Providing Survivable Interdomain Connections over an Optical Backbone Network

DIMITRI STAESSENS, *Dept. of Information Technology (INTEC),Ghent University - IBBT - IMEC, G. Crommenlaan 8, bus 201, 9050 Gent, Belgium*
PIETER AUDENAERT, *same affiliation*
DIDIER COLLE, *same affiliation*
ILSE LIEVENS, *same affiliation*
MARIO PICKAVET, *same affiliation*
PIET DEMEESTER, *same affiliation*

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1. Introduction

When we examine today's internet architecture, we notice that the IP layer network is divided into multiple domains, managed by different service providers, operating different architectures, providing different services, handling different business strategies. In order to provide survivable inter-domain connections which ensure connectivity in case of the most prevalent failures, different strategies can be followed [2]. In this work, we present how these multidomain resilience schemes can be useful in providing critical communications, based on a real life example of tele-surgery. We then present a quantitative study of the network capacity required for the domain interconnecting the different hospitals.

2. Multidomain IP recovery scenarios

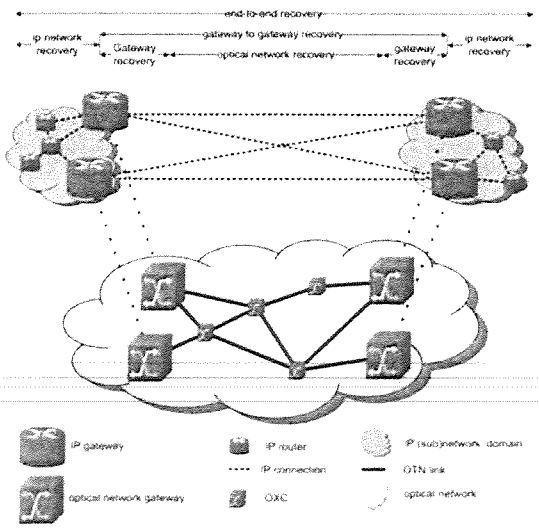


Figure 1: *Multidomain recovery*

In Figure 1 we present the terminology used for recovery in a multidomain environment. The routers connecting different domains are called *gateways*. In order to provide full recovery of any single failure, it is obvious that every IP domain will need at least two IP gateways, each connecting to its own dedicated optical gateway. We can distinguish several sections in an end-to-end recoverable connection. Inside both IP

domains, we need to protect the connection between the router and the gateway in use and this will be called *IP network recovery*. Multilayer IP network recovery inside a single domain based upon IP and G/MPLS protocols has been the subject of extensive research, and an overview can be found in [3]. The remaining part of the connection will be recovered using *gateway-to-gateway recovery*. In order to provide gateway-to-gateway recovery we can use existing *optical network recovery* [3] and *gateway recovery* techniques, and the remaining issue is how to combine these techniques in order to provide efficient resilience options [2].

We studied how different strategies presented compare to each other with respect to the capacity required in a pan-European optical backbone for a symmetrical demand between different European countries. We concluded that the most viable options are providing *two optically unprotected node-disjoint lightpaths* connecting the gateway-pairs, *protecting the primary IP connection optically*, pre-empting the backup IP connection, and *providing dynamic optical protection* [2]. Dynamical protection will require ASON functionality [6] or an intelligent optical network (ION)
In the first scenario we computed the node-disjoint routes on a slightly modified network. We compress the source and target domain into single temporary nodes, connected in star topology with the gateways. On this modified network, we use a node-disjoint shortest cycle algorithm between the two temporary nodes. If we then remove the two temporary nodes from the cycle we get two node-disjoint paths for the original network. This algorithm performs faster than using a recursive Dijkstra algorithm (i.e. computing a shortest path between two gateways, and removing this from the network before computing a second shortest path), because it is not susceptible to blocking situations. From a networking point of view, this scenario is most useful in a *protection* case, i.e. we send all traffic simultaneous over both links. This is because, in case of a failure, the recovery must be done in the IP domains, and IP or MPLS recovery is not as fast as optical recovery [5]
For the second mechanism, we computed shortest paths using the Dijkstra algorithm [1], as they need not be disjoint. In fact, the more links they share, the better due to the use of an adapted *common pool* strategy[4]. This is depicted in Figure 2: all traffic is routed over the primary IP connection, which is optically protected. Only in case of a gateway failure, we switch over to the backup IP connection. In case of the failure of a link or node in the optical domain, we switch to the optical protection path (saving the primary IP connection) and signal that the backup IP connection is no longer valid (because the optical protection path has common links with the lightpath reserved for the backup IP connection). In the dynamic case, the signalling will be the main issue, making design of a robust and efficient protocol a challenging task.

