

End-to-End Recovery in Multidomain IP-over-OTN Networks

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ABSTRACT

The internet is an aggregation of multiple networks, or “domains”, managed by different ISP companies. In order to provide survivable inter-domain connections, to ensure connectivity in case of the most prevalent failures, different strategies can be followed and we present some multidomain resilience schemes for a single optical backbone network interconnecting different IP domains. We then present a quantitative study of the network capacity required in a specific pan-European backbone network.

Keywords: Multilayer networks, Multidomain survivability, Protection, Recovery

1. INTRODUCTION

Today, internet, voice and multimedia traffic are all transported over optical networks. WDM technology is responsible for an explosion in the amount of data traversing single links of these networks [2], implying a need for fast and scalable network recovery techniques in order to provide competitive levels of reliability. Reliability is paramount for backbone network operators who interconnect different IP domains; because critical failures could lead to the isolation of entire domains, or, even worse, disconnect several parts of the internet. Up to now, most resilience mechanisms are developed for single-domain environments, which can be used more or less effectively in the current hierarchical network structure (see [1] for an overview of single-domain recovery mechanisms). However, in the near future peer-to-peer type network connections are expected to increase significantly, causing a flattened network structure with many networks on the same level. This means that end-to-end traffic will traverse through different networks and the end-to-end resilience can only be provided if interworking between different networks is considered in the resilience mechanism.

Figure 1 shows the hierarchy of recovery options within multidomain IP networks, interconnected by an optical domain. To provide end-to-end protection within a multi-layer environment, we can try to use existing recovery techniques within the different sections (IP network recovery, gateway recovery and optical network recovery) and provide proper coordination between them in order to achieve end-to-end protection and ensure inter-domain connectivity in case of single network node or link failures.

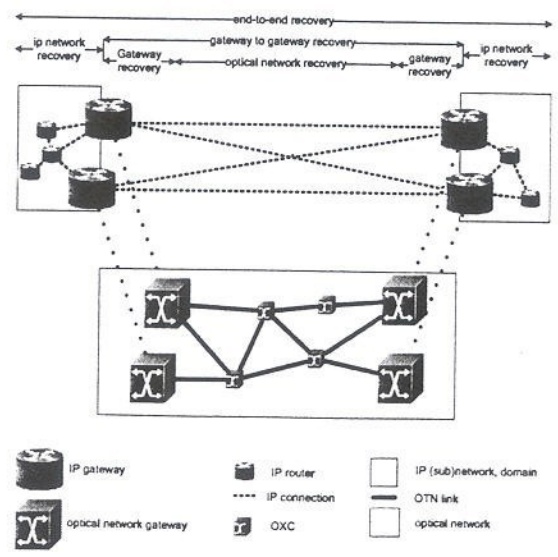


Figure 1: Multidomain recovery terminology

In what follows, several generic approaches for providing end-to-end recovery in a multidomain IP environment over an optical backbone network will be presented. We concentrate on the gateway-to-gateway recovery and assume that recovery within the domains is provided. In a following section we will then show some implications of each strategy for the dimensioning of the backbone network.

2. GENERIC END-TO-END RECOVERY TECHNIQUES

This section discusses the provisioning of recovery functionality in multilayer multidomain networks by starting from an IP-layer-only recovery scheme and then introducing optical protection. Note that, in order to ensure connectivity, each domain needs at least two gateways to serve as entry-points into the backbone network. Each gateway should be capable of handling the total amount of traffic. In case of a failure of one of these entry-points, another is available to take over. After the IP-only recovery (no optical protection), improvements towards recovery times and capacity requirements are suggested. Finally, we introduce two dynamic recovery methods, based on global recovery.

2.1 No optical protection

In this scheme, we interconnect the different domains by providing two gateway-to-gateway IP connections, implemented by optically unprotected, node-disjoint lightpaths in the interconnection domain (Figure 2). When the working lightpath (or gateways) fails, we switch all traffic over to the (unaffected) backup connection. This scheme thus provides full protection against single node or link failures in the optical backbone network and for gateway failures in the IP network. MPLS capability is required in each IP domain in order to provide a fast switchover in case of a failure. In absence of MPLS in the IP domains this scenario will not provide fast recovery for inter-domain connections.

