

# A cost evaluation of service protection strategies in ATM on SDH transport networks

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**Abstract.** Future multi-layer transport networks will involve recovery mechanisms in different layers in the overall protection of services. In this paper, we study several multi-layer recovery approaches to assure the resilience of ATM VP traffic in SDH on ATM transport networks against a set of important failures. Our study is supported by the results of a network planning case study, where we compared the investment cost of the multi-layer survivability strategies, in diverse network and traffic scenarios.

## 1. Introduction

Because of the ever-increasing amount of traffic carried by the network elements in transport networks, the impact on society of communication services lost by a failure can be tremendous; *survivability* has thus become a very important aspect of telecommunications network design. During the past years, several recovery schemes [8] have been devised for ATM and SDH technologies, allowing fast protection against malfunctions of links and nodes. Since future multi-layer transport networks will be based on SDH and ATM technologies, operators will have to choose an appropriate combination of ATM and SDH recovery schemes, in order to provide adequate resilience to different service types. This decision will be based on the recovery performance and the implementation complexity, but most of all, the cost of a particular protection strategy.

The principal objective of this paper is to evaluate different multi-layer recovery approaches in ATM on SDH transport networks in terms of investment cost. More in particular, we compare the following two options to provide resilience to ATM VP traffic against a set of important failures: (1) ensuring the resilience solely by ATM layer recovery or (2) leaving the resilience against cable cuts and SDH layer failures to an SDH recovery scheme, and using ATM layer recovery only for ATM-specific failures.

## 2. Multi-layer recovery approaches

### 2.1. Network scenario

In this paper, we consider a network scenario related to the transport of semi-permanent ATM Virtual Paths (VP) over SDH backbone networks, such as the core networks of public telecom operators. Over the past few years, many operators have carried out major investments related to the deployment of SDH transport networks. For instance, most national networks in Europe consist of a meshed transport network based upon SDH digital cross-connect (DXC) systems operating at the VC-4 (150 Mbit/s) level. One can expect that public operators will be tempted to reuse their SDH-based facilities to transport emerging ATM services over their core as well. In the initial phase of ATM deployment, operators will rather use SDH VC-4 paths (supported by the SDH DXC system) to interconnect their ATM backbone DXCs. Such configuration enables to share fiber systems between ATM and SDH native traffic. As a matter of fact, the amount of ATM backbone traffic will in the near-term not be sufficient to justify the installation of dedicated fiber systems between the ATM points of presence. Furthermore, ATM equipment may initially not be present in every backbone office, and the SDH VC-4 layer can provide flexibility to VP traffic in offices without ATM (e.g., to allow a better line system usage). Such ATM on SDH transport networks thus have a multi-layer structure (see also [4]), since the ATM VP demands are subject to routing flexibility at the VC-4 and the VP level.

In order to assure high availability of both ATM VP services and SDH native services, an operator has to

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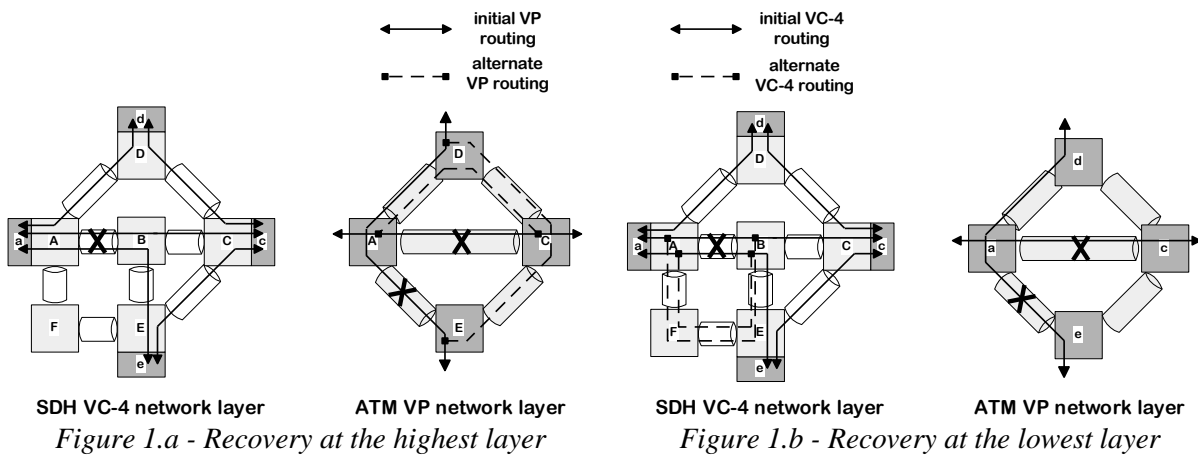
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attain that his traffic survives the most frequently occurring failures in the network. According to previous studies [1], the most important failures in ATM on SDH backbone networks include single failures of cable cuts, SDH DXC breakdowns and ATM DXC breakdowns.

