An Efficient Distributed Control Scheme for Lightpath Establishment in Dynamic WDM Networks

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Abstract. An adaptive hybrid reservation protocol (AHRP) is proposed for the purpose of quickly and efficiently establishing a lightpath in dynamic wavelength routed networks. This protocol uses a special reservation-and-probe (RESV_PROB) packet and extends the signaling to integrate forward reservation and backward reservation into one monolithic process. To decrease the blocking probability that happens in cases where two end nodes associated with a specific link simultaneously reserve the same wavelength, an adaptive wavelength selection policy is specially employed in AHRP. A discrete-event simulation tool based on ns-2 is developed to investigate AHRP’s performance, including its blocking probability, average lightpath setup delay, and signaling overhead. AHRP is also compared with existing protocols. Results show that during highly dynamic traffic conditions, AHRP possesses the lowest blocking probability, shorter setup delay, and less signaling overhead.

Keywords: wavelength division multiplexing (WDM), networks, distributed control

1 Introduction

The bursty nature and unpredictable traffic patterns of the global Internet create the need for using a dynamic network infrastructure. One potential solution is dynamic WDM networks [1]. In these networks transparent lightpaths are dynamically set up and torn down between end-nodes, so that the logical topology of lightpath connections can adapt to the varying traffic patterns. The more bursty the traffic, the higher the dynamic within the networks will be. One example is the wavelength-routed optical burst switched (WR-OBS) network [2], where the average duration of the established lightpaths is only about several tens of milliseconds.

The lightpath control mechanisms in dynamic WDM networks can be either centralized [3,4] or distributed [5–10]. In a centralized scenario, a central controller is responsible for keeping track of the current network state and processing all lightpath connection requests. While this method can allocate network resources more efficiently, it has two disadvantages. The first one is its weak scalability since the central node has to process too much information and becomes the bottleneck of the network. The second one is its poor survivability. If the central node fails, the entire network will be out of control. In contrast, distributed approaches spread the network control function among every node and eliminate processing congestion. Moreover, a single node failure will not affect other parts of the network. Therefore distributed control mechanisms are essential in large-scale WDM networks.

In Ramaswami and Segall [5], a link state routing (LSR) based control scheme was proposed. In this scheme, the state of each link in the network is flooded to every node periodically using link state advertisement (LSA) packets. With these LSA packets, each node maintains the global information on the network topology and wavelength resources. When a connection request arrives, the source node computes a route and wavelength for this call, and then reserves this wavelength along the calculated route hop-by-hop. If the reservation is successful on every link in the route, then a signaling packet is sent out to set up the optical switches along the lightpath. An example of the LSR scheme is shown in Fig. 1(a).

Unlike the adaptive routing schemes, the schemes [6–10] use a fixed shortest path for every source-destination pair. Then the lightpath control schemes degenerate to become wavelength reservation protocols. These protocols are classified into two categories
named forward reservation protocols (FRPs) and backward reservation protocols (BRPs). FRPs use a source-initiated reservation scheme. A reservation (RESV) packet, which carries a list of available wavelengths, is sent from the source to the destination hop-by-hop. Each intermediate node will remove currently unavailable wavelengths from this list according to its local link information and then lock all residual wavelengths on the list. Once the destination node receives the RESV packet and the final list is not empty, a wavelength will be selected to make the actual connections on the optical switches, and other temporarily locked wavelengths will be unlocked during this backward configuration process. This is illustrated in Fig. 1(b).

FRPs tend to temporarily lock many resources that they will not use. To overcome the disadvantage of this over-reservation behavior, BRPs use a destination-initiated reservation scheme. BRPs send a probe (PROB) packet toward the destination to collect the wavelength availability information. With this information, the destination will be able to choose one suitable wavelength and then send a RESV packet to set up the lightpath along the backward path. During this set-up procedure, it is possible that the selected wavelength, which was available on the path during