A Novel Heuristic Mechanism for Highly Utilizable Survivability on WDM Mesh Networks

Hongkyu Jeong[1], Byungjae Kim[2], Minho Kang[3], Yong-Gi Lee[4]

1, 3: Optical Internet Research Center, Information and Communications University,
P.O. Box 77, Yusong, Daejon, (305-732), Korea. E-mail: {paul, mhkang}@icu.ac.kr
2,4: Optical Technology Division, Technology Laboratory, KT E-mail: {hornet, leeyg}@kt.co.kr

Abstract: This paper presents a novel heuristic mechanism, Dynamic-network Adapted Cost selection (DAC-selection), which has higher backup path sharing rate, lower number of blocked channel requests and number of used wavelengths for reservation of working path and backup path by using unique cost function than that of widely used random selection (R-selection) mechanism and Combined Min-cost selection (CMC-selection) mechanism proposed by Lo, while maintaining 100% restoration capability.

Keywords: Heuristic, Protection, WDM mesh networks

1. Introduction

In the real world, 1+1 or 1:1 protection mechanism commonly has been adopted. However, the resource utilization rate of those protection schemes is at most 50% when applied to optical mesh networks. Thus, protection and restoration [1] are important in designing reliable optical networks and have been widely studied in the literature. Mechanisms proposed by S. Chen [2] and L. Chen [3] are the approaches that dynamically reserve backup capacity from available bandwidth. Currently, a mechanism proposed by Lo [4] made effort to enhance the drawbacks of [2,3].

However, the mechanism on [4] has remained several problems as follows: first, in a viewpoint of algorithm, when preset link threshold is exceeded, only backup path is considered to exchange it for another backup path. It is partial way to improve total network utilization, expressed by number of blocked channel request and the number of used wavelengths for reserving working path and backup path, because the mechanism didn't regard working path when preset link threshold is exceeded. In addition, checking link threshold on the next step of deciding a best pair of working path and backup path all the time, and looking for another backup path instead of previously decided backup path by reason of excess of link threshold are complex work. Second, in a viewpoint of performance evaluation method, evaluating the performance of mechanisms only by sharing rate in terms of backup capacity consumption is not relevant. Other valid evaluation method such as number of blocked channel request and wavelength consumption for reserving working and backup path should be considered. Third, in the standpoint of simulation channel request bound, the paper [4] is very limited. Only single channel request is used for comparing the performance evaluation of mechanisms. Mechanisms should be simulated on the case of receiving various channel requests.

In this paper, we solved most of matters pointed above. We considered not only backup path but also working path when we designed a cost function for dynamic-network adapted cost selection (DAC-selection) mechanism. In addition, we evaluated by using various criteria, such as backup path sharing rate, the number of blocked call requests and the number of used wavelengths for reservation of working path and backup path. Furthermore, we simulated as increasing various call request loads.

Especially, we proposed a novel DAC-selection mechanism using several heuristics for optimal WP and BP pair selection. By using special cost function, the performance of DAC-selection mechanism exceeds that of widely used Random selection (R-selection) and Combined Min-cost selection (CMC-selection) mechanism of the paper [4] using link threshold for load-balancing effect introduced in [5, 6].

2. Proposed Mechanism

Figure 1 is about DAC-selection mechanism procedures. First, we find a shortest path and paths which have additional hop lengths less than 4. For instance, if shortest path has 3 hop lengths, a path having 7 hop lengths also can be a candidate for shortest path set. And then, find link-disjoint BP set by the same rule of building WP set.

Make pairs using both one of shortest path set and one of its disjoint paths for WP and BP. For example, there are two elements in shortest path set, one is 3->5->7, and the other is 3->8->7. Link-disjoint paths relative to the path, 3->5->7, are 3->6->8->7 and 3->2->4->7. Also, link-disjoint paths relative to the path, 3->8->7, is 3->9->7. Therefore, 3->5->7 and 3->6->8->7, 3->5->7 and 3->2->4->7, 3->8->7 and 3->9->7 can be the candidate pair for WP and BP. In a pair, each element can be the WP or BP. That is, in the 3->5->7 and 3->6->8->7 pair, the path, 3->5->7, can be considered as WP or BP. If one element is selected as a WP, the other element should be selected as a BP.

