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Design and experimental implementation of a hybrid optical performance monitoring system for in-service SLA guarantee

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Abstract

This paper presents an experimental, in-service optical performance monitoring system, which is hybrid in nature due to the use of both spectral (optical signals) and time-domain (digital) measurements to guarantee Service Level Agreements (SLA). Preliminary results show that this approach is of low complexity and, combined with suitable recovery mechanisms, may be used to monitor transparent services.

Keywords

Optical performance monitoring, DWDM, optical management

1. Introduction

Intelligent, all-optical networks are envisioned as the next generation Internet. IP over reconfigurable wavelength multiplexing (WDM) is widely becoming accepted as one of the most promising candidates for this, since it decreases network layering, enhances network's reach and intelligence, and reduces opex and capex. The development of flexible, highly reconfigurable transport planes is boosted by the adoption of WDM, which offers exciting possibilities for meeting growing bandwidth without increasing the number of fibers, the advent of optical cross-connects and add-drop multiplexers, providing reconfigurability capabilities, and the optical control plane to render future networks intelligent.

However, intelligent optical networks are not expected to be built from scratch due to the need for carriers to protect their investments. The evolution from current data communications networks, which are opaque (with O/E conversions) and offer data pipelines with few service levels, has the provisioning of new value-added services as one of the key issues for their success. In this context, the need exploring the management of the SLAs established between network providers and users arises as a crucial means to fully realize the potential of this kind of networks. This is especially

important if we consider that intelligent optical networks will be capable of very fast provisioning of transparent paths through ‘physical-aware’ routing and signaling mechanisms, and we consider that lightpaths will carry simultaneously data signals with different data formats and bit rates.

2. Experimental implementation of performance monitoring

Performance monitoring in next-generation IP/WDM networks poses several difficult issues, since wavelength circuits will be dynamically changed. In contrast to current point-to-point optical communications, in future networks optical signals will be routed, added/dropped, (de)multiplexed or regenerated independently of the higher electrical layers, which results in various undesirable effects in the spectral domain. In-service Optical Performance Monitoring (OPM), known as well as spectral-domain monitoring, will be key in future optical networks, because signals transported will be likely to be affected by linear and non-linear wavelength-related effects [6]. On the other hand, time-domain impairments may occur during the life of transparent optical services, and are measured through digital techniques, such as BER or packet loss.

An ideal scenario for in-service SLA guarantee in future IP/WDM is the following: during regular network operation, embedded instrumentation will be performing monitoring tasks of optical components, such as transponders or switching fabrics, but also control plane modules [2], as well as optical signals, both at WDM and channel level. At the edges, electrical routers will measure data parameters, such as end-to-end packet loss or delay. Additionally, BER analyzers can be placed. These monitoring points will be interconnected with management elements (‘gatherers’) for performance purposes. This way all impairments, either due to fiber transmission, optical component failures or data degradation, will be detected at some point, collected and aggregated by the gatherers, and then reported and fixed according to the SLA by an event manager and/or control plane routers (e.g. restoration). In order to deploy this scenario experimentally, we must consider three design issues.

First, there has to be a trade-off between the cost of higher measurement accuracy and the waste of system margins caused by the more conservative alarm thresholds necessary with low-precision monitoring devices. The most common approach is that the management plane be able to set threshold values for all supported performance monitoring registers. Second, monitors must be placed carefully in the network to obtain all necessary data and at the same time reduce opex [8]. And third, efficient synchronization will be needed between spectral- and time-domain measurements. Relevant network elements of the experimental performance monitoring system are:

- *Management controller*: Management agent internally split into control and transport planes. Its architecture is fully described in [7, 8], and has been implemented according to a suitable information model [3, 4]. It has four main functions: responding to information queries from the monitoring system, sending alarms/notifications of status, proxying with the node’s Link Resource Manager [2].

