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## PLANIFICACIÓN Y GESTIÓN DE REDES

GRADO EN INGENIERÍA TELEMÁTICA  
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### Lab work #3. IGP-metric vs. MPLS-TE based traffic engineering assessment with Net2Plan

(1 session)

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# 1 Objectives

The goals of this lab work are:

1. Use Net2Plan to analyze the merits of different *strategic* traffic engineering alternatives: OSPF with static link costs (in different forms), dynamic MPLS-TE tunnels, and 1+1 Fast Reroute tunnels. This includes dimensioning the required link capacities in each case for given fault tolerance & latency SLAs.
2. Use Net2Plan to analyze the robustness of OSPF with static link costs, OSPF with dynamic link costs, and the same MPLS-TE flavors as before, for traffic fluctuations.

# 2 Duration

This lab work is designed for one session of three hours.

# 3 Evaluation

This lab work has been designed to guide the students in their learning of the subject. The annotations the students make in this document are for their use when studying the course, and do not have to be delivered to the teacher for evaluation.

# 4 Documentation

The resources needed for this lab work are:

- Lecture notes of the course.
- Net2Plan tool and their documentation (see <http://www.net2plan.com/>).
- Instructions in this wording.

# 5 Previous work before coming to the lab

- Read lecture notes related to network simulation and to traffic engineering.
- Refresh your reading in <http://www.net2plan.com/>, in particular, on the availability and traffic fluctuations report.

# 6 Comparison of strategic traffic engineering alternatives from a cost perspective

In this section, we take the role of a network carrier with an IP network. The carrier is interested in comparing the potential benefits of different traffic engineering policies. The IP topology of links is given, as well as the IP demands to carry. The design has the following requirements:

- Should be fault tolerant to IP adjacency failures, i.e. the simultaneous failure of the two IP links in the two directions. Each of those failures is supposed to happen once a year, and take an average of 12 hours to be repaired (i.e.  $MTTF = 365 \times 24 - 12 = 8748$  hours,  $MTTR = 12$  hours).
- The SLA of the IP flows specifies that they should not traverse an IP link with an utilization above 90%, in the non failure state, and an utilization of 100% in any single failure state.
- The capacity in the IP links must be a multiple of 100 Gbps, and bidirectional 100 Gbps modules are used.<sup>1</sup>

The traffic engineering options to compare are:

- **OSPF-uniform cost.** The IP links have all the same IGP cost (e.g. equal to one).
- **OSPF-cost prop. latency.** The IP links have an IGP cost that is proportional to the link propagation delay.
- **OSPF-cost optimized in non-failure.** The IP links have an IGP cost that is computed to optimize the congestion in the non-failure state.
- **MPLS-TE 1+1 FRR protection.** A tunnel is set for each IP flow, with two link-disjoint paths, both precomputed and pre-reserved with Fast-Reroute.
- **MPLS-TE dynamic.** A tunnel is set for each IP flow, which takes the capacitated shortest path according to the IGP weights (i.e. the shortest path with enough capacity). If the tunnel fails, its path is recomputed.

The metric comparing the two options is the total capacity in the links needed, measured as the number of 100 Gbps modules to install. For obtaining the required link capacities in each option, the student should use the `Report_availability`, with the following parameters:

- Do not analyze double failures.
- Check the `capacityAnalysis_updateLinkCapacitiesInDesign` option, if you want the input design to be modified by the report. If so, the link capacities will be set to those that are needed have the limit utilization in the worst case failure state tested.
- For the failure model, you can select that the report automatically creates one SRG for each bidirectional link bundle (i.e. an IP adjacency). Note that default options apply here.
- For the provisioning algorithm, the user can use the `Online_evProv_ipOspfAndMplsTe` algorithm. This algorithm codes the reaction of a network where IP demands can be routed by OSPF rules (static, or that can be changed everytime a reaction is simulated), and others according to some MPLS-TE flavors. The OSPF weight setting type of the algorithm should be set to static, since OSPF link weights will not be changed as a reaction to failures. More details will be explained below.

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<sup>1</sup>This means that the capacity of a link will be the lowest multiple of 100 Gbps that is able to carry a traffic  $T$ , equal to the maximum between the two link directions, with a maximum utilization of 90%.

