K. N. Toosi University of Technology

Solution 1

Optical Networking

1)

a. span: the portion of the link that runs between two amplifier sites, or between a node and an amplifier site, is called a span.
b. AWG: are commonly used as optical (de)multiplexers in wavelength division multiplexed (WDM) systems. These devices are capable of multiplexing many wavelengths into a single optical fiber, thereby increasing the transmission capacity of optical networks considerably. such a device is simply referred to as an “AWG,” or a wavelength grating router (WGR). For large N, the loss through an AWG is on the order of 4–6 dB. AWGs are generally M × N devices, where individual wavelengths on the M input ports can be directed only to one specific output port.

c. Optical Amplifier: An optical amplifier is a device that amplifies an optical signal directly, without the need to first convert it to an electrical signal.

d. ROADM: A fully configurable OADM is typically called a reconfigurable OADM or ROADM.

e. Data plane: all the functions and processes that forward packets/frames from one interface to another.

f. Control plane: all the functions and processes that determine which path to use (such as LDP, Routing protocols, etc.)

g. Nodal degree: The degree of a node is the number of links incident on that node.

h. Transceiver: A transceiver is a combination transmitter/receiver in a single package

2)

A) False, Optical amplifiers are especially located in **reginal and backbone networks**.

B) True, the problem of network engineering refers to the allocation of the network resources to demands, prior to any routed demands. Typically, there is sufficient time between such planning and running up the network based on them, whereas in traffic engineering, traffics are ongoing and any change in physical topology or arrival of new traffic must be provided properly at a small-time interval to prevent large latency.

3)The value of the reconfigurable WDM networks can be summarized:

- They provide high-level (wavelength) bandwidth management at relatively low cost, power and space requirement.
- They provide traffic on/off ramps to satisfy network connection demands while extending the value of the multiwavelength amplification via optical by-pass of the pass-through wavelengths.
- They reduce network costs and power by eliminating O-E-O conversion and electrical regeneration.
- They offer opportunity to simplify and reduce the cost of capacity upgrades.

4) Services are requests for connections that require a specific bandwidth portion and run between two nodes. The traffic in the network is the collection of services that must be carried out. The term demand is used to represent an individual traffic request between two nodes (i.e. capable of housing a lot of services)

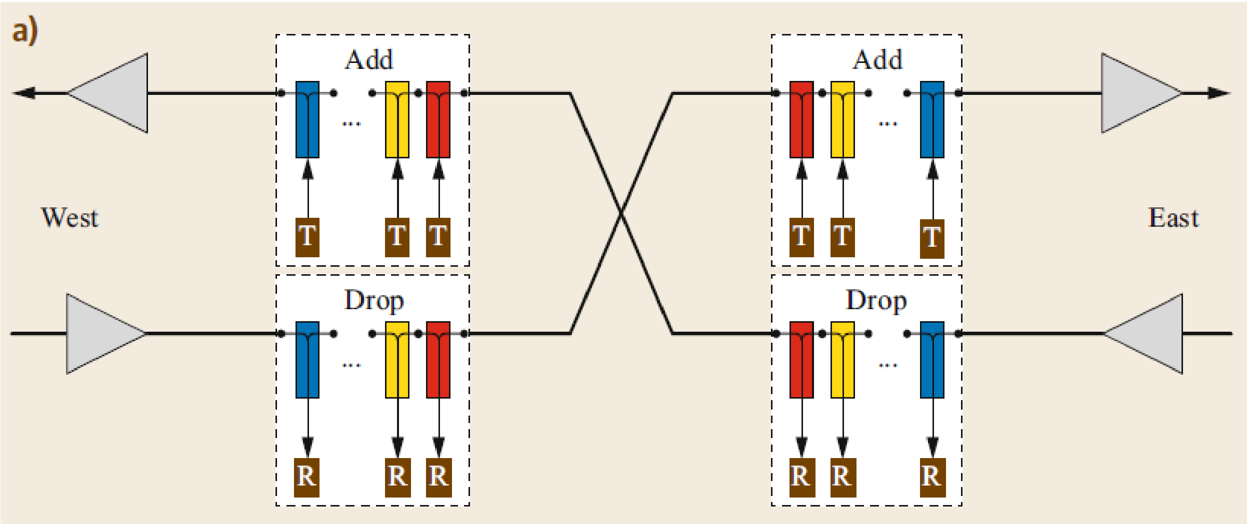
5) Both AWG and WSS are used to decompose a WDM signal to its constituent individual wavelengths. The difference is, that AWG is colorful. Once a specific wavelength is assigned to any of its output terminals during manufacturing, it cannot be unchanged. However, WSSs allow for such flexibility and adjustability. Their disadvantage is the production cost anyway.

