SURVEY REPORT

Course: 60-510 Literature Review and Survey Survey Title:

Survey on Design/Reconfiguration of Logical Topology of WDM Networks using Tabu Search

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Contents

Abstract In the past few years there has been growing interest in wide area "all Optical Networks" with wavelength division multiplexing (WDM) , using wavelength routing. Due to the huge bandwidth inherent in optical fiber, and the use of WDM to match user and network bandwidths, the wavelength routing architecture is an attractive candidate for future backbone transport networks. The huge capacity of bandwidth of optical carrier and Wavelength division multiplexing (WDM) technology has emerged as a promising technology for backbone networks. The optical layer based on WDM technology provides optical routing services to the upper layers such as the packet switching layer and the time-division multiplexing layer over the generalized multi-protocol label switching paradigm. The set of all optical communication channels in the optical layer defines the logical topology for the upper layer applications. Since the traffic demand of upper layer application fluctuates from time to time is is required to reconfigure the underlying logical topology in optical layer accordingly. The focus on this survey is to review and study of the past and recent paper on the issue of logical topology or virtual topology design and reconfiguration in WDM networks using different methodologies. But my focus on the methodology of reconfiguration of logical topology using tabu search. I have presented this literature as a table where each paper has been classified as their model, method, algorithm and policy they have employed in designing or reconfiguration of logical topology in WDM networks.

1 Introduction

In this survey,we have studied and reviewed the literature on the main research problem which is reconfiguration of logical topology in WDM optical network. First of all, about this survey is to find resource paper for the topic on "Reconfiguration of logical topology in WDM Optical Network". There are many deferent techniques for reconfiguration of logical topology but my concern is specially using Tabu search. I have also discussed a brief introduction of Tabu Search in later section for the reader to have quick understanding the concept.for detailed reader should go (F. Glover, Tabu search-Part I 1989) and (F. Glover, Tabu search-Part II 1990).Ther reader can have a basic understanding of the procedure that may permit its principles to be applied more easily to the solution of hard problems, and to give a glimpse of additional developments that lie ahead.I have used the following searching resources:

- Google Scholars
- University Library
- IEEE Xplore
- ACM Digital Library

There are 20 main papers, 5 of them are directly about Tabu Search and 15 of them about reconfigurations of logical topology and related subject masters.By reading this survey, the researchers specially those who are interested to research on "Reconfiguration of Logical Topology of WDM networks" will gain great deal of benefits to find papers from references and annotations.

1.1 Structure of the survey

I have organized this survey as Background Study in section 2,Categories of Reconfiguration of Logical Topology in section 3, using Tabu Search in section 4, and conclusion at the end.

2 Background Study

In general, virtual topology design problems can be formulated as optimization problems aimed at maximizing network throughput or other performance measure of interest . Typically the exact solution can be easily shown to NP -hard, and heuristic approaches are needed to find realistic good solutions. The routing of packet traffic on the lightpaths is also usually seen to be a part of the virtual topology problem. For this purpose, the problem can be decomposed into four subproblems.

a. The first is to decide what virtual topology to embed on a given physical topology.

b. What are the lightpaths to be implemented.

c. Routing of these lightplaths on the physical topology.

In this section We have discussed few key terminology and their definitions related to optical networking.

2.1 Context

There has been tremendous amount of discussion and reading, article of regarding on this topics. Internet technology using computer network growing rapidly. Using copper wire as a medium for networking has been useful for local area network. The optical fiber has property of very high bandwidth, makes these network attractive for backbone transport network. Now there has been growing interest in wide area optical network using wave length routing because demand of high speed network has been increasing drastically. The technique of optical networking using WDM is the perfect technology for the increasing demand. In this summary, There is brief description on the contest and motivation of the *Logical (virtual)* *topology design and formulation problem.* There will be also describe and compare the *formulations and theoretical results as well as algorithms. The reconfigurability issue*, which is another attractive characteristic of optical networks,is also discussed and the literature surveyed. Re-arrange ability is up-and-coming as a key element of today's lightwave networks, providing the ability to dynamically reconfigure the network for changing traffic conditions. Also reconfiguration need when there is network equipment failure(*This part will be not included in this survey*). One of most powerful and promising feature of optical networks is their ability to be dynamically reconfigured. This ability can be optimized, in other words increase network utilization while providing better network performance by adapting the bandwidth allocation to changing traffic loads. Reconfiguring the logical connectivity of the network is the promising feature that will operate optical network with high utilization and improved prformances.There is in depth study regarding reconfiguration issue in [1]. The main objective was to investigate three open issues:

- First: How frequently to reconfigure the network.
- second: How to structure the reconfiguration phase.
- Third: How to quantify the benefits of reconfiguration to the network in terms of measurable performance parameters.

2.2 Terminology

WDM: The technology of using multiple optical signals on the same fiber is called *wavelength division multiplexing (WDM).*

Physical Topology: A graph $G_p(V, E_P$ in which each node in the network is a vertex, and each fiber optic link between two nodes is an arc. Each fiber link is also called a *physical link*, or sometimes just a link.The graph is usually assumed to be undirected, because each fiber link is assumed to be bidirectional. There is a weight associated with each of the arcs which is usually the fiber distance or propagation delay over the corresponding fiber. An optical network is shown in Fig 2.1, where a circle represents an end-node, a rectangle represents a router node and a directed line represents a fiber. These fibers are unidirectional and the arrow on the line gives the direction in which optical signals can flow. Such a diagram is called a *physical topology*

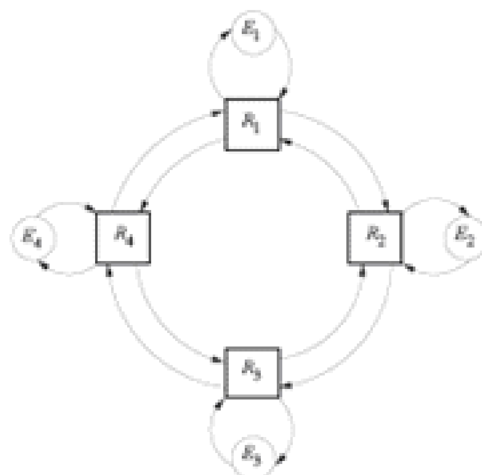

Fig 2.1: The physical topology of a typical WDM network with four end-nodes E1—E4 and four routers R1—R4.(S. Bandyopadhyay, 07. page 4.)

A *lightpath* is an optical connection from one end-node to another, that is used to carry data in the form of encoded optical signals. It is a clear optical channel between two nodes. That is, traffic on a lightpath does not get converted into electronic forms at any intermediate nodes, but remains and is routed an optical signal throughout . With the usual wavelength continuity constraint, the lightpath becomes sequence of physical links forming a path from source to destination, along with a single wavelenght which is set aside on each of these links for this lightpath.

Lightpath:

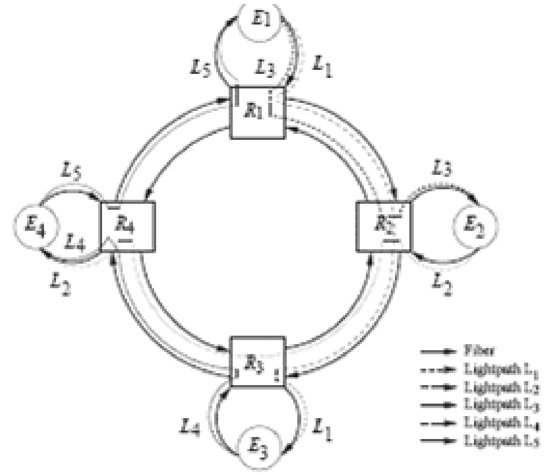

Fig 2.2: lightpath on Physical Topology.(S. Bandyopadhyay, 07. page 4.)