It is important to understand that *both* SDH and ATM recovery schemes have to be deployed in ATM on SDH networks, in order to ensure complete survivability of this failure set. This can be understood as follows. On one hand, the survivability of SDH native services can only be guaranteed by SDH recovery schemes. On the other hand, the SDH layer can not restore ATM VPs affected by the breakdown of ATM equipment. In fact, a recovery scheme operating at the ATM network layer is needed to resolve ATM equipment failures. Both recovery schemes are thus necessary for achieving the overall survivability goal. The issue relevant to this study is that an operator may opt for a SDH recovery scheme (instead of ATM layer survivability) to provide resilience to ATM VPs against burdensome failures at lower layers (such as cable cuts). This is possible because the SDH network layer acts as a serving path layer for the ATM network layer.

## 2.2. Multi-layer recovery approaches



Since ATM VP connections can make use of different (re-) routing levels (VP and VC-4), several recovery approaches can be considered for them. A first possible approach is to *resolve any expected failure at the highest possible network layer*. In our network scenario, this comes down to the following: SDH native traffic is recovered from cable cuts and SDH DXC breakdowns by the SDH recovery scheme. On the other hand, SDH paths supporting ATM VP logical links, which are affected by SDH failures, are not recovered by the SDH scheme. The responsibility for recovering ATM traffic is left to the ATM recovery scheme, irrespective whether the failure originates from an ATM or SDH equipment breakdown or a cable cut. As a result, only a single recovery scheme is responsible for the resilience of a certain traffic type. This appears favorable from a network management point of view. Another motivation for adopting this *recovery at the highest layer* approach is that often transport networks carry various classes of services, each with different survivability requirements. It seems easier to provide multiple reliability degrees when the survivability is realized by a recovery scheme residing in the higher network layers.

In spite of these advantages, the finer switching granularity of the higher network layers may involve a lot of burden in the event of physical failures, which may affect many connections at once. For instance, it is important to be aware of the *failure multiplication* occurring in multi-layer networks. This is because a single failure in a lower network layer leads to multiple failing entities in a higher network layer. This is illustrated in figure 1.a, where we show the recovery actions in case of a cable cut on a sample network. The failure scenario at the ATM network layer clearly has a more complex nature than the original failure (e.g., a cable cut may simultaneously affect many thousand VPs). Consequently, several precautions may have to be taken to ensure a satisfying recovery performance (we refer to [2] for details).

Although physical failures (e.g., cable cuts) and SDH failures (e.g., SDH DXC breakdowns) can be recovered at the ATM network layer, it seems more sensible to provide *'bulk recovery'* of these failures at the SDH network layer. The failure scenario at the SDH network layer is simpler in the number of recovery trigger signals and paths to be changed over, because SDH recovery operates at a coarser granularity, and hence enables a simpler (and probably faster) recovery.

From an overall cost point of view, SDH recovery can also be more efficient to resolve physical failures. Although the finer granularity of ATM VP routing allows a better utilization of the spare resources on a single layer basis, one must not forget that all the capacity (including the spare) of the ATM layer has to be supported by the SDH network layer. Deploying a recovery scheme and its subsequent spare resources in a certain layer implies an additional investment for all layers below. This observation may counterbalance the single-layer cost-efficiency of ATM recovery in some cases, and favor to provide the resilience at a lower network layer. The lowest layer in our network scenario is the SDH Multiplex Section layer, where it is not always possible to deploy cost-effective recovery [6] (unless rings are used), and protection or restoration in the intermediate VC-4 network layer may thus provide the best alternative.