6).

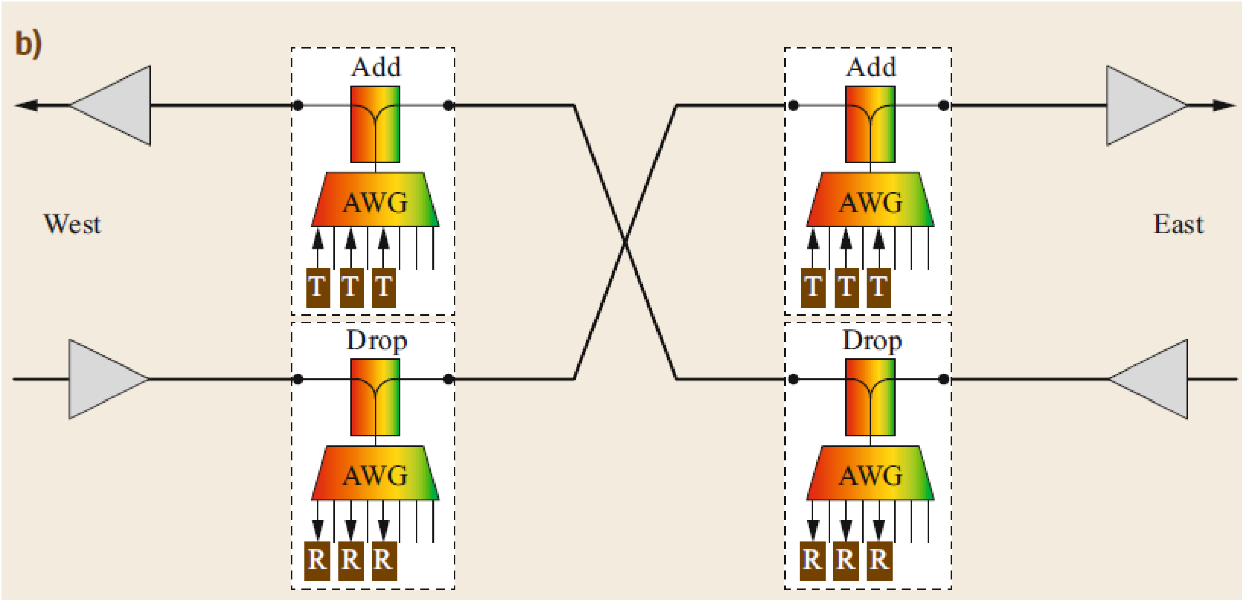
In the configuration, each transceiver is said to be **directionless** as it can transmit/receive its respective wavelength channel through any degree and thus fiber route of the node, by selecting the proper configuration of that intermediate switching functionality through the management control software. as the transceivers are all located locally within each degree along with dedicated optical wavelength multiplexing and demultiplexing capabilities, each transceiver is said to be **directional** given each transceiver inflexibility connected to the corresponding fiber route of that degree

7) One of the most important properties of an OADM is its **degree of reconfigurability**. The earliest commercial OADMs were not configurable. Carriers needed to specify up front which particular wavelengths would be added/dropped at a particular node, with all remaining wavelengths transiting the node. Once installed, the OADM was fixed in that configuration. Clearly, this rigidity limits the ability of the network to adapt to changing traffic patterns. Historically, there have been a variety of implementations of a fixed OADM topology, but the three most common approaches are to utilize:

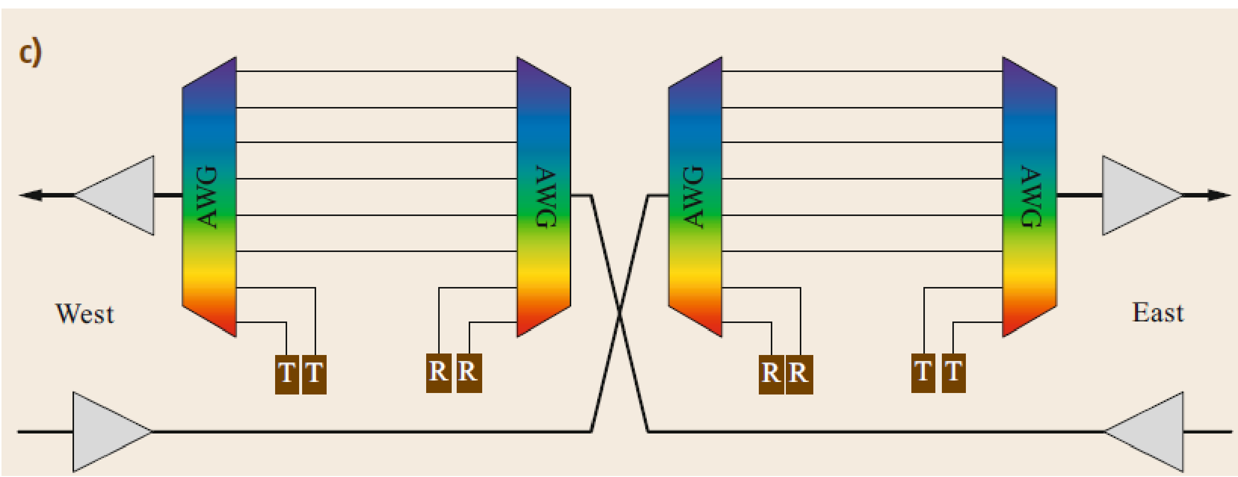
1. Individual wavelength multiplexing/demultiplexing filters placed in series, which extract/add the desired channel from/to the remainder of the channel spectrum that passes optically through the node.



