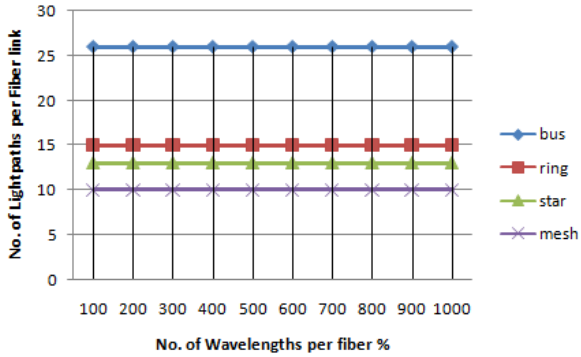

Fig 10:No. of light paths per fibre links v/s. No. of wavelengths per fibre.

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SUMMARIZATION OF RESULTS

Analysis	Bus	Ring	Star	Mesh	Final Comment
Carried / offered traffic v/s Traffic demand	4	3	2	1	Mesh topology has the best traffic handling capacity in comparison of all.
Message propagation delay Vs. traffic demand %.	1	2	4	3	Bus topology has the minimum propagation delay as single backbone network is there. No routing overhead.
No. of used wavelength channels v/s. traffic demand %.	4	3	1	2	No. of wavelength channels used should be less which is minimum in star topology.
No. of used wavelength channels Vs. Wavelength channel capacity.	3	4	2	1	Same as previous.
No. of light paths per fibre links Vs. No. of wavelengths per fibre.	4	3	2	1	Same as previous.

6. CONCLUSION

In this paper different WDM topologies are studied using MATPLAN WDM tool. These network topologies are studied for different network traffics. It is found that mesh topology is better than other topologies for heavy traffic and if traffic is low or moderate then ring topology is better. Ring topology outperforms all other topology except mesh topology. But ring topology is cost efficient than mesh topology.

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