ROUTING PROTOCOLS FOR OPTICAL NETWORKS

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ABSTRACT

In wavelength division multiplexing (WDM) networks, communication between optical cross-connect (OXC) switches takes place along all-optical WDM channels which are commonly referred to as *lightpaths*. This paper (i) describes the central algorithmic problems whose solution an optical network routing protocol must facilitate, (ii) evaluates several candidate routing protocols that could be extended to operate in a WDM environment, and (iii) surveys currently ongoing efforts to standardize extensions to one of these, namely OSPF.

Keywords: Routing, WDM, Traffic Engineering, Extended OSPF.

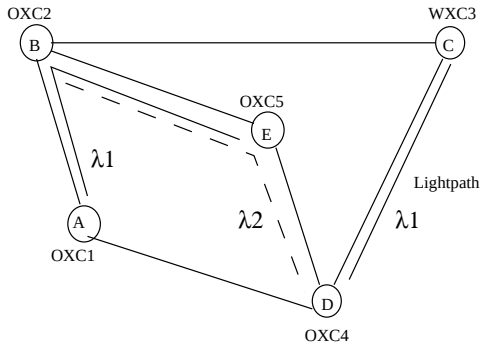

Figure 1: A WDM Routing Network with 5 OXCs

1 CENTRAL ALGORITHMIC PROBLEM

The central algorithmic problem in WDM routing is: Given a WDM network's physical topology (including the characteristics of its links) and a set of source-destination pairs, (i) *route assignment:* compute a route for a lightpath between each source-destination pair, and (ii) *wavelength assignment:* for each link traversed by this lightpath, determine the wavelength to be allocated for the lightpath on the given link. Together, these two assignment problems are often referred to as the *Routing and Wavelength Assignment (RWA)* problem. Typically, the RWA problem is solved by considering each of its two constituent subproblems in turn [20].

The RWA problem is complicated by the fact that an OXC switch may be (optionally) equipped with *wavelength conversion* hardware which permits lightpaths transient through the switch to enter and leave the switch on different wavelengths. Consider figure 1, which illustrates a WDM network consisting of five OXC switches interconnected by optical fiber links. If no switches are equipped with wavelength converters, then a lightpath in this network must always occupy the same wavelength on every fiber link it traverses. This restriction is commonly known as the *wavelength continuity constraint* for non-wavelength converting switches. An OXC switch that is equipped with wavelength conversion hardware is exempt from this constraint. The reader is referred to the book by Ramaswami and Sivarajan [18] for a comprehensive introduction to WDM network technologies.

A solution to an instance of the RWA problem must necessarily [1], [2] respect the following constraints: First, two lightpaths traveling on a given link must be assigned different wavelengths. Second, any lightpath that transits through an OXC switch that is not wavelength conversion capable, must use the same ingress and egress wavelengths. The central responsibility of the WDM routing protocol is to ensure that the information required for route assignment and wavelength assignment is maintained by the network in a scalable manner.

1.1 ROUTING ASSIGNMENT

There are three broad classes of strategies being used presently to address the routing assignment problem [20]. These strategies are referred to as *fixed routing, fixed alternate routing, and adaptive routing*.

Fixed routing is a simple technique which involves maintaining a fixed routing table at each candidate source node. The routing table consists of one entry for each candidate destination node, where the entry specifies the path from the source to the destination. Fixed routing is simple to implement, but is subject to unacceptably high blocking probabilities as wavelength availability on links becomes scarce, and when link failures occur.

In contrast, *fixed alternate routing* attempts to address the shortcomings of fixed routing by augmenting each entry in

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