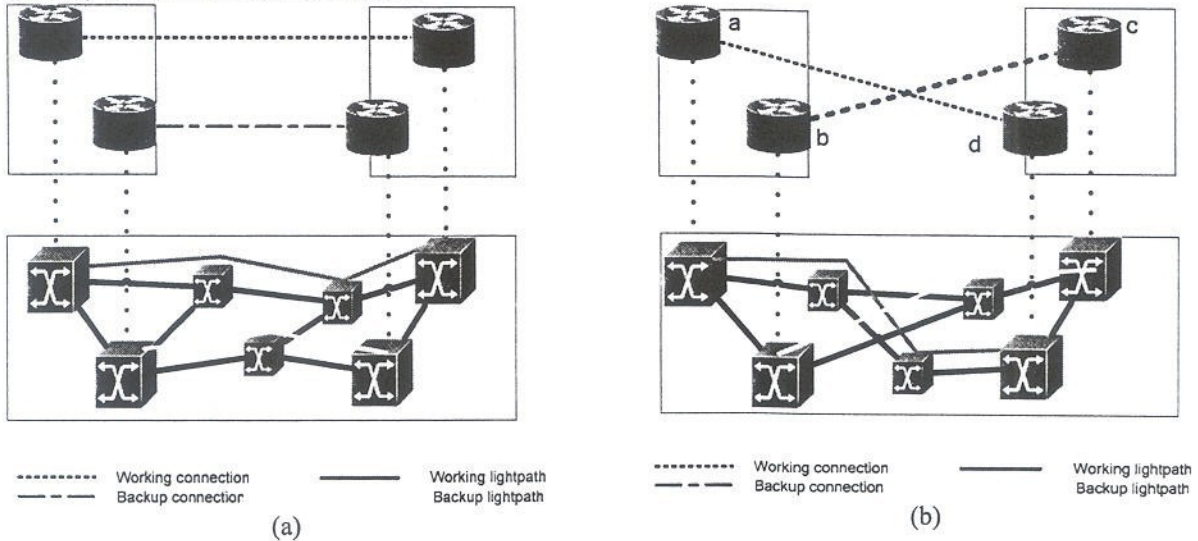


Figure 2: Two IP connections, implemented by node-disjoint lightpaths

From a conceptual point of view, this is a very simple scheme. The only issue is how to provision two node-disjoint lightpaths. The choice of which gateways to connect is not arbitrary. If we look at Figure 2(b) the connections $a-c$, $b-d$ cannot be made node-disjoint; instead the connections to be made are $a-d$, $b-c$. The choice regarding which gateways should be connected to each other must therefore be taken by the backbone network (or its operator). Calculation of the node-disjoint lightpaths can simply be done by an extended shortest-cycle algorithm.

2.2 Optical protection of both IP connections

In order to provide a more robust domain interconnection, and resolve the issue of slow recovery of IP-connection switchovers, the backbone operator can choose to protect every lightpath optically. The optical protection lightpaths for the working and backup lightpath will be called primary and secondary backup lightpath respectively. It should be kept in mind that in all of the following scenarios, the working and backup lightpath aren't necessarily disjoint.

The working and backup lightpath can be implemented as two shortest paths between two distinct gateways, and protected with optical 1+1 path protection (Figure 3(a)). In this case, the connections between two domains are protected twice, in the IP layer and in the optical layer of the interconnection domain. This scheme has the upside that, in case of a non-gateway failure, the IP links aren't disturbed, so only a critical gateway failure (or a failure of the interface between the gateway OXC and IP gateway) will lead to potential downtime in the absence of an MPLS control plane. As a downside we may expect a lot of capacity overhead required in the backbone network. Instead of providing 1+1 protection, we can provide 1:1 shared path protection (Figure 3(b)). In this way we can somewhat reduce the overhead in the optical network.