## The OSPF & MPLS-TE simulator

The `Online_evProv_ipOspfAndMplsTe` built-in algorithm codes the simulation of an IP network that routes the traffic of each demand as follows:

- If a demand is tagged as of hop-by-hop routing, it is carried using the OSPF/ECMP routing, which depends on the IGP weights configured. These weights can be kept unchanged, or can be recomputed everytime the simulation of a reaction is requested. In the latter case (`ospfWeightSettingType = dynamic`, an OSPF weight setting heuristic algorithm is used (with a maximum running time of `ospfWeightSetting_maxHeuristicTimeInSecs` seconds). The algorithm recomputes the OSPF weights attempting to balance the traffic in the new situation.
- If a demand is tagged as source-routing, it will be routed simulating an MPLS-TE tunnel. Two options are possible:
  - **CSPF-dynamic**. The full demand traffic is attempted to be routed in the shortest path of the demand, considering only those links that have enough non-reserved bandwidth by previously setup tunnels. Since we are simulating the MPLS-TE control plane reservation process, the bandwidth in the links consumed by the OSPF traffic does not count for MPLS-TE tunnel path computations. The link weights for computing the shortest path are the IGP weights. If no path is found, **the full traffic demand is dropped**. If more than one path is found, one out-of-them is chosen arbitrarily.
  - **1+1-FRR-link-disjoint**. For each demand, two link-disjoint paths are computed at the start of the process, if no 1+1 route exist. One acts as main route, the other as backup. Both paths reserve capacity in the MPLS-TE control plane, and occupy bandwidth in the links. If any of the two paths cannot reserve capacity, the tunnel is not setup. If it is, the traffic is carried in the main path, or in the backup path if the main is down, or in none if both paths are down. For those node pairs for which it was not possible to find a link-disjoint path, two paths are searched that try to be as link-disjoint as possible.

For simulating regular OSPF routing, select all demands to be of the hop-by-hop routing form. For simulating a network full routed via MPLS-TE, all the demands must be of the source routing type.

### 6.1 What-if visualization of traffic engineering alternatives

Follow the next steps:

1. Load the network design `NSFNet_N14_E42_complete.n2p`.
2. Set the IGP weight for each link to be one. For this, in the `Links` table, use the right-click option `Set IGP link weights of selected links -> as constant value`.
3. Configure the what-if analysis simulator to be the OSPF & MPLS-TE simulator described. Select `CSPF-dynamic` as the MPLS-TE routing option.
4. Make all the demands be of the form hop-by-hop routing. For this, in the `Demands` table, use the right-click option `Set routing type of selected demands`.
5. Observe the path followed by the traffic demand from Seattle to Atlanta. Is the traffic bifurcated in more than one path?

6. Set as down the two links between Seattle and Urbana. Is the previous demand being still carried? which path is being used now?

7. Set again the links up. Make the traffic of the previous demand to be of the source routing type. Update the what-if analysis module. Is the traffic carried by two paths? why?

8. Set as down the two links between Seattle and Urbana again. Is the previous demand being still carried? did the path change?

9. Set again the links up. Change the OSPF/MPLS-TE simulator to use 1+1 FRR tunnels. Is the traffic of the Seattle to Atlanta demand carried by two routes? how many of them have traffic?

**Quiz 1.** The student is encouraged to observe the reaction to failures under arbitrary combinations of links and node failures, of the different traffic engineering options.

## 6.2 Cost comparison of traffic engineering alternatives

The cost comparison should be conducted making use the `Report_availability` already introduced in the *Network Analysis* lab session. Our interest is using the report, and focus on the dimensioning of the required link capacities for meet the SLA requirements in all the failure states of interest. **For this, all the IP links should be initially set to a large capacity value (e.g. 10000), so it does not create any congestion.** Then, the report will simulate the traffic reroutings produced in each failure state, and collect the maximum occupied capacity in each IP adjacency in the worst scenario simulated.

