On IP Network Routing Performance of MENTOR-II Algorithm

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Abstract. Mesh Network Topological Optimization and Routing (MENTOR) II algorithm is a low complexity and efficient networks design algorithm for IP networks with OSPF routing protocol. This study explores the impact of design parameters on routing performance of 120 MENTOR-II networks. The routing performances of each network at normal load and at congestion threshold are calculated and compared with the optimum solution. It is found that the routing performances depend on the initial tree used in the MENTOR-II algorithm, as well as the allowable minimum and maximum link utilization. MENTOR-II networks start with shortest path tree give better routing performance than that start with minimum spanning tree. The routing performances keep very close to that of the optimal when the gap between maximum and minimum utilization is small and get as worse the gap increase.

Keywords: network design, mesh networks, traffic routing

1 Introduction

MENTOR (Mesh Network Topological Optimization and Routing) [1] is a high-speed and very efficient heuristic network design algorithms. MENTOR is flexible and can be used to design virtual circuit packet switching networks such as Frame Relay, ATM or even MPLS. However, MENTOR cannot be directly applied to designed IP router network. This is because the traffic flow assignment done by MENTOR algorithm are not always the shortest path routing and equal cost multi path routing (ECMP). To solve the problem, Cahn et al. [2] proposed a modified version of MENTOR called MENTOR-II. In MENTOR-II, only single path routing is considered and appropriate link weights are assigned to the installed links such that the traffic always routed on the path with minimum distance. Since MENTOR-II is a heuristic algorithm, the traffic assignment is not always optimal and depends on network design parameters such as the maximum and minimum link utilization.

This paper investigates the relation between design parameters and the routing performance of MENTOR-II networks. The performances at normal load and at threshold of congestion of MENTOR-II flow assignment are calculated and compared with the optimum solution obtained by solving the linear programming.

2 Problem Formulation

2.1 MENTOR-II Algorithm

MENTOR algorithm [1] starts by selecting a good spanning tree that connected all nodes of the network. Then, for any two end nodes, direct link is considered first to serve the traffic between them. A direct link is installed if the utilization is between the maximum and minimum allowable utilization. All or a portion of traffic may be overflowed to next direct path if the traffic can be bifurcated. Otherwise, all or no traffic are overflowed the next direct path. The characteristics of network obtained by MENTOR algorithm are (1) traffic demands are routed on relatively direct paths (2) links have reasonable utilization and (3) relatively high capacity links are used.

MENTOR-II [2] is similar to MENTOR but while considering a direct link to serve traffic demand between 2 end nodes, it calculated an appropriate link cost for the direct link based on ISP algorithm so that OSPF/IS-IS routers always direct traffic through a desired single shortest path route.

MENTOR-II gives fairly good results. However, the impact of design parameters, e.g. the maximum allowable utilization ρ, the different between maximum and minimum utilization s and α which is used to determined the type of spanning tree on the performance of traffic routing are not yet studied before.

2.2 Objective Function

Given a network represented by directed graph G = (N, A), it is suggested in [4] to measure the routing performance by cost a function

$$\Phi = \sum_{a \in A} \phi_a(l_a, c_a), \tag{1}$$

where c_a and l_a denote link capacity and traffic load associated with link $a \in A$. And $\phi_a(l_a, c_a)$ is an M/M/1 queuing theory style link cost function given by

$$\phi_a(l_a, c_a) = l_a / (c_a - l_a) \tag{2}$$

Equation (1) implies that it is more expensive to send flow along arcs whose loads approach capacity. However, (1) cannot be used as an objective function for linear programming technique especially when $l_a \geq c_a$. To overcome this problem, $l_a /(c_a - l_a)$ is approximated by a piece-wise linear function. As a consequence, the optimal routing problem can be formulated as the follows [4].

$$\text{Min } \Phi = \sum_{a \in A} \phi_a \tag{3}$$

Subject to:

$$\sum_{u:(u,v)\in A} f_{u,v}^{s,t} - \sum_{u:(u,v)\in A} f_{v,u}^{s,t} = \begin{cases} d_{st} \text{ if } v = t \\ -d_{st} \text{ if } v = 0 \\ 0 \text{ otherwise} \end{cases} \qquad v,s,t \in N, \tag{4}$$

$$\phi_a \geq l_a \quad a \in A, \tag{5}$$

$$\phi_a \geq 3l_a - 2/3c_a \quad a \in A, \tag{6}$$

$$\phi_a \geq 10l_a - 16/3c_a \quad a \in A, \tag{7}$$

$$\phi_a \geq 70l_a - 178/3c_a \quad a \in A, \tag{8}$$

$$\phi_a \geq 500l_a - 1468/3c_a \quad a \in A, \tag{9}$$

$$\phi_a \geq 5000l_a - 19468/3c_a \quad a \in A, \tag{10}$$

$$l_a = \sum_{t\in N} f_a^{s,t} \quad a \in A, \tag{11}$$

$$f_a^{s,t} \geq 0 \quad a \in A;\ t \in N. \tag{12}$$

Constraint (4) is flow conservation constraints. Constraints (5) – (10) describe the cost function. Constraint (11) define the load on each arc where f_a^{st} is the amount of traffic flow from node *s* to *t* that pass through arc *a*.

