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Neuron-based wavelength assignment for optical wavelength division multiplexing service systems

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Abstract

The concept of wavelength assignment (WLA) has become the key technology in optical wavelength division multiplexing (OWDM) service networks. We present an artificial neural network (ANN) scheme whose small computational complexity makes it attractive for on-line and dynamic OWDM WLA. This ANN was constructed according to the back propagation learning rule and was used to dynamically assign wavelengths for real-time traffic streams using training data. The data was derived by using the merge-split-block algorithm to assign the wavelength. To demonstrate the effectiveness of the proposed approach, a WLA including 10 nodes, four wavelengths, and 4–48 connections was performed. Our study indicates that the proposed strategy may significantly reduce the computational complexity and investment cost compared with other approaches at the expense of a small amount of training time. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Artificial neural network; Wavelength assignment; OWDM networks

1. Introduction

To meet the increasing demand for multimedia processing and communication services, fiber optic transmission technology has been accepted as the most realistic solution for the future growth of broadband transport networks [1,2]. While the classical transmission systems used the multiplexing temporal method for transmission of 155 Mb/s, 622 Mb/s, 2.5 Gb/s, even 10 Gb/s on

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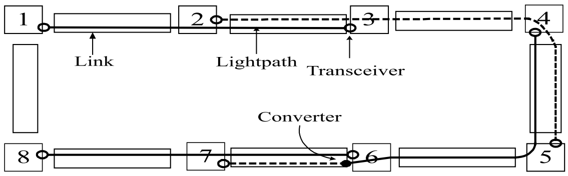

Fig. 1. An example of wavelength scheduling in OWDM ring networks.

only one wavelength, a new generation system, conceived in 1990, initiated wavelength multiplexing (optical wavelength division multiplexing, OWDM) [3]. OWDM networks allow the optical bandwidth to be efficiently exploited and each fiber link to reach gigabit capacity [4]. Each link carries high-rate traffic on optical signals at many light paths, shown in Fig. 1. OWDM networks are being developed in testbeds and expected to be an integral part of personal communication networks backbone networks in the future [5].

In Fig. 1, some of the light paths pass through a node in optical form when the traffic carried is not intended for that node. The remaining light paths are terminated at the node by one or more fixed or tunable transceivers (drop/add channel) and their traffic is converted into electronic/optical form [6]. One of the key features of multiwavelength optical networks is convertibility, i.e., the ability to dynamically optimize the network for changing traffic loads [7]. Efficient wavelength assignment (WLA) can have a good impact on network costs [8].

The design of OWDM ring networks is not a well-established science or even a stable craft. Many research activities therefore currently pay considerable attention to this issue. In Ref. [9], Gerstel analyzed the network cost in terms of the transceiver cost and the number of wavelengths with respect to the maximum numbers of hops for a light path. The work in Ref. [10] considered the problem of reconfiguring single-hop networks by retuning a subset of the slowly tunable receivers for changing traffic patterns. Baldine also studied the problem of dynamic load balancing in broadcast OWDM networks by retuning a subset of transceivers in response to the changes in the overall traffic patterns [11]. Wuttisittikukij studied the performance with and without wavelength conversion capabilities on various traffic scenarios in multiwavelength all-optical ring networks [1]. These mechanisms can produce the optimal or sub-optimal status at a specified OWDM service network. However, their computational complexity is large, thus they are not suitable for dynamic and real-time environments.

Artificial neural network (ANN) are based on an analogy of the neuron structure in the human brain. Considerable progress has been made in the application of ANN to computer and communication issues [12,13]. However, ANN applications to the WLA problem are rather limited. In this study, an ANN was developed that can solve the dynamic WLA problem by learning from previously encountered patterns. Many types of neural networks and many powerful machine learning techniques exist, but the research presented here focuses on the multilayer perceptron network with the back propagation learning rule. Results from the developed ANN are rather satisfactory compared to those scheduled using the merge–split–block (MSB) algorithm. With sufficient learning, the ANN generates results very fast and incurs only tiny deviations. This ANN will assist managers in the WLA for on-line and dynamic traffic streams.

The remaining parts of this paper are organized as follows. Section 2 describes the OWDM service systems under study and the MSB algorithm. The subsequent section depicts the construction of such an ANN. The results from preliminary experiments are given in Section 4. Section 5 discusses our work. Finally, some conclusions are given in Section 6.

2. Optical wavelength division multiplexing service systems

This section echoes Section 1, where we discussed how WLA is cost-effective. The OWDM network discussed here consists of N nodes and L links. There are $(W+1)$ wavelengths in the network where $W \ll N$. One of the wavelengths is reserved for a control channel which is shared by all nodes. Each of the nodes is equipped with one or more fixed or tunable transceivers. One of the fixed transmitters and the fixed receivers are for the control channel. The others transmitter is for the data channel. To improve the blocking performance and the network resource utilization, a number of converters, C, are also provided for the service network.

The system operates as follows. When new traffic demands arrive at an OWDM network, the WLA algorithm is invoked at all nodes to assign the data channel for transmitting and receiving data packets. The source node will transmit the scheduled traffic stream on the reserved channel. The destination node receiver should tune to the source node transmission wavelength to receive the data packets. Selecting a suitable network topology and relinquishing or forging wavelengths may impact the network cost.

2.1. Mathematical model

The network model and operating actions were given in the previous paragraphs. The problem we are concerned with is scheduling the wavelength as well as the corresponding devices such that the investment cost is minimum. As derived in [14,15], the overall network cost includes the cost of the transceivers and wavelength converters required at the nodes as well as the cost of the number of wavelengths. The mathematical model, a set of linear equalities and inequalities, for solving the WLA problem is described as follows:

$$\text{total network cost} = T_c = K_1 C_T + K_2 C_W + K_3 C_C + K4 \tag{1}$$

$$\text{objective function} = \text{minimize}(T_c) \tag{2}$$

subject to

$$\text{link capacity constraint} \quad \sum_{m=1}^{W_{\text{scheduled}}} B_{m,i} \leqslant \sum_{n=1}^{W_{\text{limited}}} B_{n,i} \quad \text{for } i\text{th link } (i \leqslant L) \tag{3}$$

$$\text{wavelength number constraint} \quad W_{\text{scheduled}} \leqslant W_{\text{limited}} \tag{4}$$

$$\text{traffic demands} \quad \sum_{m=1}^{W_{\text{scheduled}}} B_{m,i} \geqslant T \tag{5}$$

where C_T, C_W, C_C, $K4$ are the cost of each transceiver, each wavelength, each wavelength converter and the required scheduling time, respectively. K_1, K_2, and K_3 are the number of required