Accordingly, we have considered a second recovery approach, called *recovery at the lowest layer*, which comes down to resolve SDH equipment failures and cable cuts at the SDH VC-4 network layer, irrespective of the source of the affected traffic. ATM VPs affected by these failures are recovered in aggregates, because we recover the SDH paths supporting many of them. In figure 1.b, the lowest layer recovery actions in case of the cut of link A-B are represented. The SDH VC-4 paths carrying ATM VPs are recovered by the SDH recovery protocol, (the figure assumes SDH link restoration at the VC-4 level), whereas the routes in the ATM network layer remain unchanged. From an ATM layer point of view, the situation (after SDH recovery) is as if the ‘broken ATM links’ were repaired.

Remark that we still need the ATM recovery scheme in order to resolve ATM DXC breakdowns. However, the SDH layer survivability already provides adequate resilience to VPs routed directly in the ATM network layer, and thus additional ATM protection is only necessary for multi-hop<sup>1</sup> VPs (i.e., transiting at least one ATM DXC). As a result, we may expect a much lower spare capacity requirement in the ATM network layer. In other terms, since the protection of the heavier failures is left to the SDH layer, this recovery approach enables to get more value out of the ATM equipment.

Nevertheless, a successful deployment of this recovery approach still entails two challenges. A first challenge is related to the *interworking functionality*, which is needed in the network to coordinate the ATM and SDH recovery actions (together responsible for the overall resilience of ATM VPs). Indeed, in the event of physical failures, subsequent alarm messages will be passed through each layer after they are generated. More specifically, the detection of SDH path alarm messages (AU-AIS) in the SDH VC-4 to ATM VP layer adaptation function of the ATM equipment will cause the generation of VP-AIS messages. Without any *inter-layer recovery coordination* of this alarm generation, the recovery scheme at the ATM layer may be triggered (for a failure that is planned to be resolved at the SDH layer). This may create a situation for ATM layer resource competition causing network congestion and even disruption of ATM services.

The second challenge concerns the allocation of spare capacity. Because two recovery schemes are responsible for the resilience of the ATM VPs, spare capacity has to be foreseen in both SDH and ATM network layer. Care should be paid to avoid duplication of the protection. For instance, *redundant protection* may occur when the SDH recovery would also protect the ATM spare resources. Redundant protection can be avoided when the working and spare capacity of the ATM layer are carried in distinct SDH paths and when *protection selectivity* is considered in the SDH network layer. Nevertheless, although redundant protection can be avoided, we will still have to foresee some resources in the SDH network layer for the ATM spare capacity. Eventually, this second drawback can also be avoided by adopting a survivability strategy based upon the common pool concept [3]. The essence of common pool consists in supporting the ATM spare resources over the SDH spare capacity as preemptible traffic (also known as extra traffic), which provides the means to share spare capacity across network layers. We refer to reference [3] for an in-depth study of the application of this survivability concept to meshed ATM on SDH networks, and concentrate in this paper on the comparison between the above mentioned multi-layer recovery approaches.

### 3. Cost evaluation

#### 3.1. Introduction

In order to compare the multi-layer survivability strategies in a quantitative way, we have performed a set of planning case studies, using different traffic and network models. We had several realistic data sets, generated

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<sup>1</sup> Remark that when a node fails, recovery of traffic originating or arriving at that node is impossible.

for the ACTS PANEL research project [1], at our disposal. These data sets entail two network topologies, a 16-node network with 36 physical links and a larger 32-node backbone network with 70 physical links. We considered two different degrees of ATM service adoption: a medium and a high degree. Each of them corresponds to a different placement of ATM equipment in the network (i.e., different ATM-node overlay scenarios). In total, we considered four different ATM on SDH network models:

*Table 1 - Considered sample networks*

	<i>Small network (16 offices)</i>	<i>Large network (32 offices)</i>
Medium degree of ATM adoption	6 ATM-equipped offices	10 ATM- equipped offices
High degree of ATM adoption	8 ATM-equipped offices	16 ATM- equipped offices

With each ATM on SDH network is also associated a certain SDH native demand and an ATM VP demand distribution. In the remaining of this section, the resulting network/traffic models will be denoted as *small6*, *small8*, *large10* and *large16*.

