COST EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

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

Action number: COST Action CA15127 – Resilient communication services protecting end-user applications from disaster-based failures (RECODIS)
STSM title: Finding protection paths considering SRLG-disjointness and geodiversity
STSM start and end date: 02/10/2017 To 13/10/2017
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PURPOSE OF THE STSM:

Path protection mechanisms can improve end-to-end availability. If a path pair is considered for each demand, then both paths should not share a common risk of failure. The use of SRLGs (Shared Risk Link Groups) allows routing algorithms to find (maximally) SRLG-disjoint paths.
The problem to be tackled is to find two maximally SRLG-disjoint paths, which should always be link disjoint, for all traffic demands directly guided over end-to-end optical lightpaths. To make a network more resilient to disasters, geodiversity should be considered, which means that each link is at least *D* kilometers away from each other link or node used in the other path. This additional requirement implies the two paths must be node-disjoint.
The purpose of this STSM is to find maximal SRLG-disjoint paths considering geodiversity in a backbone network. We want to determine the increase of the path lengths and the cost of transmission with respect to simple link disjointness (no-SRLG nor geodiversity constraints).

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

During the STSM, we worked out an approach to find shortest disjoint paths with maximal SRLG-disjointness and geodiversity. For comparison, we calculated the shortest disjoint paths for each demand with Bhandari's algorithm (min-sum link disjoint path pair).
First we calculated the minimal number of shared SRLG's for each demand. With these results, we could calculate the shortest (maximal)-SRLG disjoint path pair for each demand.
Next, we calculated the minimal length of shared SRLG's for each demand and then the shortest paths, with least SRLG-length in common. Finally we added geodiversity to the problem.
To calculate the geodiversity one must obtain the geographical distance of each link to each link and to each node. We did this by assuming that each link goes in a straight line from node to node.

To compare the increase of costs of SRLG-disjointness and geodiversity, we assumed that we have 7 types of transponders with different properties (cost,adaptable capacity and reach).
We always choose the cheapest transponder capable of transporting the traffic of a demand, both in the active and the backup path (the latter is always the longer path). If a single

transponder can not support the necessary reach and traffic volume, the traffic must be split and more transponders will be required in a fully transparent optical network.

During the STSM, the following work was developed:

- Definition of notation
- Consistency of available data and notation
- Implementation of Linear Problem (LP) Formulations
    - Minimizing the number of SRLGs in common
    - Minimizing the length of SRLGs in common (new formulation)
    - Minimizing the path-length of a disjoint path pair with minimal number/length of SRLGs in common
- Calculation of the increase of path-length for each source-destination pair with respect to the length of the “simple” link-disjoint problem
- The distance between each link to each other link and each node was calculated, assuming that each link goes straight from node to node. This is a very optimistic way to calculate. We could have scaled it up by a factor, or alternatively scale down the desired geodiversity. Therefore if there is a geodiversity of D km, it is an optimistic value and the real geodiversity is probably lower.
- Next some additional LP formulations were implemented:
    - Maximizing the geodiversity
    - Minimizing the path-length for two D-geodiverse paths (or the maximum possible geodiversity of that source-destination)
- A new problem was formulated and solved: Minimization of the total path-length for two paths, under (maximal) SRLG-disjointness and geodiversity constraints
- An evaluation of the increase of path length, considering jointly SRLG and geodiversity constraints, for each source-destination pair with respect to the path-length of the “simple” link-disjoint problem was carried out.
- Considering a given traffic matrix and the need for tranponders, a preliminary evaluation of the increase cost, considering jointly SRLG and geodiversity constraints, for each source-destination pair with respect to the cost of the “simple” link-disjoint problem was carried out.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The main result is the unification of approaches for finding shortest paths with minimal number of SRLGs in common, while considering geodiversity.
Results were obtained for a given generic backbone network of Deutsche Telekom (DT) with 12 nodes:

- SRLG-disjointness already ensures a good geodiversity, the total path-length increase from only SRLG-disjoint to SRLG-disjoint and 50km geodiversity is very small.
- There is only one node from which you can’t reach any other node with a fully SRLG-disjoint path pair. If this node is source or destination, one of two possible SRLGs has to be used. If the objective is to have minimum length of common SRLGs, the paths get longer than when minimizing the number of SRLGs in common. That’s why for the following problems only minimum number of SRLGs in common was considered.
- An evaluation of the increase of path-length, considering jointly SRLG and geodiversity constraints, for each source-destination pair with respect to the length of the “simple” link-disjoint problem was carried out, considering a single demand per node pair, and ignoring physical constraints (reach) – which may result in traffic splitting.

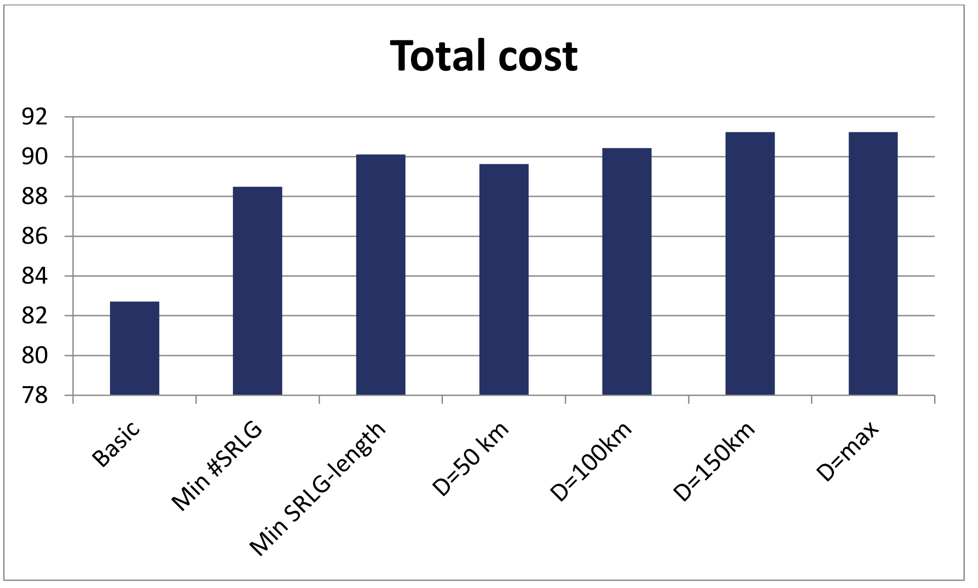

Diagram 1

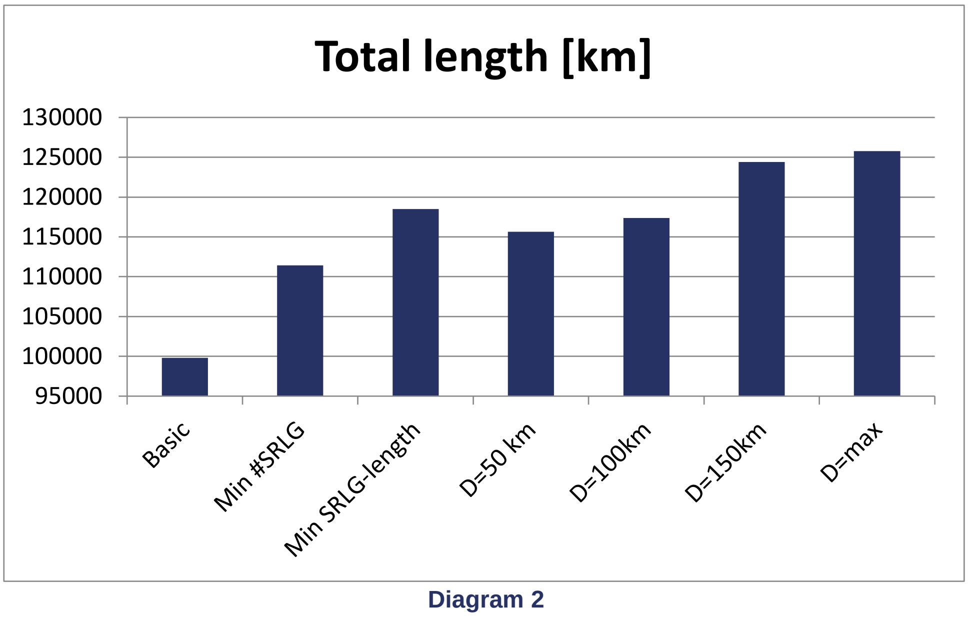

Diagram 2

- An evaluation of the increase of cost of transponders, considering jointly SRLG and geodiversity constraints, for each source-destination pair with respect to the cost of the "simple" link-disjoint problem was carried out, considering a given traffic matrix and physical constraints (reach) – which may result in traffic splitting. These results are summarized in Diagrams 1,2 and 3.

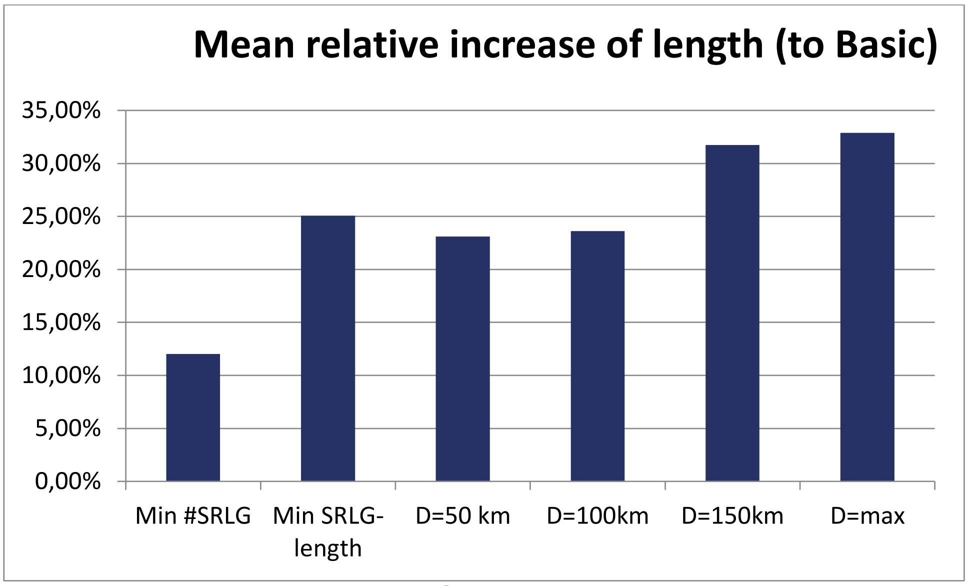

Diagram 3

Diagrams 1-3 show the total costs and path-lengths and the average increase of path lengths for all 66 demands. *Basic* are the results for the problem without SRLG disjointness and geodiversity. Only considering shortest link disjoint paths. *Min #SRLG* are the shortest pairs of paths for minimal number of common SRLGs, while *Min SRLG-length* are the shortest paths for minimal length of SRLG in common. *D=x km* are the results for the shortest paths with minimal number of SRLG in common and a geodiversity of x.
As can be seen, the increase of costs for geodiversity and SRLG-disjointness are from 8,3% (50km) to 10,3% (maximal geodiversity), while the path lengths increase from 15,8% to 26% compared with the basic model. The mean relative increase of length is even larger. This is because for demands where the source and destination are far away, there isn't a big difference between link disjointness and SRLG-disjointness with geodiversity, while for short distances between source and destination the paths could double in length with SRLG disjointness and geodiversity.

FUTURE COLLABORATIONS (if applicable)

Further experimentation in additional networks is required to check if some of the results obtained for DT still hold for other networks.

A paper for submission to an international conference is planned in the near future.

Other future collaboration will consider capacity constraints in the proposed models, which may result in an additional publication.