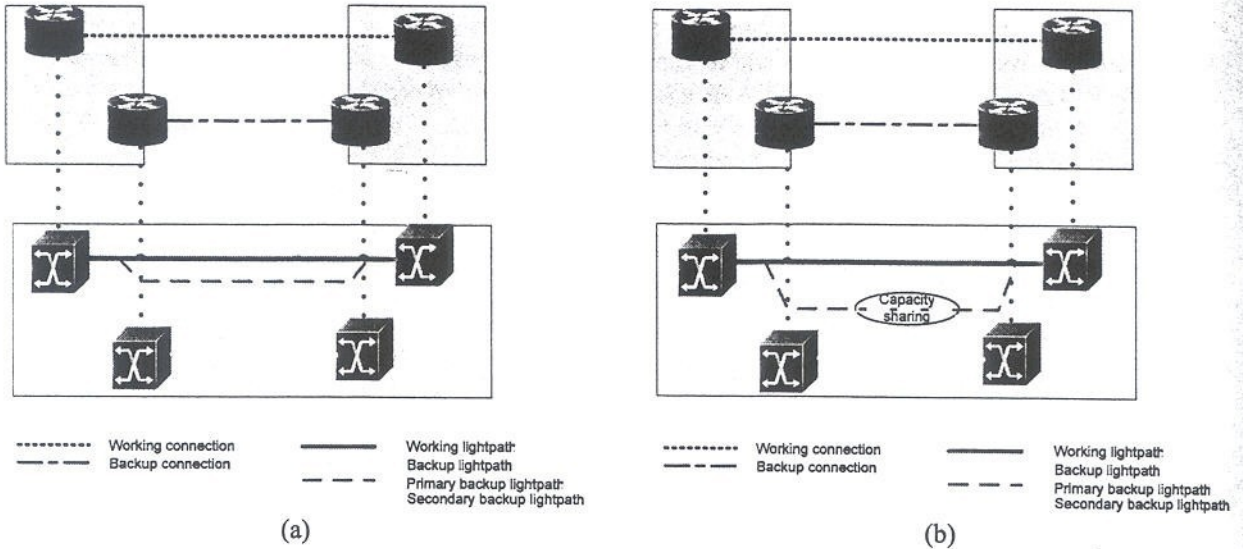


Figure 3: Protecting both implementing lightpaths optically

2.3 Optical protection of the working connection

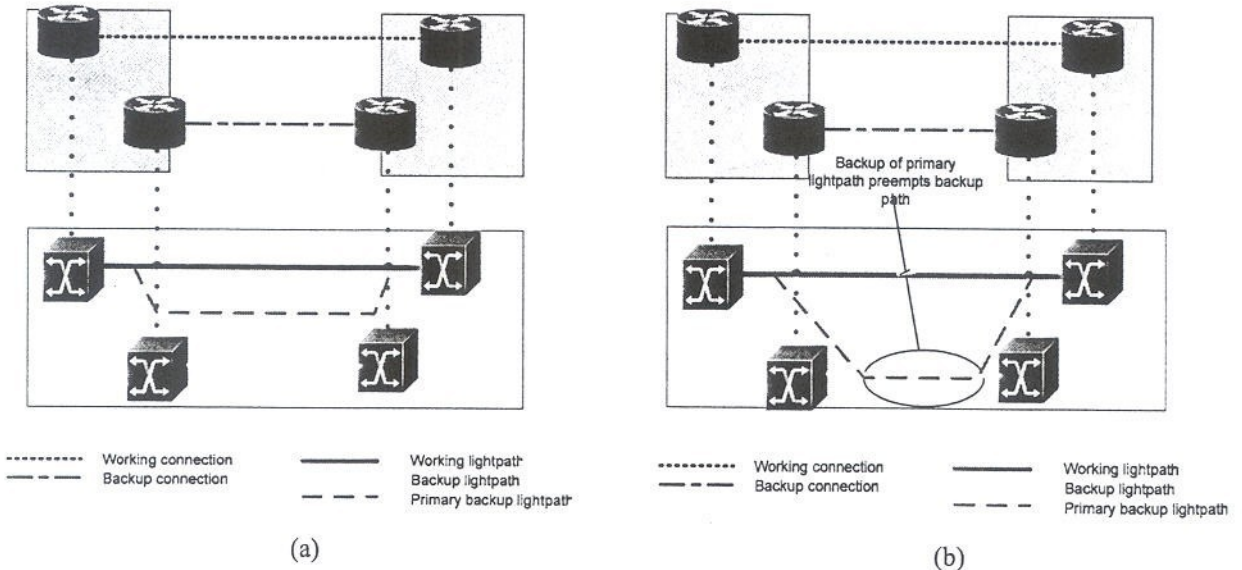


Figure 4: Only working connection optically protected

The previous proposals for providing gateway-to-gateway recovery are indifferent to the choice of the working and backup connection. One could easily swap the two connections, or distribute the traffic over both, and still get the same level of protection. When we make a definite choice of which connection will be used as primary or as backup, we can choose only to protect the working IP connection in the optical domain, and leave the backup optically unprotected (Figure 4). We can also go one step further and introduce the 'common pool' principle [1] in order to further reduce capacity usage. In this scenario, we have the backup lightpath preempt the backup IP connection in case of an internal node failure in the working lightpath, and only use the backup IP

connection in case of a primary gateway failure.

2.4 Dynamic protection

In this subsection, we consider dynamic restoration on an Automatically Switched Transport Network (ASTN[3]), more specifically, an Intelligent Optical Network (ION). In this case, the optical network is capable of setting up and tearing down lightpaths at will, and, in case of a failure, this capability is used to reroute all affected recoverable traffic. If we use the normal specification, the ION will try to reroute all requested lightpaths, thus also the backup lightpath (Figure 5(a)).