Virtual Topology: A graph $G_p(V, E_v$ in which the set of nodes is the same as that of the physical topology graph, and each lightpath is an arc. It is also called the *logical topology* , and the lightpaths are also called *logical Links*. Usually this graph is assumed to be directed, since a lightpath may exist from node A to node B while there is none from node B to node A. this graph is also weighted,with the $lightpathdistance$ of each lightpath acting as the weight of the corresponding arc.

Static lightpath allocation: *Static lightpath allocation* is a set up a lightpaths on a semi-permanent basis so that, once the lightpaths are set up to handle the expected volume of data between the ordered pairs of endnodes, the lightpaths will continue to exist for a relatively long period of time (weeks or months). This approach is called static lightpath allocation.

Dynamic lightpath allocation: *Dynamic lightpath allocation*: When the communication pattern changes sufficiently, the existing lightpaths will be taken down and new lightpaths will be set up to handle the changes in traffic. In the second approach, called dynamic lightpath allocation, lightpaths are set up on demand and, when a communication is over, the corresponding lightpath is taken down (i.e., the lightpath no longer remains operational).

Wavelength Routed Network: *Wavelength Routed Network*: In a wavelength routed network, the wavelength of the optical signal and the fiber it is using determines the subsequent path used (hence the name wavelength routed) by the signal. Since each optical signal is sent along a specified path and not broadcast to all nodes in the network, the power requirement of such a network is lower than that of a broadcast and select network. This type of network may contain a large number of end-nodes but are more complex and expensive than a broadcast and select network.

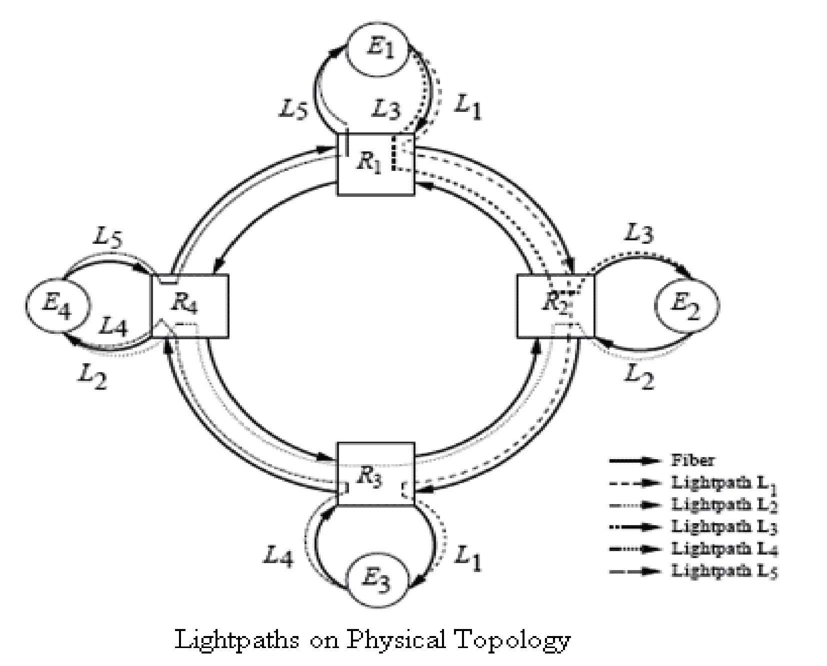

Fig 2.3: Wavelength Routed Network.(S. Bandyopadhyay, 07. page 5.)

The network shown in Fig 2.3 is a wavelength routed network since the end-nodes communicate using lightpaths which are routed from their sources to their respective destinations based on their wavelengths. For instance, the routers R1;R2 or R3 have been set up in such a way that, when signals using the wavelength of lightpath L1 is received by router nodes R1;R2 or R3, it is sent forward to router node R2, router node R3 and to end-node E3 respectively. The same is true for all the lightpaths in this network.

Broadcast and Select Network: In a *$BroadcastandSelectNetwork$* for unicast communication, the source end-node selects an appropriate wavelength Δp and broadcasts the data to be transmitted to all end-nodes in the network using the wavelength Δp. The receiver at the destination end-node must be tuned to the same wavelength Δp while the receivers at all other end-nodes are tuned to wavelengths different from Δp. The net result is that the data is detected and processed only at the destination node. A typical broadcast and select network is shown in Figure. In this figure, each end-node has one transmitter and one receiver

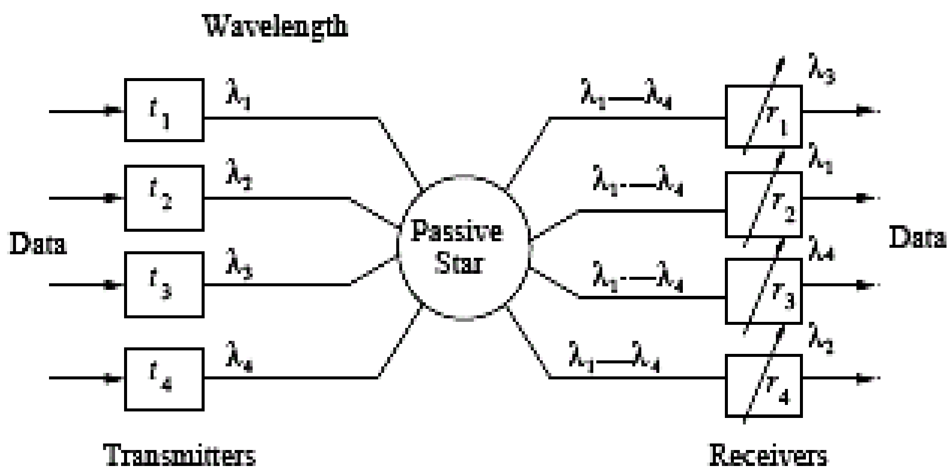

Fig 2.4: Broadcast and Select Network.(S. Bandyopadhyay, 07. page 8.)

Link Indicator: Whether a physical link exists in the physical topology from a node l to another node m, denoted by Pl_m which is 1 if a link exists in the physical topology and 0 if not.

Lightpath Indicator: Whether a lightpath exists from a node i to another node j , denoted by b_{ij} which is 1 if such a lightpath exists in the virtual topology and 0 if not.

Lightpath Distance: The propagation delay over a lightpath , denoted by d_{ij} for the lightpath from node i to node j. It is the sum of the propagation delays over the physical linked which make up the lightpath in the virtual topology.

Physical Degree: The physical degree of anode is the mumber of physical links that directly connect that node to other nodes.

Virtual Degree: The Virtual (Logical) degree of a node is the number of lightpaths connecting that node to other nodes. The number of lightpaths originating and terminating at a node may be different, and we denote them by $virtualout - degree$ and $virtualin - degree$ respectively. We speak simply of the virtual degree if these are assumed to be equal, as they often are. If this degree is assumed to be same for all nodes of the network, then this is called the virtual degree of the netowrk.The virtual degree is determined in part by the physical degree, but is also affected by the consideration of what volume of electronic switching can be done at a node.

