Exercise 1

The graph **network1.gml** represents a set of points (graph nodes) that must be connected by a communication network. Each potential link has an activation cost that is stored in the attribute 'cost' of the graph (in Euro).

Questions

1. Find the set of links that connects all nodes at minimum cost.
2. Suppose that you can install in node 3 a hub (https://en.wikipedia.org/wiki/Ethernet_hub) with the following features:

    a. If the hub is installed, the cost of a link cost from node 3 to any other node decreases by a factor of 10;
    b. The hub accepts a maximum of 4 connections;
    c. An adapter (cost: 10 Euro) must be installed in each node directly connected to the hub;
    d. Hub installation costs 100 Euro.

    Is it convenient to install the device in node 3?

[**Hint**: use the multicommodity flow formulation in the notebook MST-multi.ipynb and add extra constraints to solve #2. Edges cost can be manipulated with `networkx` methods]

Exercise 2

The graph **network2.gml** represents a set of points (graph nodes) that must be connected by a communication network. Each potential link has an activation cost that is stored in the attribute 'cost' of the graph (in Euro).

To realize the network, in each node a hub **must** be installed among different available types. Each hub type is characterized by a cost (in Euro) and by a maximum number of connections that it can accommodate (see table 1).

Hub	Cost	Max Connections
1	15	2
2	20	4
3	50	8

Realize the network of minimum cost.

[**Hint**: Starting from the multicommodity flow formulation in the notebook MST-multi.ipynb add extra an extra binary variable z_i^k equal to 1 if a hub of type k is installed in node i]