Partial Path Protection for WDM networks

Hungjen Wang, *MIT LIDS, hjwang@mit.edu*
Eytan Modiano, *MIT LIDS, modiano@mit.edu*
Muriel Medard, *MIT LIDS, medard@mit.edu*

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A wide range of protection schemes for WDM networks have been investigated in the literature [1-6]. Among them, path protection and link protection have attracted the most attention [1,5,6]. Path protection requires the protection path of a request to be completely link-disjoint from the corresponding primary path, while the link protection scheme reroutes all affected requests over a set of replacement paths between the two nodes terminating the failed link. Primary capacity cannot be shared, but protection capacity can be shared as long as a single link failure does not activate more than one protection channel along any wavelength on any link. In general, path protection is more capacity efficient than link protection [6]. In this paper, we present a new protection scheme, the partial path protection scheme (PPP). In this scheme, the network identifies a specific protection path for each link along a considered primary path. Thus, similarly to the path protection scheme, the partial path protection scheme assigns "end-to-end" protection paths to primary paths. However, in PPP, one single protection path protects only one specific link failure on one primary path, instead of the whole primary path in path protection. We consider a dynamic call-by-call system with random arrivals. Other research in the area of restoration efficiency has generally considered a batch model. That model is reasonable when call demands are known in advance. However, static batch models do not allow for dynamic provisioning of primary and protection paths in the network. Our call-by-call dynamic model is well suited to dynamic allocation of capacity for primary and protection paths. In our call-by-call model, every new call establishes its primary and protection paths according to the traffic already present in the network when the call arrives. Given the dynamic and probabilistic nature of our model, we take the call blocking probability to be the performance metric for our schemes, rather than traditional capacity efficiency metrics.

In order to optimize call blocking probability for selecting paths using PPP over some time horizon, we would have to solve a dynamic optimization problem. The extremely large state space of a dynamic program over a reasonable network and time horizon renders such an approach impractical. The complexity of a dynamic programming approach prompts us to consider two heuristics for implementing PPP. The first heuristic is a greedy approach that, for each call arrival, the system uses the fewest previously unused wavelengths to establish the primary and protection paths jointly. Wavelengths already used for protection paths can be used for new protection paths as long as a single link failure does not entail the activation of more than one protection path on any wavelength on any link. The problem formulation is an integer linear program (ILP). The second heuristic first selects the primary path, using a shortest path route. It then selects the protection paths using a shortest path algorithm in which wavelengths already assigned for protection can be used at no cost. We term the whole of the second heuristic, involving the choice of primary and of protection paths, the shortest path approach (SP). We show that the SP approach is not only significantly simpler computationally than the greedy approach, but also more effective in terms of blocking probability. This result may seem surprising at first. However, since protection paths can share bandwidth, while primary paths cannot, it is reasonable to select the most economical primary first, as done by SP, rather than consider primary and protection bandwidth jointly, as done by the greedy algorithm.
The SP approach, by selecting the primary path first, in effect prioritizes the efficient use of primary path resources over protection resources. The greedy approach seeks to minimize the total use of new wavelengths by primary and backup paths jointly. However, in a dynamic system, the efficient use of protection bandwidth is not as important as the efficient use of primary bandwidth, since in the future, protection bandwidth has a high likelihood of being shared, whereas primary bandwidth cannot be shared. The fact that SP performs better than the greedy approach highlights the significant difference between a dynamic call-by-call model and a static batch system. The main contributions of our paper are the introduction of the PPP method for establishing protection paths, the introduction of the greedy and SP approaches for implementing PPP and path protection and the use of a dynamic call-by-call model for protection.

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