- *Transport monitors* also respond to SNMP queries made by the monitoring system and send alarms caused by transmission impairments. In accordance with [5], transport monitors measure the channel power, frequency, OSNR, and their respective

drifts in a totally transparent manner. Values are obtained every 10 ms (power and wavelength) and 100 ms (optical SNR). Its capabilities comply with major performance aspects of embedded monitoring suggested in [6].

- *Optical node controller*: Active components of the transport plane are the 2x2 optical switches, the transmitters (lasers), the transceivers (E/O and O/E) and the photonic receivers. Last but not least, optical amplifiers, located in the optical links, are also active. Then, each optical node controller is responsible for monitoring the state of these active components. Its main functions are proxying with the monitoring system, interfacing with the control plane, and monitoring of the optical components it controls (transceivers, lasers, receivers and optical interfaces of the switches).

- *Edge (electrical) router/User equipment*: Although an optical network operates in an analog environment, SLAs contemplate digital parameters. Therefore, using an electrical device for near real-time in-service monitoring seems reasonable. In order to avoid intrusion in the optical data, we use the capabilities of the edge router (user equipment) to obtain IP metrics.

- Additionally, *BER analyzers* can be placed as well in order to obtain periodic BER measurements of fiber links, for instance using a part of, or time-multiplexed slot of a data wavelength.

- *Gatherers and event manager*: Performance information is collected by distributed gatherers, and then filtered and compared against tables (containing parameters measured in the network's deployment phase) by an event manager, the goal being the detection of possible SLA violations and the forwarding of significant changes in link information to the LRMs of the 'affected' nodes.

- *Network Management System*: Both the edge router and the NMS are capable of measuring utilization. Based on ITU's ASON framework [2], the OIF suggests in [5] some of these measurements, of which we retrieve arrival rates, port utilization, holding times, offered load (in Erlangs) and (un)successful circuit request counts. Moreover, the NMS is forwarded all relevant information about performance, from the distributed "monitoring network", and decides on the verification of the SLA.

3. Preliminary results: service unavailability

The hybrid performance monitoring system presented in Section 2 was implemented in the ADRENALINE testbed¹, which is an IP/DWDM network with fully transparent nodes and 8 wavelengths/link at 1-2.5 Gbps. Although 'optical' SLAs are still subject to definition [1], typical measurable parameters include throughput, end-to-end packet loss ratio and delay and service unavailability. A preliminary assessment of the hybrid system has dealt with spectral impairments resulting from component failures (laser off, Figure 1 left) and transmission (fiber cut, Figure 1 middle). In these captions we observe delays in the range of 50-100 ms in the detection of an optical signal degradation (channel power) and subsequent recovery in a 1+1 protection scenario (48.8 for recovery with degraded SLA and 96.4 ms with full recovery). To illustrate

¹ ADRENALINE testbed: All-optical Dynamic REliable Network hAndLING IP/Ethernet Gigabit traffic with QoS. <http://www.cttc.es/adrenaline/>. This work is part of the R&D project NetCat, funded by the Centre Tecnològic de Telecomunicacions de Catalunya (<http://www.cttc.es/netcat/>)

time-domain monitoring, Figure 1c depicts an ‘ideal’ BER measurement in the testbed, computed through direct interconnection of transmitter and receiver.



Figure 1: Service unavailability (left, recovery with degraded SLA, middle, full recovery) in power/time and example of BER measurement at 1 Gbps (right).

4. Conclusions and future work

We have presented a hybrid performance monitoring system that is capable of monitoring spectral- and time-domain parameters of transparent services. Preliminary results show that recovery times with this system (for degraded SLA) are comparable to SDH’s 50-ms paradigm. Future work will be focused on enhancing the system to include digital aspects, and thus assess the relative merits of hybrid monitoring. The interworking between the performance monitoring system and the control plane’s LRM will be implemented as well. Last but not least, different monitoring periods and thresholds with the LRM will have to be experimented to find a trade-off between accuracy in performance monitoring and overload of control information.

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