A cost comparison of different multi-layer recovery approaches on a network is of course very dependent on the single-layer recovery options that are followed. In our study, we concentrated on path protection schemes in both layers (that is, VP-APS in the ATM layer and end-to-end (e.g., SNCP-based) protection in the SDH VC-4 layer). Such path protection schemes (i.e., end-to-end recovery using dedicated backup facilities) will often be used for the resilience of connections of premium service level. In practice, an operator may choose recovery schemes with different characteristics in both layers. However, our aim was to evaluate the multi-layer aspect of the recovery approach, and we assumed that similar recovery schemes are deployed in both layers. For instance, it can be anticipated that using a “greedy” SDH protection scheme will be more expensive than an ATM restoration scheme, which uses its spare resources in a more efficient way.

### 3.2. Experimental results

The network cost in the different cases was evaluated by assessing the amount of physical resources such as the number of equipment and fiber systems required by each survivability approach. The amount of resources was determined through a network dimensioning process, using network design tools developed in the past by the authors. Because the recovery approaches involve different design constraints, we had to use different design procedures. The cases using a recovery at the highest layer approach were dimensioned with the network design tool described in [7]. For the lowest layer approach, we used a generalization of the multi-layer planning approach proposed in [4]. When a self-healing backup VP scheme is used at the ATM layer, we used a combination of our VP grouping heuristic [4] and the algorithm for spare capacity allocation of reference [5]. The costs taken into account during our evaluation origin from ATM equipment (backbone ATM DXC VP and its STM-1 interface cards), SDH equipment (DXC 4/4, STM-1 interfaces, STM-16 line systems), and the carrier cost. This *carrier cost* includes a cost term for the fiber and a cost term for the regenerators. We used actual equipment costs, obtained from a survey of different ATM and SDH equipment manufactures. All costs in this paper are expressed in a normalized unit, corresponding to the cost of one STM-1 port on an SDH (STM-16 type) line system.

*Table 2 - Investment costs for recovery at the highest layer*

	small6	small8	large10	large16
ATM equipment cost	2357.3	6332.2	5817.2	17552.6
SDH equipment cost	2074.9	5690.3	5767.5	16487.9
Carrier cost	1384.8	3455.5	4713.0	13031.4
ATM service cost	5817.0	15478.0	16297.7	47071.8

*Table 3 - Investment costs for recovery at the lowest layer*

	small6	small8	large10	large16
ATM equipment cost	1411.3	3294.4	3044.3	7999.5
SDH equipment cost	2193.0	5749.0	6373.4	17792.2
Carrier cost	1303.5	3569.9	4672.2	13301.2
ATM service cost	4907.8	12613.3	14089.9	39093.0

Instead of comparing the overall cost in different cases, we decided to just compare the costs related to the (survivable) transport of the ATM VP traffic. In fact, the survivability strategies considered in this paper only differ in the way they recover the ATM VPs, and the SDH native traffic is always treated the same way. In order not to let the SDH native traffic obscure the cost comparison, we decided to evaluate the share of the overall investment costs related to the ATM VP traffic. This so-called *ATM service cost* comprises the ATM equipment cost, but also the cost of the SDH facilities occupied by ATM VP traffic. Since the SDH facilities are shared between SDH paths carrying SDH native demand and SDH paths carrying ATM traffic, we attributed each service type a share of the SDH installation cost that was proportional to its usage of the total SDH network capacity. In Table 2 (and Table 3), the investment costs related to the ATM demands are listed for the recovery at the lowest layer (and highest layer respectively), for each of the considered scenarios.

It is also interesting to compare the SDH and ATM link capacity required by each approach. These are shown in table 4 for both SDH and ATM network layers. Again, we only consider the link capacity related to the ATM demands (that is, we exclude the SDH layer capacity occupied by the SDH native traffic). We have expressed the capacity (of both network layers) in a normalized unit, which represents 150 Mbit/s.

Table 4 - Link capacity

	Recovery at the highest layer				Recovery at the lowest layer			
	small6	small8	large10	large16	small6	small8	large10	large16
ATM VP	154	439	392	1287	54	143	129	360
SDH VC4	280	759	785	2199	246	658	743	2090

It seems that in the network and traffic scenarios considered by us, the recovery at the highest layer approach requires a higher investment budget (up to 20% more) than the recovery at the lowest layer approach. There are several explanations for this result. First of all, with recovery at the lowest layer, only multi-hop VPs require additional ATM layer protection (and subsequent ATM layer spare capacity). This results in a lower ATM spare capacity requirement than the recovery at the highest layer approach. Secondly, the approaches differ in the constraints that must be satisfied in finding working and backup VP routes. With the recovery at the highest layer approach, the routes of a VP must be disjoint in both physical links and nodes. For the lowest layer approach, the only requirement is to have no transit ATM DXC in common. Hence, the recovery at the lowest layer approach leads to looser constraints (i.e., more room for optimization), since the VP routing possibilities are less limited.

