## Question 1

**Assume that a network 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 length $W_l$. There are $|R|$ requests, where request $r = (s, d) \in R$ originates from source node $S(r) = s \in N$, terminates at destination node $D(r) = d \in N$, and requires transmission rate $B_r$.**

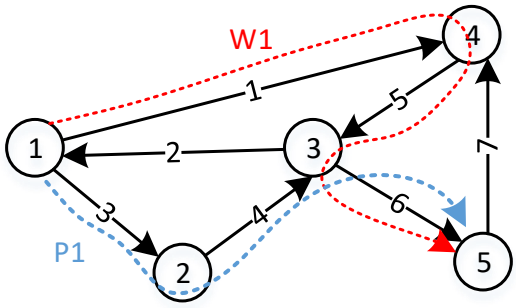


Figure 1: A sample network topology in which a working path and its corresponding maximally link-disjoint path are shown.

*(a) Assume that each request requires a maximally link-disjoint protection path. Write an optimization problem formulation whose solution yields the working and protection paths. No physical layer constraint is applied.*

*(b) Assume that the transmitter linewidth is $\sigma_\lambda$ and the chromatic dispersion with the dispersion parameter $D_\lambda$ limits the transmission ditance. Upgrade your proposed formulation to include dispersion requirements on the working and protection paths.*

*(c) Can you upgrade your proposed formulation such that the working and protection paths are maximally node-disjoint?*

*(d) What happens if your proposed formulation is infeasible? Can you enhance your formulation such that the lowest number of requests are dropped to make the formulation feasible?*

## Question 2

**In Fig. 2, a new connection on the south link is desired; only $\lambda_1$ is available on this link. The only available transponders are deployed on add/drop ports 1 and 2. Is it possible to establish the new connection? Why? If the connection cannot be established, how can the problem be fixed?**

*Question 2 continued on next page...*


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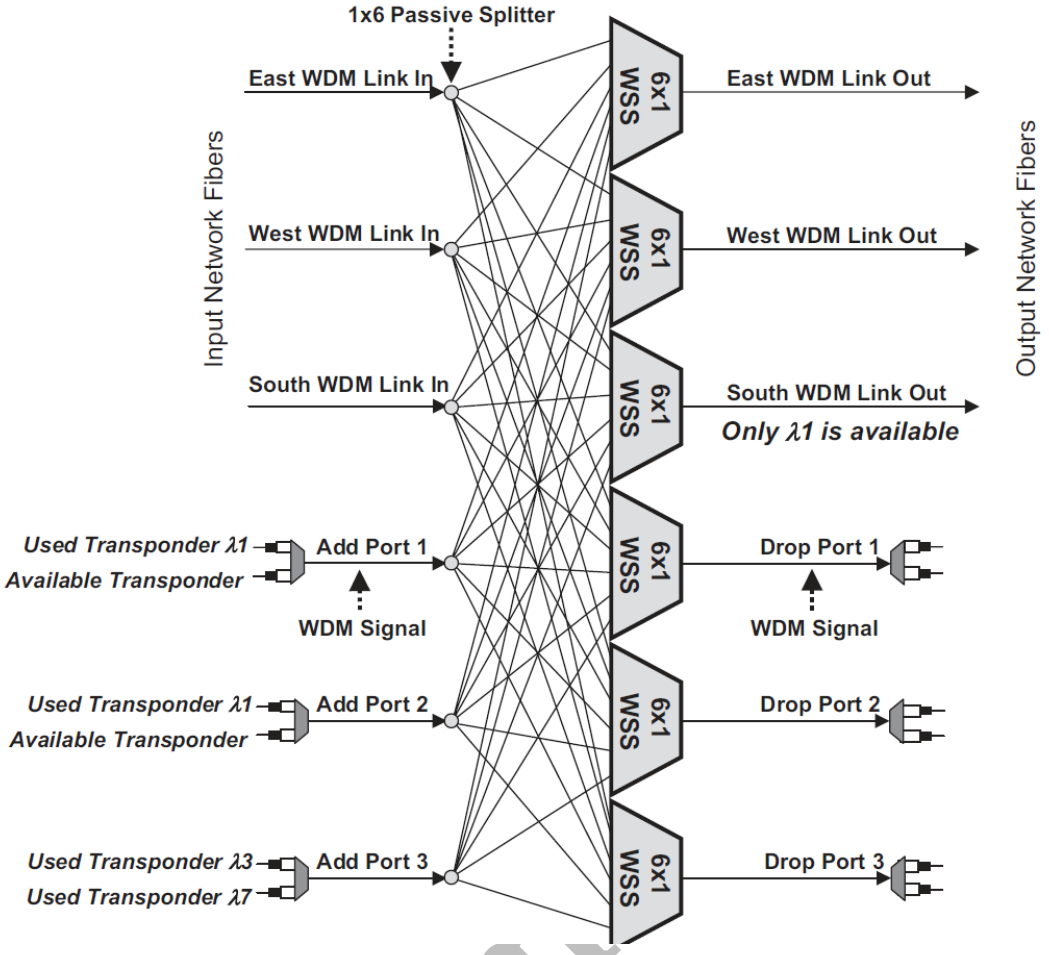


Figure 2: A broadcast-and-select ROADM architecture.

## Question 3

**We discussed that Raman scattering is an undesired impairment for fiber transmission. However, Raman scattering can be useful and utilized for optical amplification. Explain briefly how Raman scattering can be used for optical amplification.**

## Question 4

**For an $M$-ary with $M = 4$, if signal-dependent noise is the dominant noise source in the receiver, please find the eye levels $x_1$ and $x_2$ which would make all three eyes to have equal sensitivity.**

Mohammad

*Question 4 continued on next page...* 

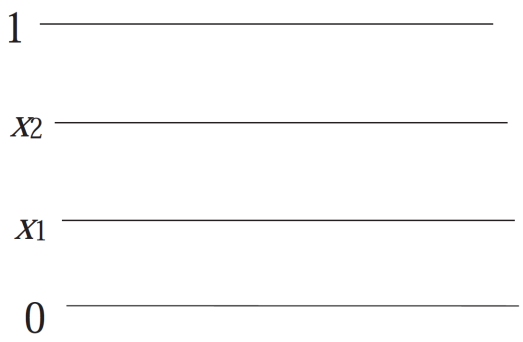


Figure 3: An $M$-ary optical system with $M = 4$ levels.

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