The Performance for Heuristic Algorithms for Virtual Topology Design in All-Optical WDM Networks

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ABSTRACT
For a given network physical topology and traffic pattern, our objective is to design the logical topology and the routing algorithm on that topology so as to minimize the Congestion. The virtual topology design problem is a mixed integer linear formulation. Heuristic algorithms for this problem where suggested to relax MILP problem such as Heuristic Topology Design Algorithm (HLDA), the minimum-delay logical topology algorithm (MLDA) heuristic, Random logical design algorithm (RLDA) and traffic independent logical design algorithm (TILDA). In this paper, we compare the performance of several heuristic topology design algorithms using large networks such as 14 NSFNET. The results shows that MLDA and TILDA tend to design logical topologies using a smaller number of wavelengths than HLDA while RLDA gave a vibrating results in which we cannot depend on to get an accurate performance.
Keywords: wave division multiplexing (WDM), heuristic topology design algorithm (HLDA), minimum-delay logical topology algorithm (MLDA), random logical design algorithm (RLDA), traffic independent logical design algorithm (TILDA), virtual network topology (VNT).

1. INTRODUCTION

In this paper we consider the design of virtual topologies in wavelength routed WDM optical networks. This includes determining a set of potential lightpaths and then solving the RWA problem for this set. We refer to a combination of these sub-problems as the Virtual topology and Routing and Wavelength Assignment problem (V RWA). Finally, packet switched traffic must be routed over the established virtual topology. This will be referred to as Traffic Routing (TR). Determining a good virtual topology with respect to various optimization criteria is a complex problem. Normally there are Five various objectives for virtual topology design. These functions allow selecting the objective function to optimize. These functions are Minimizing Average Weighted Number of (Virtual) Hops, Minimizing Network Congestion, Maximizing Single Hop Traffic, Minimizing Number of Used Wavelengths Channels and Minimizing Maximum Link Load in Number of Lightpaths. Most algorithms suggested for virtual topology design are evaluated by considering a single optimization criterion to be the measure of quality of their obtained solutions. Ramaswami in (1) design virtual topology based on minimizing Network Congestion with a delay parameter constraints (The delay parameter is assumed to be ∞). The virtual topology design problem is mixed integer linear formulation (MILP) which is very hard to solve special for large practical networks. The majority of approaches used to solve the virtual topology design problem, decompose it into sub-problems. Heuristic algorithms for this problem are suggested to relax MILP problem such as Heuristic Topology Design Algorithm (HLDA), the minimum-delay logical topology algorithm (MLDA) heuristic, Random logical design algorithm (RLDA) and traffic independent logical design algorithm (TILDA). In this paper a comparison of the different algorithms using minimizing network congestion objective function is studied. Congestion is defined as the maximum traffic load on any virtual link. Minimizing Network Congestion according to the relation $f_{max} = \max_{ij}(f_{ij})$, where the lightpath flow f_{ij} is total amount of traffic flow offered onto a lightpath from node i to node j and f_{ij}^{sd} is the component of traffic due to a node pair (s, d) offered onto a lightpath from node i to node j. Numerical examples are used for 14 NSFNET network as a large practical network is applied.

The rest of this paper is organized as follows. In Section 2 a brief of the related work is given, the problem definition is discussed in section 3 this includes notations. Numerical results and a detailed analysis of the obtained results are given in Sections 4. We finish in section 5 with conclusions.

2. RELATED WORK

An exact mixed integer linear formulation (MILP) for complete virtual topology design in WDM networks with full wavelength conversion is given in [2]. In [1], the authors formulate a MILP for virtual topology design with the objective to minimize congestion. There is no constraint on the number of wavelengths used. The authors suggest various heuristic algorithms, the best of which are the LP Logical Design Algorithm (LPLDA) and the Heuristic Topology Design Algorithm (HLDA). HLDA has become a well-known heuristic algorithm for the *VRWA* problem which considers a limited number of wavelengths in networks with no wavelength conversion.

HLDA attempts to establish lightpaths between pairs of nodes in decreasing order of their corresponding traffic. A MILP which minimizes congestion in networks with a limited number of wavelengths and no wavelength converters is given in [3]. The variables representing the virtual topology and physical paths are rounded while a wavelength assignment heuristic is applied to assign wavelengths to individual lightpaths. Traffic is routed over the virtual topology using a linear programming formulation (LP) consisting of only the traffic constraints of the relaxed MILP.

