SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA15127
STSM title: Evaluating and Improving the Survivability of Carrier Networks to Geographical Correlated Disasters
STSM start and end date: 11/11/2017 to 18/11/2017
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PURPOSE OF THE STSM:

Large-scale natural disasters like earthquakes, tornadoes, etc, are becoming more frequent in time and wider in scope. To evaluate the capacity of carrier networks to maintain its functions when affected by such disasters, we need to include geographical correlation when modelling the network elements that are affected by a disaster.

The evaluation of carrier networks in the presence of such disasters has been addressed through algorithmic approaches that enumerate all maximal vulnerable regions of the network. Nevertheless, previous works did not take into account how such vulnerable regions can be used to improve the network survivability to such disasters, i.e., not all maximal vulnerable regions are useful and many non maximal vulnerable regions must also be taken into account.

Then, the survivability improvement of carrier networks to geographical correlated disaster requires the definition of upgrading strategies that can achieve the maximum improvement at the minimum cost and such strategies very much depend on how the survivability has been previously evaluated.

In this STSM, the aim was to develop upgrading strategies suitable for carrier networks, to be included in Chapter 2.2 of RECODIS book. The goal was to define upgrading strategies based on optimization problems that use the information given by the previously identified vulnerable regions of interest. Therefore, the adaptation to the main goal of the previous methods on vulnerable regions enumaration was also an aim of this STSM.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSM

The work has been conducted in two steps. The first step was on disaster survivability evaluation and the second step was on network upgrading strategies. In the following, the report describes separately for each step the conducted work and plans for near future.

1. Disaster survivabity evaluation

The STSM work started by a brainstorm (i) on the properties of the vulnerable regions that are of interest as an input to the upgrading strategies of carrier networks and (ii) on known algorithmic approaches able to enumerate vulnerable regions. The conclusions of this brainstorm were as follows.

Consider a network defined by a graph G=(N,E) where the geographical location of the nodes and the geographical route of the links is known. Consider a geographical distance D in kilometers.

Assume the set F containing all sets of network elements (nodes and links) that can be shut down by a circle of diameter at most D. A maximal element of F is a set of F that is not a subset of another element of F. It is known [1] that the number of maximal elements of F is at the order of the number of nodes |N| for real world networks and there are polynomial algorithms to enumerate all maximal elements of F when the networks are defined on an Euclidian plane.

Consider the classification of each set of F as as a disruptive set or non-disruptive set. A disruptive set is a vulnerable region that, if all its element fail simultaneously, the surviving network in a non connected network. A non disruptive set is a vulnerable region that, if all its elements fail simultaneously, the surviving network is still connected. This classification can be conducted in polynomial time.

For network upgrade strategies, the disruptive sets are more useful since the aim is to select additional links that make the network more connected for any vulnerable region. Moreover, a maximal non-disruptive set can contain maximal disruptive sets.

So, a method to enumerate regional failures which are maximal and non maximal disruptive sets on geographical networks (i.e., not applicable only on Euclidean planes) was devised to be implemented and tested afterwards.

[1] János Tapolcai, Lajos Rónyai, Balázs Vass, László Gyimóthi, “List of shared risk link groups representing regional failures with limited size”, INFOCOM, 2017

2. Upgrading strategies

After the main conclusions of the first step, a brainstorm on possible upgrading strategies that make use of the previously enumerated disruptive sets was conducted. The adopted approach is to select a minimum cost set of additional links that connects as much as possible the network components that result from each disruptive set. Moreover, when the number of disruptive sets is too large, the disruptive sets are ordered by their ATTR (average two-terminal reliability) value (which can be evaluated also in polynomial time) in an increasing way and the most relevant ones are considered. The conclusions of this brainstorm were as follows.

Consider the current network graph G=(N,E) augmented by geographical edges and nodes representing possible routes through which new optical links can be installed. Each augmented edge has an associated installation cost. The aim is to select a set of additional links that minimize the total cost of the new edges that are required to be installed. The solution must guarantee that the ATTR of the worst set must be not lower than a target value.

To reach such solutions, at first, compute a set S of maximal disruptive failure regions considering the augmented graph (disruptiveness classification is based only on existing nodes and links) and compute S’ by eliminating from S the elements whose ATTR is higher than the targeted value. Then, define and solve an ILP (integer linear programming) model that selects the minimum cost set of additional nodes that turn all elements of S’ into non-disruptive elements.

This solution might still be not valid since turning a maximum cardinality disruptive set into a non-disruptive set does not prevent that a subset of it that is also a disruptive set to become a non-disruptive element. So, a new set S is again computed based on the previous solution and a new set S’ is computed again by eliminating from S the elements whose ATTR is higher than the targeted value. If set S’ is empty, the previous solution is optimal. Otherwise, add the new set S’ to the previous set S’ and solve again the resulting optimization problem.

An heuristic approach is obtained if, when moving from one solution to the next solution, we fix the links of the previous solution and we use only the last set S’ instead of adding it to the previous set S’. At the end, the heuristic and the exact approaches will be compared in terms of running times versus solution quality.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

- A method to enumerate regional failures which are maximal (and non maximal) disruptive sets on geographical networks. The method is being implemented and tested on publicly available data sets of network topologies.
- An upgrading strategy to improve the survivability of carrier networks to geographical correlated disasters, aiming to compute a minimum cost set of additional links that can reach a targeted

survivability level.

- An exact and an heuristic approach to implement the upgrading strategy.

FUTURE COLLABORATIONS (if applicable)

The work conducted on this STSM was the first step of the joint collaboration. In the next months, the collaboration will continue in the development, implementation, analysis and evaluation of the methods and strategies defined during the STSM.

The plans are to submit a conference paper on the first semester of 2018 and, then, a journal paper until the end of 2018. This joint work is to be included on the Chapter 2.2 of RECODIS book.