Physical Hop: The number of physical links that make up a lightpath is called the physical hop length of the lightpath.

Logical Hops: The number of lightpaths a given traffic packet has to traverse, in order to reach from source to destination node over a particular virtual topology, is called the virtual or logical hop length of the path from that source to that destination in that virtual topology.

Traffic Matrix: A matrix which specified the average traffic between every pair of nodes is the physical topology .If there are N nodes in the network, the traffic matrix is an

N x N matrix $\Lambda = [\lambda^{(sd)}]$, where $\lambda^{(sd)}$ is the average traffic from node s to node d in some suitable units, such as arriving packets per second , or a quantized bandwidth requirement. This matrix provides in numerical terms the nature of how the total network traffic is distributed between different source-destination node pairs. that is , the pattern of the network traffic.

Virtual Traffic Load: When a virtual topology is established on a physical topology, the traffic from each source node to destination node must be routed over some lightpath. The aggregate traffic resulting over a lightpath is the the load offered to that logical link. If a lightpath exists from node i to node j , the load offered to that lightpath is denoted by λ_{ij}. The component of this load due to traffic from source node s to destination node d is denoted by $\lambda_{ij}^{(sd)}$. The maximum of the logical loads is called the congestion , and denoted by $\lambda_{max} = max_{i,j}\lambda_{ij}$.

2.3 What is Network Reconfiguration

The motivation of logical topology design is to optimize the network performance, improving the congestion, delays and throughput metrics. And the network can dynamically change its logical topology corresponding to the changing traffic conditions. It is called as logical topology reconfiguration.This is one of the key feature of multiwavelength optical network, that is the ability to dynamically optimize the network for changing traffic patterns. The general approach to the logical topology reconfiguration problem has been a two-phase operation: first phase being a logical topology design for the new traffic conditions and second phase being a transition period from the old logical topology to the newly designed one, it should achieve the minimal traffic disruption.

2.3.1 *Reconfigurability Considerations*

Reconfiguration might take place in different time scales such as infrequently as traffic pattern slowly changes over time, dynamically upon new call arrives or continuously as the connectivity adapts to bursts of packets starting and terminating. Its involves retuning of transmitters and receivers.The problem of reconfiguring a network from one virtual topology to another is a related problem to virtual topology design. Two possible approaches to this problem are discussed in this section.

***Cost Approach*:** In this approach, it is assumed that the current virtual topology as well as the new virtual topology that the network must be reconfigured to is known, together with the physical topology details. The cost can be expressed in terms of the number of wavelength routers that need to have their optical switching reprogrammed, or the total number of optical light paths and eliminate old ones. These metrics are appropriate since they reflect the amount of time the network must be taken off line to make the changes, as wells as the reprogramming effort for the reconfiguration. Other similar metrics may also be applicable. It may be the case that the network cannot be taken off line at all but that a succession of intermediate virtual topologies have to be designed to eliminate single, or groups of, routers that can be reconfigured and put back in operation. Much more complicated metrics reflecting total time taken to reconfigure as well as the effort to redesign the intermediate topologies need to be developed in this case.

Optimization Approach:Another approach is to assume that only the current virtual topology is given, together with the changed traffic pattern and/or physical topology that make reconfiguration necessary. This is the approach taken in (Banerjee 1996). The reconfiguration algorithm proposed in (Banerjee 1996) involves solving the new virtual topology problem on its own without reference to the current virtual topology to obtain a new optimal solution with a new optimal value for the objective function that is noted. The virtual topology design problem is then reformulated with an additional constraint that constrains the old objective function to this noted value,and a new objective function that involves minimizing the number of light paths that mist be either added or removed.

While this method is guaranteed to find a solution that result in a virtual topology that optimal for the new condition, it does not achieve a balance between finding an optimal new virtual topology and one that involves a little change from the old one as possible. It is possible that a very costly reconfiguration will be under taken for only a slight gain in network performance. More balanced formulations of this problem may be possible, and heuristics designed on such formulations are likely to perform better in practice.

2.4 What is Tabu Search ?

With roots going back to the late 1960's and early 1970's, Tabu Search was proposed in its present form a few years ago by (Glover,1986), and has now become an established optimization approach that is rapidly spreading to many new fields. The basic ideas of Tabu Search have also been sketched by (Hansen,1986). Together with simulated annealing and genetic algorithms, Tabu Search has been singled out by the (Committee on the Next Decade of Operations Research 1988)as "extremely promising" for the future treatment of practical applications.

Tabu Search is a general heuristic procedure for guiding search to obtain good solutions in complex solution spaces. Its rules are sufficiently broad that it is often used to direct the operations of other heuristic procedures.One of the main components of TS is its use of flexible (adaptive) memory,which plays an essential role in the search process. Discoveries of more refined ways to exploit this memory, and of more effective ways to apply it to special problem settings, provide one of the key research thrusts of the discipline and account for its growing success in treating hard problems.One of the useful aspects of tabu search is the ability to adapt a rudimentary prototype implementation to encompass additional model elements, such as new types of constraints and objective functions. Similarly, the method itself can be evolved to varying levels of sophistication.

It would be viewed that the optimal topology design problem as a search problem. Since the search space, consisting of all possible logical topologies of a given WDM network is vast, a Tabu Search technique has been used to limit the time needed to find candidate logical topologies. As an initial point of departure, the TS may construct with a simple descent method, which may be formulated as follows:

(a) Choose an initial solution s in X
s* := s and k := 1

(b) While the stopping condition is not met do

k:=k+ l

Generate V* $\subseteq$ N(s, k)

Choose the best s' in V*

s := s'

if f(s') ¡ f(s*), then s* := s'

end while

3 Summary of Research: Reconfiguration of Logical topology

In this section I have discussed the main problem the authors mentioned and comments on them. I have put them as a table and categorized.

3.1 Static Traffic Control and Transitional Approach

Table 1.0		
Papers	**Brief Description**	**Comments**
Din, D (2007)	Described the logical topology configuration transition problem which minimize the average weighted hop distance. Their main goal is to find an optimal transition sequence (from current to new)such the objective cost can be minimized. The objective cost considered in this paper is the average weighted hop distance.	The authors referred [Murata, 2005] where they worked on developing heuristic algorithm but the authors claimed that Genetic Algorithm can get better performance then heuristic. In this paper the static traffic demand is studied.Their claim is that the algorithm in more accurate than the one proposed in [Y. Zhang et al 2005].
H. Takagi, Y. Zhang, X. Jia and Hid. Takagi(2006)	The authors developed heuristics for reconfiguration of logical topology focused on wide area WDM optical network considering less disruption at transition phase.	The authors claimed that the previous work (D. Bansiec and B. Mukhejsp 2000), (B. Ramamunhy and A. Ramkishnan,2000) did not mention about disruption at the moment of transition phase from old one to new one. And also worked on local area network. Keeping that in mind they have developed new hueristic that is better then MILP design.

Table 1.0 cont...		
Papers	**Brief Description**	**Comments**
Murata,M. Zhang, H. and Ji, Y.(2005)	They have demonstrate by providing three different heuristic algorithm and compare with existing NSFNET network and showed that their algorithm provide better performance that is less disruption when there is a transition needed for the design of logical topology to the network	The authors did not referred this work to previous works but an extensive math calculation has been done to established their logic. However, the authors mentioned that the traffic demand of upper layers is not taken into account like previous(H.Takagi, et al, 2002 and G.S.K Reddy et al June 2000)
Xu,S. Sezaki, K., Tanaka, Y. (2002)	In this paper the authors also took minimum transition approach which gives less disruption in the phase of transition of one logical topology to another.	They claimed that their algorithm gives closer results instead of optimal one under certain degree of performance loss. Their heuristic algorithm is reference model of [D. Banejee and B. Mukherjee,2000,this algorithm is the improved MILP.