Furthermore, all the ATM link capacity (including spare) has to be supported in the SDH network layer as well. Although no SDH spare capacity has to be provisioned for the ATM VPs with recovery at the highest layer, the extra deployment of the ATM spares involves more SDH paths to support the ATM network layer. This will increase the amount of SDH facilities ‘occupied by ATM layer capacity’. In fact, the SDH capacity required for the ATM VP demands is about the same for both recovery approaches (see table 4). With the recovery at the lowest layer, part of the spare resources for VP resilience are only put in the SDH network layer, and only have an impact on the needed facilities of one network layer instead of two.

Concluding, it seems better to resolve burdensome physical and SDH failures using bulk recovery at the SDH VC-4 network layer than using ATM layer recovery schemes. This makes it possible to get more value out of the ATM equipment rather than wasting some of the (more expensive) ATM layer capacity on the rather “mundane” task of protecting against lower layer failures.

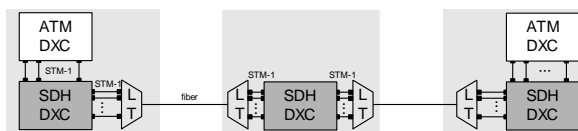


Figure 2.a - Original node configuration

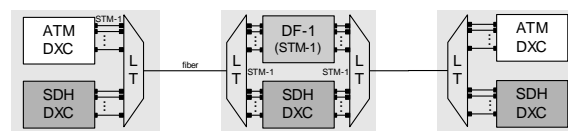


Figure 2.b - Configuration using an STM-IDF

However, other motivations (see for instance section 2.2) may still convince a network operator to adopt the recovery at the highest layer approach. In that case, it is meaningful to decrease in some way the cost of the SDH layer capacity necessary to support the ATM network layer. A possible manner to obtain these SDH resources at a lower price is to use STM-1 distribution frames (i.e., hard-wired interconnections of STM-1 interface ports) instead of SDH digital cross-connects for the VC-4 flexibility of the ATM VP traffic. The

resulting configuration is illustrated in figure 2.b. This equipment configuration provides the means to save interface ports on the SDH DXCs, which are now only accessed by SDH native traffic.

With recovery at the lowest layer, we can of course not replace the SDH DXC functionality by an STM-1 distribution frame (DF), since the SDH VC-4 layer has to provide fast recovery of physical and SDH layer failures. The manually operated STM-1 DF can not be seen as a device able to ensure fast rerouting in the SDH layer, and does also not include any monitoring or management capabilities. In the recovery at highest layer approach, the VP resilience is provided solely by the ATM VP layer, and it is more acceptable to use STM-1 DFs to obtain the SDH VC-4 level flexibility for the VP traffic.

*Table 5 - Results for STM-1 DF configuration*

	small6	small8	large10	large16
ATM equipment cost	2357.3	6332.2	5817.2	17552.6
SDH equipment cost	1206.9	3294.3	3413.5	9515.9
Carrier cost	1384.8	3455.5	4713.0	13031.4
ATM service cost	4949.0	13082.0	13943.7	40099.8

Table 5 presents the resulting investment costs of the networks with STM-1 DF configuration (recovery at the highest layer). The results prove that the STM-1 DF configuration lowers the price to be paid for the SDH layer capacity (compare with table 3). In fact, using the STM-1 DF enables to implement the recovery at the highest layer approach at an investment cost comparable to the investment cost of the lowest layer approach.

#### 4. Conclusions

In this paper, we studied different multi-layer recovery approaches to ensure the resilience of ATM VP and SDH native services against a set expected failures. In order to evaluate the various multi-layer survivability strategies in terms of investment cost, we carried out a network planning case study. Based on our results, we conclude that it seems to be cheaper to resolve burdensome failures like cable cuts in the SDH network layer. In this recovery approach, a large part of the spare capacity has to be foreseen in the SDH layer only, which enables to get more value out of the ATM equipment. When other motivations would still convince an operator to employ the recovery at highest layer approach, an alternative equipment configuration using a cheaper STM-1 distribution frame to obtain the VC-4 level flexibility for ATM traffic may be appropriate.

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