Review of Static Light Path Design in WDM Network

Harpreet Kaur
BBSBEC,
Fatehgarh Sahib

Munish Rattan, PhD
GNDEC, Ludhiana

ABSTRACT

As use of internet is increasing rapidly so we need networks supporting high bandwidth and data rates. Need of high bandwidth evolve the need of WDM network and routing information over them .In this paper we have reviewed various routing and wavelength assignment algorithms used in literature .We have also described the contribution of nature inspired techniques in enhancing the performance of optical networks.

Keywords

Genetic Algorithm, Differential Evolution ,Variable Neighborhood Search, Multi-objective, Optimization.

1. INTRODUCTION

In WDM networks, the whole capacity is divided into multiple channels that have different wavelengths.WDM networks consist of wdm nodes across which optical traffic can be transmitted using light paths. If there are no wavelength converters then light path must use same wavelength over the fiber links it is transmitting, this is known as wavelength continuity constraint .The light path that have same physical link but they cannot be assigned same wavelength . This is called wavelength clash constraint [1,6].

For a given set of light paths to be established, the process of finding routes for light path and assigning wavelength for the route is called routing and wavelength assignment problem.RWA problem can be considered under two types of traffic i.e. static and dynamic. Static RWA means that connection requests are known in advance. one has to route the request and allot suitable wavelength for it. This is also called as offline RWA. Dynamic RWA means that connection requests arrive in random fashion with random settling and tearing times.

Ultimately, objective function needs to be optimized in either type of RWA.

The rest of the paper is organized as follows. In the next section we present review of already existing and proposed techniques for static routing and wavelength assignment in optical network. Further, we discussed the use of nature inspired techniques for routing and wavelength assignment in optical networks. Finally we provide the summary with future scope to conclude the paper.

2. Techniques For static RWA

In static routing, the light paths are known in advance so main objective is to minimize the number of wavelengths when traffic request is routed for a given topology. The problem may be multi objective i.e. minimizing blocking probability, throughput or failures among the connections etc. [2].

According to the objective taken there are number of techniques proposed in literature. Mostly RWA is solved by decomposing the problem in two parts i.e. routing problem and wavelength assignment problem. The proposed routing algorithms are:

2.1 Shortest Path Routing (SPR)

In this type firstly shortest path is selected using Dijkstra algorithm based on current state of the network. Path is measured in terms of number of hops .Then wavelength is assigned using first fit algorithm if request is unsuccessful using first wavelength then second wavelength is tried and process goes on repeating. If request is unsuccessful for all wavelengths then call is said to be blocked. In this there will be unconditional delay due to selection of shortest paths [14, 11].

2.2 Resource Utilization based Routing Algorithms (RUR)

In this algorithm, set of K shortest paths are calculated based on minimum resource utilization i.e. taking in account number of regenerators, hop count and lastly length [14].

2.3 Bin packing based Routing Techniques [6]

2.3.1 *FF RWA*

In this routing, only one copy of graph G is created and higher indexed bins are formed if they are required. The connection request is routed in this graph(bin Gi) if it has shortest path between Si and Di exist such that length denoted by Pi is less than H .Wavelength i is assigned to route once the bin is used to route the request, then all the edges of Pi are deleted. Once all the edges in bin vanish means that it doesn't have capacity to route any other requests.

2.3.2 *BF RWA*

In this routing, if number of bins is created then best fitted bin is one having shortest path between source and destination pair compared to other bins.

2.3.3 *FFD RWA*

(First Fit Decreasing RWA) In this technique, first longer light path is routed in a bin and fills the remaining space with shorter light paths .

2.3.4 *BFD- RWA:*

(Best Fit Decreasing RWA) It first arrange requests in decreasing order of their shortest paths in G and then follows BF-RWA. These bin based routing algorithms not only minimize the number of wavelength but also the physical length between source and destination.

These bin based algorithms not only reduces the hop length, reduces the number of wavelengths required but also reduces the chance of light path request to be blocked.