3. SIMULATION RESULTS

We will use two traffic pattern P1, P2 To evaluate the different algorithms using Congestion taking 14-node NSFNET as an examples, PI is called the NSFNET traffic pattern, this traffic pattern created by picking 42 (an average of three per node) s-d pairs at random and allocating a random amount of traffic chosen from a uniform distribution in U (0, 100) for each s-d pair, Each remaining s-d pair is then allocated a random amount of traffic chosen from a uniform distribution in U (0,l). This captures a situation where most of the network traffic is concentrated among 42 pairs, with little traffic among the remaining ones." The second pattern (P2) is using a uniform distribution pattern in U(0,100). In Fig. 1, we plot the minimum achievable Congestion as a function of the node degree for logical topologies designed by Heuristic logical design Algorithm (HLDA) using traffic pattern (P1). Next, in Fig. 2, we plot the same function for the traffic pattern (P2).For each of the above cases; we used different numbers of wavelengths varies from 2 to 10. We observe that Logical topology design heuristic (HLDA) works well when the traffic is concentrated among a small fraction of the total number of source-destination pairs in the network, but does not work well when the traffic is distributed more evenly among the source-destination pairs, since it is a greedy heuristic based on assigning lightpaths to s-d pairs with large traffic. We observe also that the degree constraints may play a significant role in limiting the performance of a logical topology than the number of wavelengths available. In Fig. 1 we observed that 6 wavelengths where sufficient to achieve the best congestion for node degree up to eight.

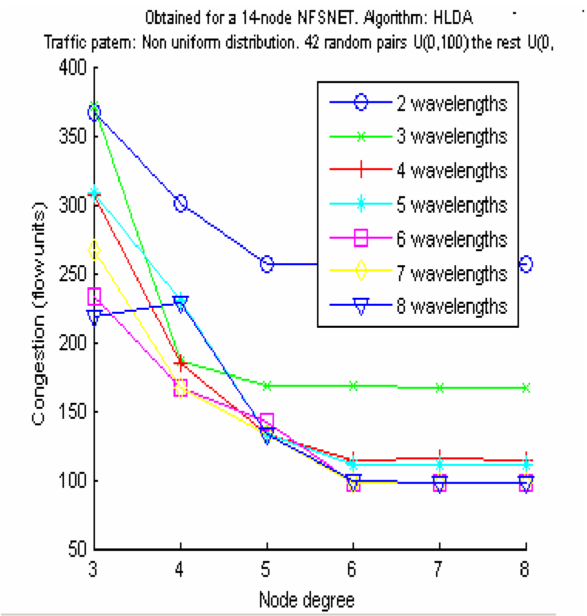


Fig. 1. Congestion versus logical degree for different Matrix PI by the topology design algorithm HLDA numbers of the available traffic wavelengths for in the 14-node NSFNET example.

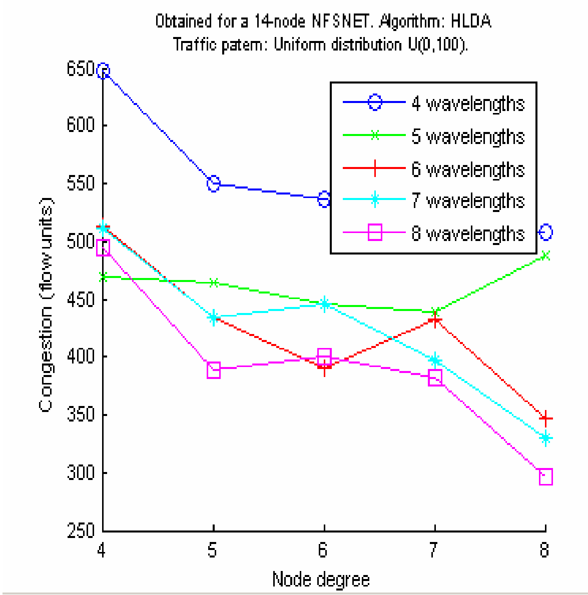


Fig. 2, Congestion versus logical degree for different numbers of the available wavelengths for the traffic matrix P2 by the topology design algorithm HLDA.