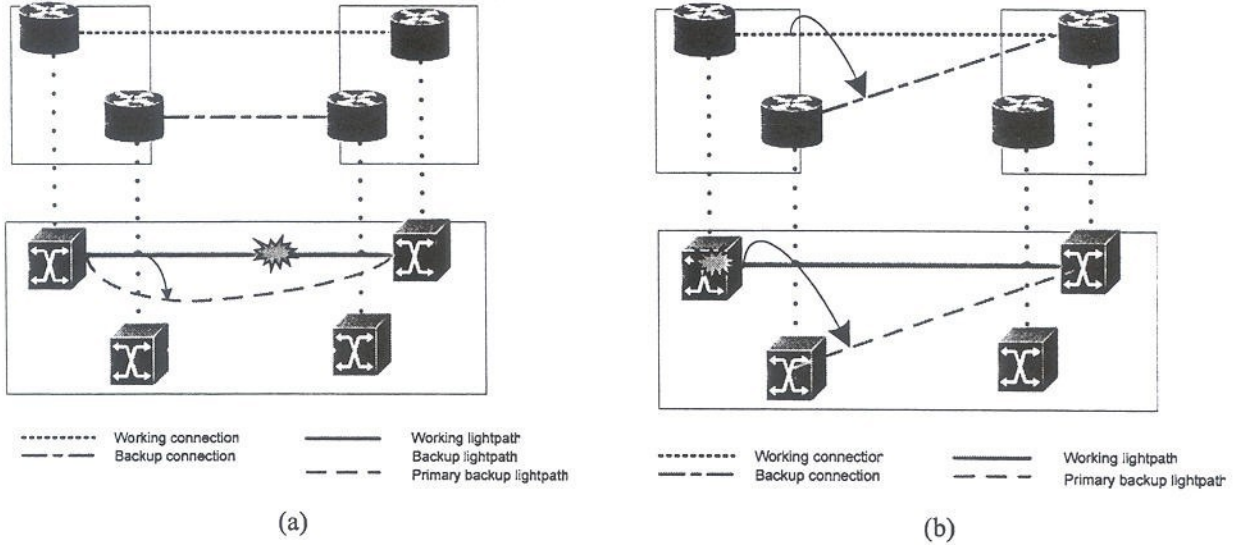


Figure 5: Dynamical protection

We can also choose to set up only the working lightpath, and let the ION recover only the working lightpath in case of a failure. When a gateway failure occurs, we should be able to switch over to a backup gateway to recover the traffic. This scenario is highly specific for multidomain survivability, since the traffic originating (from the interconnection provider point of view) in the failing gateway can in fact be recovered, which is not possible in conventional single-domain networks.

3. CASE STUDY

We evaluated these resilience options on the e1 network [4] with a backbone network connecting the different domains. The requirements were that all IP domains in the e1 network should be interconnected; every IP domain had at least two interfaces towards the optical backbone in order to ensure connectivity in case of an IP or Optical gateway failure. One adaptation we made on the e1 multidomain network was to aggregate Croatia and Slovenia into a single domain in order to get at least two gateways per domain in the core network. Traffic for the simulations is taken from the e1net traffic matrix [4], and routed as STM-16 traffic over the network.

