6.972 Optical Networks | 28 November 2001

MIT, Fall 2001 | Due friday 7 December 2001 by 5 pm

Problem set #6

Problem 6.1 (Dedicated protection and shared protection) Consider a WDM bidirectional ring with N nodes where N is odd. Adjacent nodes are connected by two fibers, one in each direction. Assume that each node transmits 1 wavelength to each of the other nodes, i.e. uniform 1-wavelength all-to-all traffic. Under this traffic assumption, we shall consider two schemes of providing redundant link capacity for service recovery from a single link failure. Note that in each fiber, some wavelengths are used for primary lightpaths, while the others are used for protection lightpaths.

(a) Consider the following dedicated protection scheme. Each lightpath has a dedicated back-up path travelling on the same wavelength in the opposite ring direction, as shown in figure 1.

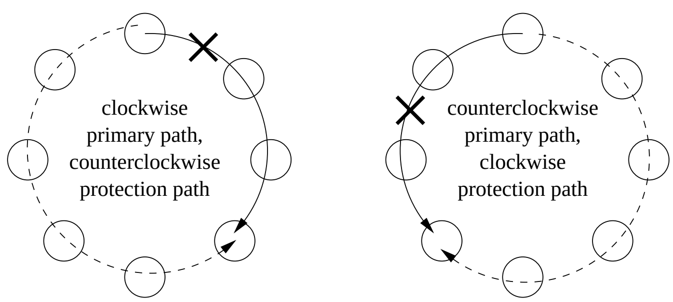

Figure 1: Primary and protection lightpaths in the dedicated protection scheme.

For each lightpath, transmitted signals are splitted onto the primary path and the protection path. The receiver of the lightpath receives signals from both paths, and chooses the signals from the protection path over the primary path when it detects the loss of signals on the primary path. In terms of N, give an expression of the minimum required number of wavelengths in each fiber for this scheme.

(Hint: For any pair of nodes, say nodes i and j, the primary lightpath from i to j and the primary lightpath from j to i can be on the same wavelength in one ring direction. Their protection lightpaths can be on the same wavelength in the opposite ring direction.)

(b) Consider the following shared protection scheme in which protection link capacity can be shared among different primary light paths. For each lightpath, signals are transmitted onto the protection path on the same wavelength only after the detection of a link failure. Assume link-based restoration as shown in figure 2. When a link fails, transmitted signals on each disrupted lightpath are switched onto the protection path on the same wavelength in the opposite ring direction.

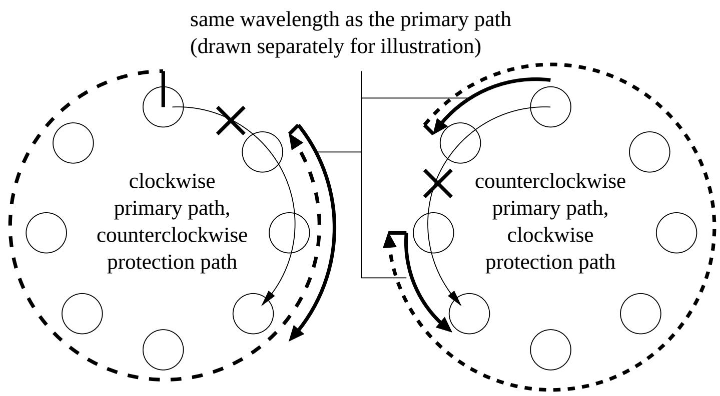

Figure 2: Link-based restoration in the shared protection scheme.

Due to sharing of protection link capacity, we expect the minimum required number of wavelengths in each fiber to be less than that of part (a). The price to pay is higher complexity in network management in performing service recovery. (In part (a), only the receivers of the disrupted lightpaths take part in the service recovery process.) In terms of N, give an expression of the minimum required number of wavelengths in each fiber for this scheme.

(Hint: Use the optimal (in number of wavelengths) routing and wavelength assignment (RWA) in problem 8.6 to find the minimum number of primary wavelengths. Under that RWA, consider how many protection wavelengths are needed to perform link-based restoration.)

Problem 6.2 (Traffic grooming in a unidirectional ring) In some practical scenarios (e.g. in some local-area networks), network planners aim to minimize the cost by minimizing the amount of optical termination equipments instead of minimizing the number of wavelengths in each fiber.

Consider a WDM unidirectional ring with $N+1$ nodes shown in figure 3. Adjacent nodes are connected by a single fiber in the clockwise direction. Note 0 is a hub node to and from which each of the other N nodes transmits and receives r units of traffic. Let g be the maximum transmission rate supported by a single wavelength. Assume that $r < g$.

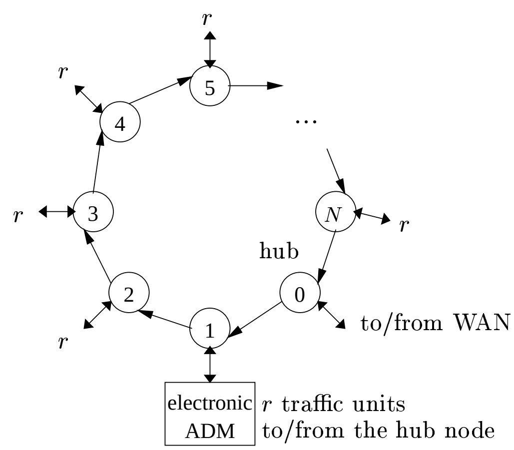

Figure 3: Single-hub WDM unidirectional ring.

Suppose the available electronic add-drop multiplexers (ADMs) are not tunable, i.e. each unit sends and receives on a common and fixed wavelength. For node i to transmit/receive traffic to/from the hub node on wavelength λ_k, both node i and the hub node must be equipped with wavelength-λ_k ADMs. Practically, the cost of ADMs can dominate the total network cost. Therefore, we try to minimize the number of ADMs in this problem.

When $2r \leq g$, at least 2 non-hub nodes can share the same wavelength to reduce the total number of ADMs. As a specific example, if $2r \leq g$, node 1 and node 2 can both use wavelength λ_1 to transmit and receive traffic to and from the hub node. With wavelength sharing, 3 ADMs (instead of 4 ADMs) are used to support traffic between nodes 1 and 2 and the hub node. Observe that some ADMs may have to relay transmitted signals which belong to other nodes.

(a) Given that we have an unlimited number of wavelengths in a fiber, write an expression for the minimum required number of ADMs in terms of N, r, and g.

(b) For $N = 10, r = 2$, and $g = 5$, write down an optimal (in number of ADMs) ADM assignment. In other words, specify how many ADMs at what wavelengths are used at each node in order to minimize the total number of ADMs.

(c) With the same parameters as in (b), i.e. $N = 10$, $r = 2$, and $g = 5$, what is the minimum required number of wavelengths (regardless of the total number of ADMs)?

(d) Assume the same parameters as in (b) and (c), i.e. $N = 10$, $r = 2$, and $g = 5$. Subject to the constraint that only the minimum required number of wavelengths can be used, write down an optimal ADM assignment. What is the minimum total number of ADMs in this case?

(Hint: Let W_{min} denote the minimum required number of wavelengths in part (c). Given that only W_{min} wavelengths can be used, traffic from/to some nodes need to be splitted onto multiple wavelengths. Observe that a node whose traffic is splitted onto k wavelengths needs k ADMs. Since the hub node always uses W_{min} ADMs, minimizing the total number of ADMs is equivalent to minimizing the total number of traffic splits over the all nodes.)

Problem 6.3 Do problems 8.23 and 8.25 in chapter 8 of the book (second edition).