A Wavelength Assignment Considering the Number of Hops in Limited-range Wavelength-Routed Networks

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Abstract—In this paper, we propose a new wavelength assignment scheme that improves the blocking probability of WDM networks that use limited-range wavelength converters.

I. INTRODUCTION

Wavelength-routed networks are attractive for realizing the next generation wide-area networks since they offer a data transmission scheme for WDM all-optical networks [1]. The simplest wavelength-routed networks have the wavelength continuity constraint. The constraint can be avoided by the use of wavelength converters at intermediate nodes. However, realistic wavelength converters have limited wavelength conversion capability, and the difference between the input and output wavelengths is limited [2]. Routing and wavelength assignment (RWA) is a very important issue since it decides the wavelength utilization efficiency and blocking probability in wavelength-routed networks [3].

In this paper, we propose a distributed wavelength assignment scheme that considers the number of hops under the existence of limited-range wavelength converters. The proposed scheme identifies available wavelengths starting from a different initial area according to the number of hops in the request. That is, nodes start the wavelength search from a wavelength closer to the center wavelength when the path has large number of hops. On the other hand, when it has a small number of hops, the search starts from a wavelength far from the center. This decreases the blocking probability and the number of wavelength conversions needed.

II. LIMITED-RANGE WAVELENGTH CONVERTER

Wavelength converters based on FWM (Four-Wave Mixing) are becoming extremely popular [2]. Unfortunately, the output signal strength of such a wavelength converter degrades as the difference between the input wavelength and the output wavelength increases. The relation between the input wavelength and the output wavelength is modeled as the following equation [2].

\[ \lambda_{\text{max}}(1,j-k) \leq \lambda_{o} \leq \lambda_{\text{min}}(W+j+k) \]  

where \( W \) wavelengths, \( \lambda_{1} \) to \( \lambda_{W} \), are multiplexed into an optical fiber, wavelength conversion range is \( k \), the wavelength input to the wavelength converter is \( \lambda_{i} \), and the wavelength output by the wavelength converter is \( \lambda_{o} \).

III. PROPOSED SCHEME

In this paper, we propose a wavelength assignment scheme that considers the number of hops in a connection. In the following, we denote the number of wavelengths as \( W \), the maximum number of hops in a network as \( H_{\text{max}} \), the wavelength conversion range is \( k \), and the number of hops in a connection request as \( h \).

A. Wavelength assignment at the source node

The number of output wavelengths possible varies with the input wavelength and the conversion range as shown in Equation (1). When the input wavelength is near the center wavelength, the number of possible wavelengths is maximized. On the contrary, when it is distant from the center wavelength, the number is minimized. Our approach is to vary the search area of available wavelengths with the number of hops; increasing the number of hops increases the search area. The initial search area is allocated from both ends of the wavelength range. As a result, a connection request with a large number of hops tends to use wavelengths near the center wavelength. If there are vacant wavelengths in the search area, assignment starts from the wavelength nearest the center wavelength and the first available wavelength is assigned. In this way, connection requests that have many hops are more likely to be assigned wavelengths near the center wavelength. Requests with few hops tend to be assigned wavelengths far from the center. This procedure can improve the blocking probability of connections with many hops, which reduces the blocking probability of the entire network, as well as the number of wavelength converters needed.

Figure 1 shows the search area and the search order of our proposed scheme where \( W = 8 \), and \( H_{\text{max}} = 4 \). For example, \( \lambda_{6} \) to \( \lambda_{6} \) are the search areas of a 3-hop connection. The search area contains as many wavelengths as there are hops from either end of the wavelength range. This symmetry makes the proposed scheme is effective regardless of the number of hops.

B. Wavelength assignment at intermediate nodes

Figure 2 shows the search order of the proposed scheme at an intermediate node. If available, the input wavelength \( \lambda_{i} \) is assigned to the next link. Otherwise, we start the search from the wavelength distant from the center wavelength. Next,
Blocking Probability
0.01
0.02
0.03
0.04
0.05
0.06

Network Load (Erlang) ρ

First-Fit
Random & Proposed
All Case 1 Case 2 Case 3

Fig. 3. Blocking probability versus network load ρ

Fig. 4. Blocking probability versus wavelength converter density (ρ = 3.0, k = 1)

Wavelengths without Converter
Case 1 λ1
Case 2 λ2, λ4
Case 3 λ1, λ2, λ4

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References

IV. PERFORMANCE EVALUATION

Computer simulations were conducted to evaluate the blocking probability. It is assumed that the network topology is a unidirectional ring with eight nodes, the number of wavelengths is fourteen, the connection requests arrive at each node independently following a Poisson process, and source-destination pairs were uniformly distributed. We compared three wavelength assignment schemes: First-Fit assignment, Random assignment, and the proposed scheme.

Figure 3 shows the blocking probability versus the network load where each node has a limited-range wavelength converter. When wavelength converters have limited-range wavelength conversion capability, First-Fit assignment greatly increases the blocking probability compared to full-range conversion. The proposed scheme and Random assignment better suppress the impact of limited-range wavelength conversion on the blocking probability than First-Fit assignment. We see that the proposed scheme and Random assignment have almost same blocking probability. Given the above results, we compared the proposed scheme with Random assignment which has better blocking probability than First-Fit assignment.

Figure 4 shows the blocking probability versus the wavelength converter density. "All" indicates all nodes have sufficient numbers of limited-range wavelength converters to handle all input wavelengths. "Case 1", "Case 2", and "Case 3" represent the situations in which some wavelength converters are eliminated. In the proposed scheme, the utilization of wavelength converters whose input wavelength lies on the side or the center is lower than that of other wavelength converters. There is almost no difference in the blocking probability of the proposed scheme even though some wavelength converters were eliminated. On the other hand, Random assignment allowed the blocking probability to rapidly increase as the number of wavelength converters eliminated was increased.

The node checks the wavelength near the center. The first available wavelength is assigned to a connection request. In the example in Figure 2, the node searches for a wavelength in the order λ3, λ2, λ1, λ4, λ5. As a result, fewer wavelengths near the center are selected which leaves them available for assignment to connections with many hops. Moreover, the number of wavelength conversions for a connection with large number of hops is also reduced. Consequently, the proposed scheme can reduce the impact of eliminating underutilized wavelength converters.