3.2 Dynamic Traffic Control Approach

Table 2.0		
Papers	**Brief Description**	**Comments**
Tak,S. et al (2005)	Discussed about reconfiguration process framework when traffic changed very often. They have also formulated an algorithm called Pareto Evolutionary algorithm that optimize two objective function using Pareto optimality.	Considered two objective in their reconfiguration framework, • Process • Policy They have claimed that their algorithm yields efficient performance in the process of entire reconfiguration process
Gencata, A., Mukherjee, B.(2003)	Studied the problem of reconfiguration of virtual topology under dynamic traffic changes in WDM mesh networks.Load on the lightpaths is constantly monitored and the decision to delete a lightpath is taken if its load decreases below a lower limit. It load increases above an upper limit on ta lightpath, new lightpaths are setup to reduce its load.	They have claimed that their approach is a new as comparing to others as static traffic designing approach.The tradeoff is provided by taking a window of allowable load on the lightpaths.
Arakawa, S., Murata, M (2002).	Discussed about the designing logical topology when traffics are dynamic, that is incremental traffic change. They have used dedicated Lightpath Management Node (LMN)for managing the node.	They have claimed that they introduced new approach to manage the logical topology by their study, which is reconfiguring backup lightpath first. There is main constrain in their algorithm is to measure traffic continuously.

Table 2.0 con't...		
Papers	**Brief Description**	**Comments**
Rouskas, G.N., and Ammar, M.H. (2002)	Disruption caused by virtual topology reconfiguration has been defined as the total number of lightpaths being added and removed during reconfiguration.Loss of packets due to incorrect routing is also defined as reconfiguration cost.	Though this type of model effectively compares the reconfiguration cost in migrating to two different virtual topologies, it fails to differentiate between the schemes that do the reconfiguration from a given virtual topology to a given target virtual topology.Science nodes recognize the new virtual topology only after the routing table entries have been updated, packets may be lost by the nodes until their routing table entries updated; this is also an issue.
Ricciato, S. Salsano, S. and Listanti, M.(2002)	An MILP formulation for the design of a virtual topology with the objective of minimizing a complex resource utilization is given.	But the problem is the sequence of traffic matrices which is to occur is he future has to be known in priori.
Wei, J.Y.(2002)	An integrated traffic engineering approach for IP over WDM networks is resented in which the IP layer attempts to delay reconfiguration by balancing the load among different possible routes between a router pair in the virtual topology.	This is effective in preventing traffic disruption due to small changes in the traffic demand and so, virtual topology reconfiguration is triggered only when the min-cul capacity of the virtual topology saturates.

Table 2.0 con't...		
Papers	**Brief Description**	**Comments**
Banerjee, D. and Mukherjee, B. (2000).	An MILP formulation for the target virtual topology best suited to the changed traffic matrix and achievable by minimal disruption to the existing virtual topology in presented.	However, in this formulation, there is no tradeoff between resource utilization and traffic disruption.
Banerjee,D.and Mukherjee,B. (2000)	Study in this paper mainly focuses on the design of optimal logical topologies, for which an exact integer linear programming formulation is presented. For the reconfiguration problem, authors propose a methodology to obtain the new logical topology, based on optimizing a given objective functions, and minimizing the changes required to obtain the new logical topology from the current logical topology.	There are some limitation in this paper and a modification to the reconfguration algorithm in [B. Ramamurthy and A. Ramakrishnan,2000) is proposed, to include the trade-offs between the amount of reconfiguration steps and the ohjective that is to be optimized. Because The reconfiguration algorithm searches all possible optimal logical topology corresponding to the certain traffic, and finds the closest one, extensive search degrade the performace
Tam, A.N. and modiano, E.(2000)	3 branch-exchange is proposed that makes a small change to the current virtual topology.In Baldine, I(1998) proposed flexible approach to balance the load on the network and reduce the disruption to the traffic.	Hence, it limits the disruption.But when to trigger the reconfiguration is not addressed.

3.3 Performance Base Design Approach

Table 3.0

Papers	Brief Description	Comments
Sinha, S. Rammohan, N. and Murthy, C.(2005)	The authors presents a simple and flexible framework to evaluate the gain achieved by reconfiguration based on two conflicting objectives of increasing throughput and reducing disruption.	The work has been done in this study is a very good resource for those who want to study reconfiguration of logical topology on dynamic traffic changes. The authors referred previous work on this issue but he claimed that there is no tradeoff between cost and performance. On that regards, authors worked on grooming on weblength.
Zheng, J., Zhou, B., Moufra, H. (2004)	Discussed and proposed heuristics t dynamically reconfigure the lightpaths, established over and underlying WEM optical network to support a VPN service in response to changing VPN traffic.	Their algorithm based on Genetic Algorithm and claimed by simulation results that, it could significantoy inceased the network throughput and is effective in achieving the optimization objectives in the virtual topology design and reconfiguration of VPNs over all-optical WDM networks.
Liu, K. et al (2002)	In this study the authors has sated-up a test bed to prove that the performance of WDM network is efficient with their algorithm	They have done extensive work keeping in main tasks are traffic monitoring, analysis and aggregation, bandwidth prediction, reconfiguration trigger, topology design and topology migration. This work is a milestone their work has been approved by DARPA.

3.4 General Discussion on Reconfiguration & Linear heuristic formulation

Table 4.0

Papers	**Brief Description**	**Comments**
Baldine, I. and Rouskas, G. (2001)	Studied on the issues arising in the reconfiguration of logical topology designing. For example, how frequently to reconfigure the network, how to structure the reconfiguration phase and how to quantify the benefits of reconfiguration to the network in terms of measurable performance parameters.	In overall, their algorithm demonstrated that with the slow tunable devices, it is possible to build traffic-adaptive high performance multiwavelength networks cost-effectively by simultaneously re-tuned the receivers and transmitters.Though it will disrupt the major protion of the network. A tradeoff between the portion of the network disrupted and the reconfiguration time is given
Ramamurthy, B and Ramakrishnan, A.(2000)	Discussed about developing a linear heuristic algorithm for designing virtual logical topology using reconfiguration procedure. Their algorithm based on less disruption in the WDM network at the time of transition of topology from one phase to another.	The have claimed that their approach is difference from the previous (D. Banerjee and B. Mukherjee 1997) which is less re-tuning, that is less reconfiguration required when traffic changed dynamically.
Labourdette, J.F.P., Hart, G.W. and Acampura, A.S. (1994)	Virtual Topology Reconfiguration is done by finding out the sequence of destination or source exchanges of two lightpaths called branch-exchange in the current virtual topology to migrate to the target virtual topology	However, the sequential scheme has a long transition period and hence , resources are inefficiently utilized for a long duration.

4 Tabu Search in Reconfiguration

In this tabular format of tabu search, I have described several papers regarding for designing logical topology using tabu search methodology. I have described in previous section that why tabu search in designing logical topology. Though it is redundant to mention that this algorithm is widely used in practice since it usually provides a solution close to the optimal one. Furthermore, it allows to tackle combinatorial optimization problems of realistic size.