Cost function of DAC-selection mechanism finds best wavelength number for minimizing wavelength consumption considering current wavelength allocation state and it calculates the total cost. Thus, each candidate pairs get a cost which is minimum value about the WP and BP. After calculating the cost of candidate pairs, we sort the candidate pairs from minimum cost to maximum cost. And then, choose a best pair having minimum cost. The concrete contents of the cost function for DAC-selection will be illustrated later on.

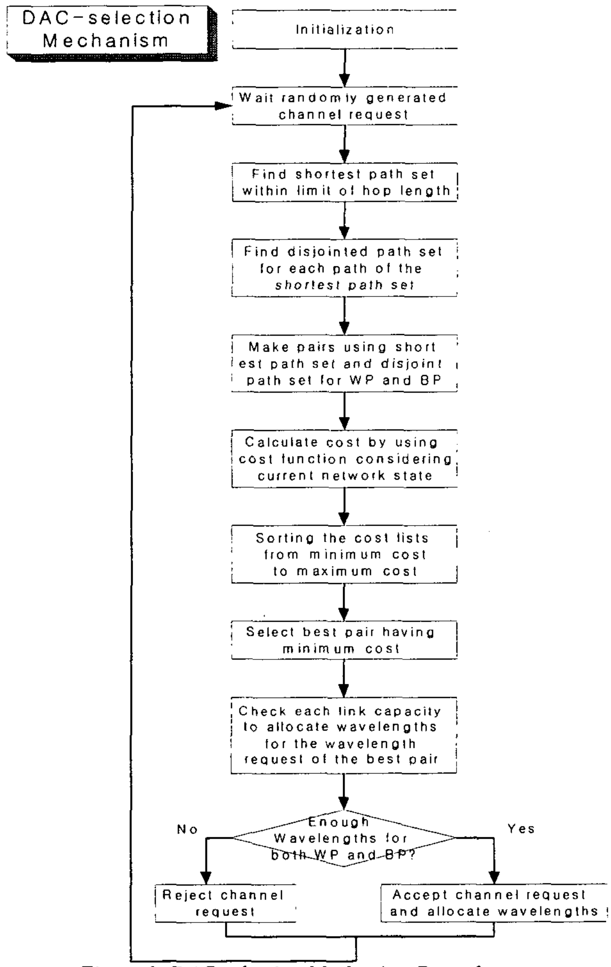


Figure 1: DAC-selection Mechanism Procedure

Figure 2 is the cost function DAC-selection. The summation cost can be calculated as follow formula:

$$Cost^{*} = (W_1 \times AC + W_2 \times (WC + BC) + W_3 \times CC)$$

,where $W_1 << W_2 << W_3$, W_j is much bigger than W_i, $i < j$, $i=\{1,2,\}$ and $j=\{2,3\}$

, where $AC = [\sum_{i \in WP} \sum_{j \in BP} (R_{Allocated_i} + R_{Allocated_j})]_{Average}$

$R_{Allocated}$ is average rate of previously allocated wavelengths compared to total link capacity in the links passed by WP or BP. AC (Average Cost) is the cost of average link capacity allocation rate on the links passed by WP and BP. This is very simple, but powerful method. Because it is possible to evenly distribute the channel request traffic on entire network. Using this heuristic, we can derive the load-balancing effect [4,5,6]. Compared to the function of link threshold and average sharing rate on the CMC-selection mechanism [4], this heuristic method reduces the complexity by not using link threshold and just by calculating average link capacity allocation rate with the similar complexity to calculate sharing cost of CMC-selection. Complexity computation is remained for future works.

WC (Working path Cost) means the cost of reserving working path. That is, the cost is the same as the number of required wavelengths.

$BC = \min_j (BR_j - SBR_j), j = 1,..., W$, where BR_j is required number of wavelengths for BP reservation in the jth wavelength number

SBR_j is the number of sharable wavelength for BP reservation in the jth wavelength number. Therefore, BC should find the wavelength number which consumes minimum wavelengths. BC (Backup path Cost) is the number of actually required wavelengths. It means that sharable wavelengths are not included in the number of required wavelengths.