It should be note that the traffic assignment performed by MENTOR-II algorithm is single shortest path routing and the amount of total traffic on each link is limited by the maximum utilization ρ [6]. As a result, the following constraints (13) – (15) must be included to solve optimal routing.

$$l_a / c_a \leq \rho. \tag{13}$$

$$f_a^{s,t} \leq split_{u,v}^{s,t} * d_{st}, \qquad split_{u,v}^{s,t} \in \{0, 1\}, \tag{14}$$

$$\sum_{v\in N} split_{u,v}^{s,t} \leq 1. \tag{15}$$

The optimum solutions used to compare with MENTOR-II networks in section 3 are obtained by solving (4) subject to (5) – (15).

In order to make possible comparisons across different network sizes and topologies, in stead of (3), Fortz et al [4] defined a normalizing cost as

$$\Phi^* = \Phi / \Phi_{\text{UNCAP}} \tag{16}$$

In the equation Φ_{UNCAP} is normalized scaling factor

$$\Phi_{\text{UNCAP}} = \sum_{s,t\in NxN} d_{s,t} h_{s,t} \tag{17}$$

where h_{st} = minimum hop count between *s* and *t*.

3 Performance Evaluations

3.1 Network Generations

In order to evaluate the routing performance of MENTOR-II algorithm, a number of 10-node networks are generated. For each network, only full-duplex link with multiple 155 Mbps channels are considered. The total 120 networks are generated as follows. First, DELITE [3] is used to synthesize 4 sets of 10 nodes N1, N2, N3 and N4. Each set has different location distributions obtained by varying SEED parameter. The traffic demand matrix for each set is also generated by DELITE with default setting and total traffic in and out of each node are set to 200 Mbps. For each set, two groups of networks corresponding to Minimum Spanning Tree (α=0) and Shortest Path Tree (α=1) are generated. For each type of spanning tree, 15 networks are generated by varying of ρ, $\rho \in$ (0.4, 0.5, 0.6) and s, $s \in$ (0.0, 0.1, 0.2, 0.3, 0.4).

3.2 Routing Performances

For each of 120 MENTOR-II networks, the normalized MINTOR-II routing cost and the normalized optimum solution are calculated. The optimal solution is obtained by solving integer linear programming problem proposed in section 2.2 by GLPK [6].

The performance of MENTOR-II routing at normal load condition is measured by % of cost different from optimality (ΔC) [5]

$$\Delta C = \frac{\Phi^*_M - \Phi^*_O}{\Phi^*_O} \times 100 , \qquad \textbf{(3)}$$

where Φ^*_M and Φ^*_O , respectively, are normalized routing cost of MENTOR-II algorithm and the optimum solution measured at demand used to design the network.

To evaluate the performance at threshold of congestion (Φ^*= 10⅔), normalized cost of MENTOR-II and the optimal solution are calculated for different scaling of projected demand matrix. The performance of routing at the threshold of congestion is measured by % of demand different from optimality (ΔD) [5]

$$\Delta D = \frac{D_M - D_O}{D_O} \times 100 , \qquad \textbf{(19)}$$

where D_M and D_O, respectively, are the scaling traffic demand of MENTOR flow assignment, and that of optimum solution measured when Φ^*= 10⅔.

3.3 Experiment Analysis

To make clear relation between routing performances and design parameters, ΔC and ΔD of the same α, ρ and s are averaged, and plotted versus the $\Delta U = s\rho$

Fig.1-2 showed that, for MENTOR-II network with α =0, both average ΔC and ΔD get large as ΔU increase and tend to even larger as maximum utilization ρ increase. This means the performance of the network will close to that of the optimum if the different between the maximum and minimum utilization decrease. The performance is even better if maximum utilization increase, i.e. more spare capacity.

In Fig.3-4, for α =1, the networks give better performance than networks with α =0. This is because most of the obtained networks are spanning trees, their performances are the same as that of the optimum, i.e. average ΔC and ΔD are 0 for most values of the ΔU and maximum utilization. The MENTOR-II network with α =1 also tends to give better performance when the gap between the maximum and minimum utilization decrease.