4.1 Utilizing short temp memory

Table 5.0		
Papers	**Brief Description**	**Comments**
Lee, G., sugang, X., Tanaka, Y.(2006)	In this paper the authors worked on finding better algorithm for designing logical topology for WDM network by applying Tabu search algorithm	The authors referred their previous researches [S. Xu et al 2004. Because in Simulation Annealing, there is no memory search that could not guarantee for revisit of neighborhood.
Kuri, J., et al(2002)	Discussed on developing routing algorithm that minimized the utilizations of number of channel in physical link in WDM network on a *specific time*. Since they have found that this is a combinatorial problem, they used tabu search meta heuristics to solve the problem.	Claimed that they found optimal solution in terms of shortest path routing strategy which branch and bound algorithm is used. They have mentioned that it could be used for large size of networks.
Kuri, J., Puech, N. and Gagnaire, M.(2002)	Defined the logical topology design problem considering implementation cost, one of them is, small congestion with large number of lightpath, other one is less expensive topology with higher congestion.	They have claimed that their solution is closed to optimal considering implementation cost which Kuri at el (2002) did not mentioned. They also claimed that their solution is better than MILP based solution which can not deal with large number of nodes.
Achan, K.(2000)	Main purpose of this paper is to provide basic framework for how to apply Tabu Search in designing Logical Topology.	This thesis paper is very good resource for those who want to apply tabu search method for designing Logical Topology.Authors applied short temp memory for searching neighborhood, more features of tabu search can be applied for better results.

4.2 Diversification and Intensify Approach

Table 6.0

Papers	Brief Description	Comments
Boljuncic, B., Skorin-Kapov, D. and Skorin-Kapov, J,(2004)	In this paper the authors implemented the most important mechanism of Tabu Search which is diversification and intensify search.	Using of long term memory in tabu search, their algorithm performed better then previous (Skorin-Kapov, Labourdette,1995), where utilized short term memory approach of tabu search. Defined the problem as minimizing congestion and total flow using tabu search algorithm. The authors used long temp memory search mechanism of Tabu search. They claimed that using tabu search the results increased around 3.66% of previous experiments (Skorin-Kapov, Labourdette,1995)by modify the algorithm and applying diversification and intensification.
Grosso, A., Leonardi, E. and Nucci, A. (2001)	In this letter the authors developed a methodology for designing of the optimal logical topology configuration over a WDM wavelength routed network when there is dynamic traffic change. They have utilized the tabu search methods and by experimenting results they have showed the it is promising.	The authors mentioned about previous work regarding on the issue of logical topology reconfiguration (J. skorin-Kapov and J.F. Lavurdette 1995)but there was in absence of traffic uncertainties. They have encouraged for the further investigation of Tabu Search methodologies.

Table 6.0 cont...

Papers	Brief Description	Comments
Skorin-Kapov, J., Lagourdette, J.(1995)	In this article the authors defined the problem of minimization of congestion in logically rearrangeable multihop network using tabu search heuristic.	The authors worked on this subject because the relevant work on ShuffleNet regular topology by (Banerjee and Muldaerjee 1993), where the objective is to minimize a weighted average hop

5 Conclusion

The effort has been given in this survey for the investigation of recent and past research on reconfiguration and design of logical topology in Wavelength Division Multiplexing networks using tabu search. Some of the research was in broadcast networks but detailed investigation is beyond the capability of this survey. The main focus was the methodology, algorithm, policy and what was the con's has been presented in the form of table in previous section on design and reconfiguration of logical network. I have categorized few papers on the basis of reconfiguration of logical topology which is a milestone and which are directly related my survey topic.Those papers are given as a table 7.0 below for quick references.

Table 7.0	
Catagory	**Comments**
Static Traffic Control and Transition Approach	In this section I have put those papers as in the form of table that are studied about static traffic and transitional approach for topology that transfer from old one to new efficiently.
Dynamic Traffic Control Approach	In this subsection I have presented those papers that have been studied whose traffic has been controlled dynamically.
Performance Based Design Approach	In this subsection I have put those papers that mainly studied as congestion minimization has been take in the part to increase the performance of the networks.
General Discussion on Reconfiguration	In this subsection I have presented those papers that are taking care of few problems as follows, 1. How to perform virtual topology reconfiguration to a target virtual topology 2. When to trigger Virtual Topology Reconfirmation and 3. What should be the target virtual topology for reconfiguration.
Utilizing Short Term memory	In this subsection I have put those papers that are designed for topology design using tabu search and utilizing the terminology short term memory
Diversification and Intensify Approach	In this subsection I have presented that are used long term memory of tabu search for designing topology design.

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6 Annotation

[1]

Murata, M., Zhang, Y., Takagi, H., and Ji, Y. (2005) "**Traffic Based Reconfiguration for Logical Topologies in Large-Scale WDM Optical Networks**", *Journal of Lightwave Technology*, 23(10): 2854-2867.

Keywords: Reconfiguration, Logical topology, Optical Networks, Wavelength Division Multiplexing (WDM), Protocol, Heuristic Algorithm, Time Division Multiplexing (TDM).

The authors claimed that there was a problem of higher level of disruption in transition phase of reconfiguration of logical topology.That means, at the level we need to shift to new logical topology from old logical topology in the optical networks and the disruption is high at that phase in previous papers (N. Sreenath et al 2001). In this paper the authors proposed an algorithms that yield much better performance (less disruption to the network) than previous algorithms mostly with comparable computation time. In this paper, they proposed three reconfiguration algorithms, called Fix-MBF, Ad-MBF, and MAPF that take into account of the traffic demand of upper layers. These algorithms are evaluated by using two kinds of performance measures: one indicating the quantity of disrupted resources, i.e., the mean and the maximum numbers of disrupted transceivers, *MDT* and *MD*, and the other indicating the user performance.

The authors focused on reconfiguration ***(transition approaches)*** for logical topologies in large scale wavelength-routed optical networks. They propose several heuristics that move the current logical topology efficiently to the given target logical topology. The proposed algorithms are evaluated in comparison with existing algorithms in an NSFNET-like network model with 16 nodes and 25 links.

They have makes extensive reference describing mathematics which they have used in there solution. This paper is the part of research work at University of Tsukuba at Japan. There are lots of tables, graphs and statistics to show detailed work and evaluation for reader to realize the concepts. It has quite large number(25) of reference at the end of this paper.
[2]
Din, D. (2007). **"A Genetic Algorithm for Solving Virtual Topology Configuration Transition Problem in WDM Network"**, *Computer Communications*, 30(4): 767-781.

Keywords: Genetic Algorithm, Virtual Topology Reconfiguration, Wavelength-Division-

Multiplexing (WDM), Heuristic, Optical Network.

The main concern is in this paper is to minimize the disruption at the transition phase of reconfiguration. The author has pointed out that the reconfiguration of logical topology has many side effects. One of them is *disruption* of traffic transformation from source to destination node. The author defines the problem as, the WDM virtual topology configuration transition problem (WVTCTP) which minimizes the *average weighted hop distance* is studied, which is minimizing the *lightpath distance*. Since the WVTCTP is NP-hard, a genetic algorithm (GA) is proposed to solve it. Authors have been referred to [Murata, 2005] that also worked on the same issue by using deferent's Heuristic algorithm, but in this paper the author implements GA*(Genetic Algorithm)*.The authors claimed that from his previous researches and simulated results shows that the proposed GA can get better performance than heuristic, simulated annealing, and iterative improving methods.

