Demonstration of Proactive Restoration in Cognitive Heterogeneous Reconfigurable Optical Networks

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***Abstract*— An emulation study has been carried to demonstrate the benefit of a proactive restoration technique in cognitive heterogeneous optical networks. Results show the advantages of that method in terms of recovery percentage and disruption time.**

Keywords-component; proactive restoration, reactive restoration, cognition, heterogenous optical network

I. Introduction

Cognitive Heterogeneous Reconfigurable Optical Networks (CHRONs) [1] have been proposed to deal with the increasing heterogeneity of wide area optical networks by introducing cognitive techniques in their operation procedures. CHRONs, like most optical communication networks are typically based on the establishment of all-optical connections between network nodes (not necessarily adjacent in the physical topology). These connections are known as lightpaths.

However, despite the continuous efforts in improving the optical technology, failures affecting lightpaths (e.g., fiber cuts, hardware or software failures, or quality degradation) remain unavoidable. There are two methodologies to deal with failures: protection and restoration. While the former approach reserves resources not only for the intended (primary) lightpath but also for a the backup lightpath *a priori*; the latter approach only reserves resources for the primary lightpath, and then reacts searching a backup solution just when a failure is detected. Hence, protection schemes minimise the impact of failures at the expense of a lower efficiency in the use of resources. On the contrary, restoration uses network resources in a more efficient way but increases the disruption time when a failure appears (i.e, the time elapsed until the backup solution is established and activated). The disruption time, when restoration is employed, can be reduced if an element with capacity for forecasting failures is introduced, so that it can trigger the restoration process before the failure takes place. We call this procedure *proactive restoration*. That approach cannot be used for abrupt failures, like fiber cuts, but some failures are related to a progressive decrease of end-to-end Quality of Transmission (QoT) parameters of connections. For instance, the transient of their BER (Bit Error Rate) from the normal operative value to the FEC (Forward Error Correction) threshold can have a duration that spans up to tens of seconds depending on the severity of fiber and electronics impairments [2], and thus can be detected by relying on information retrieved by network monitors and employing forecasting methods, as demonstrated in past works [3,4].

In the EU FP7 CHRON project [1], protection was incorporated in its cognitive techniques. Extending that work, we now propose the use of reactive and proactive restoration and show a first set of emulation results, which demonstrates the benefit of using proactive vs reactive restoration in terms of disruption time and blocking probability.

II. Proactive Restoration in CHRON

CHRON is based on a centralized architecture where an element called Cognitive Decision System (CDS) decides how to control network resources and traffic routing. The CDS uses cognitive methods, which exploit their capability to learn from previous history in order to optimize network performance. A Control and Management System (CMS) is in charge of configuring the network according to CDS decisions, updating the network status and resource availability, and notifying any anomaly. The architecture also includes a Network Monitoring System (NMonS), which consists of different monitors distributed in the network and provides traffic status and optical performance measurements to the CDS using the CMS. While different approaches to determine the route and wavelength of the lightpaths can be used, in this paper fixed alternate routing (considering all the possible routes from the source to the destination ordered by hop distance), and the First-Fit [6] wavelength assignment heuristic, are used for both primary and backup lightpath establishment. Moreover, the Elapsed Time Matrix (ETM) method [7] is used in those heuristics to minimize the problem of relying on a potentially non-updated Traffic Engineering Database (TED). On the other hand, a cognitive QoT estimator [8] has been implemented in the CDS to ensure the QoT of the lightpaths.

Proactive restoration takes place when the QoT of a lightpath suffers a progressive degradation and thus a proactive corrective action is executed before the failure does really take place. The estimation of the degradation is done by the CDS by analysing the monitored values that arrive using the CMS. When the CDS forecasts a failure of a set of lightpaths due to a significant QoT degradation, it immediately searches for an alternative path and wavelength for all affected lightpaths. After that, it will trigger the CMS to establish the backup lightpaths while the primary ones continue in operation. Moreover, the failing device is excluded from new path computations until the operator verifies that it works fine. Once a backup lightpath is established and activated, the traffic carried by the primary lightpath is sent using that backup one and the primary lightpath is released by the CMS. If the

