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: Enhancing the robustness to multiple node failures of RMSA strategies in Elastic Optical Networks
STSM start and end date: 31/03/2019 to 06/04/2019
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PURPOSE OF THE STSM

The objective of this STSM is in the scope of RECODIS WG4: Malicious Human Activities. This STSM aims to develop efficient Routing, Modulation and Spectrum Assignment (RMSA) strategies to enhance the robustness of Elastic Optical Networks to multiple node failures.

Large-scale failures are becoming more frequent in time and wider in scope severely disrupting telecommunication networks and services. Large-scale failures might involve only network links or network nodes and links (a node failure implies that its links fail). For example, in malicious human attacks, node shutdowns are harder to realize than link cuts but are the most rewarding in the attacker's perspective (a node shutdown also shuts down multiple links). Moreover, power outages shut down nodes since fiber links do not require power supply.

The aim of this STSM is to combine my current Ph.D. work on the network evaluation and design of optical networks based on multiple node failures with the expertise of Prof. Krzysztof Walkowiak on efficient routing, modulation and spectrum assignment algorithms for Elastic Optical Networks.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSM

In this STSM, we consider as large-scale failures the case of multiple node failures as they are the most harmful. Consider (i) a given Elastic Transparent Optical Network defined by a graph G=(N,E), (ii) a given set of services where each service is characterized by a set of estimated traffic demands and (iii) an available set of modulation formats.

The services can be unicast and anycast. In unicast services, each demand is characterized by a pair of end nodes and a demand value. In anycast services, each demand is characterized by a source node, a given set of anycast destination nodes and a demand value.

In this work, we consider RMSA strategies based on restoration techniques (as opposed to protection techniques) where, in the case of failures, the non-affected lightpaths are not reconfigured and affected lightpaths are restored as much as possible on the surviving network resources. A RMSA strategy defines how the estimated demands are allocated to optical lightpaths in the normal operation and how they are reallocated in a failure of multiple nodes.

As a first step of this work, two already known RMSA strategies were evaluated. The first one consists in a first-fit strategy, where a set *k*-shortest paths is initially computed for each demand and, for each path, the most spectral efficient modulation format is selected. Then, each demand is routed using the lowest available spectrum on the shortest path. The second known strategy is an adaptation of the AFA-CA (Adaptive Frequency Assignment – Collision Avoidance) strategy proposed in [1].

Moreover, this later heuristic is further adapted, but instead of using the proposed collision metric to decide which demand should be assigned, we propose a Path Availability metric that measures the odds of a given candidate path not being affected by a multiple node failure. If we assume independence between the failure of each node, the Path Availability metric can be computed by the product of the non failure probabilities of each node composing the path.

Then, given this metric for each candidate path, during this STSM, a new robust RMSA strategy (identical to the AFA-CA) was develop, implemented and tested that assigns lightpaths to candidate paths with high Path Availability.

Additionally, during this STSM, I gave a seminar on “Evaluation and Design of Transparent Elastic Optical Networks Resilient to Multiple Node Failures” in the Department of Systems and Computer Networks, where I presented the results of my Ph.D. research to Prof. Krzysztof Walkowiak working group.

[1] M. Klinkowski and K. Walkowiak. Routing and spectrum assignment inspectrum sliced elastic optical path network. *IEEE Communications Letters*, 15:884–886, 08 2011.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The preliminary computational results obtained during this STSM showed that by assigning the estimated demands based on the Path Availability metric provides a lower amount of disrupted traffic when a multiple node failure occurs when comparing it to the first-fit and AFA-CA methods.

Nevertheless, if the network traffic is considerably high, using only this proposed metric to allocate each demand, it causes a higher spectrum fragmentation to the restoration phase and then the total amount of connected traffic (non-disrupted plus restored traffic) is lower than using the AFA-CA strategy.

When combining both methods (*i.e.* using the framework of the AFA-CA method with the proposed metric used initially, in each iteration, to break ties between demands that allocate in identical spectrum slots), the computational results show that this strategy gives a good trade-off between non-disrupted traffic by a multiple node failure and the total amount of allocated traffic after restoration.

FUTURE COLLABORATIONS (if applicable)

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

The expected outcomes of the STSM is the submission of a conference paper shortly after the STSM and the submission of a journal paper until the end of 2019.