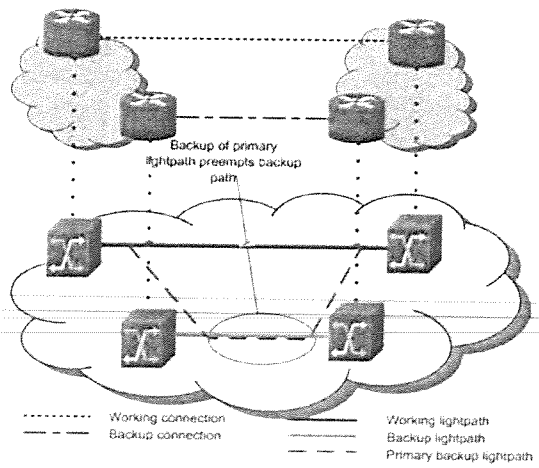


Figure 2: *Multidomain recovery based on common pool*

3. Optimization towards network capacity usage

After all this preliminary work, we are now concentrating on optimization in the mentioned example of telesurgery, using the NSFNET (slightly adapted, as we require two gateways for each hospital) as a backbone network connecting different hospitals. We use this example because of some attractive properties, namely that this is a critical service, requiring high levels of reliability of the network and that streaming of high-definition video, voice and patient vital stats and information requires a lot of bandwidth in the upstream direction. Another property is that the traffic is asymmetrical: in the downstream direction, there is only a small bandwidth requirement for voice and some data communication. There are therefore 2 types of hospitals: server hospitals and client hospitals. We therefore suggest STM-4 (OC-12) traffic in the upstream direction and STM-1 (OC-3) traffic in the downstream direction, the backbone network is considered an STM-64 (OC-192) network, with grooming capability. What we are researching now, is how much capacity it will require for the backbone to provide this service. We will use the strategies explained above, and compute lower bounds for the network capacity in each case using Integer Linear Programming techniques, with different capabilities of the network. We expect very low requirements if we assume grooming is possible, so we can use the "spare" capacity in the downstream direction as backup capacity. With this as a reference, we can compare how the non-optimized shortest-path and shortest-cycle algorithms perform. We are also considering the option of setup of multicast trees in the optical domain, further reducing the bandwidth requirement.

References

[1] Dieter Jungnickel, *Graphs, Networks and Algorithms, Second Edition*, Springer, NY, 2005

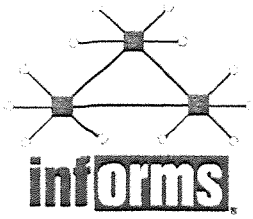
[2] Dimitri Staessens, Leen Depré, Didier Colle, Ilse Lievens, Mario Pickavet, Piet Demeester, *A Quantitative Comparison of Some Resilience Mechanisms in a Multidomain IP-over-Optical Environment*, ICC 2006, submitted.

[3] Jean-Philippe Vasseur, Mario Pickavet and Piet Demeester, *Network Recovery*, Morgan Kauffman, NY, 2004.

[4] Mario Pickavet, Piet Demeester, Didier Colle, Dimitri Staessens, Bart Puype, Leen Depré, Ilse Lievens, *Recovery in Multilayer Optical Networks*, IEEE J. Lightwave Technology, vol. 24, No.1, January 2006

[5] Christian Guillemot, *VTHD French NGI Initiative: IP and WDM Interworking with WDM Channel Protection*, ,presented at the 2000 IP over DWDM conf.

[6] ITU-T Recommendation G.807/Y.1302, *Requirements for automatic switched transport networks (ASTN)*, ITU-T Standardization Organization, July 2001, www.itu.int



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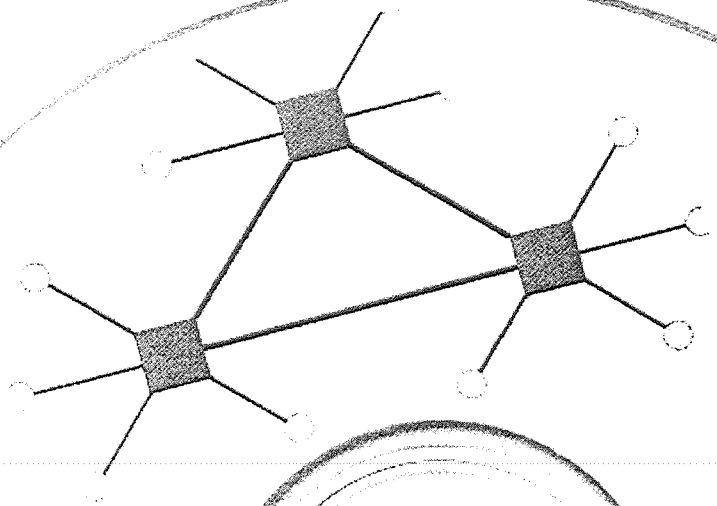

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