2.4 Fixed Alternate Routing

In this routing, a routing table is formed which consist of all the possible routes between source and destination starting from the shortest path up to the largest possible route. When connection request arrives the route is selected randomly starting from the shortest path on which wavelength can be allotted. If there exist no route on which wavelength can be allotted then the connection is blocked [2].

This technique makes the task of setting up and tearing off light paths easier, provides fault tolerance and reduces the blocking probability compared to shortest path routing.

2.5 Adaptive Routing

In this routing when connection request arrives, a route is selected among the N shortest path which has maximum number of free wavelengths for single hop connection. And in multi hop connection route selected for source destination pair is the one which don't have any common wavelength among N other shortest paths. This routing improves the blocking probability of the network [15].

This technique improves the link utilization hence improves the capacity of the network.

This technique improves the link utilization hence improves the capacity of the network.

2.6 Waveband Switching Routing

In this technique, firstly K shortest paths are selected between source destination pairs when the connection request arrives, then rerouting techniques are employed so as to reduce number of ports. It also outperforms traditional routing in terms of performance [4].

2.7 Priority and Maximum Revenue based routing and wavelength assignment

In this technique firstly the connection requests are divided into two sets i.e. HPM (high priority matrix) and LPM (low priority matrix). In this, light paths must be formed whereas light paths in LPM can be setup to optimize revenue when there is not enough resource to accommodate all. Since requests in HPM need to be fulfilled so cost for that will always be fixed, the problem is to maximize the cost contribution from LPM. For this two algorithms are proposed i.e. SILP and SP.

Maximize

$$\sum_{S,d\in D} \left[\sum Esd^i\, Psd^i + \sum_{1\le i\le n} Bsd * PRI \right]$$

With the following constraints

$$\sum (\mathbf{Esd^i + Bsd^i}) \le \mathbf{1}\ \forall (m,n) \in E \qquad 1)$$

$$\sum \mathbf{Esd^i} \le \mathbf{\Theta sd}\ \ \forall (s,d) \in D \qquad 2)$$

$$\sum Bsd^I \le \lambda sd,\ \forall (s,d) \in D \qquad 3)$$

Equation 1 represents the constraint that no two route can use same link. Equation 2 and Equation 3 ensures that number of routes found is less than desired number. Value of PRI is kept larger than highest market price so that algorithm fulfills all requests in HPM [16].

SR Algorithm

In this algorithm in HPM connection requests are arranged in decreasing order of their shortest path and stored in list A and in LPM connection requests are arranged in decreasing order of their cost and stored in list B. Firstly, route and wavelength for first request in list A is found, then resources used by it is removed from network resource availability data. The process is repeated for next request in list A and so on. If the algorithm couldn't find any light path for the request then it terminates. After all requests of list A are fulfilled then algorithm works to find light path for first request in list B. If succeeds the network resource availability is updated and the process repeats [16].

2.8 Alternate Shortest Path Algorithm

In this algorithm for every connection request route is selected on shortest path with at least one unoccupied channel if not then alternate shortest path with unoccupied channel is selected if still not possible then call is blocked [11].

2.9 Maximum empty channel routing

In this type of routing as soon as the call request arrives all the possible paths are inspected and route is established on the one having maximum number of empty channels [11].

2.10 Resource Utilization based Routing Algorithm

It is a fixed alternate routing in this set of 'n' shortest paths are selected which uses minimum resources provided hop count; path length and number of regenerator are minimized. In this weight is assigned to each link between i and j nodes.

$$Cij = \{(W-aij -2)/W * (R-rj -2)Lij/R \ \} \text{ when } Rj =1$$

$$\{(W-aij -2)/W* Lij/R \ \} \text{ when } Rj = 0$$

$$Csd = \sum Cij$$

Where W = Number of toatal equipped wavelength

aij = Number of available wavelengths in link

R = Total equipped regenerators

Rj =1 regeneration required at node j

Rj =0 regeneration is not required j

rj =Number of equipped regenerators

Lij = Length of link(i,j) [14] .