In Fig. 3 and Fig. 4 , We used The minimum-delay logical topology algorithm (MLDA) heuristic to design the virtual topology tacking the congestion as an objective function for both the traffic patterns P1 and P2 respectively. We observed that (MLDA) is capable to realize tighter delay constraints without much increase in the congestion

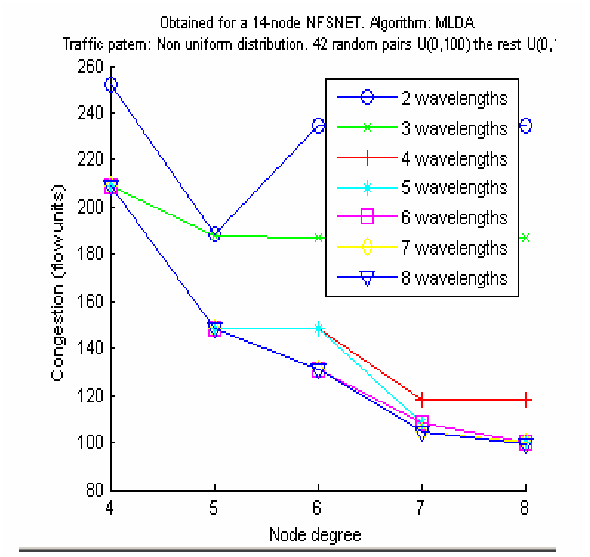
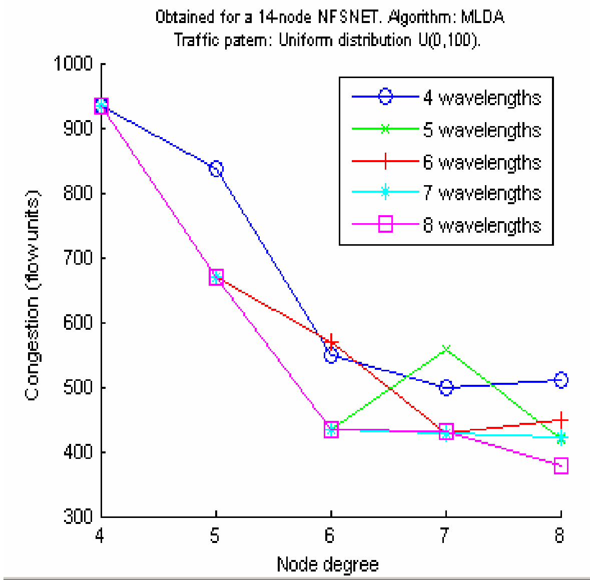


Fig. 3. Congestion versus logical degree for different numbers of the available wavelengths for the traffic matrix PI by the topology design algorithm MLDA in the 14-node NSFNET example.



Fig, 4. Congestion versus logical degree for different numbers of the available wavelengths for the traffic matrix P2 by the topology design algorithm MLDA in the 14-node NSFNET example.

In Fig. 5 and Fig. 6, we used Traffic independent logical design algorithm (TILDA) for both traffic patterns P1 and P2 respectively. We observed that both (MLDA) and (TILDA) used a smaller number of wavelengths than (HLDA) for the same node degree. In Fig. 7 and Fig. 8 we explored the use of Random logical design algorithm (RLDA). We observed that this algorithm has no perfect results and we cannot depend on its results, since it has varying values.

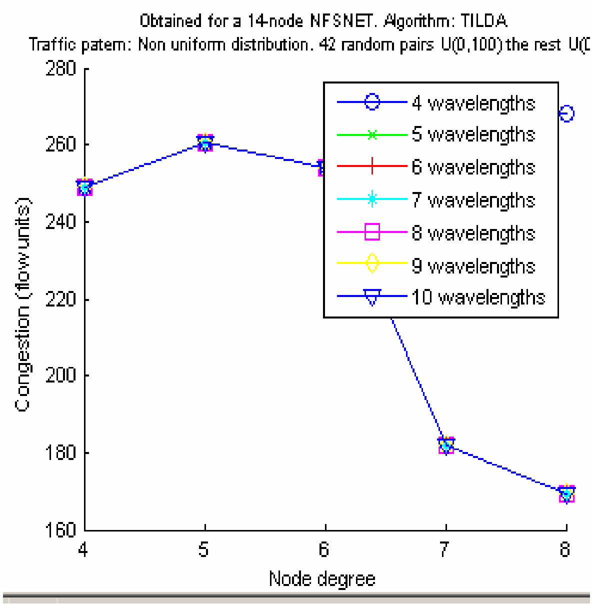


Fig. 5. Congestion versus logical degree for different numbers of the available wavelengths for the traffic matrix PI by the topology design algorithm TILDA in the 14-node NSFNET example.