CC (Capacity Cost) = 1 if there is no more wavelength to allocate on a link which WP and BP pass by. As the cost of CC is greatly big, the pair getting this cost should be the last candidate. Although this pair is selected to the best pair this pair will not be accepted at the last step.

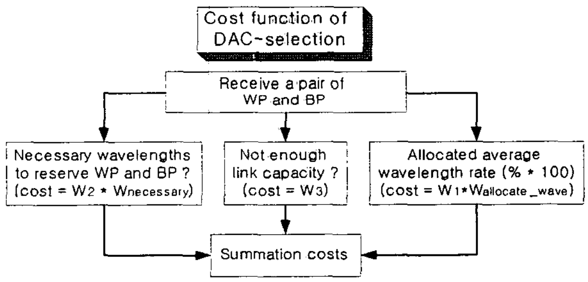


Figure 2: Cost Function Block of DAC – Selection Mechanism

3. Performance Evaluation and Analysis

For the simulation, we used one of real world topologies, New Jersey Lata network, which is shown in figure 3.

3.1 Performance Metrics

Three performance metrics are used to evaluate the proposed mechanism. They are:

1) Wavelength sharing rate

$$R_{Sharing} = \frac{\sum_{i \in BP} R_{Total_i} - \sum_{i \in BP} R_{Used_i}}{\sum_{i \in BP} R_{Total_i}}, \text{ where } \sum_{i \in BP} R_{Total_i} :$$

Summation of total wavelengths required for reserving BP, including number of shared wavelengths

$\sum_{i \in BP} R_{Used_i}$: Summation of wavelengths actually allocated for reserving BP

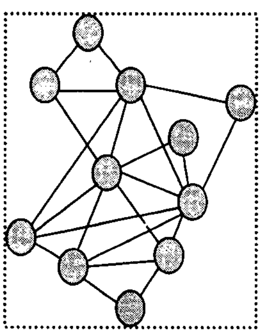
2) Number of blocked channel request

It is possible to get the value just by counting the number of blocked channel requests.

3) Number of additionally used wavelengths

Among R-selection, CMC-selection and DAC-selection mechanisms, required wavelengths of DAC-selection mechanism are the base point. Thus, the number of additionally used wavelength can be the plus or minus value. That is, if the number of required wavelengths at the DAC-selection mechanism is bigger than that of other mechanism, the number of additionally used wavelength has minus value. Number of additionally used wavelength can be simply calculated by subtracting the number of required wavelengths of R-selection or CMC-selection mechanism from that of DAC-selection mechanism.

3.2 Assumptions



- Each link capacity (W) is limited to 80 for New Jersey Lata network
- Each node doesn't have wavelength converter.
- For each experiment we run 50 times simulation, and then take average.
- We simulated as increasing 50 channel request load up to 650

Figure 3: New Jersey Lata Network

3.3 Simulation Results

New Jersey Lata network topology consists of 11 nodes, and we consider the network composed of the nodes with no wavelength converter.

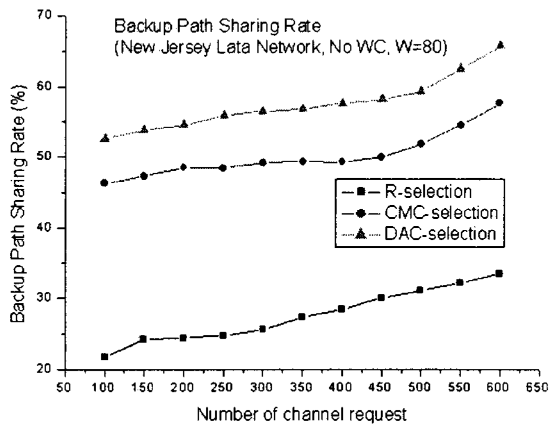


Figure 4. Backup Path Sharing Rate on New Jersey Lata network topology

In figure 4, backup path sharing rate of DAC-selection is highest among the mechanisms. As increasing channel requests, the sharing rate is growing gradually. Because the number of sharable wavelengths increases, later coming channel requests get more chances to share backup path with previously allocated backup paths. Especially, the gap of backup path sharing rate between R-selection and DAC-selection mechanism is remarkable.

