A Computational Model for Estimating Blocking Probabilities of Multifiber WDM Optical Networks

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***Abstract*—In this letter, we propose a computational model for calculating blocking probabilities of multifiber wavelength division multiplexing (WDM) optical networks. We first derive the blocking probability of a fiber based on a Markov chain, from which the blocking probability of a link is derived by means of conditional probabilities. The blocking probability of a lightpath can be computed by a recursive formula. Finally, the network-wide blocking probability can be expressed as the ratio of the total blocked load versus the total offered load. Simulation results for different fiber-wavelength configurations conform closely to the numerical results based on our proposed model, thus demonstrating the feasibility of our proposed model for estimating the blocking performance of multifiber WDM optical networks.**

***Index Terms*—Blocking probability, multifiber wavelength division multiplexing (WDM) optical networks, wavelength assignment.**

I. Introduction

THE common practice of installing bundles of multiple fibers motivates the research of multifiber wavelength division multiplexing (WDM) optical networks. In such a network, each link includes multiple fibers, and each fiber contains multiple wavelengths. On a lightpath in multifiber WDM networks, a wavelength that cannot continue on the next hop can be switched to another fiber if the same wavelength is unoccupied in at least one of the other fibers. Multifiber WDM optical networks are attractive alternatives to single fiber WDM optical networks with wavelength converters. An F-fiber W-wavelength network (i.e., each link has F fibers, and each fiber supports W wavelengths) is functionally equivalent to an FW-wavelength network with wavelength conversion of degree F. The research in [1] showed that it is possible to use fewer wavelengths in each fiber with multiple fibers than with a single fiber.

Many studies on the blocking probability analysis of WDM optical networks have been reported. The analytical model for a static-routing WDM network was proposed in [2]. For single fiber networks, the deployment of wavelength converters was shown to reduce the network-wide blocking probability. The blocking probability of a lightpath under the assumption of circuit-switched network traffic models was formulated in [3], and the lightpath length, the node degree, and the interference length were identified to be the three most important parameters. The upper and lower bounds of the loss probability were analyzed in optical burst-switched WDM networks with fiber delay lines (FDLs) [4]. In [5], the authors proposed the multifiber link-load correlation (MLLC) model to study the blocking performance for multifiber networks. The MLLC model considers the status of wavelength trunks and the link-load correlation. According to their simulations, a limited number of fibers were sufficient to guarantee high network performance.

In this letter, we analyze blocking probabilities in multifiber WDM optical networks from a bottom up manner. The wavelength occupancy states of a fiber are analyzed by a Markov chain, from which the link blocking performance is evaluated. The lightpath model is derived based on the wavelength occupancies of the intermediate links in a lightpath, and the network-wide blocking probability is obtained by combining the lightpath blocking probabilities. In Section II, we propose our computational model. In Section III, the simulation and computational results are presented and compared. Section IV provides the conclusions.

II. Analytical Model

In this section, we derive the computational model of the multifiber WDM networks. First, we develop the fiber model as a Markov chain; then we extend it to the link model, which includes multiple fibers; the lightpath model is based on the idle wavelength availability in all of the intermediate links; the network-wide blocking probability is obtained at the final step.

A. Assumptions and Notations

The following assumptions are applied. *1)* The network $G(f, w, N, E)$ is an even multifiber WDM network without wavelength converters. $n = |N|$ is the number of nodes, while $e = |E|$ is the number of links. Each link consists of a bundle of f fibers, and each fiber has w wavelengths. *2)* Connections arrive according to a Poisson distribution. The average holding time of a connection is exponentially distributed with a mean of one unit. *3)* An entire wavelength channel is allocated to a single connection. *4)* An incoming connection can be switched to any fiber at the next hop as long as the same wavelength is free. The employed fiber is selected randomly. *5)* A connection is dropped immediately if it is blocked. *6)* Loads of individual fibers and links are independent. Wavelength occupancies in fibers and links are independent.

In addition, we also assume that static shortest lightpath routing is employed as the routing policy, and wavelengths are assigned randomly. Since no wavelength converters are in the

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