Efficient Routing Algorithms for Hierarchical Optical Transport Networks[1]

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Abstract *Automatically Switched Optical Networks (ASON) specifications strongly recommends a hierarchical network architecture. In this paper authors propose three hierarchical routing algorithms, aiming to optimize the global network performance, while guaranteeing scalability.*

Introduction

In order to guarantee the network scalability, the ITU-T in G8080/Y.1304 [1] strongly recommends a hierarchical architecture for *ASON* (Automatically Switched Optical Networks). One of the main tasks to do to accomplish with this recommendation is to adapt the routing mechanisms to such a hierarchical architecture. Hierarchical routing allows to optimise the network performance by reducing large communication overhead while providing efficient routing. In this paper we propose three different routing algorithms for hierarchical ASON, namely BHOR (*Balanced Hierarchical Optical Routing*), PHOR (*Prediction Hierarchical Optical Routing*) and BAPHOR (*Balanced Prediction Hierarchical Optical Routing)*. BHOR and PHOR are respectively inferred from the algorithm proposed in [2] and from the *Prediction Based Routing* mechanism (PBR) presented in [3]. BAPHOR is generated by a combination of the other two aiming to include their main benefits while avoiding their potential negative effects.

Hierarchical routing description

A whole hierarchical network structure should be subdivided into routing areas (*RAs*), (see Fig.1) containing physical nodes with similar features. These *RA* nodes should exchange topology and resource information among themselves in order to maintain an identical view of the *RA*.

Assuming source routing (ASON recommendation), routes and wavelengths are selected on the source nodes reacting to any incoming request. We also assume static fixed-alternate routing, where a fixed number of routes to each destination node are precomputed at the source nodes. In this paper the three algorithms compute the two shortest routes in a hierarchical structure, that is, if the destination node belongs to the same *RA* the route is completely defined. Otherwise, if the destination node belongs to a different *RA*, the route is specified by both the route from the source node to the last node on its *RA* and the different *RAs* to reach the destination node.

BHOR description

There are three basic components impacting on how BHOR selects the ligthpath: the length of the selected lightpath (*Hn*), the degree of congestion (*Cd*), and the degree of obstruction (*Od*). The length, *Hn*, is simply the number of hops. The degree of congestion, *Cd*, is the wavelength availability, that is, the minimum number of available wavelengths of that colour in that route. Unfortunately, because of the update policy the degree of congestion may not be accurate enough. For this reason, the degree of obstruction, *Od*, tries to minimize the impact of such inaccuracy on the lightpath selection process. *Od* represents the number of links on the route where such a wavelength is defined as potentially obstructed wavelength (POW). Assuming that the hierarchical network mechanism is based on a threshold-based updating, the POW definition must take into account the value of this threshold. Being *B* (any link is a bundle of *B* fibres) the total number of a certain wavelength λ_i on a link, *R* the current number of available λ_i on this link, and according to the threshold-based update policy, the wavelength λ_i is defined as POW, namely λ^{POW}_i on a certain link, when $R \le pr$ (being *pr* a percentage of the threshold value). Then, for every lightpath the weight is calculated as $W(\lambda_i) = Hn(Od/Cd)$. *Od/Cd* factor stands for a balance between the number of potentially obstructed wavelengths and the real congestion. The length of the path is also included in order to avoid those paths that are either widest but too long or shortest but too narrow. By computing $W(\lambda_i)$ we will know the weight of each wavelength on an end-to-end path in a *RA*. However in a hierarchical network a wavelength could be defined as POW on different hierarchical levels, so the above expression must be applied to different hierarchical levels as well. Let $W_j(\lambda_i)$ be the weight calculated in a hierarchical level *j*, let *n* be the number of hierarchical levels, then, $W_h(\lambda_i)$, the hierarchical weigh for the end-to-end lightpath is computed as expressed in Eq(1), and the selected lightpath is that minimizing $W_h(\lambda_i)$.

$$W_h(\lambda_i) = \sum_{j=1}^{n} W_j(\lambda_i) \qquad (1)$$

PHOR description

The PHOR (*Prediction Hierarchical Optical Routing*) is based on the PBR mechanism [3] and it works as follows. First, it precomputes the two shortest routes to each destination in the hierarchical structure. Then it predicts the route and the wavelength to be assigned according to the routing information obtained in previous connection establishments. The