2. Band demultiplexer/multiplexers placed in series, which extract/add a contiguous segment of wavelength channels from/to the remaining channel spectrum that passes optically through the node.



3. Full demultiplexers/multiplexers with local add/drop paths connected to collocated optical transceivers (Following figure) and express wavelengths created by individual optical connections between same-channel demultiplexer outputs and multiplexer inputs.

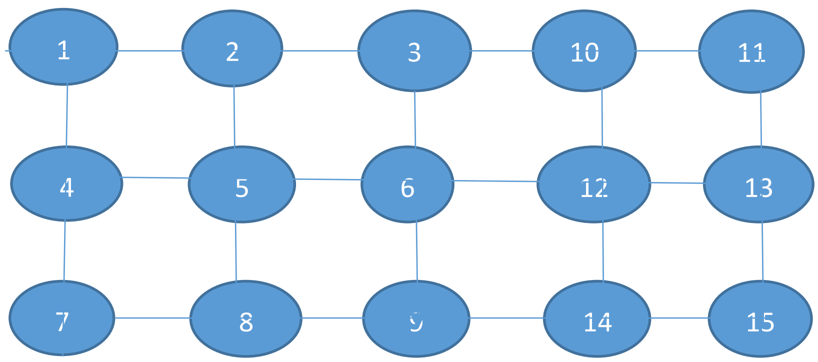


8) it is not connectionless. The WDM output of the M×1 WSS (which is connected to the WDM input of 1 × N WSS) can carry one connection per wavelength. This restricts the cascade structure by not allowing two connections with different input and output ports to be carried on the same wavelength.

9) Since different tiers of an optical network deal with different types of traffics (whether in scale or number), a unified technology cannot be used in all tiers. For

instance, with respect to WDM technology, backbone networks generally have 80-160 wavelengths per fiber, regional networks have roughly 40-80 wavelengths per fiber, metro-core WDM networks have anywhere from 8-40 wavelengths per fiber, and access networks typically have no more than 8 wavelengths.

10) Due to the symmetry of the network, we only need to calculate the number of wavelengths dropped or entered at nodes 1 to 6 according to the following topology:



Since optical reach is 150km, all-optical connection can traverse at most 3 links between source and destination. We, therefore, assume here that all connections are at most 3-hops long. For nodes 1, 2, 3, 4, 5, and 6, there are 8, 12, 13, 10, 13, and 15 wavelengths dropping, respectively. Hence the total number of dropped wavelengths anywhere in the network are equal to: 4 ×(8 wavelengths dropping) + 4 ×(12 wavelengths dropping) + 2×(13wavelengths dropping) + 2 ×)10wavelengths dropping) + 2×(13wavelengths dropping) + 1 ×(15 wavelengths dropping) = 167

The number of wavelengths traversing nodes 1 to 6 without dropping is twice as much as the number of wavelengths traversing those nodes in each direction. Without loss of generality, we assume that the two shortest paths between two nodes in the two opposite directions form a rectangle rather than being routed on equal nodes and links (the convention does not affect the solution since we are summing up the number of wavelengths at all nodes). An example of such a rectangle is the 1-2-3-6-5-4-1 rectangle where a connection from node 1 to node 6 is routed across nodes 2 and 3 and the opposite-direction connection from node 6 to node 1 is routed across nodes 5 and 4. These rectangles should be constituted of 6 links at most due to optical reach consideration. There are 10 rectangles with 6 links, 8 rectangles with 4 links, 6 rectangles with 3 links (such as 2-3-10-11), and 14 rectangles with two links (such as 1-2-3). The number of wavelengths traversed on these rectangles is equal to 8, 4, 4, and 2 respectively, yielding a total number of traversing wavelengths as 164.

so, the nodal drop ratio is $=\frac{167}{167+164} = 50.453172\%$