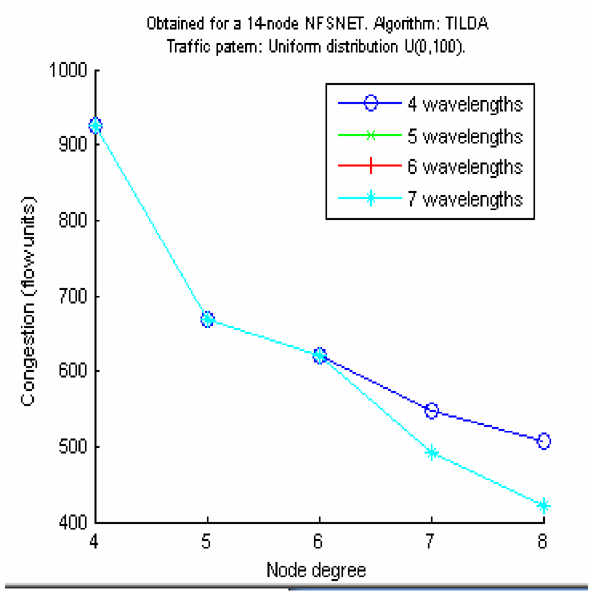


Fig. 6. Congestion versus logical degree for different numbers of the available wavelengths for the traffic matrix P2 by the topology design algorithm TILDA in the 14-node NSFNET example.

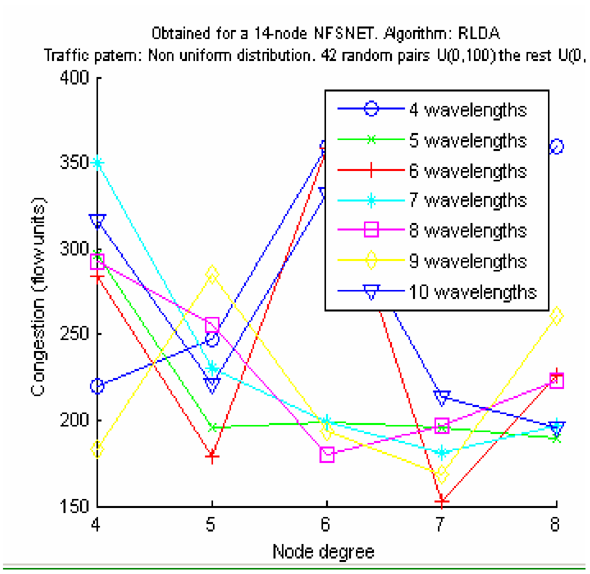


Fig. 7. Congestion versus logical degree for different numbers of the available wavelengths for the traffic matrix PI by the topology design algorithm RLDA in the 14-node NSFNET example in the 14-node NSFNET example.

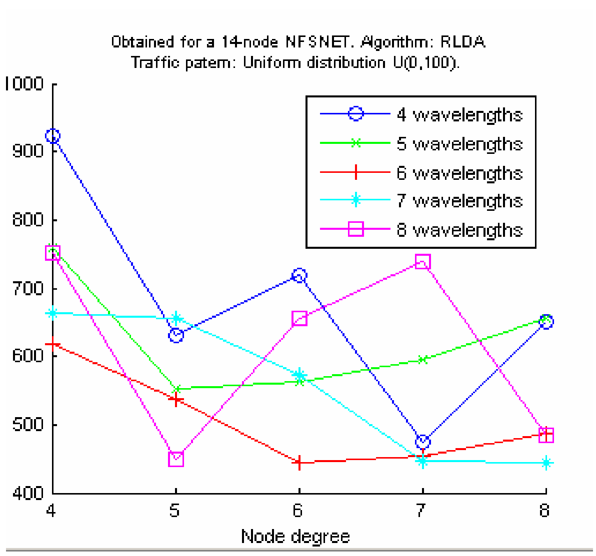


Fig. 8, Congestion versus logical degree for different numbers of the available wavelengths for the traffic matrix P2 by the topology design algorithm RLDA in the 14-node NSFNET example.

4. CONCLUSIONS

We can summarize the results and conclusions as flows:

a) Virtual topology design problems can be formulated as optimization problems aimed at achieving a certain performance measures of interest. Typically, the exact solution can be shown to be NP-hard, and heuristic approaches are needed to find;
b) Node degree constraints may play a more significant role in limiting the performance of a logical topology than the number of wavelengths available in the 14 node NSFNET;
c) MILP is hard to perform on normal PCs especially for large networks such as 14 NSFNET, while the other Heuristic algorithms gives near optimum results in practical processing time;
d) MILDA and TILDA tend to design logical topologies using a smaller number of wavelengths than HLDA;
e) RDLA gave a vibrating results in which , we cannot depend on to get an accurate performance.

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