The author of this paper, Der-Rong Din is Ph.D holder and a faculty member of the National Chiao University of Taiwan. His research interest is on WDM, Algorithm. There are lots of tables, graphs and statistics to show detailed work and evaluation for reader to realize the concepts. It has 27 references at the end.

[3]
Xu, S., Sezaki, K., Tanaka, Y. (2002). **"A Heuristic Method of Logical Topology Reconfiguration in IP/WDM Optical Networks",** *IEEE Region 10 Annual International Conference, Proceeding/TENCON*, 2:1174-1177.

Keywords: IP/WDM networks, Logical topology, Reconfiguration, Heuristic method, MILP.

The authors in this paper focused mainly on the method of logical topology transition with small operations. Instead of searching the exact solution of the logical topology reconfiguration, they have tried to find an approach to an approximated solution. First they have introduced an improved transition approach based on the proposal which is refered in [D. Banejee and B. Mukherjee, (2000)].

The idea was to find a closer and better logical topology from old one without requirement of the best target logical topology. By this approach, the authors claimed that they have found a relative good target under certain degree of performance loss, but with minimum transition operation, which is more important to the real network operation by achieving minimal traffic disruption. They have proposed a heuristic approach of the second phase which is the transition phase.The authors in this paper are from Waseda University of Japan in the faculty of Advanced Research Institute for Science and Engineering. There are lots of graph and statistic with explanation.

[4]
Lee, G., Sugang, X., Tanaka, Y. (2006). **"A Logical Topology Design with Tabu Search in IP over WDM Optical Networks"**, *Communications, 2006. APCC '06.Asia-Pacific Conference 2006,* : 1 - 5.

Keywords: Meta-heuristic, WDM networks, Tabu search, Simulated annealing, Logical topology design.

The main objective of this research work is found the better algorithm for designing Logical Topology in the wavelength routed WDM optical network by comparing several other algorithm. The authors referred their previous researches [S. Xu, N. Koyama, and Y.

Tanaka, 2004] on the issue in which they applied several Simulating Annealing (SA) and Genetic Algorithm (GA). In this paper authors proposed Tabu Search (TS) algorithm for indirect neighborhood discovery. They have claimed that TS algorithm has better network performance then others. They have demonstrated simulation model and numerical result. There is graphs and picture for reader to understand. There is reference at the end.

[5]

Arakawa, S., Murata, M. (2002). **"Lightpath Management of Logical Topology With Incremental Traffic Changes for Reliable IP over WDM Networks"**, *url: citeseer.ist.psu.edu/arakawa02lightpath.html*.

Keywords: IP over WDM, Logical Topology, Optimization Problem, Wavelength Division Multiplexing, Quality of Protection, Network Management

In this paper the authors introduced Lightpaths management algorithm called MRB (Minimum Reconfiguring for Backup Lightpath). Due to the QoS (Quality of Service) each topology has a backup topology. They have used a dedicated Lightpath Management Node (LMN) for managing the node, when there are needs for new lightpath the LMN manage.

The authors claimed that they have introduced the new approach to manage the logical topology by this study. The authors referred that all previous researches has been done on static traffic. When the traffic increases, firstly they reconfigured the backup lightpath because backup lightpath is not being used until there is a fault. The main constrain is they has to measure the traffic continuously. They implement the MRB algorithm by CPLEX. They introduced three phase in order to satisfy the increase of traffic mainly Initial Phase, Incrementing Phase and Readjusting Phase.

The authors showed in their work that they were able to establish the frame work for designing logical topology but need improvement in their algorithm. The authors introduced the Readjusting Phase but implementation left for future work.

The authors defined the MRB algorithm clearly in this paper for reader to better understand but left related work for future. There is a small reference at the end.

[6]
Tak, S., Lee D., Prathombutr, P., Park, E.(2005). **"Modeling and Evaluation of a Reconfiguration Framework in WDM Optical Networks"**, *Springer Berlin/ Heidelberg*, 3741:171-182.

Keywords: Wavelength Division Multiplexing, Reconfiguration, Optical Networking, Optimization Algorithm, Logical/Virtual Topology.

In this paper the authors considered the reconfiguration problem is a multi-objective problem, one is Process and other is Policy. The process of reconfiguration considers two objectives, AHT (objective function of minimizing Average Hop distance of Traffic) for network performance and NLC (objective function of minimizing Number of Lightpath routing Changes) for network cost. They have used the PEAP (*Pareto Evolutionary Algorithm adapting the Penalty method)* that optimizes two objective functions by using the concept of Pareto optimality. The reconfiguration policy picks a solution from the set of non-dominated solutions using the MDA *(Markov Decision Action).* Authors claimed and the experimental results show that their reconfiguration framework incorporating the PEAP and the MDA yields efficient performance in the entire series of reconfiguration processes which is ILP or Heuristics.

This is piece of research work of jointly of University in Korea and Thailand. There are pictograph, detailed algorithm in the whole and reference at the end.

[7]

Liu, K. H., Liu, C., Pastor, J. L., Roy, A., and Wei, J.Y. (2002). **"Performance and Testbed Study of Topology Reconfiguration in IP over Optical Networks"**, *IEEE Transactions on Communications*, 50(10):1662-1679.

Keywords: GMPLS, IP over WDM, IP/WDM testbed, network control, NGI, optical Internet, optical networks, OXC, performance analysis, traffic engineering, virtual topology, WDM reconfiguration.

The authors of the paper have presented a traffic-management framework for reconfigurable IP/WDM networks, because their claim and the simulation results show that the reconfiguration algorithms provide higher network throughput and reduced average hop distance over the fixed topology.

The main components are traffic monitoring, analysis and aggregation, bandwidth prediction, reconfiguration trigger, topology design, and topology migration. They presented three "one-hop traffic maximization"- oriented heuristic algorithms, RD (Residual-Demand Heuristic Algorithm), RDHP *(Residual demand count hop product)*, and DHP *(Demand-hop counted problem)* for lightpath topology design and one heuristic algorithm, IRM *(Incremental reconfiguration migration)*, for reconfiguration migration. To verify the performance of the presented reconfiguration algorithms, they have conducted a simulation study.There are many graphs and simulation results in the paper and large references at the end.

[8]

Banerjee, D., Mukherjee, B. (2000). **"Wavelength-Routed Optical Networks: Linear Formulation, Resource Budgeting Tradeoffs, and a Reconfiguration Study"**, *Networking, IEEE/ACM Transactions on*, 8(5):598 -607.

Keywords: Ligntpath, reconfiguration, optical network, optimization, integer linear programming.

In this paper, the authors present the design of a lightpath-based optical network as an *integer linear programming* (ILP) optimization problem, and use the problem formulation to seek an optimal network design. They used the branch-and-bound methodology in the CPLEX optimization package for solving the integer set of equations. They have demonstrated that terminating the optimization within a few iterations of the branch-and-bound method provides high-quality solutions. They also present a number of engineering techniques to make the network design problem more computationally tractable, thus allowing the network designer to balance between the time taken to obtain a solution and the optimality of the solution.

The authors have also proposed an algorithm, which can be used for virtual topology reconfiguration. The claimed that the proposed algorithm computes a new virtual topology from an existing virtual topology such that, the new virtual topology is optimal with respect to the changing traffic patterns, among all such optimal virtual topologies. This paper has been cited 43 times.

