# Hand in problems Week 4

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December 2018

## Exercise & Solution

**Consider an optical network with four IP routers numbered 1 to 4, as given in Figure 1. We want to implement this network over the WDM infrastructure showed in Figure 2, where four nodes, A, B, C and D, are connected in series. The nodes A and D are OLTs and the nodes B and C are coupled to the fiber using single channel OADMs.**

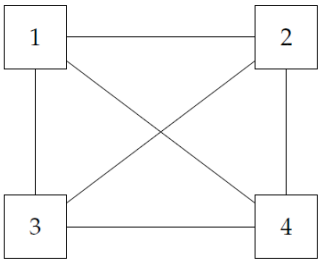



Figure 1: Desired IP network. Each router connects to all others.

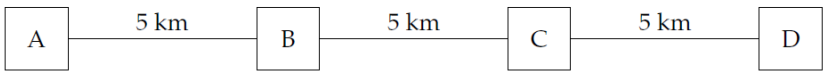



Figure 2: WDM infrastructure. A linear network where each node is 5 km apart from its nearest neighbour.

**The losses in the network are given by:**

- **The fiber has a loss of 0.25 dB/km,**
- **The OLTs have the insertion loss 0.2 dB.**
- **the OADMs have a passthrough loss of 2 dB, a loss of 0.75 dB for the add path and a loss of 0.75 dB for the drop path**

The wavelength planning for the system given above can be implemented in different ways, if there was any information on which routers need to have the least loss then one could take different measures while planing the network. In our case we are considering that all the routers are the same then we are taking a more direct approach to our network planing. First we can give our connecting wavelengths $\lambda_i$ in a matrix $C$ where the elements $C_{i,j}$ are the wavelength that connects $i \to j$, we have selected the wavelengths in the range $\lambda_i \in [1310\ nm, 1600\ nm]$ of the electromagnetic spectrum. The proposed optical system was planned as follows with Matrix C given in Eq.1 and as is shown in the setup in Fig.3 where we used this two to model the losses.

$$C = \begin{bmatrix} 0 & \lambda_1 & \lambda_2 & \lambda_3 \\ \lambda_1 & 0 & \lambda_1 & \lambda_4 \\ \lambda_2 & \lambda_1 & 0 & \lambda_1 \\ \lambda_3 & \lambda_4 & \lambda_1 & 0 \end{bmatrix} \tag{1}$$

We also selected to arrange the OADM's as is shown in Fig.3 this selection is the one that will be most important for the network since depending on how it is selected some paths have more or less loss when they communicate with each other, this will be further discussed calculating for both arrangements.

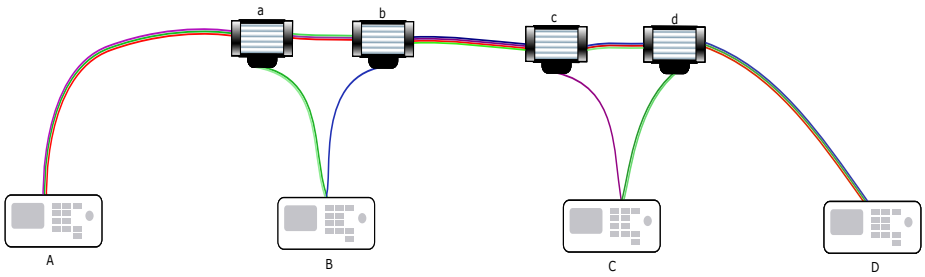



Figure 3: Optical system where the routers are named with capital letters and the OADM's are named by small letters. A visual representation f the colors used to connect the system is shown and one can see the optical path each has to travel. Note that green is used for to communication links so we have shown this using to slightly different tones of green.

Now we can proceed to calculate the loss in the network given by the previews colors in the setup, we are going to do this in to different matrices one that take

into account the loss due to the distance $L_{i,j} = 0.25\ dB \cdot L$ (independent of arrangement) and the loss given by the system $S$ (dependent of arrangement).

$$L = \begin{bmatrix} 0 & 1.25 & 2.5 & 3.75 \\ 1.25 & 0 & 1.25 & 2.5 \\ 2.5 & 1.25 & 0 & 1.25 \\ 3.75 & 2.5 & 1.25 & 0 \end{bmatrix} \tag{2}$$

Now the losses of the system $S$ depend on the signal passing over an OADM or any of the parameters specified in the question. We follow the losses as are given in Fig.3.The losses as are shown in Eq.3 for the system. We toke into account that there is an insertion loss on the OLT's but there is no drop loss giving us a matrix that is not symmetric. This happens since there is a difference of 0.2dB when going from $1 \to j$ than from $i \to 1$

$$S = \begin{bmatrix} 0 & 0.95 & 4.95 & 8.2 \\ 0.75 & 0 & 5.5 & 4.75 \\ 4.75 & 5.5 & 0 & 0.75 \\ 8.2 & 4.95 & 0.95 & 0 \end{bmatrix} \tag{3}$$

Now we can calculate the loss if we had a system where we change the arrangements of the OADM's as follows $b \to a$ and $d \to c$ giving of a loss by the networks $S'$.

$$S' = \begin{bmatrix} 0 & 2.95 & 6.95 & 8.2 \\ 2.75 & 0 & 1.5 & 6.75 \\ 6.75 & 1.5 & 0 & 2.75 \\ 8.2 & 6.95 & 2.95 & 0 \end{bmatrix} \tag{4}$$

We can average out both of this losses and we would get that $\bar{S} = 3.1375$ and for the other arrangement of the OADM's $\bar{S'} = 3.6375$ showing that the the network Fig.3 constructed has the minimum average loss. We could improve on the losses if we were not only considering wavelength planning but we were also implementing some type of TDM in the network, with multiple tools we could reduce the loss even more. The total losses for the system are:

$$T = S + L = \begin{bmatrix} 0 & 2.2 & 7.45 & 11.95 \\ 2 & 0 & 6.75 & 7.25 \\ 7.25 & 6.75 & 0 & 2 \\ 11.95 & 7.45 & 2.2 & 0 \end{bmatrix} \tag{5}$$

# References


[1] R. Ramaswami, K. Sivarajan and G. Sasaki: Optical Networks: A Practical Perspective, 3rd Ed. ISBN: 978-0-12-374092-2

[2] G. P. Agrawal: Fiber-optic communication system, 4th Ed. ISBN:9780470505113