COMP9334 Revision Problems for Week 11

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1. A network is represented as a directed graph $G = (N, E)$ where $N = \{1, 2, ..., n\}$ is the set of nodes and E is the set of directed edges. The cost of using link $e_{ij} \in E$ is c_{ij} and the remaining capacity on link e_{ij} is r_{ij}. The propagation delay of link e_{ij} is d_{ij}. A customer of the network wants the network to carry a flow of size b for it. The customer has the following requirements:

   - The flow's source and destination are respectively node $n_1 \in N$ and node $n_2 \in N$
   - The network must provide 2 different paths with for the flow. The flow normally uses only the first path but if it fails, it is switched to the second (or backup) path.
   - Both paths begin at the source and end at the destination.
   - All the links of both path must have at least a capacity b, i.e. links with a residual capacity less than b cannot be used.
   - The total propagation delay in each path must not be greater than $d_{\max}$
   - The two paths must not have any common link.
   - The total cost of the two paths is minimised.

   (a) Formulate an integer programming problem which solves for both paths simultaneously.

   (b) Using the data given below, find the paths for the customer.
      - Number of nodes = 6. The nodes and edges in the network are defined overleaf in AMPL format.
      - The cost, propagation delay and residual bandwidth are given overleaf in AMPL format.
      - Source node = 1. Destination node = 4;
      - $b = 2$.
      - $d_{\max} = 8$.

You will find the following pre-ample useful if you are using AMPL.
In the "mod" file:

```
set NODES; #set of nodes
set EDGES within {i1 in NODES,i2 in NODES: i1 <> i2}; #set of edges
param cost {(i,j) in EDGES};
param delay {(i,j) in EDGES};
param remaining_bandwidth {(i,j) in EDGES};
```

In the "dat" file:

```
set NODES := 1,2,3,4,5,6;
set EDGES := (1,2),(2,1),(2,3),(3,2),(3,4),(4,3),(4,5),(5,4),(5,6),(6,5),
(1,6),(6,1),(2,6),(6,2),(2,5),(5,2),(3,6),(6,3),(3,5),(5,3);

param:    cost    delay  remaining_bandwidth    :=
[1,2]      1        5         9
[2,1]      3        1         6
[2,3]      2        4         4
[3,2]      3        3         3
[3,4]      2        1         4
[4,3]      3        3         7
[4,5]      3        3         4
[5,4]      2        4         4
[5,6]      4        3         5
[6,5]      1        1         6
[1,6]      3        3         3
[6,1]      4        4         4
[2,6]      2        1         5
[6,2]      3        2         6
[2,5]      1        2         7
[5,2]      2        2         9
[3,6]      1        2         3
[6,3]      3        1         4
[3,5]      2        3         1
[5,3]      2        3         3;
```