The NOBEL2 Approach to Resilience in Future Transport Networks

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Abstract

IST project NOBEL2 results on resilience strategies for next-generation optical transport networks are presented, paving the way towards cost-effective, scalable and easy-to-maintain multi-service network architectures.

Introduction

Network evolution towards a unique IP multi-service network introduces important challenges that shall be cost-effectively fulfilled. Some of these have been recognized and studied in the course of the IST NOBEL2 project. This paper summarizes the results and presents a framework for improved and efficient resilience in emerging network scenarios.

Resilience differentiation and QoR

There is growing interest that not only quality, but also resilience must be differentiated per service. The Quality of Resilience (QoR) concept is aimed at enabling provisioning of services with different resilience characteristics, such as availability or duration of downtimes in the same network, which provides quantitative description and permits comparison among several resilience mechanisms. In essence, the idea behind QoR is to combine multiple recovery-related parameters into one unique index. In the NOBEL2 project, the following parameters were taken into account: connection availability, recovery time, bandwidth guaranteed after successful recovery operations, reordering and duplication of data, additive latency/jitter and, additionally, decision about usage of pre-emption, implementing resilience to multiple failures [1]. Estimation of the QoR measure has been analytically defined [2], leaving a high freedom level in parameter estimation. In broader sense, it enables comparison of different procedures for optimization purposes, thus being useful for carriers. In stricter sense, it gives insight into interdependencies between selected parameters, improving network behaviour comprehension.

Resilience in multi-layer networks

Today's IP backbone networks are based on complex hierarchical architectures with static point-to-point links between routers. In order to overcome scalability limitations, operators are going ahead with the deployments of wavelength switched optical networks under GMPLS control functions and the fast reconfiguration capabilities of optical nodes, such R-OADMs. In these networks, resilience mechanisms can be carried out at several alternative layers instead of being exclusively managed at the IP layer. The question is which layer is most efficient for carrying out this functionality. In the NOBEL2 project, a traffic availability study was conducted, comparing four different architectural options to implement the 68-node European reference network. The architectures under study were: 1) IP/MPLS over point-to-point WDM and duplicated IP routers per node (interconnected through physically disjoint links); 2) IP/MPLS over point-to-point WDM; 3) IP/MPLS over OTN with coloured interfaces; 4) IP/MPLS over Ethernet over WDM. Three network resilience schemes were considered: 1) no protection with traffic routed through two disjoint paths using load sharing; 2) 1+1 protection; 3) 1:N protection such that working/protection paths are disjoint. Rounding up, two alternatives are evaluated: no bypass capability through the optical layer or, conversely, bypass with direct optical channels. The results of this comparison show that architectures with only a single IP router per node are advisable with respect to traffic availability and equipment cost. Bypassing the IP layer via underlying layers is cost efficient although it reduces the degree of protection resource sharing.

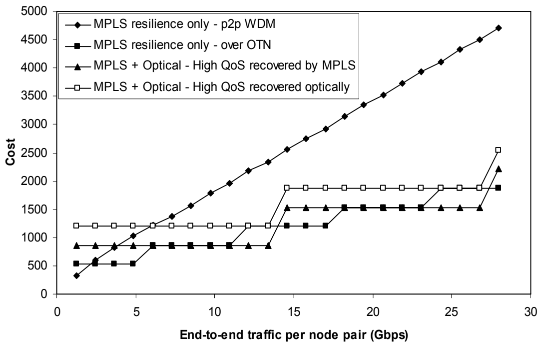

Figure 1: CapEx vs. offered traffic (6x6 torus network)

A second study was carried out to reveal whether it is more efficient to restore failures at the optical layer rather than restoring them by MPLS. Torus networks of varying size and 10 Gbps optical channels were assumed. Traffic was divided in two resilience classes (high and low). Network capacity was dimensioned to carry all traffic under normal operation and to support full recovery of the high resilience class in the event of failure. Four strategies were evaluated: 1) MPLS over point-to-point WDM and MPLS resilience only; 2) MPLS over OTN and MPLS resilience only and, MPLS over OTN and both MPLS and optical resilience, with the highest QoS class recovered either by MPLS (3) or optically (4). In these cases, escalation strategies between the recovery mechanisms are required to control the network states, which can be reached by implementing hold-off timers for the optical resilience or a recovery token signal for the MPLS resilience (typically Fast-Reroute), such as described in [3]. Results for a 6x6 torus are shown in Figure 1. For low end-to-end traffic interest between nodes, an MPLS over point-to-point WDM is the most efficient option, as an optical network leads to mostly empty end-to-end channels in this case, thus leading to poor resource utilization. However, for higher end-to-end traffic, a cross-over takes place beyond which optical solutions become more cost-efficient than a pure IP/MPLS solution. The gains of introducing optical solutions are more pronounced for larger networks and the additional cost of optical resilience marginal.

