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

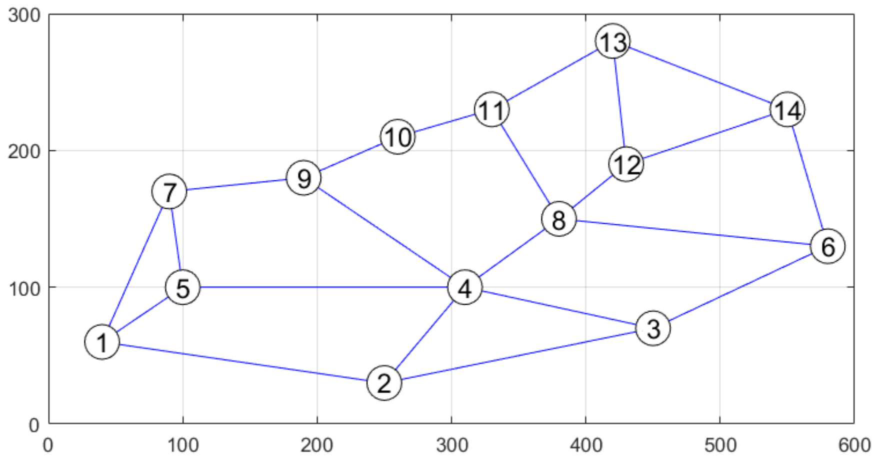
Mini-Project 2

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 6th of January of 2023.

Description of the network, supported services and energy consumption models

Consider the MPLS (Multi-Protocol Label Switching) network of an ISP (Internet Service Provider) with the following topology composed by 14 nodes and 22 links and defined over a rectangle with 600 Km by 300 Km:



The length of all links is provided (in Km) by the square matrix L. The network supports a unicast service whose flows characteristics are given by matrix *T_uni*. This matrix has a number of rows equal to the number of flows (one row per unicast flow) and 4 columns:

- first column defines the source node of the flow,
- second column defined the destination node of the flow,
- third column defined the throughput (in Gbps) of the flow from source to destination,
- fourth column defines the throughput (in Gbps) of the flow from destination to source.

The network also supports an anycast service whose flows characteristics are given by matrix *T_any*. This matrix has a number of rows equal to the number of flows (one row per anycast flow) and 3 columns:

- first column defines the source node of the flow,
- second column defined the source upload throughput (in Gbps) of the flow,
- third column defined the source download throughput (in Gbps) of the flow.

To load all input matrices, run on your script: `load('InputDataProject2.mat')`

Consider that each router has a capacity of 500 Gbps and its energy consumption is $E_n = 10 + 90 \times t^2$, where t is given by the total traffic load supported by the router divided by its capacity.

When a link is fully operational, its energy consumption is $E_l = 6 + 0.2 \times l$ (where l is the length of the link, in Km) if the link has a capacity of 50 Gbps or is $E_l = 8 + 0.3 \times l$ if the link has a capacity of 100 Gbps. On the other hand, when a link is in sleeping mode, its energy consumption is $E_l = 2$, whatever the link capacity is.

Task 1 (evaluation: 7.0 values)

In task 1, consider that all links have a capacity of 50 Gbps and that the anycast nodes of the anycast service are network nodes 5 and 12.

1.a. Determine the link loads of all links when all traffic flows (of both services) are routed through the shortest path provided by the network (using the lengths of the links). Determine the resulting worst link load.

1.b. Determine the network energy consumption of the previous solution and the links that are put in sleeping mode.

1.c. Consider the optimization problem aiming to compute a symmetrical single path routing solution to support both services which minimizes the resulting worst link load. Assume that each anycast flow is routed through the shortest path and use a *k*-shortest path algorithm (using the lengths of the links) to determine the candidate routing paths for each unicast flow. Develop a Multi Start Hill Climbing algorithm with initial Greedy Randomized solutions to solve this optimization problem.

1.d. Run the algorithm developed in task **1.c** for 30 seconds with *k* = 2. Register the worst link load and the network energy consumption of the best obtained solution, and the running time at which the algorithm has obtained its best solution. Compare these results with the results of tasks **1.a** and **1.b** and explain the differences.

1.e. Repeat task **1.d** but now with *k* = 6. Compare these results with the previous ones and take conclusions on the influence of the number of candidate routing paths in the obtained results for this optimization problem.

Task 2 (evaluation: 7.0 values)

In task 2, consider again that all links have a capacity of 50 Gbps and that the anycast nodes of the anycast service are network nodes 5 and 12.

Consider the optimization problem aiming to compute a symmetrical single path routing solution to support both services which minimizes the resulting energy consumption of the network.

2.a. Assume that each anycast flow is routed through the shortest path and use a *k*-shortest path algorithm to determine the candidate routing paths for each unicast flow. Develop a Multi Start Hill Climbing algorithm with initial Greedy Randomized solutions to solve this optimization problem.

2.b. Run the algorithm developed in task **2.a** for 30 seconds with *k* = 2. Register the worst link load and the network energy consumption of the best obtained solution, and the running time at which the algorithm has obtained its best solution. Compare these results with the results of tasks **1.a** and **1.b** and explain the differences.

2.c. Repeat task **2.b** but now with $k = 6$. Compare these results with the previous ones and take conclusions on the influence of the number of candidate routing paths in the obtained results for this optimization problem.

2.d. Compare the results obtained in task **1.e** and task **2.c** and explain the differences.

Task 3 (evaluation: 6.0 values)

In task 3, consider that all links can be set with a capacity of either 50 Gbps or 100 Gbps, and that the anycast nodes of the anycast service are network nodes 5 and 12.

Note that changing the capacity of a link from 50 Gbps to 100 Gbps consumes more energy when is fully operational (on one hand) but might enable more links to change to sleeping mode (on the other hand). So, the network consumption of the network might be less when some links are changed from 50 Gbps to 100 Gbps.

Consider the optimization problem aiming to compute the capacity that should be assigned to each link and the symmetrical single path routing solution to support both services so that the resulting energy consumption of the network is minimized.

3.a. Assume that each anycast flow is routed through the shortest path and use a *k*-shortest path algorithm to determine the candidate routing paths for each unicast flow. Develop a Multi Start Hill Climbing algorithm with initial Greedy Randomized solutions to solve this optimization problem.

3.b. Run the algorithm developed in task **3.a** for 60 seconds with $k = 6$. Register the worst link load and the network energy consumption of the best obtained solution, the links whose capacity were changed from 50 Gbps to 100 Gbps, and the running time at which the algorithm has obtained its best solution. Compare these results with the results of task **2.c** and explain the differences.

3.c. Consider that you can select the two anycast nodes of the anycast service among nodes 4, 5, 6, 12 and 13 (where there are available Data Centers to host the server of the service). Try all possible combinations of two nodes and select the one that obtains the best solution of the optimization problem addressed in this Task 3. Register the two selected anycast nodes, the worst link load and the network energy consumption of the best obtained solution, and the links whose capacity were changed from 50 Gbps to 100 Gbps. Compare these results with the results obtained in task **3.b** and explain the differences.