2.11 Resource balance based Link Disjoint Routing (RBR)

In this routing, link disjoint paths are selected provided balance is between minimum resources used and disjointed level of the paths. If completely disjointed path is used it will definitely use more number of resources so it will be better to use partially disjointed path. In this weight is calculated for every path.

$$Coff^i = 2\, Rnode^i\, (H^i - Rnode^i\,)10 \log(L^i)$$

$Rnode^i$ = It is the necessary times 3R regenerator in path

H^i = number of total hops

L^i = represents toatal length

The path having minimum $Coff^i$ is selected as first best path and 2nd best path is evaluated using

$$Coff^i = Coff^i + C\, best\, [Lcommon]/[Llast]$$

C best = Last best path selected

Lcommon = set of common links in best path selected

Llast = Links of Last best path selected [14].

2.12 Resource Optimization based with customized Link Disjoint Degree Routing (ROR)

In this technique path is chosen according to priority of minimum network resource consumption provided with required link disjoint degree 'D' where

Ddegree = 100 * (1 – (Llast –Lpath)/Llast

Llast = Links of Last best path selected

Lpath = Links of considerable path [14].

3. EVOLUTIONARY TECHNIQUE FOR SINGLE OBJECTIVE STATIC RWA

The static RWA problem in wdm optical network is also solved with genetic algorithm for single objective the optimization i.e. minimizes the number of wavelengths. A hybrid approach is used for the initialization of the population, this approach depends on K shortest path for every source destination pair. A special cost function based on frequency of occurrence of an edge in different S-D paths is used to find the fitness of chromosome. An m-point crossover is used to maintain diversity in solution space. Wavelength assignment is done using graph coloring technique. This technique outperforms first fit algorithm [5].

4. MULTI-OBJECTIVE RWA USING HYBRIDEVOLUTIONARY APPROACH

In this technique two objective functions are optimized i.e. maximize number of accepted commodities and minimizing the number of wavelengths on each network edge. In this technique genetic algorithm is used for routing and minimum degree first for wavelength assignment (GA-MDF) [8] and fast non dominated sorting GA (Genetic Algorithm) to search for non dominated solutions (i.e. best solution).Normally there are number of non dominated solutions, so in this algorithm pruned optimal mechanism is used to reduce the number of non dominated solutions [3, 13].

The objective function used is

Fobj= Wc (Q – Qa) / Q + Ww (Ka / Kmax)

Wc = weight for maximizing number of commodities

Ww = weight for maximizing required number of wavelengths

Q = total number of requests

Qa = total number of accepted requests

Ka = minimum required wavelengths

Kmax = total wavelength

Advantages: Results of NSGA-II are more diverse than weighted sum approach

Disadvantages: It is more time consuming [9].

An hybrid evolutionary technique is used for static RWA in which two different multi objective algorithms are combined. One algorithm is population based i.e. differential algorithm [12] and another algorithm i.e. variable neighborhood search is used. Differential evolution basically adds the weighted difference between two population vectors to a third vector. Also the concept of pareto tournament (DEPT) is added to compare the individuals keeping only the non dominated solutions in the population. In DEPT each individual receives a scaler value based on number of individuals that dominates and number of individuals by which it is dominated.

Variable neighborhood search [7] tries to escape from local optima trap by modifying the neighborhood space. This algorithm is changed to adapt it to multi- objective context i.e. MO-VNS. Results of the algorithm are compared with various multi-objective ant colony optimization and NSGA II (Fast Non dominated genetic algorithm which proved to be improved one [1].

