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# The selection and scheduling of telecommunication calls with time windows

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**Abstract**

We consider the bandwidth scheduling problem that consists of selecting and scheduling calls from a list of available calls to be routed on a bandwidth-capacitated telecommunication network in order to maximize profit. Each accepted call should be routed within a permissible scheduling time window for a required duration. To author's knowledge, this study represents the first work on bandwidth scheduling with time windows. We present an integer programming formulation of the problem. We also propose a solution procedure based on the well-established Lagrangean relaxation technique. The results of extensive computational experiments over a wide range of problem structures indicate that the procedure is both efficient and effective.


*Keywords:* Telecommunications; Bandwidth packing; Scheduling; Integer programming; Lagrangean relaxation

## 1. Introduction

This paper considers the bandwidth scheduling (BWS) problem that arises in the area of telecommunications. The problem involves selecting and scheduling calls from a list of available calls to be routed on a bandwidth-capacitated telecommunication network in order to maximize profit. Each available call is characterized by a revenue, a demand or traffic requirement, a duration, and a scheduling time window for routing the call. Each accepted call should be routed within the permissible time window for the required duration of the call. A path/route should also be selected from among all possible paths in the network to route the demand of each accepted call during each time of the entire duration of the call.

To author's best knowledge, the current study represents the first work on bandwidth scheduling with time windows. The bandwidth scheduling (BWS) problem can be considered the extension and generalization of the bandwidth packing (BWP) problem found in the literature. This latter problem does not

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consider durations and scheduling time windows for routing calls. Alternatively, it assumes that all available calls have the same duration of one time unit and the same scheduling time window of length one. In practice however, the durations and permissible scheduling time windows vary. A good example would be the scheduling of teleconferences for customers on a telecommunication network.

The use of time windows allows a client to specify an interval/window of acceptable times for routing the call rather than just one time. This arrangement increases the chance that the call getting accepted, thereby benefiting the customer; it also enables better "packing" of the calls in the network links, resulting in better overall bandwidth utilization and increased revenue for the network operator. In addition, it allows for the effective implementation of discriminatory pricing policy. For example, clients can be charged more for requesting calls to be routing during "peak-hours" (i.e., period of high utilization of the network) and less for requesting calls to be routing during "off-peak-hours" (i.e. period of low utilization of the network). Of course, after the network operator solves the bandwidth scheduling problem, he/she notifies each client about the start time of his/her call to get ready to transmit the call. The major contributions of this study are indeed the introduction and formulation of this more practical and general problem and the development of an effective method to solve based on the Lagrangean relaxation technique.

The bandwidth packing (BWP) problem as known in its generic form in the literature has been first introduced by Cox et al. [5]. The problem is not just applicable to phone networks. As stated by Parker and Ryan [16], the problem is quite general and applies to telecommunications networks used to carry mainly high bandwidth applications that can share communication channels such as video-on-demand, multimedia services, video teleconferencing, and of course voice and text. It is also important to note that the term "call" as used in the literature dealing with this problem refers to a request to use the network resources to transmit traffic between a pair of communicating nodes usually for extended durations compared to phone conversations.

Anderson et al. [3], Laguna and Glover [12], Cox et al. [5], Parker and Ryan [16] and Park et al. [15] studied the bandwidth packing problem. They formulated the problem and presented heuristic solution procedures based on tabu search [3,12], genetic algorithm [5], column generation [16], and branch-and-bound technique using column generation and cutting plane approaches [15]. More recently, Amiri et al. [2] and Rolland et al. [17] incorporated the queueing delay issue in the problem. Amiri and Barkhi [1] extended the problem to allow the demand of a call to vary by the hours of the days. They did not consider, however, durations and scheduling time windows of available calls.

The purpose of this paper is to present this new (BWS) problem and propose an optimization based approach to solve it efficiently. This approach is based on a straightforward implementation of the well-established Lagrangean relaxation technique. The remainder of this paper is organized as follows. In Section 2, a mathematical formulation of the (BWS) problem is presented. A Lagrangean relaxation of the problem obtained by dualizing a subset of the constraints and a heuristic solution procedure are presented in Section 3. Computational results are reported in Section 4. The conclusions are summarized in the last section.

## 2. Formulation of the problem

In order to formulate the bandwidth scheduling problem in a telecommunications network, we are given the network topology, the capacity of the links, the flow costs, and the list of available calls. Each available call is characterized by a revenue, a demand or traffic requirement, a duration, and a scheduling time window for routing the call. The (BWS) problem consists of determining the set of calls to route and the assignment of these calls to the paths in the network to maximize profit while satisfying the bandwidth capacity limitations and permissible time window restrictions.