SF2812 Applied Linear Optimization, 2015/2016
Project assignment 1A
Due Tuesday February 23 2016 15.15

Discussion between the groups is encouraged, but each group must individually solve the assignments. It is *not* allowed to use solutions made by others in any form. Please see the course web page for more detailed information on the rules for the assignments.
Instructions on how to present the project assignments can be found at the course web page.
The exercises are divided into basic exercises and advanced exercises. Sufficient treatment of the basic exercises gives a passing grade. Inclusion of the advanced exercises is necessary for the higher grades (typically A-C). A member of a group who has not worked on the advanced exercises says so in the self assessment form.
Instructions for the report:

- The report should have a leading title page where the project name and the group members' names, personal number and e-mail addresses are clearly stated.
- The report should be written using a suitable word processor.
- The contents should be such that another student in the course, who is not familiar with the project, should be able to read the report and easily understand:
  1. What is the problem? What it the problem background? This does *not* mean a copy of the project description, but rather a suitable summary of necessary information needed in order to understand the problem statement.
  2. How has the group chosen to formulate the problem mathematically? What assumptions have been made? If these assumptions affect the solution, this should be noted.
  3. What is the meaning of constraints, variables and objective function in the mathematical formulation?
  4. What is the solution of the formulated optimization problem? If suitable, refer the mathematical solution to the terminology of the (non-mathematical) problem formulation. (There could be more than one optimization problem.)
- Most project descriptions contain a number of questions to be answered in the report. The report *must* contain the answers to these questions. They should, however, in a natural way be part of the content of the report and not be given in a "list of answers". The purpose of the questions is to suggest suitable issues to consider in the part of the report where the results are interpreted and analyzed. Additional interpretations are encouraged as well as generalizations and other ways of modeling the problem.
- A suggested outline of the report is as follows:
  1. Possibly a short abstract.
  2. Problem description and background information.
  3. Mathematical formulation.
  4. Results and analysis (interpretation of results).
  5. A concluding section with summary and conclusions.

Deviations from the outline can of course be done.

- Each member of the group should fill out a self assessment form and append at the end of the report.
- GAMS code should not be part of the report, and should not be referred to in the report.
- Each group should upload the following documents via the Bilda page of the course no later than by the deadline of the assignment:
  - The report as a pdf file including self assessment forms. (If you are unable to include the self assessment forms in the pdf file you may upload them as separate files, or as a last resort leave them in paper form at the beginning of the presentation lecture.)
  - GAMS files.

  Please upload your documents as individual pdf and gms files, and not as zip files.

The company Nett provides capacity in telecommunications networks. Nett does not own its own networks, but rather lease capacity from other providers. Nett has just acquired capacity in a backbone communications network in Europe, which may be modeled by a network with seven major nodes. The nodes are located in Stockholm, London, Paris, Berlin, Warsaw, Madrid and Rome.
In the network, capacity is available to Nett in links between the seven main nodes as follows (Gbit/s):

	Lon	Par	Ber	War	Mad	Rom
Sto	11	14	25	30		
Lon		21			17	
Par			22		31	19
Ber				26		18
War					18	22
Mad						15

When acquiring this network lease, Nett has also overtaken a requirement to provide 50 Gbit/s between Stockholm and Rome, and 40 Gbit/s between London and Warsaw. This is a new situation for Nett, and they want to find a good strategy for providing the capacity. They are also concerned that the network may not be able to cope with the capacity requirement, since they were able to obtain the network because of complaints from customers of the previous operator.

Basic exercises

1. The company wishes to get a feeling for how much slack there is in the network. Help them to do so by routing the traffic in such a way that the maximum utility of any link in the network is minimized, where the utility of a link is defined as the amount of traffic through the link divided by the capacity of the link.

The reason for considering the maximum utility is that the traffic will be spread evenly.

Create a model in GAMS and solve the problem.

Remark: Capacity is to be interpreted as traffic in both directions. However, it is suggested to model the traffic between two nodes as a flow from one node to the other. For example, 50 Gbit/s between Stockholm and Rome may be modelled as a flow of 50 Gbit/s from Stockholm to Rome, or as a flow of 50 Gbit/s from Rome to Stockholm.

2. In order to create more slack in the network, the company has considered buying extra capacity in one or several links in the network. Give them a recommendation as where to buy extra capacity in order to decrease the maximum utility.

Advanced exercises

3. Nett has obtained a request on providing capacity between Berlin and Madrid, in addition to the two existing requirements. They are not sure how much capacity they would be able to provide between Berlin and Madrid. Help them to figure this out.

4. Now go back to the situation with the two original demands only. The Nett network designers are a bit concerned about how uncertainty in link capacities affect the optimal solution. The capacities given in the table are expected values of the capacities that Nett has signed a contract to obtain. In reality the capacities fluctuate around these expected values. In each moment, the available capacity in the links is known. The 50 Gbit/s-demand may be rerouted, if needed. For technical reasons, the 40 Gbit/s-demand must be determined on beforehand, and may not be rerouted to match fluctuations in the capacity. Help Nett to compute a solution which is good for handling this uncertainty. Is this solution very different from the one computed for the basic exercise?

The capacity table can be found at the Bilda page of the course.

Good luck!