Dynamical Configuration of Transparent Optical Telecommunication Networks*

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Abstract. *All-optical* telecommunication networks allow for switching connections by *lightpaths* which can pass several network links without any opto-electronic conversion. Upon arrival of a connection request, it must be decided online, i.e., without knowledge of future requests, if it is accepted and in that case on which lightpaths the connection is routed. This *online problem* with the goal of maximizing the total profit gained by accepted requests is called *Dynamic Singleclass Call Admission Problem* (DSCA). We present existing and new algorithms for DSCA as well as their theoretical and practical evaluation.

1 Introduction

The links of an *all-optical* telecommunication network consist of *optical fibers* by which data is transmitted using optical signals. With *optical switches* in the network nodes, an optical signal may be transmitted along several fibers without leaving the optical layer, i.e., no opto-electronic conversion is performed at intermediate nodes. Such an optical channel is called a *lightpath.* In the absence of optical conversion devices, each lightpath uses just one wavelength since the optical switches maintain the wavelength of a passing signal. Applying the technique of *wavelength division multiplexing* (WDM), it is possible to transmit several optical signals of different wavelengths along one fiber at the same time. Hence, multiple lightpaths may traverse one fiber simultaneously if they have different wavelengths. However, any two lightpaths which share one fiber must use different wavelengths. This condition is called *wavelength conflict constraint.*

One crucial aspect in today's telecommunication service is the following. In many real-world applications like telephony and video conferencing demands change in a highly dynamic way. This requirement can be realized in all-optical networks using novel optical switches that are software-controlled and reconfigurable within milliseconds, thus, data connections can to be set up and taken down on demand. Moreover, the requested demands usually become known only shortly before they are actually required, which results

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in substantial uncertainty for planning. We refer to them as *connection requests* or *calls*. Depending on the provided capacities of the optical network, the customers may suffer service blocking, especially in situations of demand peaks. Hence, for each newly arriving connection request, the network operator has to decide whether he accepts or rejects the call. In doing so it is also admissible to reject a call even if a corresponding connection could still be established. For accepted calls fixed lightpaths must be provided for the total holding time of the connection. Each accepted call yields a specific profit. We call this problem with the goal of maximizing the total profit gained by accepted connection requests *Dynamic Singleclass Call Admission Problem*, or DSCA for short. Note that the decision on each request must be made irrevocably and without knowledge of future calls. Therefore, DSCA is counted among the so-called *online optimization problems* (see [3] for details on online optimization).

In this paper we are concerned with all-optical networks without wavelength conversion capabilities and assume that there is no crucial limit in the switching capability of the optical switches in the network. As a consequence, the only bottleneck for realizing lightpaths results from the fiber capacities, i.e., the numbers of provided wavelengths. From now on, we will refer to all-optical networks simply as *optical networks.*

1.1 Related Work

In previous work for DSCA, the following simplifying assumptions are usually made on the problem parameters: Each network link consists only of one optical fiber, each fiber is equipped with the same set of wavelengths, and each call requires only one lightpath and yields the same profit, i.e., the goal of maximizing the total profit is equivalent to minimize the *blocking probability* for a connection request.

Also motivated by the need for distributed implementations, particularly simple algorithms for DSCA have previously been proposed. These schemes restrict for each pair of end nodes the set of allowed routes for connecting lightpaths to a few predefined paths. The actually used path is chosen according to availability and some priority order. For the selection of the wavelength, first approaches used fixed and random wavelength search orders [4,2], i.e., the first possible wavelength in the given order is chosen. In [1], Bala, Stern, Simchi, and Bala propose adaptive search orders that incorporate network state information, namely the current utilizations of different wavelengths.

As a counterpart, Mokhtar and Azizoglu present five algorithms, also called *greedy algorithms*, where any lightpath can potentially be chosen. In particular, these algorithms always accept a connection request if possible. Greedy algorithms are based on shortest path computation and different strategies for selecting the wavelength. Experimental results exposed the superiority of this approach over the algorithms above using restricted path