Impairment Constraint Based Routing (ICBR) with Service Differentiation in Survivable WDM Networks

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Abstract *We propose and evaluate a novel survivable Impairment Constraint Based Routing (ICBR) algorithm with service differentiation at the Bit Error Rate level. Simulations show significant improvement in connection blocking compared to conventional ICBR solutions.*

Introduction

Existing Impairment Constraint Based Routing (ICBR) algorithms for transparent wavelength division multiplexing (WDM) networks exhibit improved connection blocking[1,2] compared to conventional routing algorithms. With ICBR, physical impairments, that degrade the signal quality, are considered as constraints during route computation, thus avoiding the establishment of lightpaths with poor signal quality. In addition, since network resilience has become an important aspect in WDM optical networks (i.e., a single link failure in such high capacity networks may disrupt a huge number of services and cause an enormous loss of data), this aspect needs to be addressed in the context of ICBR algorithms as well.

The future Internet is expected to support a variety of services with different QoS requirements. Existing ICBR schemes[1,2] decide blocking of connection requests using a single signal quality threshold. This practice may unnecessarily block requests that could otherwise sustain a higher BER than the single BER threshold currently used. To overcome this deficiency, we recently proposed[3] a novel ICBR algorithm supporting BER-level differentiation of services. Given the criticality of efficient resilient routing mechanisms in high capacity WDM networks, this paper extends our past work[3] through the specification of a new ICBR algorithm that supports both survivability and service differentiation.

Proposed algorithm

Fig. 1 presents the flowchart of the proposed algorithm. At the initialization phase, the algorithm collects the network topology information and the physical parameters required for the calculation of the Q-penalty[2] of each link. The rest of the algorithm consists of *two phases*: primary path provisioning and protection path provisioning (both dedicated and shared path protection are supported). In the *primary path provisioning phase* two routing algorithms are considered: *(i)* shortest path routing, with link physical distance corresponding to link cost, and *(ii)* impairment constraint routing, where the Q-penalty is used as link cost. In both cases, *k* alternative routes for each connection request are computed by using the Dijkstra algorithm. If there is at least one common available wavelength on every link of each computed route, then the route is stored in the set of candidate routes. If no route is found, the request is blocked. In the case of shortest path routing, the shortest route is selected first and the BER of the route is calculated. If the BER doesn't satisfy the signal quality requirement, the connection request is blocked. In the case of impairment-aware best-path (IABP[3]) and our proposed algorithm, the BER of all candidate routes is calculated. In IABP approach the route with minimum BER is selected. With our approach, the BER of all candidate routes is compared against the signal quality requirement of the request[3] and the route with maximum BER that satisfies the signal quality requirement is selected. Next, the first wavelength among a list of available wavelengths of the selected route is chosen to form the primary path for the

