Segment Restoration Scheme with QoT-guarantees in GMPLS-controlled Translucent Networks

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Abstract: *The paper proposes and evaluates a segment restoration scheme exploiting regenerators used in provisioning. The scheme guarantees seamless quality of transmission (QoT) in failure-prone dynamic GMPLS-controlled translucent networks.*

Introduction

Translucent networks (i.e., with a limited number of regenerators placed in few nodes) are a cost-efficient solution that offer an efficient bandwidth utilization and guarantee lightpath quality of transmission (QoT) [1]. Indeed, a limited number of opto-electronic regenerators, shared at the nodes, allows to efficiently aggregate traffic and to perform the 3R regeneration required to assure lightpath QoT. Lightpath routing with guaranteed QoT can be performed by the GMPLS control plane, during both the provisioning and the restoration phases.

Regenerator placement, lightpath routing, and wavelength assignment in static translucent networks were thoroughly studied, in both provisioning and protection scenarios [1-3]. In [2,3], to ensure survivability against single link failures, segment protection is used that efficiently shares the regenerators between the working and protection routes. However, few research works focus on dynamic GMPLS-controlled translucent networks and they are mainly focused on the provisioning phase. The main issue is that the current GMPLS protocol suite does not encompass regenerator presence. To overcome this issue, in [4], extensions of RSVP-TE protocols are used to disseminate information about regenerator availability during the provisioning phase. However, in dynamic traffic conditions, such as during restoration, regenerator availability information can be inaccurate.

This paper proposes a *segment restoration scheme* (SRS) for GMPLS-controlled translucent networks. SRS scheme exploits the regenerators already in-use by working lightpaths, for restoration purposes. Backup segment is, thus, defined between regenerator nodes (and terminal nodes) and is selected to guarantee QoT. The behavior of dynamic GMPLS-controlled translucent networks during lightpath restoration is evaluated when either SRS or path restoration is utilized.

Segment Restoration Scheme (SRS)

A translucent network with a distributed GMPLS control plane consists of N nodes with optical cross-connecting functionalities and L bi-directional WDM links. Each link supports W wavelengths in each direction. M nodes ($M \leq N$) are equipped with a regeneration module composed of $r \leq W$ wavelength-

independent regenerators.

As in [4], during the signaling phase, network nodes exploit RSVP-TE extensions to acquire both QoT parameters and number of available regenerators associated to the traversed path. Each traversed node stores QoT and regenerator availability information in local databases, i.e. *QoT Parameter Database (QPD)* and *Regenerator Database (RD)* respectively. By exploiting QPD and RD, upon lightpath provisioning request, the source node computes the route and selects intermediate nodes where regeneration should take place in order to ensure QoT in each optical segment. Then, source node indicates selected regenerator nodes in the RSVP-TE *regenerator object (RO)* [4]. Exploiting RO, each traversed node is informed about the lightpath nodes performing regeneration.

In the proposed SRS, upon link failure, the node detecting the failure, e.g. the downstream node of the failed link, sends an RSVP-TE *Notify* message to the *SRS initiating node (SRIN)*. SRIN is the upstream node closest to the failed link among the source node and the nodes regenerating the disrupted lightpath. SRIN computes a backup optical segment to the *segment restoration terminating node (SRTN)*. SRTN is the closest downstream node among nodes regenerating the disrupted lightpath and the destination node.

If QoT (evaluated by using QPD) can be ensured on the computed optical segment, SRIN sends an RSVP-TE *Teardown* message to the SRTN to free resources along the failed segment. Then, SRIN sends an RSVP-TE *Path* message to the SRTN to gather available resource information along the backup segment. Upon reception of the *Path* message, SRTN selects an available wavelength and sends SRIN an RSVP-TE *Resv* message to reserve the resources for restoration. When SRIN receives *Resv* message, the lightpath is restored. Otherwise, if QoT cannot be ensured, an RSVP-TE *Notify* message is sent to the lightpath source node by SRIN. Upon receiving the *Notify*, the source node computes a backup route to the destination and selects intermediate regenerator nodes to ensure QoT in each optical segment as in the provisioning phase. Then, RSVP-TE message exchange is triggered from source to destination to free resources

Fig.1: Restoration blocking probability contributions experienced by SRS and PRS vs. traffic load (λ/μ Erlang)

along the failed path and to reserve resources on the computed backup route.

Simulation Results

The performance evaluation of SRS is carried out by means of a custom C++ event-driven simulator on the Pan-European network topology [5], with $N=27$, $L=55$, $W=40$, $M=7$, and $r=4$. The M nodes with regeneration capability are placed according to the regenerator placement algorithm based on signal quality prediction [6]. Lightpath requests are uniformly distributed among the source-destination pairs. Both inter-arrival and holding times of the lightpath requests are exponentially distributed with an average of $1/\lambda = 10^4$ s and $1/\mu$, respectively. Upon reaching steady state conditions in provisioning, a link failure is generated with uniform distribution. Simulation results are plotted with the confidence interval at 95% confidence level. The QoT model [4] accounts for noise, chromatic dispersion, polarization mode dispersion and self phase modulation. SRS performance is compared against *path restoration scheme (PRS)*. In PRS a backup route is always computed by the source node toward the destination. During both provisioning and PRS, the route and the regenerator nodes are selected by exploiting QPD and RD. To limit the regenerator usage, a constraint on the maximum number of regenerator nodes per lightpath $N_r=1$ is imposed before and after the failure. Performance are evaluated in terms of: *forward blocking* experienced during the forward signaling phase of the restoration (i.e., Path message is blocked due to the lack of available wavelengths), *backward blocking* [5] experienced during the backward signaling phase (i.e., Resv message is blocked due to resource contentions), and *regenerator blocking* due to lack of regenerators or inaccurate regenerator availability information.

Fig. 1 shows the several contributions of the restoration blocking versus the traffic load. SRS reduces regenerator blocking with respect to PRS. Indeed, in SRS fewer regenerators need to be specifically reserved during restoration and thus

Fig.2: Overall restoration blocking probability experienced by SRS and PRS vs. traffic load (λ/μ Erlang)

inaccurate information on regenerator availability has less impact on the blocking. Forward blocking becomes significant in SRS for high traffic loads. This is due to the high concentration of restoration segments (and thus the high resource usage) on the links around the failed link. No forward blocking is experienced by PRS because backup path links are widespread. For the same reason, in SRS, resource contentions are more probable and backward blocking experienced by SRS is higher than in PRS. Fig.2 shows the overall restoration blocking probability versus the traffic load, i.e., λ/μ . SRS achieves lower blocking probability than PRS.

Finally, SRS and PRS are compared in terms of mean restoration time (ΔT), defined as the mean time between the failure and the instant in which an *Resv* message reaches SRIN (in case of SRS) or the source (in case of PRS). SRS decreases the restoration time achieved by PRS of 15% assuming a negligible packet processing time.

Conclusions

This paper analyzed dynamic restoration in GMPLS-controlled translucent networks. A segment restoration scheme (SRS) has been proposed. In SRS, the regenerators already in-use by working lightpaths are exploited. Simulation results show that SRS achieves a lower blocking probability with a faster restoration time than path restoration scheme.

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