1. Consider the physical topology and demand matrix below. Each link in the physical topology is bidirectional and consists of two fibers, with one fiber in each direction. Each fiber can support a maximum of 2 wavelengths. The demand matrix indicates the number of OC-12 SONET circuits required between each source-destination pair. The circuits are bidirectional; thus, the same capacity is required in each direction. Each wavelength operates at a rate of OC-48; thus, up to 4 OC-12 circuits can be multiplexed onto a single wavelength. The maximum number of OC-48 transceivers at each node is 3.

(a) Use the MAX SINGLE-HOP heuristic to find a logical topology for the required demand. List the lightpaths in the order that they are established. Find the $V^{ij}$ and the $V^{ij}_{min}$ for your solution.

(b) Show how much traffic is being carried by each lightpath. Find the $\lambda^{sd}_{ij}$ for all traffic which is traversing multiple hops over the logical topology. $\lambda^{sd}_{ij}$ is defined as the number of s-d OC-12 circuits traversing a lightpath which has been established between nodes $i$ and $j$.

2. Consider a 4-node ring network with bi-directional fiber links (one fiber in each direction). Assume that each node has 2 units of OC-12 traffic for every other node. Each wavelength has a capacity of OC-48. Compare the required number of wavelengths and transmitters/receivers for point-to-point, hub, and fully-connected logical topologies. Show how the traffic is routed over each of the logical topologies.

3. Consider a three-node network. Nodes A and B are connected by a bi-directional fiber link (one fiber in each direction), and Nodes B and C are connected by a bi-directional fiber link. Nodes A and C are not directly connected to each other. Suppose there are two wavelengths and each node has two transmitters and two receivers. A unidirectional lightpath has been set up from C to A through B on wavelength $\lambda_1$. A bi-directional lightpath has been set up between A and B on wavelength $\lambda_2$. The capacity of a lightpath is 10 Gb/s. The unidirectional lightpath from C to A is carrying 2.5 Gb/s of traffic, and the bi-directional lightpath between A and B is carrying 5 Gb/s of traffic in each direction.

(a) Draw the auxiliary graph for this network according to the paper, ”A Novel Generic Graph Model for Traffic Grooming in Heterogeneous WDM Mesh Networks.”

(b) Suppose a new request needs to be satisfied. The request goes from A to C (unidirectional), and requires 5 Gb/s with a granularity of 2.5 Gb/s. Show the different ways that this request can be satisfied using the graph in the previous part.
(c) Suppose that after setting up the previous request, the next request is from A to B (unidirectional) and requires 7.5 Gb/s with a granularity of 2.5 Gb/s. For each of the solutions in the previous part, show how the new request can be satisfied.

![Network Topology](image)

Figure 1:

4. Consider the physical network topology in Fig. 1. There are two wavelengths available per fiber. The following lightpaths are to be established in the given order, with two possible alternate routes as given. Assume that links are bidirectional and the lightpaths are full-duplex. Note that some of the lightpaths may be blocked. i) Lightpath C-D: (Route 1: C-A-D; Route 2: C-E-F-D) ii) Lightpath B-D: (Route 1: B-A-D; Route 2: B-E-F-D) iii) Lightpath D-F: (Route 1: D-F; Route 2: D-A-C-E-F) iv) Lightpath A-B: (Route 1: A-B; Route 2: A-C-E-B) v) Lightpath A-F: (Route 1: A-D-F; Route 2: A-B-E-F) vi) Lightpath A-D: (Route 1: A-D; Route 2: A-C-E-F-D)

(a) Find the routes and wavelength assignments using fixed alternate-path routing with the alternate routes as shown. Choose from the alternate paths using a least-congested path policy. In the case of a tie, choose the shortest path. Use first-fit wavelength assignment.

(b) Repeat using fixed alternate-path routing policy with shortest-path first selection and first-fit wavelength assignment policy.