The student should fill in the following table:

Cost analysis of traffic engineering alternatives

Traffic eng. option	# of 100 Gbps modules	Worst e2e latency (ms)
OSPF-uniform cost		
OSPF-cost prop. latency		
OSPF-cost optimized in non-failure		
MPLS-TE dynamic (IGP costs 1)		
MPLS-TE dynamic (IGP costs prop.latency)		

Follow the next steps for computing each alternative:

- (In all the cases) Select the option `capacityAnalysys_updateLinkCapacitiesInDesign`. This will make the link capacities to be the ones required to meet the network design requisites. To compute the total number of capacity modules needed, in the `Links` table, use the right-click option `Set selected links capacity -> To match given utilization`. Then, the number of capacity modules needed in the previous table can be easily derived from the last row of the `Links` table, `Capacity` column. Also, save the files in each case with a different name. They will be used later.
- (In all the cases) Select the `static` option in the `ospfWeightSettingType`, since we want to test the situation when OSPF costs do not change during the reaction of a failure.
- **OSPF-uniform cost.** Before running the report, set all the demands as hop-by-hop routing, set all the IGP link weights to one, using the right-click option `Set IGP link weights of selected links -> as constant value`.
- **OSPF-cost prop. latency.** Before running the report, set all the demands as hop-by-hop routing, and set the IGP links weights using the right-click option `Set IGP link weights of selected links -> proportional to link latency`. Set the weight associated to the minimum latency link to be one, and of the maximum latency link to be ten, and make the weight be an integer.
- **OSPF-cost optimized in non-failure.** Before running the report, set all the demands as hop-by-hop routing, set IGP weights to be those computed using one of the algorithms available that optimize the IGP weights to minimize congestion in the non-failure state. In particular, the student should use the algorithm `Offline_fa_ospfWeightOptimization_ACO` with its default parameters, during 10 seconds.
- **MPLS-TE dynamic (IGP costs prop.latency).** Before running the report, set all the demands to be of the source-routing form, and then remove all the existing routes, to let the algorithm compute their owns. Set the IGP weights of all links to one.

Evaluate, according to the results, the different alternatives in aspects like:

- Which OSPF option provides the best end-to-end latency values? what aspect is influencing the design towards this?

- Which MPLS-TE option provides the best end-to-end latency values? what aspect is influencing the design towards this?

- Which options provide the best bandwidth-efficient option (less capacity to be installed)? what aspect is influencing the design towards this?

- Aside of the cost savings (if any), mention at least two potential benefits of using MPLS-TE instead of pure OSPF? mention also some drawbacks.

**Quiz 2.** Repeat this cost analysis with other topologies and traffics.

## 7 Comparison of traffic engineerings for tactical purposes

In this section, we will use the `Report_trafficFluctuationAnalysis` to evaluate how the different methods are prepared for re-routing, in case the traffic shifts.

The report automatically selects the demands with higher traffic in the network (up to a maximum of `maxNumPeakDemands`), and for each of them creates a traffic peak, where the traffic of that demand is multiplied by a factor (`trafficPeakMultiplicativeFactor`), while the traffic of the rest of the demands is unchanged. Then, simulates the network reaction of a user-defined algorithm, and computes how much traffic is correctly carried in the new situation.

Follow the next steps:

1. Load the NSFNET designs previously saved, which have the required capacity to meet the fault tolerance target, and that have the performances reported in the table of the previous section.
2. In each case, run the `Report_trafficFluctuationAnalysis`, with the parameters:
  - Simulate 5 situations, with traffic peaks that multiply the demand traffic by five, one for each the 5 largest demands. Run the report again, for a peak of 10 also in the same 5 largest demands.
  - The reaction algorithm used will be the same as before, configured in each case appropriately to simulate the network reaction.

Thanks to this, we will be able to complete the information of each alternative observed before, adding the evaluation of how robust the design will be to these traffic fluctuations.

Fill in the following table.

Cost analysis of traffic engineering alternatives

Traffic eng. option	% of traffic ok (peak $\times 5$ )	% of traffic ok (peak $\times 10$ )
Static OSPF-uniform cost		
Static OSPF-cost prop. latency		
Dynamic OSPF-cost optimized		
MPLS-TE dynamic (IGP costs 1)		
MPLS-TE dynamic (IGP costs prop.latency)		

Discuss the following questions:

- Why do you think that even  $\times 5$  peak in a demand can be absorbed without oversubscription?

- In what aspects MPLS-TE can be worse than dynamic OSPF for traffic balancing? in what aspects can be better?

## 8 Work at home after the lab work

The student is encouraged to complete all the tasks that he/she could not finish during the lab session, and the Quizzes proposed.