When we compare the capacity requirements against each other, we see that optical protection will always require extra capacity in the backbone network (Figure 6). The more we share backup capacity between backup paths and the more intelligently we provide protection (e.g. by not protecting backup connections optically), the less capacity we need in order to ensure connectivity between different domains.

Figure 7 shows a comparison between static and dynamic recovery with respect to the IP line card requirements. When we assume that the total traffic between the domains is 3 lightpaths, we set up two connections *a-c* and *b-d*, each requiring 3 lightpaths in the static case. For the dynamic case, we must consider all failure scenarios [5]. In the failure free scenario, we need 3 IP capacity in routers *a* and *c*, since we only set up connection *a-c*. When router *a* fails, we tear down lightpaths *a-c* and set up 3 lightpaths for the new connection *b-c*, so router *b* needs capacity 3, but we can reuse the 3 free IP cards in router *c*. Similarly, a failure of router *c* leads to the setup of *a-d* and *d* needs capacity 3. A failure in gateway *b* or *d* does not require rerouting, so, in both the static as working-path-dynamic case, all IP routers need capacity 3. We can see that dynamic recovery of the working path has no IP capacity advantage over static recovery. This is because of the capacity-efficiency of the multidomain static recovery mechanism. We provide protection against two gateway

failures with only one backup IP connection. In normal scenarios, dynamic protection requires less IP capacity than static protection [6].

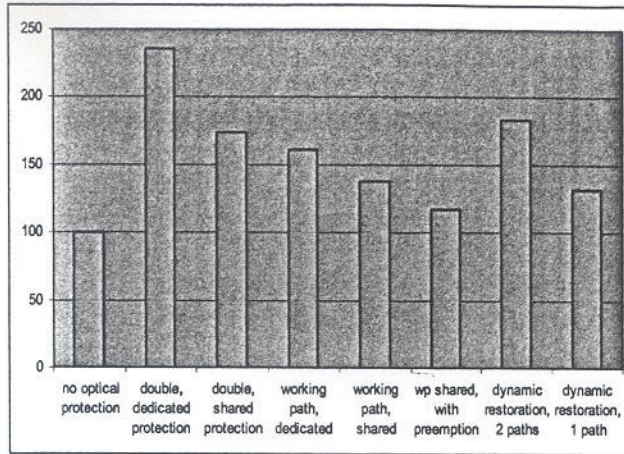


Figure 6: Optical capacity requirements

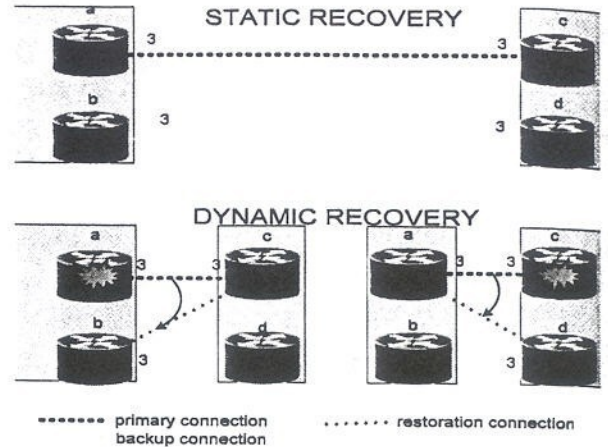


Figure 7: IP capacity, static vs. dynamic

4. CONCLUSIONS

In this paper, we have presented several schemes for protection of the interconnection between different IP domains over an optical backbone network. Several static schemes were given with varying degrees of sharing, and then two dynamic schemes are presented.

Comparison of these resilience strategies shows that sharing of capacity in the optical layer has a significant impact on the total capacity requirement for the backbone network. We also showed that dynamic recovery does not improve the IP layer capacity requirements. This is a direct consequence of the multidomain nature of the network, where we can setup a working and backup connection originating and terminating in different gateways.

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Workshop on

Design of Next Generation Optical Networks:
from the Physical up to the Network Level Perspective

Ghent, Belgium

February 6th, 2006

Organization by COST291 & IWT GBOU ONNA



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