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# Issues in robust network dimensioning - the case of FSO networks

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## 1 Introduction

The considerations of our work are devoted to the problem of networks link dimensioning. The main application area we investigate are networks that apply Free Space Optics (FSO) which is a broadband wireless optical transmission technology. The communication links are provided by means of a laser beam sent from the transmitter to the receiver placed in the line of sight. A major disadvantage of FSO Links (with respect to fiber links) is their sensitivity to weather conditions such as fog, rain and snow, causing substantial loss of the transmission power over the optical channel due mostly to absorption and scattering. Thus, although the FSO technology allows for the fast and low-cost deployment of broadband networks, its operation will be affected by this sensitivity, manifested by substantial losses in links' transmission capacity with respect to the nominal capacity. Therefore, a proper approach to FSO network dimensioning should take such losses into account so that the level of carried traffic is satisfactory under all observed weather conditions.

## 2 Objectives and context

The work presented is part of the project activities of the Laboratory of Excellence (LABEX) at the Université de Technologie de Compiègne (UTC) in France, on the Control of Technological Systems of Systems (MS2T). It is in continuation of the work presented in [1, 2, 3] and is essentially devoted to wireless networks, like FSO networks that are subject to failures involving partial loss of links capacity. FSO networks exhibit several important advantages, but this technology remains vulnerable to weather conditions, causing substantial loss of transmission power over optical channel. All this motivates the network optimization problem we study : how to dimension the network links at the lowest cost, and at the same time assure the traffic demand satisfaction at an acceptable level for all observed /predicted weather conditions.

## 3 Modeling and solving the problem

To construct our approach we start with building a reference failure set using a set of meteorological records for a given period of time ( for example a period of one year), against which the network must be protected. Typically, the given weather condition affects a subset of the network links. Each affected link loses a portion (percentage) of its nominal capacity (i.e., the bit-rate realized when weather is fine). Such a loss is called the failure (degradation) ratio that we can assume as a value between 0 (no capacity loss) and 1 (100% of capacity lost).

The values of the failure ratio are 0.25, 0.50 and 1.00. In consequence, each particular weather condition that can be observed define a failure state that can be called a multiple partial link failure state. For the sake of simplicity we assume that the link connecting two given areas is affected by the worse of the weather condition in the two areas. The observed conditions are translated into the multiple partial link failure states corresponding to all hourly periods in the considered one-year time horizon, which gives  $365 \cdot 24 = 8760$  "hourly" states in total.

Next, the mathematical formulation of the robust network dimensioning problem uses the above failure set. In contrast to related investigations on resilient networks, we deal with the problem involving a very large number of failure states, described by the so called uncertainty set ( an instance of the budgeted uncertainty set), but this makes the problem intractable because of the size of the failure set. All this calls for a more sophisticated approach which uses a cut-generation algorithm. This algorithm is composed of a master problem and a slave problem where we test feasibility of the link dimensioning with respect to the reference failure set defined as the set of failures to all hourly periods in an one-year time horizon. This failure set, being large, makes the problem difficult. Furthermore, the weather conditions are changing over years, which give to the problem the uncertainty dimension. To deal with this we propose to approximate the reference failure set with a so-called K-set, which covers all possible failures involving at most K links. This K-set stands for uncertainty polytope of failures in our case and can be defined as the subset of possible combinations of K (or less) links that can be affected simultaneously with the same failure ratio  $\beta(e)$  ( for example  $\beta(e) = 0.25$  for all link  $e$  ).

We have also studied alternative uncertainty sets involving geographic areas around a group of node instead of K-links sets defined previously or other sets involving nodes and links and/or different levels of failure. All this gives more flexibility and in some cases reduces the link dimensioning cost while increasing the overall traffic satisfaction ratio. We have tested our model under several types of uncertainty sets and for both pure FSO and hybrid FSO/fiber networks. It is shown that the cut-generation algorithm works quite well for all considered failure sets and instances.

## Références

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