SHORT TERM SCIENTIFIC MISSION (STSM) – SCIENTIFIC REPORT

The STSM applicant submits this report for approval to the STSM coordinator

Action number: CA15127
STSM title: Optimization Model for Designing FSO Networks Resilient to Weather Conditions
STSM start and end date: 18/06/2018 to 01/07/2018
Grantee name: Michal Pioro

PURPOSE OF THE STSM/

(max. 500 words)

The purpose of the STSM was to extend the FSO (free space optics) network optimization model involving a protection strategy called *Flow Thinning* (FT) proposed in the M. Pióro et al. paper "Optimizing flow thinning protection in multi-commodity networks with variable link capacity" (Operations Research, vol. 64, no. 2, pp. 273-289, 2016). The extension aims at including the state space (i.e., the set of states corresponding to restricted availability of link capacities) described by the so called *uncertainty polytope* that is capable to efficiently describe the varying weather conditions. As FSO networks are vulnerable to weather conditions, their transmission quality can be easily degraded if special measures are not taken. The FT strategy is capable of effective handling of the end-to-end transmission continuity in FSO networks under fluctuating channel capacity due to changing weather conditions.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

(max. 500 words)

During the STSM, a previous optimization model for resilient network dimensioning for an implementable version of FT, called affine flow thinning (AFT) was extended and tested. With AFT, the capacity of each tunnel is adjusted according to an optimized, tunnel-specific affine flow thinning function, whose arguments are the fractions of currently available link capacities (in relation to the maximum link capacities) on a pre-specified, tunnel-dependent subset of links. The main novelty of the extended model is characterization of the link availability states by means of the so called state polytope instead of a limited list of preselected states. This feature makes it possible to dimension AFT networks for representative sets of states that can be met during network operation.

Dimensioning of FT networks is not an easy task because of non-compactness of the related linear (or mixed-integer) programming formulations. Roughly speaking, in such formulations the set of columns (i.e., variables) corresponds to the flows of the tunnels in different link availability states, and the set of rows (constraints, called cutting planes) corresponds to link availability states. Both sets grow exponentially with the size of the network graph and the number of considered link availability states; in effect, the formulations must be treated by both column generation (called path generation in the considered case) and row generation (cutting-plane generation). Introducing uncertainty polytopes is possible due to applying, on top of path generation, a systematic algorithm for cutting-plane generation.

The elaborated cutting-plane generation is based on the Benders decomposition technique and is implemented in the form of an iterative algorithm solving an appropriate master problem interlaced with the originally elaborated feasibility tests delivering new constraints (cutting-planes) for the master. The numerical results that show the (good) efficiency of the approach were obtained by means of the CPLEX solver.

During the STSM, a further extension of the resilient network dimensioning model was initially elaborated in order to cover the so called quadratic flow thinning (QFT) – an improved version of AFT.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

(max. 500 words)

The major result of the STSM consists in adding the uncertainty polytope state characterization to the existing mixed-integer programming resilient optimization (dimensioning) model of FSO networks applying flow thinning – and important feature not fully investigated so far. This required elaboration of original feasibility tests (in the form of linear programming formulations) delivering certain Benders-type cuts, and embed them into an iterative network optimization algorithm.

The results achieved during the STSM will form the basis for a section in Chapter 3.11, on optimization of FSO mesh networks resilient to weather conditions, in the RECODIS final book "Guide to Disaster-resilient Communication Networks".

FUTURE COLLABORATIONS (if applicable)

(max. 500 words)

The collaboration of Prof. Michal Pioro (the STSM applicant) with University of Avignon will continue, with further visits planned for later this year.