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# A New Efficient Online-Optimization Approach for SDH/SONET-WDM Multi Layer Networks

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**Abstract:** This paper presents and evaluates a new simple greedy algorithm for rerouting connections in a dynamic SDH/SONET-WDM multi layer network to improve resource efficiency and thus increase network performance.

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## 1. Introduction

An enhanced automatically switched SDH/SONET-WDM multi layer network is one feasible solution within the context of ASTN/ASON that provides dynamics on both layers in order to cover the dynamics of IP traffic as well as to support connections with different capacity requirements.

A major task in such dynamic multi layer networks is routing and grooming of connections. For each arriving connection, the routing and grooming scheme selects the best path with respect to the current network state, i. e., the path selected is optimal for the instant of establishing the connection. But due to the statistical nature of traffic neither the arrival of the next connections nor the holding time of established connections is not known in advance. Thus, this can not be considered during the connection setup. But when terminating a connection the assigned resources are released. They can at this time be used for rerouting existing connections in order to improve the network performance by increasing the resource efficiency.

This path consists of either a single light path with sufficient free capacity and the new connection is groomed to. Otherwise it is composed of a sequence of light paths with intermediate hops where the connection must be regroomed. To establish the connection, all required resources are then assigned.

In literature, several approaches are presented that rely on a global optimization or at least try to reorder a high number of connections. In contrast to that, in this paper we present a simple greedy algorithm for SDH/SONET-WDM multi layer networks that improves the network performance by reusing the path of the terminating connection for rerouting an established connection. It has a low computational complexity and a low signalling effort and can thus be easily integrated in dynamic network scenarios but still achieves significant performance improvements.

## 2. Rerouting Concept

The algorithm's main target is to increase the amount of free resources in the network available for new arriving connections. An established connection is rerouted to the path of a terminating connection if this reduces the resource usage of the connection. For preselecting the connections that can be routed on the same path we use the following definition:

All connections in the network are classified into connection groups $G_{s,n,b}$ based on their source and destination node $s$ and $d$, respectively and their bandwidth $b$. Within a connection group, all connections are ranked according to metrics that are derived from the amount of resources a connection occupies. With this, the algorithm can be described as follows:

If a connection $C$ of connection group $G_{s,n,b}$ is about to be terminated, the algorithm starts. It determines another connection $C'$ of the same connection group with the worst ranking. If such a connection can be found, the first connection $C$ is terminated without releasing its occupied resources. Instead, the second connection $C'$ will be rerouted onto the path of the terminating connection $C$ by shifting the assignment of the resources from connection $C$ to connection $C'$. Then, the resources originally occupied by connection $C'$ are released. Otherwise, if no connection can be found with a worse ranking, connection $C$ will be terminated and its resources will be released.

A simple example for this is shown in **Fig. 1** consisting of three multi layer nodes A, B and C that are pairwise connected by one wavelength $\lambda$. On each wavelength two SDH/SONET connections of a fixed capacity of one unit can be groomed. Initially, among connections between nodes A and C and C and B three connections are established

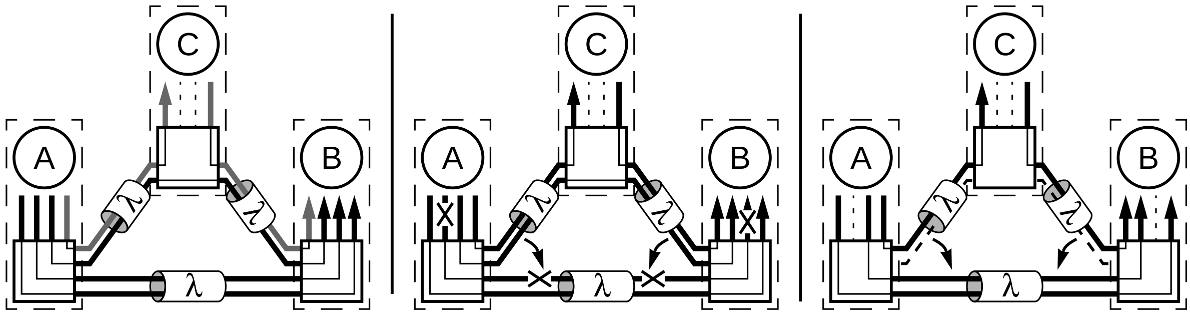


**Fig. 1.** Principle rerouting process in three steps

between nodes A and B. Two of them are groomed to a wavelength that is directly routed from node A to node B without intermediate nodes. The third is groomed to a two-hop light path with an intermediate hop in node C (Fig. 1 left). Now, one of the connections on the direct light path will be released. As the third connection occupies more resources due to its additional hop, it will be rerouted onto the path of the terminating connection (Fig. 1 center). Finally, the two-hop light path is released (Fig. 1 right). It can be seen that without rerouting only new connections could be provisioned between nodes A and B using either of the light paths. By rerouting the connection now all feasible different end-to-end connections can be additionally established leading to an increased flexibility.

For ranking the connections within a connection group, several approaches are feasible differing in the considered resources (e.g., transponders or wavelength hops) or in the computational complexity. In this paper we use two simple schemes to calculate the required metrics. Both schemes try to characterize the resource usage of the path for maximizing the savings:

a. The total number of wavelength hops represents the occupied resources in the optical layer. With this, detours can be detected (*OptHops*).
b. The number of grooming hops represents the resources required for intermediate grooming. Reducing the amount of intermediate grooming also reduces the blocking probability at the ingress and egress of the optical network (*GroomHops*).