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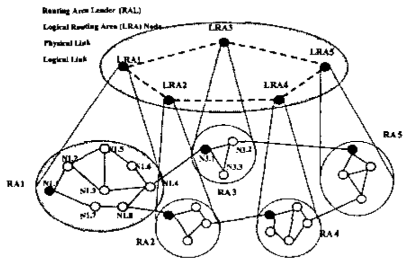

Fig.1 Hierarchical network topology used in simulations.

network state information is not used to take routing decisions, so the update process is completely unnecessary. Each source node registers, for each of its possible destinations, previous information about both the wavelength and the route allocated. For every wavelength on every route (lightpath) to every destination there is one register, named wavelength register (*WR*), which is updated with a 0 if a connection is established in that lightpath; otherwise it is updated with a 1. These *WRs* are the indexes to access new tables, named Prediction Tables (*PTs*). Every entry in the *PTs* has a two-bit counter. If the counter value is lower than 2 (0 or 1), the lightpath can be selected. Otherwise (counter value 2 or 3), the lighpath is predicted to be not available. The algorithm selects the lightpath as follows. Wavelengths on each route are weighted and sorted according to the minimum number of available wavelengths per link along the lightpath. Note that this availability is only from the point of view of the source node because there is not updating. The Prediction Tables (*PTs*) are checked in this computed order. The lightpath selected is the first fulfilling two conditions: the *PT* counter is lower than 2, and there is wavelength availability in the corresponding node's output link. If the connection can be established, the selected *PT* counter is decreased, otherwise it is increased.

BAPHOR description

In order to combine BHOR and PHOR to obtain the best from both of them, we propose a hybrid algorithm named BAPHOR (*Balanced Prediction Hierarchical Optical Routing*). The main idea underlying such algorithm is that the aggregated network state information of the external *RAs* can be replaced by a prediction about the availability through the external *RAs*. On the other hand, the network state information within the *RA* is flooded. The BAPHOR algorithm, as the BHOR algorithm, bases its decision on choosing the ligthpath that minimizes the hierarchical $W_h(\lambda_i)$ weight. But now $W_h(\lambda_i)$ is computed according to Eq(2). For the first hierarchical level (into the *RA*) the $W(\lambda_i)$ weight is *Hn(Od/Cd)*, but for the following hierarchical levels (out of the *RA*) the weight to add corresponds to the *PT* counter value of the ligthpath.

$$W_h(\lambda_i) = Hn\left(\frac{Od}{Cd}\right)(j=1) + \sum_{j=2}^{n} PTcounter\,(j) \qquad (2)$$

Performance Evaluation

Fig.2 depicts the connection blocking figures for BHOR, PHOR, BAPHOR and for the well known First-Fit RWA algorithm, assuming the network topology of Fig.1, (5-fibre and 16 wavelengths on each link), the connection demands and the connection holding time following an exponential distribution, and ranking the traffic load from 48 to 100 Erlangs. Fig.2a correspond to update the network state database at every change in the network, and Fig 2.b) to update it every 10 changes. These results show that updating the database every change, the BHOR and the BAPHOR have the best performance. But, updating every 10 changes the BAPHOR obtains the lower connection blocking. This is justified because it combines the benefits of both, BHOR (load balance) and PHOR (more updating independence). Note that PHOR does not depend on the updating frequency.

Conclusions

In this paper we adapted two known routing algorithms (BHOR and PHOR) to a hierarchical ASON architecture. Then, we combined these two algorithms in a third one (BAPHOR) to obtain the maximum benefit of the hierarchical structure. BAPHOR shows very good performance in terms of blocking probability and signalling overhead when computing lightpaths. The main conclusion of the paper is that the combination of hierarchical and prediction routing approaches may let to a significant reduction of the blocking probability and the signalling overhead.

References

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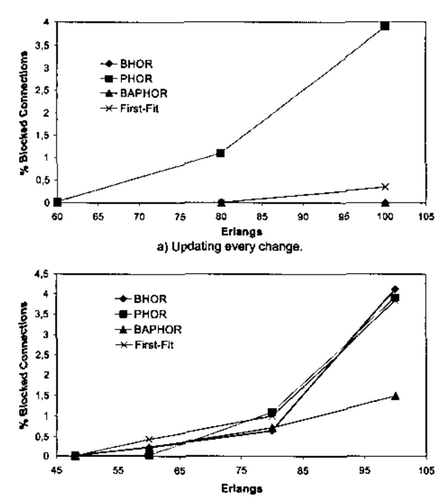

Fig.2. Percentage of blocked connection