[9]

Zheng, J., Zhou, B., Moufta, H.(2004). **"Virtual Topology Design and Reconfiguration of Virtual Private Networks (VPNs) over All-Optical WDM Networks"**, *Photonic Network Communication*, 7(3): 255-266.

Keywords: Virtual private network, virtual topology design, reconfiguration, WDM network.

In this paper the authors proposed heuristics to dynamically reconfigure the lightpaths, established over an underlying WDM optical network to support a VPN service, in response to changing VPN traffic. The authors claimed that their algorithm as *balanced alternate routing algorithm* (BARA), which is based on genetic algorithm.

To make the problem computationally tractable, the authors approximately divide BARA into two independent stages: route computing and path routing. At the route computing stage, a set of alternate routes is computed for each pair of source destination nodes in the physical topology. At the path routing stage, an optimal route is decided from the set of alternate routes for each of the lightpaths between a pair of source destination nodes. The authors have used genetic algorithm to improve the computational efficiency. The authors did not referred this work on any previous research how over there is extensive math has been simulated for reader to better understand.

The authors claimed that the simulation results showed that BARA could significantly increased the network throughput and is effective in achieving the optimization objectives in the virtual topology design and reconfiguration of VPNs over all-optical WDM networks.

[10]

Gencata, A., Mukherjee, B. (2003). **"Virtual-topology Adaptation for WDM Mesh Networks under Dynamic Traffic"**, *IEEE-ACM Transactions on Networking* , 11(2): 236-247.

Keywords: Dynamic traffic, mesh network, mixed-integer linear program (MILP), optical network, virtual-topology reconfiguration, WDM.

In this paper the authors defined the problem as reconfiguring the virtual topology under dynamic traffic changes in WDM mesh networks. The authors claimed that they have designed a new approach because they measure the traffic continuously instead of static traffic on most previous study.

They have formulated an optimization problem which determines whether or not to add or delete lightpaths at the end of a measurement period, one lightpath at a time, as well as which lightpath to add or delete. The formulation for optimization problem turns out to be a mixed-integer linear program. The authors also admitted that their problem definition can be improved by different heuristics using MILP formulation which is presented in this paper. The authors did not refer this work to any previous research however, there is extensive math simulation, and graph and testing has been done. This paper has been cited 15 times is ISI web of knowledge.

[11]
Achan, K. (2000). **"Tabu Search in Multi-hop Optical Network Design"**, *University of Windsor (Canada)*, 71 pages, AAT MQ52497,

Keywords: Meta-heuristic, WDM networks, Tabu search, simulated annealing, Logical topology design.

In this paper the authors mainly focused mainly on providing a basic framework for applying tabu search to the logical topology design problem. They did not address the issues like long term memory and more over they stopped their search as soon as they found an integer solution. They admitted that tabu search approach is relatively new in the arena of the research of logical topology design.

The authors did not refer this work to any other related study, how over they implement their problem on the basis of how to utilize tabu search algorithm in L.T design. They claimed that their approach give better results by comparing HLDA, which is a heuristic. Since they admitted that tabu search is quite new area of research, there is more component of tabu search to implement to improve the results. This paper is an MSc thesis work in University of Windsor.

[12]
Kuri, J., Puech, N., Gagnaire, M., Dotaro, E. (2002). **"Routing foreseeable lightpath demands using a tabu search meta-heuristic"**, *GLOBECOM'02-IEEE Global Telecommunications Conference*, 3(Cat. No.02CH37398):2803-7.

Keywords: Optical networks, dynamic lighpath provisioning, WDM, tabu search.

The authors of this paper proposed a routing algorithm that minimized the number of required WDM channels in the physical link in networks which takes in the account of the property of problem of routing on a set of lightpaths demands for which start and end times may fixed. The routing problem formulated as combinatorial optimization problem.

They have devolved tabu search Meta heuristics to solve this problem. They claimed that there is a gain in find optimal solution in terms of compared to shortest path routing strategy which branch and bound algorithm is used. There is no referred research mentioned in this paper though extensive mathematical experiment has been done in this works. They have admitted that this work has been implemented in a small size of network but future planned for larger networks. There are five references at the end.

[13]

Baldine, I. and Rouskas, G. (2001). **"Traffic Adaptive WDM networks: A Study of Reconfiguration Issues"**. *IEEE/OSA Journal of Lightwave Technology*,19(4):433-455.

Keywords: Broadcast optical networks, Markov decision process, reconfiguration policies, wavelength-division multiplexing (WDM).

In this paper the authors studies the issues arising in the reconfiguration phase of broadcast optical networks. Although the ability to dynamically optimize the network under changing traffic conditions has been recognized as one of the key features of multiwavelength optical networks, they claimed that this is the first in-depth study of the tradeoffs involved in carrying out the reconfiguration process.

The main problem objective was to investigate three open issues: how frequently to reconfigure the network, how to structure the reconfiguration phase, and how to quantify the benefits of reconfiguration to the network in terms of measurable performance parameters. In order to address the first issue, they developed a formulation based on Markov decision process theory. For the second issue, they presented a class of parameterized retuning strategies for carrying out the reconfiguration phase. Finally, using simulation, they have quantified the benefits of reconfiguration in terms of important performance measures such as average packet delay and packet loss. Overall, their work demonstrates that by employing slowly tunable devices, the results showed that it is possible to build traffic-adaptive high-performance multiwavelength networks cost-effectively.

I. Baldine is an Advance Network Research Engineer and Ph.D. in Computer Science and G.N. Rouskas is an associate professor in North Carolina State University and did his Ph.D. in computer science. The paper contains a variety of figures graph and table to assist the reader in understanding the concept clearly and ends with a short list of references and authors bio-data. This paper has been cited eleven times. The authors did not refer any previous study through this study but it will be very useful resource for my research topic.

[14]
Sinha,S., Rammohan, N. and Murthy, C. (2005). **"Dynamic Virtual Topology Reconfiguration Algorithms for Groomed WDM Networks"**, *Photonic Network Communications*, 9(2):181-195.

Keywords: WDM networks, Traffic grooming, Virtual topology reconfiguration, Maximize throughput, Minimize disruption, Minimum hitting set

In this paper the authors presents a simple and flexible framework to evaluate the gain achieved by reconfiguration, based on the two conflicting objectives of increasing throughput and reducing disruption. They presented adaptive reconfiguration algorithms which determine the change in the virtual topology with a corresponding change in the demand set. These algorithms incrementally add lightpaths to a given virtual topology and delete a minimum number of lightpaths to facilitate their addition. One of the algorithms improves throughput by making changes to the existing virtual topology and another one reduces disruption by making changes to the virtual topology suited for the new demand set.

The authors claimed that the simulation results showed the improvements the throughput and the flexibility and robustness compared to two other (IAA-FWD and IAA-BWD). There is no referred previous research study in this paper but the extensive work has been demonstrated through out the simulation. There are large numbers of graphs, pictures, and statistics in this paper that help reader to get the cleat concept. There are 15 references at the end.

[15]

Boljuncic, V., Skorin-Kapov, D.and Skorin-Kapov, J. (2004). **"A tabu search approach towards congestion and total flow minimization in optical networks"**, *Systems Engineering Society of China, co-published with Springer-Verlag GmbH*, 13 (2):180-201.

