HELSINKI UNIVERSITY OF TECHNOLOGY — **Exercise 5**
Networking Laboratory — 26.3.2002
S-38.164 Laajakaistainen välitystekniikka, Kevät 2002 — Aalto / Hyytiä

1. This problem compares simple add/drop multiplexer architectures.
   (a) First consider the fiber Bragg grating based add/drop element shown in Figure 1(b). Suppose a 5% tap is used to couple the added signal in to the output, and the grating induces a loss of 0.5 dB for the trasmitted signals and no loss for the reflected signal. Assume that the circulator has a loss of 1 dB per pass. Carefully compute the loss seen by a channel that is dropped, a channel that is added, and a channel that is passed through the device. Suppose the input power per channel is 15 dBm. At what power should the add channel be transmitted so that the powers on all channels at the output are the same?
   (b) Suppose you had to realize an add/drop multiplexer that drops and adds four wavelengths. One possible way to do this is to cascade four add/drop elements on the type shown in Figure 1 in series. In this case, compute the best-case and worst-case loss seen by a channel that is dropped, a channel that is added, and a channel that is passed through the device.

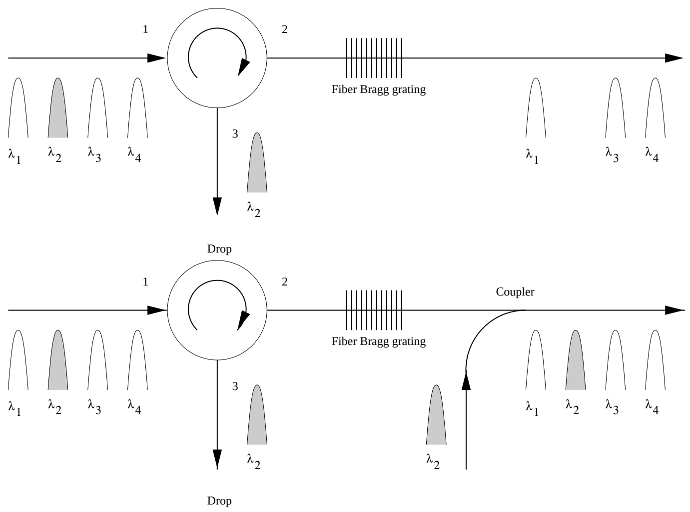

Figure 1: Optical add/drop elements based on fiber Bragg gratings.

   (c) Another way to realize a four-channel add/drop multiplexer is shown in Figure 2. Repeat the preceding exercise for this architecture. Assume that the losses are as shown in the figure. Which of the two would you prefer from a loss perspective?
   (d) Assume that fiber gratings cost \$500 each, circulators \$3000 each, filters \$1000 each, and splitters, combiners and couplers \$100 each. Which of the two preceding architectures would you prefer from a cost point of view?

2. Construct a 16×16 broadcast star interconnecting 32 directional couplers along the lines given in slide 30 of lecture 8.

3. a) Consider the (static) 4×4 wavelength router with 4 wavelengths depicted in slide 31 of lecture 8. There are 16 fibers between the input and output stages, connected in a way that prevents identical wavelengths from different input ports from being combined on the same output port, thus avoiding interference among the different channels. Formulate the routing rule used, i.e. tell how the output port number i is determined from the input port number j and wavelength index k.

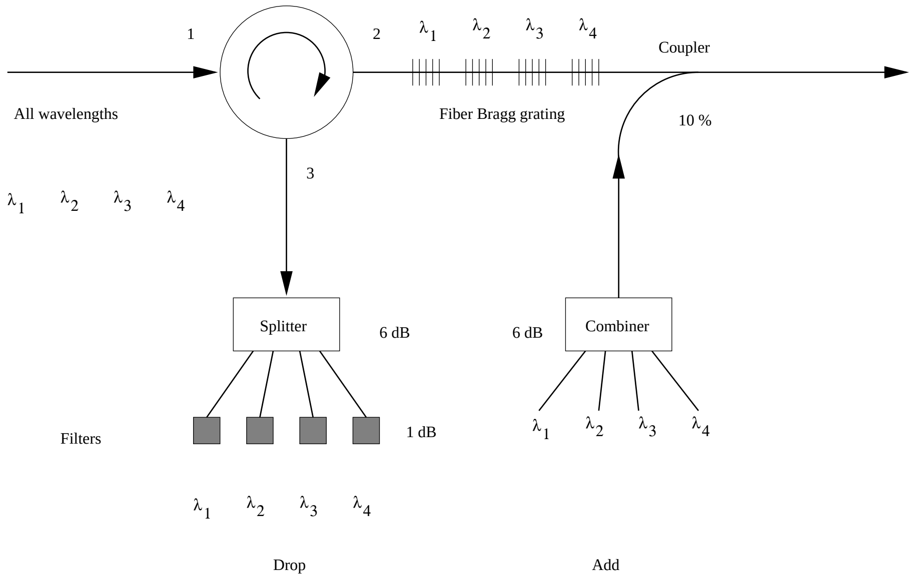

Figure 2: A four-channel add/drop multiplexer architecture.

b) Generalize the rule to a $N \times N$ wavelength router with N wavelengths.

4. Consider the (dynamic) 4×4 wavelength selective cross-connect with 4 wavelengths depicted in slide 37 of lecture 8. As you see, it contains 4 permutation switches, one for each wavelength. Determine the connection states of these four permutation switches that together correspond to the permanent state of the 4×4 wavelength router depicted in slide 31 of lecture 8. (Thus, for example, the wavelength λ_2 appearing in the input port 4 should be routed to the output port 1.)

5. Realize the full connectivity between 3 end systems by interconnecting 3 wavelength add-drop multiplexers (see slide 45 of lecture 8) into a unidirectional ring and using wavelength routing to provide the optical connections needed. Solve the routing and channel assignment problem. How many wavelengths are needed (at minimum)? How many optical transceivers are needed in each NAS? Show the states of all add-drop switches in WADM1.