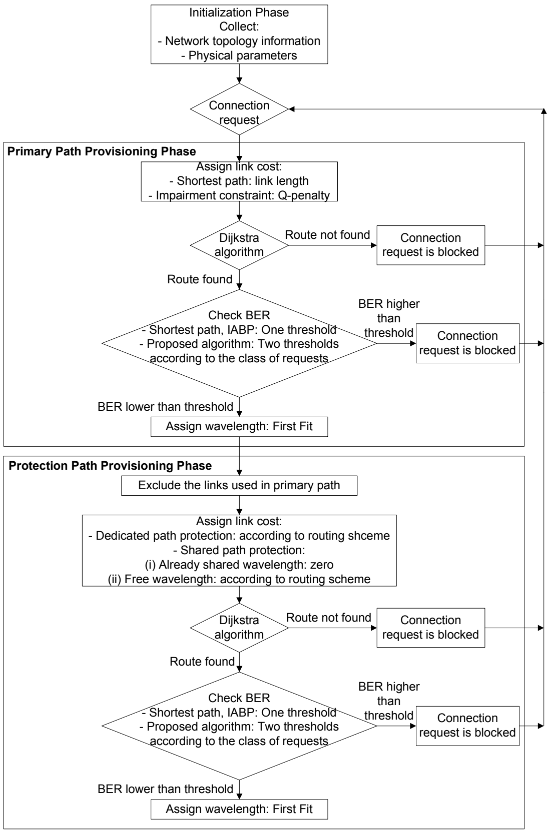


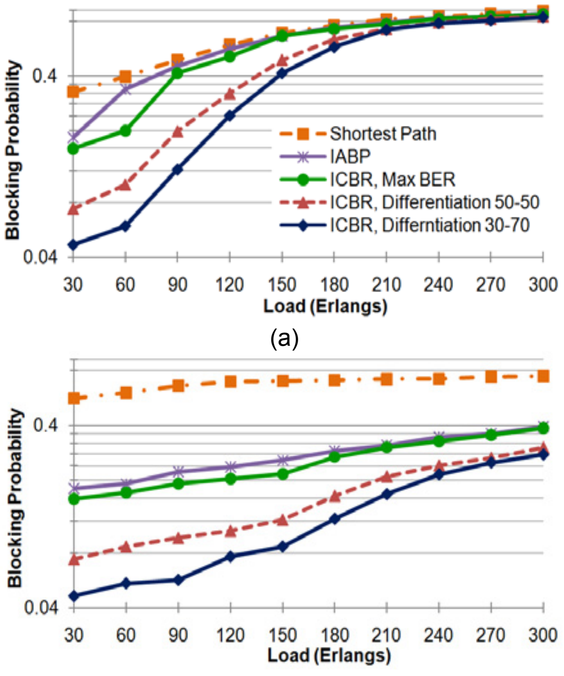
Fig. 1: Flowchart of the proposed algorithm

request. In the *protection path provisioning phase*, the links used in the primary path are excluded from the topology to obtain a protection path that is link-disjoint to the primary path. Subsequently, link costs are assigned. For the dedicated path protection case, link cost assignment works in the same way as the primary path link cost assignment. For the shared path protection case, link costs are set to zero for all those wavelengths that are sharable, i.e., used by already provisioned protection paths whose primary paths are link-disjoint with the currently provisioned primary path. Otherwise, link costs are assigned similar to the primary path routing algorithm used. For both protection schemes, BER checking and wavelength assignment are carried out identically to the primary path provisioning phase.

Performance Evaluation

The Pan-European test network topology[4] is used for the evaluation of our algorithm through simulations. We assume that the bandwidth of each connection request is one wavelength unit and that wavelength conversion capability is not available, imposing the wavelength continuity constraint. Connection requests are randomly generated following a Poisson distribution and are served sequentially. The source/destination pair of each request is randomly chosen with uniform probability and the connection holding time is exponentially distributed. Each simulation experiment runs until the 90%-confidence level becomes less than 10% of the sampled mean. We consider two classes of connection requests with regards to signal quality requirement, namely requesting BER less than 10^{-15} (Class-1) and 10^{-9} (Class-2). We consider two cases regarding the compensation of Class-1 vs. Class-2 requests to the overall traffic load: a) 30%-70% and b) 50%-50%. A Class-1 request is blocked, if there is no lightpath connecting the two endpoints of the request that exhibits BER less than 10^{-15}; whereas a Class-2 request is blocked if there is no lightpath with BER less than 10^{-9}. Moreover, in our algorithm the lightpath with the maximum BER that satifies the signal quality requirement of the request is selected. Instead, in the conventional approaches (shortest path and IABP), connection requests of either Class-1 or Class-2 are blocked if there is no route with BER less than 10^{-15}.

Fig. 2 depicts the simulation results in terms of the total blocking probability including both blocking due to insufficient resources and due to impairment constraints. Evidently, a significant improvement is achieved by our algorithm, as compared to both shortest path and IABP routing. Specifically, in the 30%-70% differentiation case the benefit obtained by our algorithm with dedicated path protection is up to 37% and 33%, and up to 61% and 17% in the case of shared path protection, compared to shortest path and IABP algorithms, respectively. For the case where Class-1 and Class-2 requests are equally weighted, the benefit of applying our algorithm is lower due to the increased resource occupancy by the Class-1 traffic. Notice that the IABP routing treats all requests as Class-1 irrespective of the real BER requirement (therefore corresponds to the case where 100% of the requests are of Class-1) and selects the lightpath with minimum BER.



(a)

(b)

Fig. 2: Blocking probability versus load (a) Dedicated path protection (b) Shared path protection

Conclusions

In this paper we presented and evaluated an ICBR algorithm supporting both survivability and differentiation of services at the signal quality level. Significant improvement compared to shortest path and IABP approaches is achieved by more efficient resource utilization that is in accordance with per service BER requirements, hence avoiding unnecessary connection blocking.

Acknowledgements

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