Keywords: Heuristic solvability, tabu search, multihop, rearrangeable optical networks, minimal total flow, maximal throughput.

The authors in this paper defined the problem as minimizing congestion and total flow using tabu search algorithm. They referred their work with previous study such as (Skorin-Kapov, Labourdette, 1995), where they worked on short term memory search approach. But they claimed that they used modified formulation. Furthermore, previous research distinguished between arbitrary and regular network topologies. This work deals with arbitrary networks since they are more general and exist for every network size. In the use of tabu search they have employed the so-called candidate list strategy for the partial evaluation of neighborhood due to the computational complexity of evaluating the complete neighborhood. Tabu search algorithm is proposed as a two phase strategy. The first phase performs more aggressive diversification of search, while Phase 2 attempts to intensify search around the best obtained solutions.

They have claimed that their results showed average 3.66% increase then the results of the best published paper (Skorin-Kapov, Labourdette, 1995) so far. They have evaluated with extensive math calculation as a results of experiments and large number of references at the end. It is good source of my research work.

[16]
Kuri, J., Puech, N. and Gagnaire,M.(2002). **"A Tabu Search Algorithm to Solve a Logical Topology Design Problem in WDM Networks Considering Implementation Cost"**, *Proc. SPIE* , 4909:174-183.

Keywords: Logical topology design, WDM, tabu search, network optimization, network planning.

The authors developed this methods because of MILP can not handle large number of node with optimal solution. In this paper the authors defined the problem as to solve of the designing a logical topology for packet-switched traffic over WDM mesh network using tabu search algorithm. The cost of mapping such logical topology over a physical network is taken into account. The algorithm provides approximate solution of a good quality (close to the optimal).
They claimed that this algorithm is a trade off between cost and performance with

- Small congestion with large number of lightpath
- Less expensive topology with higher congestion

Their goal is to design logical topology and routing of the packet switched traffic demands so that the congestion is minimal. They have compared the quality of tabu search with the results of former ILP algorithm. They have claimed that the tabu search algorithm computed approximate solutions that compared with optimal ones. The authors did refer Kuri at el.(2002), where they did not talk about implementation cost in their study in previous, though they have experiments several algorithm with same problem definition through out math calculations. There is a small number of references at the end.

[17]

H.Takagi, Y.Zhang, X.Jia and Hid.Takagi(2006). **"Reconfiguration Heuristics for Logical Topologies in Wide-area WDM Networks"**, *IEICE Transactions on Communications*, E89-B(7):1994-2001.

Keyword: Logical topology, reconfiguration, Wave Length Division Multiplexing, lightpath, Heuristics, optical, network.

The authors developed new procedure as they claimed because of previous sutdy(D. Bansiec and B. Mukhejsp 2000), (B. Ramamunhy and A. Ramkishnan,2000)did worked only on local area network and did not worked on transition procedure from old one to new one. In this paper, the authors focused on wide-area WDM optical network and propose several reconfiguration heuristics algorithms that attempt to shift from one logical topology to another while keeping the network availability as much as possible. They referred to the previous studies and claimed that they proposed new reconfiguration schemes that take a lightpath as the minimum reconfiguration unit. The proposed algorithms are evaluated by means of numerical experiments.

They evaluated two simple algorithms, SPF and LPF, has low computational complexity but poor performance. A tree search algorithm TS provides very good performance with large computational complexity. The minimal disrupted lightpath first (MDPF) algorithm is proposed as a simple algorithm with reasonable computational complexity. They have showed that the performance of MDPF is close to that of TS but with much lower computational complexity. It has various types of graphs, tables, static's for reader to understand easily. There is reference at the end of the paper.

[18]

Skorin-Kapov, J., Labourdette, J.(1995). **"On Minimum Congestion Routing in Rearrangeable Multihop Lightwave Networks"**. *Journal of Heuristics*, 1: 129-145.

Keywords: logically rearrangeable networks, multihop, optical networks, tabu search.

The authors developed a method to reconfigure logical topology by using Tabu Search, where long term memory search mechanism has been used. They have proceed in this method because, relevant work on ShuffleNet regular topology includes (Banerjee and Muldaerjee 1993), where the objective is to minimize a weighted average hop distance. In (Banerjee, Muldaerjee, and Sarkar 1994) the authors developed heuristic algorithms applied to linearly constrained (bus) optical networks with the additional assumption that the traffic flows are symmetric.

In this article the authors defined the problem of minimization of congestion in logically rearrangeable mutihop lightwave networks. They considered a networks which is equipped with a small number of transmitters and receivers using same wavelength creates a logical link (i, j) through which traffic could be sent. The main objective is to find best connectivity diagram and corresponding flow assignment so that the maximal flow on any link is minimized. They developed a tabu search heuristic that yields a suboptimal connectivity diagram and an optimal flow assignment on it.

They have conducted an experiment with some real world traffic matrix and on some randomly generated problems of larger dimension. They have claimed that a tabu search based heuristic is promising approach for handling this NP-hard combinatorial problem. Their algorithm is coded in C and the routing subproblem was solved using Cplex 3.0 callable library. The claimed and proved by their experimental results that using tabu search to design logical is a promising improvement.

[19]

Grosso, A., Leonardi, E. and Nucci, A. (2001). **"Logical Topologies Design over WDM Wavelength Routed Networks Robust to Traffic Uncertainties"**, *IEEE Communications Letters*, 5(4): 172-174.

Keywords: Optimization, topology design, WDM networks.

In this letter the authors developed a methodology for designing of the optimal logical topology configuration over a WDM wavelength routed network, when some or all the traffic relations are affected by a degree of uncertainty meaning a dynamic traffic change. The authors referred to the previous work (Skorin-Kopov J., and Laburdette j.F.1995, where he mentioned about the same type of work but there was an absence of traffic uncertainties.They claimed that for the traffic uncertainties, their work is a novel approach.Their optimal topology relies on tabu search meta heuristic. They have referred couple of previous work (B. Mukherjee at el 1996, J. Skorin-Kapov 1995) on this issue and claimed that they are the first researcher studied to find the best logical topology under the degree of traffic uncertainty. They have also claimed that their methodology is a novel approach without any further discussions.

[20]

Ramamurthy, B and Ramakrishnan, A. (2000). **"Virtual Topology Reconfiguration of Wavelength-routed Optical WDM Networks"**, *IEEE, Global Telecommunications Conference*, 2(2000):1269 - 1275.

Keywords: Optical networks, wavelength division multiplexing (WDM), lightpath, reconfiguration, network control and management, and linear programming.

In this paper the authors developed a new algorithm of virtual topology transition from one phase to another using efficient reconfiguration procedure.The authors mentioned that the previous (D. Banerjee and B. Mukherjee,1997) worked has done using mathematically linear rigorous formulation for solving the lightpath reconfiguration problem in wavelength division multiplexed (WDM) optical networks.The main difference of their work from the previous is that the minimizing of re-tuning, that is, if they can retain as many lightpaths (virtual links) as possible from the present topology and still satisfy the changed traffic requirements and generate a new optimized topology, therefore it will be doing less reconfiguration (re-tunings).

They have claimed that they have developed new method as limiting the value of matrix can enable network operator limit the disruption. Therefore they used the term reconfiguration as a constrain. Byrav Ramamurthy and Ashok Ramakrishnan are professors from Department of Computer Science and Engineering University of Nebraska - Lincoln. They have used various graphs, statistics and large useful reference at the end.