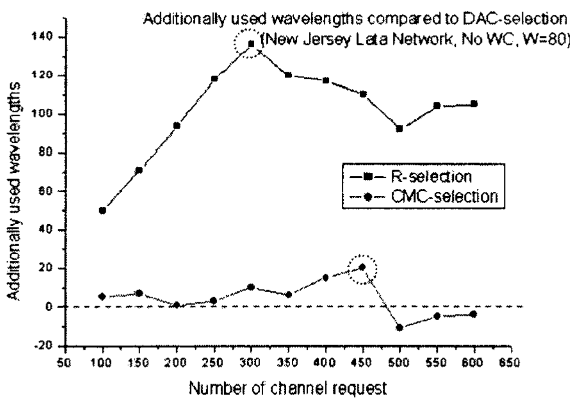


Figure 5. Number of additionally used wavelengths on New Jersey Lata network topology

The number of used wavelengths of DAC-selection mechanism is the base point as we mentioned before. In addition, the red circles indicate the point where channel request blocking happens. So, the position of the red circles can be different.

In figure 5, we can confirm that the number of used wavelengths of CMC-selection mechanism is increasing gradually with small degree until channel request blocking happens. In the case of that of R-selection mechanism, the number of additionally used wavelengths is increasing with huge degree until it meets channel request blocking.

However, if channel request blocking happens, the evaluation result of number of blocked channel request should have higher priority to evaluate the performance of mechanisms. Because number of blocked channel request shows how many channel requests the network employing a mechanism can accept without channel request blocking.

Nevertheless, in the case of the situation having similar number of blocked channel request among mechanisms, the number of additionally used wavelengths is meaningful.

Therefore, we can draw a conclusion about performance evaluation as follow: number of blocked channel request has higher priority as a criterion to evaluate simulation results of each mechanism. The number of additionally used wavelengths has lower priority relatively than that of number of blocked channel request, but in the case of channel request non-blocking situation and similar number of blocked channel requests, the number of additionally used wavelength can be considered significantly.

Figure 6 shows the number of blocked channel request. Blocking happens at the 450 channel request in the case of CMC-selection and DAC-selection, and it grows continuously. The gap of the number of used wavelengths is much and DAC-selection mechanism has small number of blocked channel request, so we can reach a conclusion that DAC-selection mechanism has better performance than that of CMC-selection mechanism.

In the New Jersey Lata network DAC-selection mechanism has better performance in terms of backup path sharing rate, number of blocked channel request and the number of used wavelengths, compared to that of R-selection and CMC-selection mechanism.

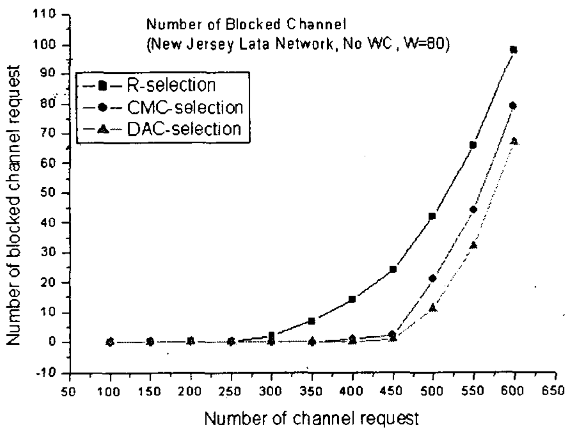


Figure 6. Number of blocked channel request on New Jersey Lata network topology

4. Conclusion and Future Works

In this paper, we proposed DAC-selection mechanism which use several heuristics such as allocated average wavelength rate (AC), working path cost (WC), backup path cost (BC), capacity cost (CC). DAC - selection mechanism shows not only much higher sharing rate but also even lower number of used wavelengths and the number of blocked channel requests than that of R-selection and CMC-selection mechanism. In addition, we suggested cost summation formulas for our proposed DAC-selection mechanism.

Here, we would like to mention the following areas of investigation which may merit further study.

1. Simulate on the various topologies, such as NSFNet or full-mesh network topology
2. Compare the performance result with that of simulation environment where each node has wavelength converter

5. Aknowledgment

This work was supported in part by the Korea Science and Engineering Foundation (KOSEF) through OIRC project, KT, ETRI, and Samsung Group

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