COSC 364
Internet Technologies and Engineering
Second Assignment

Andreas Willig
Dept. of Computer Science and Software Engineering
University of Canterbury
email: andreas.willig@canterbury.ac.nz

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1 Administrivia

This assignment is part of the COSC 364 assessment process. It is worth 15% of the final grade. It involves formulating an optimization problem, writing a program (in Python, Java or C) to generate an LP file for this problem and using CPLEX to get numerical solutions.

You will again work in groups of two persons, it is not an option to work alone or in larger groups. Since there may be an odd number of students in the course I will allow for one group with three persons, and this group will get an extra task (to be discussed with me). Submissions by individuals or larger groups not having an agreed extra task will not be marked.

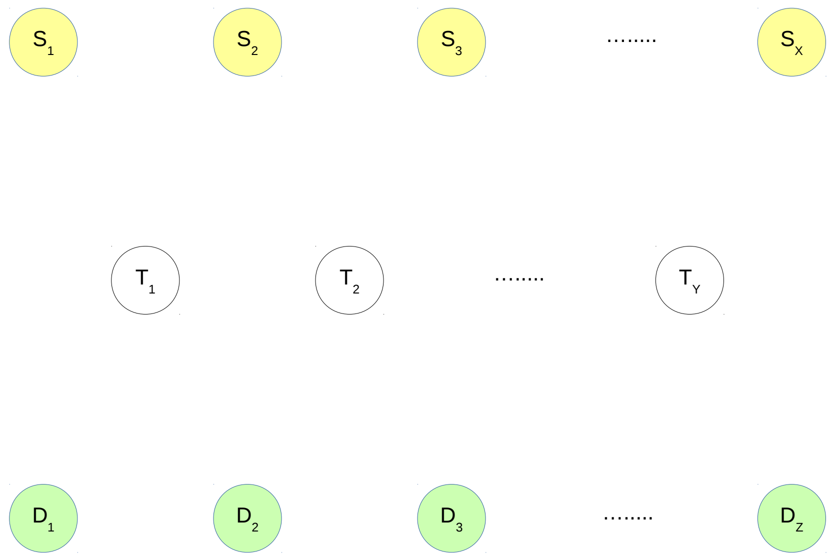
It is quite likely that the problem description below leaves a lot of things unclear to you. Please do not hesitate to use the "Question and Answer Forum" on the Learn platform for raising and discussing any unclear issues. **Important:** Please do not email me with technical questions, rather send such questions to the learn forum, so that all students can benefit.

Important: this assignment description refers to version 1.0 of the planning booklet!

2 Problem Description

Broadly, the problem builds on the lab problems described in Section 7.4 of the planning booklet in Version 1.2, in particular problems 7.4.1 and 7.4.2. Furthermore, it is also related to problem 5.2.6.

We are given a network with the following structure:



There are X source nodes denoted as $\{S_1, S_2, \dots, S_X\}$, Y transit nodes denoted as $\{T_1, T_2, \dots, T_Y\}$ and Z destination nodes denoted as $\{D_1, D_2, \dots, D_Z\}$. A source node has links to all transit nodes, and a transit node has links to all destination nodes. A source then has as many paths available towards a destination as there are transit nodes. Instead of using the δ_{kpl} notation introduced in Section 5.1.2 of the planning booklet it might be easier to use decision variables of the form x_{ikj}, referring to the part of the demand volume between source node i and destination node j that is routed through transit node k.

The capacities of the links have to be determined. We denote these capacities as follows:

- For a link between source node S_i and transit node T_k we denote its capacity by c_{ik}.
- For a link between transit node T_k and destination node D_j we denote its capacity by d_{kj}.

Furthermore, between source node S_i $(1 \leq i \leq X)$ and destination node j $(1 \leq j \leq Z)$ there is a demand volume of

$$h_{ij} = i + j$$

units. There is a global requirement that **each demand volume shall be split over exactly three different paths**, such that each path gets an equal share of the demand volume. In other words, if we denote by x_{ikj} the amount of flow for the demand volume between source i and destination j that uses the path through transit node k, then x_{ikj} must be positive for exactly three values k_1, k_2, k_3 (i.e. $x_{ik_1j} > 0$, $x_{ik_2j} > 0$ and $x_{ik_3j} > 0$) and must be zero for all other $k \in \{1, \dots, Y\}$.

With this background, solve the following tasks:

- The objective is to balance the load (i.e. the total amount of incoming traffic flow) on all the transit nodes. Formulate an optimization problem for generic values of X, Y and Z (with $Y \geq 3$), subject to the usual constraints and the additional requirement that each demand volume should be split over exactly three paths. Determine the load on the transit nodes, the capacities of all links and the value of each flow. Please give a mathematical formulation (showing the objective function, the decision variables and all constraints) and explain it carefully.
- Write a program in either Java, Python or C, which accepts three positive integer numbers X, Y and Z as input and which generates a valid LP file for the above problem.
- Fix $X = 7$ sources and $Z = 7$ destinations. Run your program for each $Y \in \{3, 4, 5, 6, 7\}$, solve the resulting LP file with CPLEX and record the following outputs:
  - The CPLEX run time on your computer (under Linux the `time` command is handy).
  - The load on the transit nodes.
  - The capacity of the link with the highest capacity.

3 Deliverable

Each pair of students submits a **single `.pdf` file** which includes answers to the questions given below. It is sufficient when one member of a team submits this. The file needs to include:

- A title page listing name and student-id of both partners, and indicating the percentage contribution of each partner. **Note**: this must be agreed upon by you and your partner, the relative weights will influence grading.
- A section showing your problem formulation and your explanation for this.
- A section showing the results for the CPLEX execution time, the number of links with non-zero capacities and the highest-capacity links for varying Y. Please explain your results.
- The source code of your program as an appendix.
- A generated LP file (for $X = 3$, $Y = 2$ and $Z = 4$) as an appendix.

Note: Please make sure that your `.pdf` file contains all fonts. This condition is checked upon submission.

The documentation has to be submitted to the departmental coursework dropbox, see `http://cdb.cosc.canterbury.ac.nz`. The submission deadline is **Friday, June 2, 2017, 11.59pm**. Late submissions are **not** accepted. To be on the safe side, it is recommended to submit preliminary versions, you can submit multiple versions to the course dropbox. I will take the last version before the deadline.

4 Marking

The marking will be based on the deliverable only, and the main components are the correctness of the shown results and problem formulation, the explanation of the problem formulation and the results, and the correctness of the included LP file.

When after a quick glance I find that your source code is particularly ugly and un-organized, I will apply deductions of up to 10% of the achievable marks. These will be applied to both team members equally.

References