The main advantages of this approach lie in its simplicity with respect to the computation complexity and signalling effort. At the connection's setup it is only once classified to a group. Even more, with the schemes presented above its metric must also be calculated only once as they will remain unchanged during the lifetime of the connection. Further, when releasing a connection only very few steps are necessary to decide on a connection to be rerouted or not.

With respect to signalling, with this algorithm it is only necessary to switch the connection to be rerouted at its source and destination nodes and thus only these switching operations must be signaled. Neither intermediate nodes need to be informed nor any other connection will be affected by this. Even more, using VCAT and LCAS the connection can be switched hitless without interruption which is a major requirement of network operators. Especially this is usually not provided by approaches that try to optimize the entire network or to globally reroute connections.

## 3. Case Study

In the following, we present results of a case study in a Pan-European reference network topology (COST 266 CoreNetwork, [1]). In the model we use here, the SDH/SONET-WDM multi layer network consists of multi layer nodes with blocking-free cross connects on the SDH/SONET layer as well as on the WDM layer. The cross connects of the different layers are connected by transponders.

The offered traffic for each node pair is derived from a population model according to [1]. The links are tightly dimensioned according to [2,3] with a wavelength capacity of STM-64 and the nodes are equipped with the maximum number transponders. All connection requests arrive according to a Poisson process and holding times are negative exponentially distributed. We used a traffic mix consisting of 40% STM-1, 40% STM-16 and 20% STM-64 connections by volume.

For routing and grooming two non-integrated schemes (MH-pLP and MH-pMH) and one integrated routing scheme (WIR) are used here. MH-pLP first tries to use an existing direct light path, setups a new if no direct light path can be found. If this is also not successful, a multihop path can be used. MH-pMH first tries to use an existing direct lightpath or a multi hop path on different existing lightpaths. It only setups a new direct lightpath if otherwise

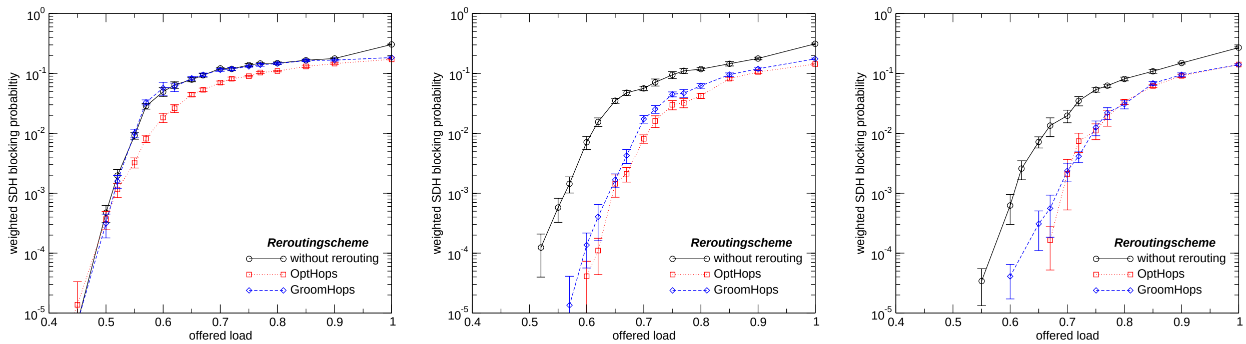


**Fig. 2.** Achievable improvement of network performance for different routing and grooming schemes left: MH-pLP, center: MH-pMH, right: WIR

no path can be found [3]. Further, the integrated scheme WIR [4] determines different paths based on existing and non-existing lightpaths, rates them and selects the path with the best rating.

**Fig. 2** shows the weighted SDH blocking probability versus the offered load for the three routing schemes MH-pLP, MH-pMH and WIR from left to right. In each diagram, the results are plotted for the case without rerouting as well as with rerouting applying the rating schemes *OptHops* and *GroomHops*.

In general it can be seen that introducing rerouting reduces the blocking probability, especially for the routing schemes MH-pMH and WIR. This performance improvement can be directly used by network operators to either increase the quality of service perceived by their customers or to reduce the required resource overbuild in the range of 10%. Only for the combination of the rating scheme *GroomHops* and the routing scheme MH-pLP the difference with and without rerouting is minimal. This is reasonable as this routing scheme usually only uses paths without intermediate grooming. Thus, with respect to the rating criteria grooming nodes all connections are equal leading to the conclusion that the routing scheme and the metrics scheme must be aligned.

Comparing the two rating schemes it can be seen that the scheme based on the number of wavelength hops *OptHops* leads to at least the same or even a better performance than the grooming hops based scheme *GroomHops*. This due to the fact that the nodes are fully equipped with transponders and thus the bottleneck mainly lies in the availability of free wavelengths.

## 4. Conclusions

In this paper we presented a simple greedy algorithm to improve resource efficiency by rerouting connections and thus the network performance. We showed in a case study the reduction of the network blocking probability which can be more than one order of magnitude. Future work will extend this algorithm by to more complex schemes for calculating the rating metrics as well as extend the concept to rerouting of entire lightpaths.

## 5. References


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