MINCOD-MTD: A RWA Algorithm in Semi-Transparent Optical Networks

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Abstract. *This paper proposes a new RWA algorithm that takes into consideration the Maximum Transmission Distance (MTD) parameter to be applied to semi-transparent optical networks, achieving a considerable benefit in terms of blocking probability reduction*.

Introduction

The introduction of transparent switches and the consequent implementation of fully transparent networks seem very promising, both from technical and economic viewpoint, for the future of optical transport networks. Many efficient Routing and Wavelength Assignment (RWA) algorithms have been specifically developed to minimize the blocking probability in fully transparent networks loaded by dynamic traffic.

Full transparency is not however always achievable in long distance networks, due to the degradation an optical signal accumulates in propagation. In semi-transparent optical networks regenerators are employed when the quality of the signal falls below the level required for an acceptably correct detection.

In general, the physical model for computing the global impairment of an optical connection (a lightpath) has to take many parameters and system characteristics into account. The Bit Error Rate (BER), which represents the quality of the signal perceived by the user, can be evaluated as a function of the so-called Q Personick's factor [1, 2]. The Q factor is given by a formula (not reported here for brevity) that takes into account the most important linear (as a function of the optical signal-to-noise ratio) and non linear impairments.

Such type of model can be used to evaluate the BER in a satisfactory way for operational or design purposes. When this method cannot be applied for lack of information or because a simpler approach is preferred, the concept of Maximum Transmission Distance (MTD) can be used instead. The concept is simple: inside a given optical network MTD is the maximum distance a signal can be routed on without any regeneration. MTD depends on the type and quality of the optical components as well as the accuracy of the optical design. MTD should be evaluated along the worst paths of the network (i.e. critical paths characterized by non uniform amplifier spacing, low quality components and critical fibre types). Therefore, wavelengths can be classified into three classes (gold, silver and bronze), each one characterized by a different value of the MTD. This definition and details are investigated in the Nobel project [3].

This paper proposes a routing algorithm to compute the routes, named Minimum Coincidence and Distance (MINCOD) algorithm, and a method to assign wavelength based on the MTD concept turning out a new RWA algorithm called MINCOD-MTD which is applicable to the semi-transparent optical networks. The MINCOD-MTD guarantees that lightpaths setup in the network are physically feasible and robust against signal impairments, with limited computational complexity. In particular, the paper presents the evaluation of performance in terms of blocking probability on dynamic traffic of a semi-transparent case-study network in which MINCOD-MTD is used as RWA algorithm.

The MINCOD-MTD RWA Algorithm

The goal of the proposed MINCOD-MTD algorithm is to maximize the number of established connections accomplishing the physical impairment constraint, such as the Maximum Transmission Distance (MTD) in a semi-transparent optical network. We assume that in a semi-transparent network routes are divided into transparent sub-routes between signal regenerators.

The algorithm tackles the problem of selecting the suitable end-to-end k-paths where the traffic must be forwarded. In order to enhance the route selection the algorithm takes into account the concept of minimum coincidence between routes to balance the traffic load, hence reducing the network congestion. Next, the MINCOD-MTD algorithm is explained in detail.

Firstly, the MINCOD algorithm chooses the shortest path (in distance) from the list of feasible paths between the source-destination node pair, already pre-computed and ordered by the SPF (Shortest Path First) algorithm. Secondly, it associates a metric to the shortest routes left. This metric is named Minimum Shared Link (MSL) and is computed according to the following expression:

$$\mathbf{MSL = DP * (1+SL)}$$

where DP is the end-to end distance of the particular path and SL is the number of links shared between the particular path and the path previously selected in the first step. The MINCOD algorithm selects the path with minimum MSL as the second path. Finally, this process is repeated in order to provide an ordered list of k-paths.

Once there are k routes computed according to the MINCOD algorithm, the MINCOD-MTD checks for every route and wavelength (lightpath) if the distance of every sub-route of the route is shorter than the MTD of that wavelength class. Notice that it always checks first wavelengths of the bronze class. If this condition is not accomplished, the algorithm will check the wavelengths of the second class (silver), and so on. The MINCOD-MTD algorithm also checks if that wavelength has availability in all the links of the route. The selected lightpath is the first fulfilling the MTD constraint and with availability in all the links of the route.

Performance Evaluation

A set of simulations have been carried out on the topology of the PanEuropean network shown in Figure 1. The simulation environment consists of the following features:

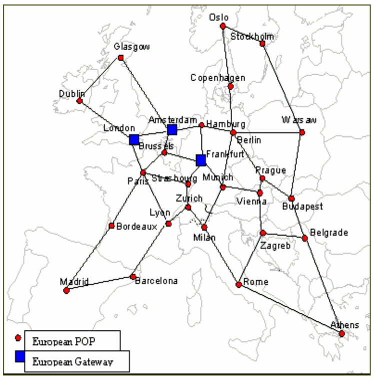

Figure 1. PanEuropean Network

- 2 fibres per link and 40 wavelengths per fibre.
- Wavelengths are divided into three classes, gold, silver and bronze, with MTD of 4000, 3500 and 3000 km respectively.
- Nodes Madrid, Barcelona, Paris, Dublin, Milan, Frankfurt, Amsterdam, Prague, Stockholm and Athens act as source and destination; and nodes, Frankfurt, Amsterdam, Vienna, Milan, Prague and Warsaw have regenerators.
- The traffic is modelled according to a Poisson distribution for the connection arrival time and an exponential distribution for the holding time.
- Every simulation is computed using 90.000 call connections.

Three algorithms are compared considering 1 or 2 pre-computed routes: SP-MTD, computes the shortest route in distance; Link Disjoint-MTD computes 2 shortest and link disjoint routes; and finally the MINCOD-MTD computes 2 routes according to the MINCOND routing algorithm.

Results of Figure 2 show the improvement achieved when the routing algorithm selects the route among several pre-computed routes. While SP-MTD always uses the same shortest route, the rest of the algorithms use 2 routes to balance the traffic load reducing the blocking probability.

We can also observe that the MINCOD-MTD algorithm produces the lowest percentage of blocked connections. The improvement with respect to the algorithm selecting among link disjoint routes is due to the fact that the MINCOD-MTD algorithm performs a trade-off between the distance and number of shared links.

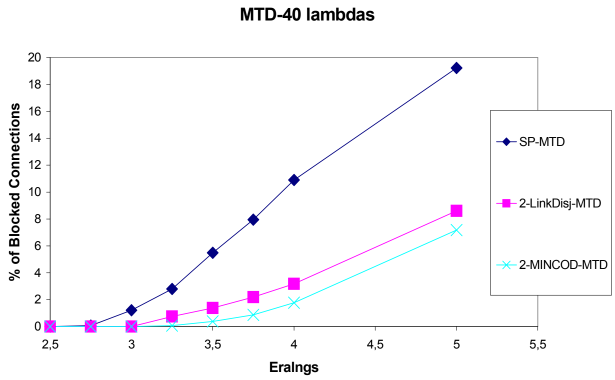

Figure 2. Percentage of Blocked Connections versus traffic load

Conclusions

This paper demonstrates the advantages, in terms of blocking probability, of using a routing algorithm which balances the traffic load not only considering the shortest path but also taking into account the minimum shared links between the pre-computed end-to-end routes. An efficient method to assign wavelengths according to the MTD physical impairment provides consistency to the RWA algorithm to be applied in semi-transparent optical networks.

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