5. CONCLUSION & FUTURE WORK

In this paper we have reviewed the already proposed techniques for the static RWA problem in optical network. We have also discussed the significance of using nature inspired techniques for improving the performance of RWA problem. Comparative study of all proposed algorithms revealed that usage of hybrid evolutionary techniques for multi objective optimization proved to be quite promising for static RWA. So, future lines for research in optical networks can be using hybrid evolutionary techniques for multi-objective optimization with dynamic traffic patterns and the problem may be extended to solve traffic grooming along with routing and wavelength assignment .

6. REFERENCES

[1] A.R. Largo ,M. A. Vega-Rodriguez 2013 Applying MOEAs to solve the static Routing and wavelength Assignment problem in optical WDM networks J. Engineering Application of Artificial Intelligence. 26 ,pp. 1602-1619.

[2] H. Zang, J.P. Jue, and B. Mukherjee 2000 A Review of Routing and Wavelength assignment approaches For Wavelength Routed Optical WDM Network Baltzer Science Publishers, pp. 47-60.

[3] H.A. Taboada,D.W. Coit 2008 Multiobjective scheduling problems:determination of pruned Pareto sets IIE Transactions . 40 ,pp. 552-564.

[4] L. Guo, X. Wang,W. Ji, W. Hou, T. Wu, and F. Jin 2008 A New waveband Switching Routing Algorithm in WDM Optical Networks In Proceedings Of International Conference On Advanced Communication Technology , Gangwon-Do, pp. 2151-2154.

[5] N. Banerjee and S. Sharan 2004 An Evolutionary Algorithm for Solving the Single Objective Static Routing and Wavelength Assignment Problem in WDM Network In Proceedings Of International Conference On Intelligent Sensing and Information Processing, pp. 13-18.

[6] N. S. Kapov 2007 Routing and wavelength assignment in optical networks using bin packing based algorithms European Journal of Operational Research .177, pp. 1167-1179.

[7] P. Hansen and N. Mladenovic 2001 Variable Neighbourhood Decomposition search Journal of Heuristic. 7 ,pp. 335-350.

[8] P. Leesutthipornchai, N. Wattanapongsakorn,C. Charnsripinyo 2009 Multiobjective design for routing wavelength assignment in wdm networks. In Proceedings of International conference on New trends in information Service Science ,Beijing,China(June 30-July 2),pp. 1315-1320.

[9] P. Leesutthipornchai , C. Charnsripinyo and N. Wattanapongsakorn 2010 Solving multi-objective routing and wavelength assignment in wdm using hybrid evolutionary computation approach. J. Computer Communication,pp. 2246-2259.

[10] R. Ramaswami and K.N. Sivarajan 1995 Routing and wavelength assignment in all optical networks.IEEE/ACM Transaction On Networking . 3,pp. 489-500,1995.

[11] R. Randhawa and J.S. Sohal 2010 Static and dynamic and wavelength assignment algorithm for future transport networks. J. Optik . 121, pp. 702-710.

[12] R. Storn and K. Price 1997 Differential Evolution –A Simple and Efficient Heuristics for Global Optimization over continuous Spaces. Journal of Global Optimization . 11,pp 341-359.

[13] S.K. Konak,D.W. Coit ,F. Baheranwala 2008 Pruned Pareto-optimal sets for the system redundancy allocation problem based on multiple prioritized objectives. Journal of Heuristics . 14,pp. 335-337.

[14] T. Chap, X. Wang, S. Xu, and Y. Tanaka 2011 Link-Disjoint routing algorithms with link-Disjoint degree and resource utilization concern in translucent WDM optical networks. In Proceedings of International Conference on Advanced Communication Technology, pp. 357-362.

[15] Y. Sun, J. Gu, and D.H.K.,Tsang 2001 Routing and wavelength assignment in all optical networks with multihop connections.Journal Of Electronics and Communications. 55, pp. 10-17.

[16] Y. Wang, T.H. Cheng, and M. Ma 2007 Prority and Maximum Revenue based Routing and Wavelength Assignment for All Optical WDM Network. In Proceedings of International Conference on Research Innovation Vision of the Future,pp. 135-138.