MATHEMATICAL QUESTIONS

Question 1

Show that the total noise figure of the cascade of amplifier stages shown in Fig. 1 is given by Friis formula

$$F_{tot} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \cdots + \frac{F_n - 1}{G_1 G_2 \cdots G_{n-1}}$$

, where G_i and F_i are amplification gain and noise figure of stage i, respectively.

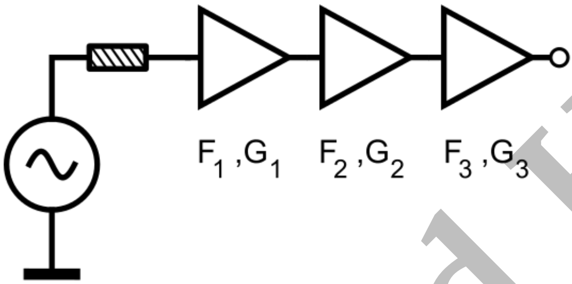

Figure 1: Cascade of several amplifiers.

Question 2

Consider the configuration shown in Fig. 2, where 5 ROADMs are cascaded. The ROADM at node C is nominated for regeneration; however, it doesn't have reuse property. Assume that the optical reach is 1000 km and a connection from A to Z should be setup. The connection is added at node A on the wavelength λ_1 and after regeneration at node C, is relocated to wavelength λ_5. Discuss why the regeneration at node C is not enough to setup the connection. Conclude that regenerating a connection at a node with a no-reuse ROADM is not desirable.

Question 2 continued on next page. . .

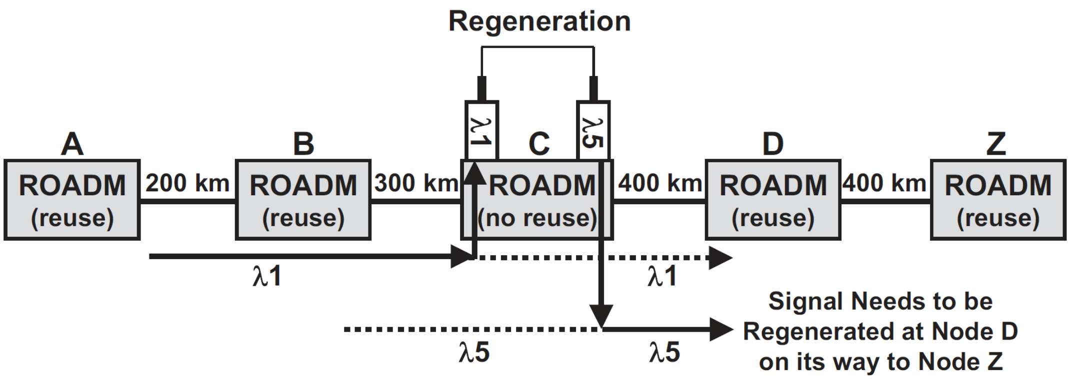

Figure 2: 5 cascaded ROAMs, where the ROADM in node C is nominated for regeneration and doesn't have reuse property.

Question 3

Noise figure (NF) is a commonly used metric for regeneration algorithm. Consider two adjacent links, both with a NF of 20 dB and a net gain of 0 dB.

(a) What is the NF (in dB) of the two-link path (ignore any network element at the junction of the two links)?

(b) In general, if the two links have a NF of L dB (and 0-dB net gain), what is the NF of the two concatenated links?

(c) How about if M links each with a NF of L dB (and 0-dB net gain) are concatenated?

Question 4

Consider the nodal architecture of Fig. 3, which allows transponders to be used for regeneration in any direction through the node. Assume that the node is equipped with a broadcast-and-select directionless ROADM. Assume that the two transponders used for a particular regeneration are located on the same add/drop port of the ROADM. Are there any wavelength constraints imposed by this architecture for the incoming and outgoing wavelengths of the regenerated connection?

Question 4 continued on next page...

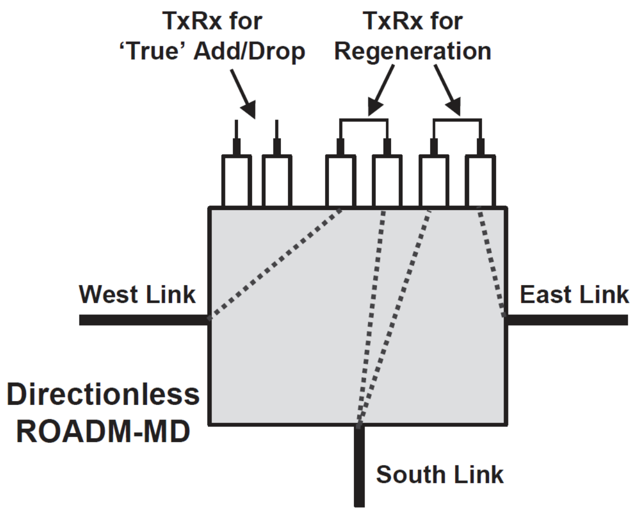

Figure 3: Regeneration via back-to-back transponders in a node with broadcast-and-select architecture.

SOFTWARE QUESTIONS

Question 5

Consider the sample optical network of Fig. 4 and assume that the its topology is described by directional graph $G(N, L)$, where each link $l = (b, e) \in L$ begins at node $b \in N$, ends at node $e \in N$, and has a metric of W_l, which can be distance, noise figure, and son on.

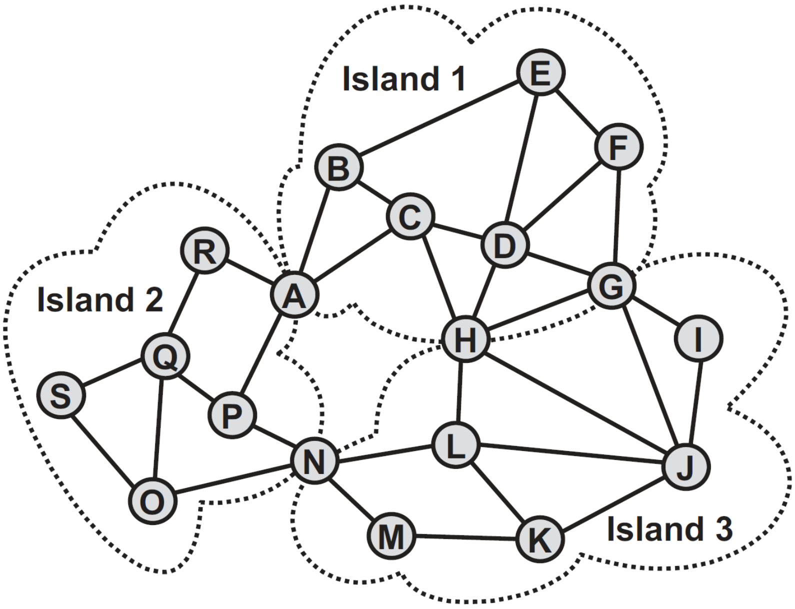

Figure 4: A sample optical network.

(a) Propose a heuristic algorithm to partition the network into islands of transparency.

(b) Implement your proposed heuristic in Paython/MATLAB and validate its results for several sample network topologies.

BONUS QUESTIONS

Question 6

As you may know, partitioning the network into islands of transparency may result in unnecessary regeneration. For example, in Fig. 4, the connection from P to B is regenerated at A although B is not far away from P. Improve your impersonation in Question 5 to avoid such unnecessary regenerations as much as possible.

Question 7

Return your answers by filling the LaTeXtemplate of the assignment.