COSC 364
Internet Technologies and Engineering
Second Assignment

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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.

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.

Note that this assignment description refers to version 1.0 of the planning booklet.

2 Pair Work

An important sub-goal of this assignment to give you some pair-work experience. The rules around this are as follows:

- You are expected to work in groups of two persons, submissions of larger groups will not be marked.
- It is your responsibility to find a partner.

- An individual submission comes with an automatic penalty of 15%, unless there is exactly one individual submission. No exception other than those related to "special consideration" will be given to this rule. Clearly, sometimes things may not work out well with a partner. An important piece of advice in this context is to **start early** with the assignment, so that you have enough time to find a new partner, should that happen.

If you do not find a partner on your own (you could try to post on the `learn` forum!), then you can send me an email, stating the programming languages that you can possibly work in. I will then try to find a suitable partner for you from those who sent similar emails.

3 Plagiarism Warning

Your submissions are logged and originality detection software will be used to compare your solution with other solutions (from this year and from previous years). Dishonest practice, which includes

- letting someone else create all or part of an item of work,
- copying all or part of an item of work from another person with or without modification, and
- allowing someone else to copy all or part of an item of work,

may lead to partial or total loss of marks, no grade being awarded and other serious consequences including notification of the University Proctor.

You are encouraged to discuss the general aspects of a problem with others. However, anything you submit for credit must be entirely your own work and not copied, with or without modification, from any other person. If you need help with specific details relating to your work, or are not sure what you are allowed to do, contact your tutors or lecturer for advice. If you copy someone else's work or share details of your work with anybody else, you are likely to be in breach of university regulations and the Computer Science and Software Engineering department's policy. For further information please see

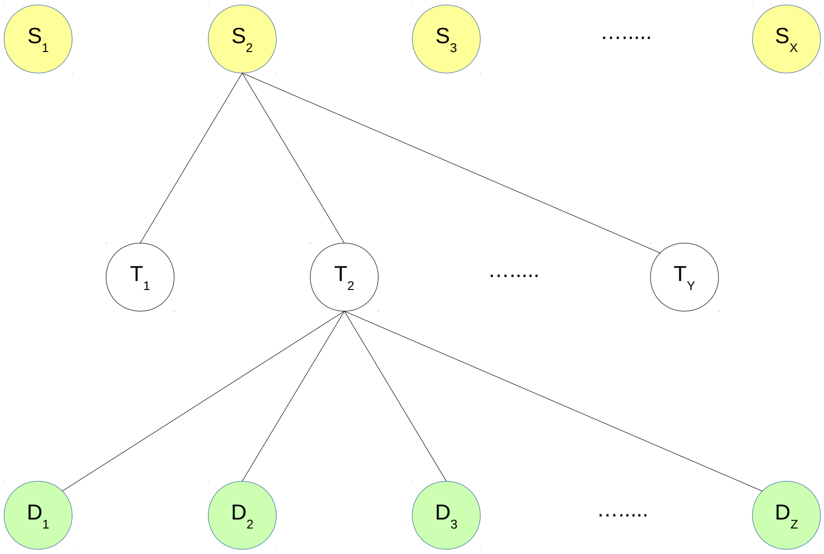
- Academic Integrity Guidance for Staff and Students
  `www.canterbury.ac.nz/ucpolicy/GetPolicy.aspx?file=Academic-Integrity-Guidance-For-Staff-And-Students.pdf`
- Academic Integrity and Breach of Instruction Regulations in the University Calendar
  `www.canterbury.ac.nz/regulations/general-regulations/academic-integrity-and-breach-of-instruction-regulations/`

You will have to sign a plagiarism declaration upon submission of your assignment report.

4 Problem Description

Broadly, the problem builds on the lab problems described in Section 7.4 of the planning booklet in Version 1.0, 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 $\{S_1, S_2, \ldots, S_X\}$, Y transit nodes denoted as $\{T_1, T_2, \ldots, T_Y\}$ and Z destination nodes denoted as $\{D_1, D_2, \ldots, D_Z\}$. 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

$$h_{ij} = 2i + j$$

units. There is a global requirement that **each demand volume shall be split over exactly two 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 two values k_1, k_2 (i.e. $x_{ik_1j} > 0$ and $x_{ik_2j} > 0$) 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 two 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 and in detail.

- 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 $X = 9$ sources and $Z = 9$ destinations. Run your program for each $Y \in \{3, 4, 5, 6, 7, 8\}$, 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). Make sure that no other compute-intensive process is running at the same time as you run CPLEX.
  - The load on the transit nodes.
  - The capacity of the link with the highest capacity.

5 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, the spread of transit node loads (i.e. the difference between the largest and the smallest transit node load), and the highest-capacity links, all for varying Y. Show these results as a graph or as a table. 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.
- The signed plagiarism declaration.

Note: Please make sure that your `.pdf` file contains all fonts and can be completely printed on UC printers – if it cannot be printed it will **not be marked**. Files not submitted in `.pdf` format will **not be marked!**

The documentation has to be submitted via the `learn` page for COSC364. The submission deadline is **Friday, May 31, 2019, 11.59pm**. Late submissions are **not** accepted, unless approved through the UC special consideration process.

6 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 unorganized, I will apply deductions of up to 10% of the achievable marks, but otherwise you will not receive any extra marks for the source code.