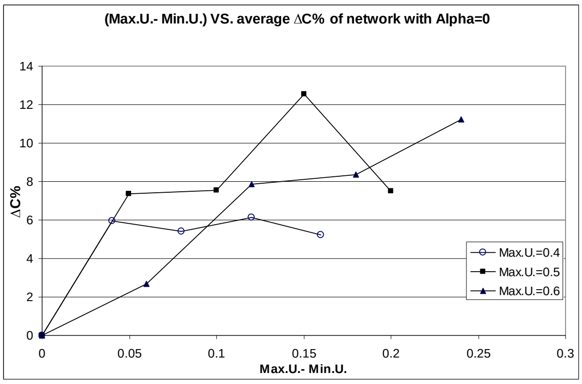

Fig.1 Average ΔC vs. ΔU for Alpha=0

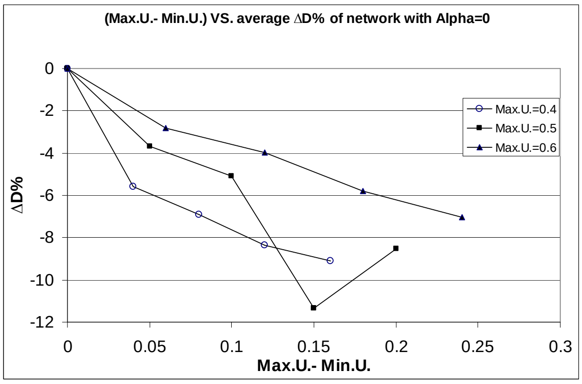

Fig.2 Average ΔD vs. ΔU for Alpha=0

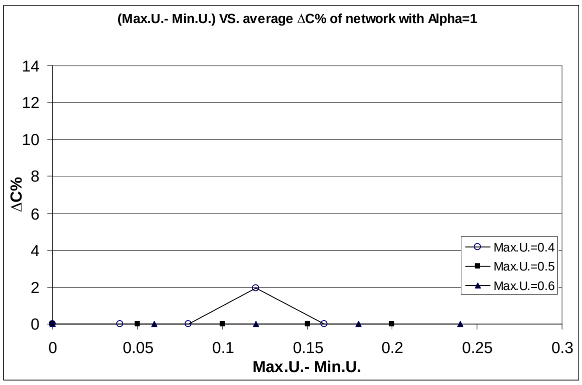

Fig.3 Average ΔC vs. ΔU for Alpha=1

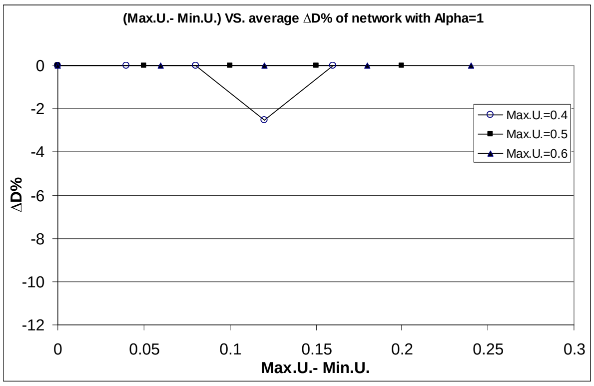

Fig.4 Average ΔD vs. ΔU for Alpha=1

4 Conclusion

This study has explored the relations between design parameters and traffic routing performance of MENTOR-II algorithm. Traffic routing of 120 MENTOR-II networks have been analyzed in term of performances at normal load and when starting to congest. It can be concluded that the MENTOR-II networks start with shortest path tree (α =0) tends to give better routing performance than that start with minimum spanning tree (α =1). In term of allowable link utilization, the routing performances of MENTOR-II keep very close to the optimal result when the gap between the maximum and minimum utilization is small and get worse as the gap increase.

References:

[1] Aaron Kershenbaum, Parviz Kermani, and George A. Grover, MENTOR: An Algorithm for Mesh Network Topological Optimization and Routing. In: IEEE Transaction on Communications, Vol.39, April 1991, pp.503-513 (1991)

[2] Robert Cahn, Wide Area Network Design, Morgan Kaufmann Publisher, San Francisco, CA, (1998)

[3] Robert Cahn: The Design Tool: Delite (software), http://www.kt.agh.edu.pl/~mwa grow/projektowanie sieci telekomunikacyjnych/DeLite/setupex.exe (1998)

[4] Bernard Fortz and Mikkel Thorup: Internet traffic engineering by optimizing OSPF weights. In: Proc. IEEE INFOCOM, vol. 2, Mar. 2000, pp.519–528 (2000)

[5] Kairat Jaroenrat, Pisit CharnKeitkong: On Routing Performance of MENTOR Algorithm. WSEAS TRANSACTION ON COMMUNICATIONS, Issue 9, Vol.5, September 2006, pp. 1769-1776. (2006)

[6] Andrew Makhorin: GLPK (GNU Linear Programming Kit). http://www.gnu.org/ software/glpk/ (2000)