DEPARTAMENTO DE ELETRÓNICA, TELECOMUNICAÇÕES E INFORMÁTICA

MESTRADO EM ENGENHARIA DE COMPUTADORES E TELEMÁTICA

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MODELAÇÃO E DESEMPENHO DE REDES E SERVIÇOS

MINI-PROJECT 2:

TRAFFIC ENGINEERING OF TELECOMMUNICATION NETWORKS

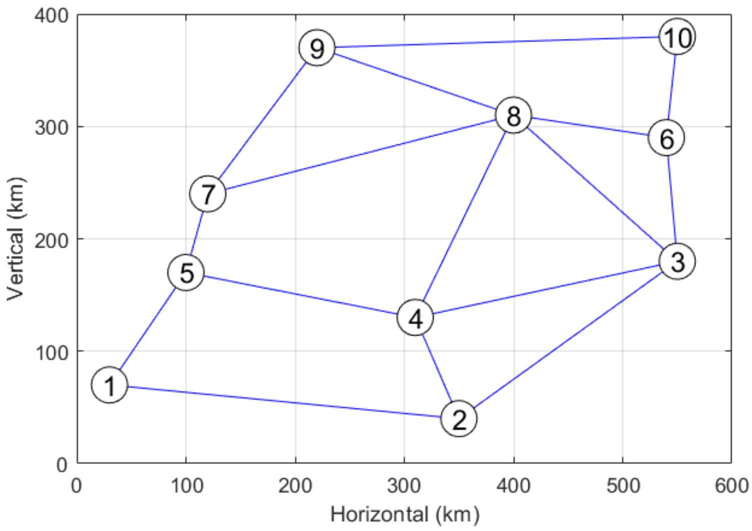
Mini-Project 2

Assignment Description

Develop this mini-project in a group of 2 students. Implement all tasks using MATLAB to obtain the requested results. Justify all obtained results and draw all conclusions as complete as possible. Write a report with all results together with their analysis and conclusions. Include in the report all developed MATLAB codes duly explained. The report must be sent in PDF format to asou@ua.pt until the end of 2^{nd} of February of 2022.

Network and service description

Consider the MPLS (Multi-Protocol Label Switching) network of an ISP (Internet Service Provider) with the following topology composed by 10 nodes and 16 links and defined over a rectangle with 600 Km by 400 Km:



The length of all links is provided by the square matrix L. The capacity of all links is 10 Gbps in each direction. Consider a unicast service defined with the following 9 flows (throughput values b_t and $\underline{b}_t$ in Gbps):

t	o_t	d_t	b_t	$\underline{b}_t$
1	1	3	1.0	1.0
2	1	4	0.7	0.5
3	2	7	2.4	1.5
4	3	4	2.4	2.1
5	4	9	1.0	2.2
6	5	6	1.2	1.5
7	5	8	2.1	2.2
8	5	9	1.6	1.9
9	6	10	1.4	1.6

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Task 1 (evaluation: 6.0 values)

In this task, the aim is to compute a symmetrical single path routing solution to support the unicast service which minimizes the resulting worst link load.

1.a. With a k-shortest path algorithm (using the lengths of the links), compute the number of different routing paths provided by the network to each traffic flow. What do you conclude?

1.b. Run a random algorithm during 10 seconds in three cases: (i) using all possible routing paths, (ii) using the 10 shortest routing paths, and (iii) using the 5 shortest routing paths. For each case, register the worst link load value of the best solution, the number of solutions generated by the algorithm and the average quality of all solutions. On a single figure, plot for the three cases the worst link load values of all solutions in an increasing order. Take conclusions on the influence of the number of routing paths in the efficiency of the random algorithm.

1.c. Repeat experiment **1.b** but now using a greedy randomized algorithm instead of the random algorithm. Take conclusions on the influence of the number of routing paths in the efficiency of the greedy randomized algorithm.

1.d. Repeat experiment **1.b** but now using a multi start hill climbing algorithm instead of the random algorithm. Take conclusions on the influence of the number of routing paths in the efficiency of the multi start hill climbing algorithm.

1.e. Compare the efficiency of the three heuristic algorithms based on the results obtained in **1.b**, **1.c** and **1.d**.

Task 2 (evaluation: 6.0 values)

Consider that the energy consumption of each link is proportional to its length. Consider also that a link not supporting traffic in any of its direction can be put in sleeping mode with no energy consumption. In this task, the aim is to compute a symmetrical single path routing solution to support the unicast service which minimizes the energy consumption of the network.

2.b. Run a random algorithm during 10 seconds in three cases: (i) using all possible routing paths, (ii) using the 10 shortest routing paths, and (iii) using the 5 shortest routing paths. For each case, register the energy consumption value of the best solution, the number of solutions generated by the algorithm and the average quality of all solutions. On a single figure, plot for the three cases the energy consumption values of all solutions in an increasing order. Take conclusions on the influence of the number of routing paths in the efficiency of the random algorithm.

2.b. Repeat experiment **2.a** but now using a greedy randomized algorithm instead of the random algorithm. Take conclusions on the influence of the number of routing paths in the efficiency of the greedy randomized algorithm.

2.c. Repeat experiment **2.a** but now using a multi start hill climbing algorithm instead of the random algorithm. Take conclusions on the influence of the number of routing paths in the efficiency of the multi start hill climbing algorithm.

2.d. Compare the efficiency of the three heuristic algorithms based on the results obtained in **2.a**, **2.b** and **2.c**.

Task 3 (evaluation: 4.0 values)

Assume that all routers are of very high availability (i.e., their availability is 1.0). Compute the availability of each link based on the length of the link assuming the model considered in *J.-P. Vasseur, M. Pickavet and P. Demeester, "Network Recovery: Protection and Restoration of Optical, SONET-SDH, IP, and MPLS", Elsevier (2004)*. In this task, the aim is to compute a pair of symmetrical routing paths to support each flow of the unicast service.

3.a. For each flow, compute one of its routing paths given by the most available path.

3.b. For each flow, compute another routing path given by the most available path which is link disjoint with the previously computed routing path. Compute the availability provided by each pair of routing paths. Present all pairs of routing paths of each flow and their availability. Present also the average service availability (i.e., the average availability value among all flows of the service).

3.c. Recall that the capacity of all links is 10 Gbps in each direction. Compute how much bandwidth is required on each direction of each link to support all flows with 1+1 protection using the previous computed pairs of link disjoint paths. Compute also the total bandwidth required on all links. Register which links do not have enough capacity.

3.d. Compute how much bandwidth is required on each link to support all flows with 1:1 protection using the previous computed pairs of link disjoint paths. Compute also the total bandwidth required on all links. Register which links do not have enough capacity and the highest bandwidth value required among all links.

3.e. Compare the results of **3.c** and **3.d** and justify the differences.

Task 4 (evaluation: 4.0 values)

Consider the same availability values as in Task 3. In this task, the aim is to compute a pair of symmetrical routing paths to support each flow of the unicast service with 1:1 protection which minimizes the highest required bandwidth value among all links.

4.a. For each flow, compute 10 pairs of link disjoint paths in the following way. With a k-shortest path algorithm, first compute the k = 10 most available routing paths provided by the network to each traffic flow. Then, compute the most available path which is link disjoint with each of the k previous paths.

4.b. Develop a multi start hill climbing algorithm for this optimization problem using the 10 pairs of link disjoint paths computed in **4.a** for each flow. Run the algorithm during 30 seconds. Present the pair of routing paths of each flow (and its availability) and the average service availability of the best solution. Present the highest required bandwidth value among all links. Compare this solution with the one in **3.d** and take all possible conclusions.