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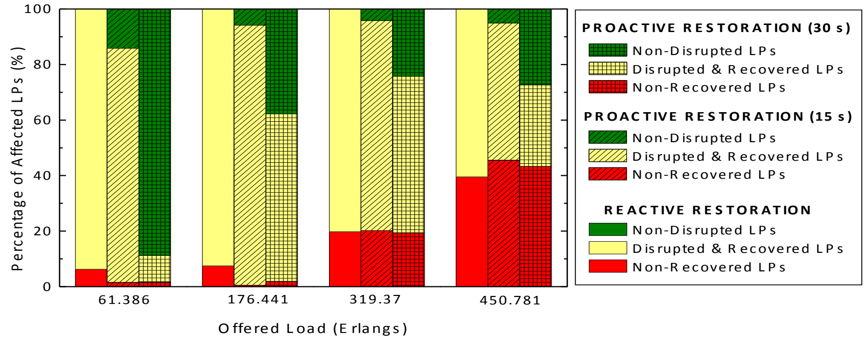

Figure 1. Percentage of recovered (with and without suffering disruption) and non-recovered lightpaths (LPs) in case of failure.

establishment of the backup lightpath does not succeed, the primary lightpath continues in operation.

III. EMULATION RESULTS

The 14-node Deutsche Telecom network has been emulated assuming that each cable of consists of one fiber per direction, and each fiber is configured with 32 fixed-grid wavelength channels. Emulated users send lightpath setup requests (up to 3,000) to the CDS according to a Poisson process. The control plane is implemented by means of standard GMPLS protocols (derived from the DRAGON open-source suite [8]), with some modifications on the encoding of the information carried by the RSVP-TE and OSPF-TE packets. In order to evaluate the performance of proactive and reactive restoration, a cable degradation (due to, e.g., noise increase in an amplifier) leading to QoT failures is caused every 900 s. Two different scenarios have been tested in proactive restoration: assuming that the CDS predicts the failure either 15 or 30 seconds in advance.

Fig. 1 shows the success percentage of the restoration process. The lightpaths affected by the failure can be either recovered without any disruption, recovered after some disruption, or non-recovered (due to lack of resources, absence of a backup solution with enough QoT or to problems caused by using a non-updated TED). The results show that thanks to the use of proactive restoration it is possible to have a lower probability of non-recovered lightpaths, and even recover a number of lightpaths without any disruption. On the other hand, as higher is the time in which the failure is estimated in advance, better results are produced with the proactive method (a higher number of lightpaths are recovered without disruption). Obviously, as the traffic load decreases, the results also improve: since fewer lightpaths have to be recovered, more network resources are available leading to establishing successful backup lightpaths in less time.

Fig. 2 shows the mean disruption time suffered by those lightpaths that are recovered but suffer some disruption between the failure and the set-up and activation of the backup lightpath. The proactive restoration process reduces the disruption time, e.g., more than 55% for 15 s in advance failure detection. Moreover, if the problem is predicted with more time in advance, the disruption time is further decreased. On the other hand, the mean time required by the CDS to find a backup solution is less than 3 seconds and, thus, the main component of the restoration time is due to the CMS signalling to establish and activate the lightpaths. This is a very important issue as having a backup solution predesigned (as in protection strategies) is not enough to avoid disruption unless it is already established in the network.

IV. CONCLUSIONS

We have presented a comparison analysis of the performance obtained using proactive and reactive restoration techniques. The study is done in a network emulator in order to validate the disruption times caused by the failure. Results show that the proactive restoration technique behaves much better than the reactive one as it suffers less blocking probability and it reduces the disruption time.

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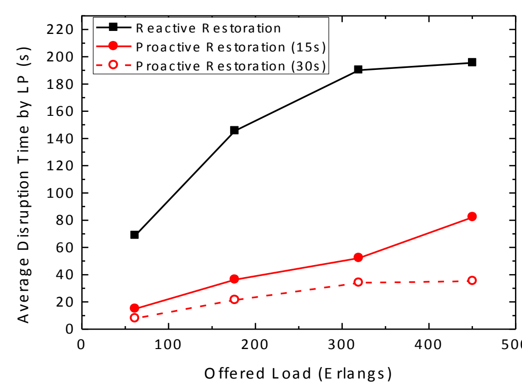

Figure 2. Average disruption time