# Graph Optimization
# Lab assignment

(Due June 18, at 20)

**Problem 1** Consider a network described by a directed graph $G = (N, A)$. A set of demands $K$ represents different commodities to be routed on the graph, each described by three parameters, a source node $o_k \in N$, a destination node $t_k \in N$, and an amount of flow $d_k$ to be sent from the source node to the destination node. Demands are unsplittable and must be routed on a path with at most $h$ arcs. Each arc has a capacity that limits the amount of flow that can be routed on the arc. The amount of capacity on each arc must be integer and must be decided. All the arcs must have the same capacity. The goal is to find the minimum amount of capacity on arcs that allows to route all the demands.

1. Formulation the problem as an Integer Linear Programming model and write the model for AMPL.
2. Develop a heuristic approach and implement it in AMPL.
3. Develop a relaxation for the problem and implement it in AMPL.

**Additional questions**

1. Discuss the impact (in term of quality of solution and computational time) of the maximum number of arcs constraint.
2. Can some well-known valid inequalities be applied to the problem? Do they improve the continuous relaxation value?

Apply the methods above to the instances in the directory `NDinstances`. The parameter definition is described in the file `parameterDefiniton.mod`. Describe in a pdf file the formulation and the approaches and report for each instance the obtained results and the needed computational time. Report also the answer to the additional questions. Upload the pdf file and the .mod and .run files as a zip file on the Beep directory `submissionND`. Rename all the files as your last name.

Some parameters reported in the `parameterDefiniton.mod` file may not be needed.

**Problem 2** In a facility location problem, a set of $I$ clients must be assigned to a mid level facility. Each client $i$ has a weight $t_i$. A client can be assigned to a mid level facility if their assignment cost $d_{ij}$ is below a threshold $R$. Mid level facilities must be selected among a set of $J$ candidate sites: opening a facility in candidate site $j$ cost $c_j$. Each open mid level facility $j$ has a weight $a_j$ and must in turn be assigned to a high level facility. High level facilities must be selected among a set of $K$ candidate sites: opening a high level facility in site $k$ costs $g_k$. Assigning a mid level facility $j$ to a high level facility $k$ costs $l_{jk}$. Both mid level and high level facilities are capacitated: let $\Gamma$ denotes the mid level facility capacity, while $\Lambda$ denotes the high level facility capacity. The goal is to minimize the overall costs (opening an assignment costs at both levels).

1. Formulation the problem as an Integer Linear Programming model and write the model for AMPL.
2. Develop a heuristic approach and implement it in AMPL.
3. Develop a relaxation for the problem and implement it in AMPL.

**Additional questions**

1. Discuss the impact (in term of quality of solution and computational time) of the threshold $R$.
2. Can some well-known valid inequalities be applied to the problem? Do they improve the continuous relaxation value?

Apply the methods above to the instances in the directory `FLinstances`. The parameter definition is described in the file `parameterDefiniton.mod`. Describe in a pdf file the formulation and the approaches and report for each instance the obtained results and the needed computational time. Report also the answer to the additional questions. Upload the pdf file and the .mod and .run files as a zip file on the Beep directory `submissionFL`. Rename all the files as your last name.