Control Plane Resilience in GMPLS networks

GMPLS introduces the freedom of the control plane to be physically separated from the transport plane. Hence, the control plane may fail independently from the transport plane and vice versa. A thorough study within the NOBEL2 project concluded that control link failures mostly impact on RSVP-TE signalling. Particularly, connection release is unfeasible, as long as IP routing does not re-converge. In fact, the loss of an RSVP-TE teardown message delays connection release, leaving allocated but unused resources, which increases blocking probability due to a lack of resources. Similarly, loss of RSVP-TE path message delays connection establishment tens of seconds, until next RSVP-TE path retransmission. This might be unacceptable for certain service requirements, thus blocking the request. Four different control plane topologies over a 9-Node meshed transport plane with node degree 2.89 were compared from a resilience viewpoint (Figure 2). Departing from the study above, a new parameter P_d was defined, which identifies the probability that at least one connection request or release becomes affected by a control link failure along the total recovery time, denoted by Δt.

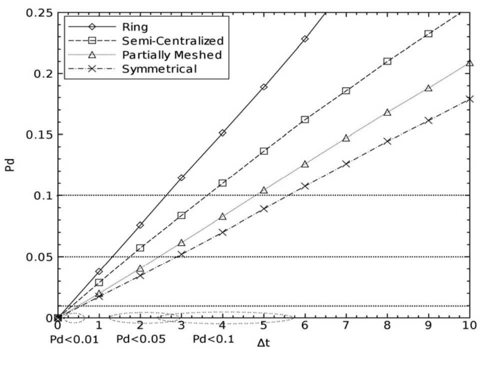

Figure 2: P_d vs. Δt (s) for each topology under study

The *Symmetrical* topology follows exactly the same topology as the transport plane. The *Ring* topology tries to save control plane resources by interconnecting all control plane nodes in a ring. The *Partially meshed* topology becomes a hybrid between the *Symmetrical* and the *Ring* ones, so that shorter routes between control plane nodes can be found and the burden per link can be lighten compared to the *Ring* topology. Finally, a *Semi-centralized* topology is also proposed, where each control plane node manages several transport plane devices. The obtained results show that both the *Ring* and *Semi-centralized* topologies become highly affected by control link failures, as each control link supports several control channels. Therefore, several communications become disrupted due to link failure. Interestingly, the *Partially meshed* topology presents similar results as the *Symmetrical* one but requires fewer resources than the latter. Focusing on this one, to assure Pd<0.1, Δt ≈ 5 s are sufficient. However, a stringent Pd<0.01 requires Δt to be ≈ 500 ms.

Multicast Resilience in Metro Networks

IPTV or VPNs services require highly resilient infrastructures and point to multipoint connectivity. While most of existent L1/L2/L3 transport solutions include dedicated or shared protection mechanisms for point to multipoint connections, new resilience mechanisms, able to dynamically restore multicast connections according to current network resource state, would present significant advantages in terms of service availability and resources optimization. The introduction of dynamic multicast restoration would not require important architectural changes in metro networks, as currently deployed ring topologies interconnected by a dual homing approach can easily evolve towards meshed topologies based on Double Rings with Dual Attachments (DRDA). Such topologies provide high connectivity and multiple back-up paths for restoration purposes, while reusing current network fibre deployments (Figure 3).

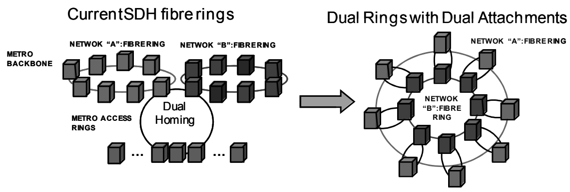

Figure 3: Metro Network evolution towards DRDA

A resilience evaluation of DRDA topologies showed thay they allow the operator to achieve “five-nines service availability” (99.999% of the time) with traditional MTTR values of hours and days. This becomes essential to provide multicast services which demand full-time connectivity, such as IPTV.

Acknowlegments

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References

[1] J. Tapolcai et al., IEEE ICC 2006 (2006)
[2] NOBEL2 project, Deliverable D2.3 (2007)
[3] D. Colle et al., IEEE JSAC vol.20 n°1 (2002)