Local Searches on Telecommunication Network

This document helps you to represent a telecommunication network as **Figure 1** in terms of matrices. These matrices can be then employed to optimize the telecommunication network in your practical work. Afterward, you will learn how to apply different local searches to change/improve the solutions.

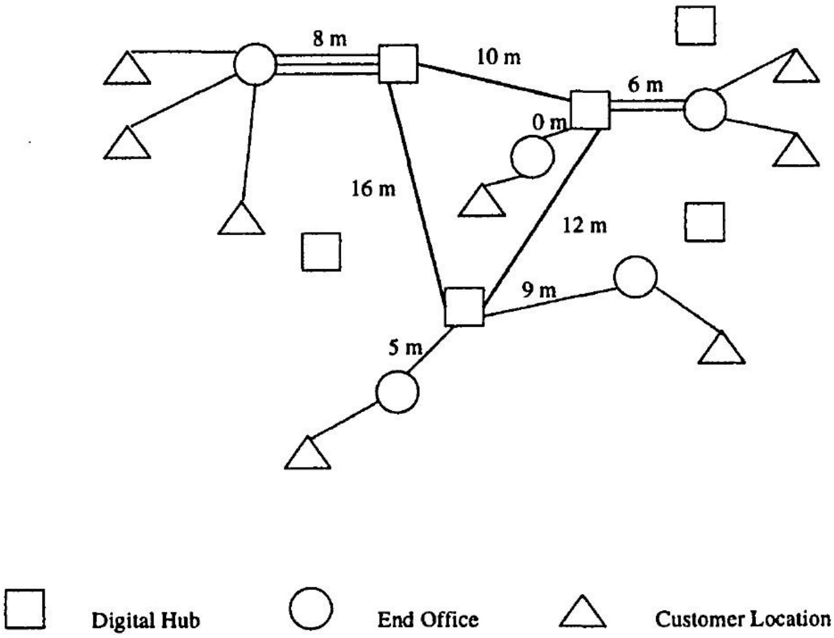

Figure 1. A telecommunication network

Note: This document is useful only for "***Telecommunication Network Optimization***" case study.

1. Multiple-part Solution Representation

By looking at the network of **Figure 1**, it can be observed that each network (as a solution) requires three parts to be represented. But first consider that this network includes $\boldsymbol{C}$ number of customers, $\boldsymbol{M}$ number of end offices and $\boldsymbol{N}$ number of digital hubs. Three parts of the solutions representation (SR) are explained as follows:

1.1. Customer-End office Allocation

In this part, we decide which Customer is allocated to which End office. This part of the SR could be a $(1\times C)$ matrix that is filled by the numbers $m=\{0,1,2,\ldots,M\}$. If the value of the c^{th} cell of the matrix is equal to m ($m\neq0$), it implies that the c^{th} Customer has been allocated to the m^{th} End-office. In addition, if the value of the c^{th} cell of the matrix is equal to 0, it implies that the c^{th} Customer is not served (covered) in the network. **Figure 2** depicts the *Customer-End office Allocation* part in a network with C=8 Customers and M=4 End offices; wherein customers 1, 2, 4, 5, 6 and 7 have been allocated to End-offices 2, 1, 3, 2, 4 and 3, respectively. In addition, Customers 3 and 8 are not served.

Customer	1	2	3	4	5	6	7	8
End-office	**2**	**1**	**0**	**3**	**2**	**4**	**3**	**0**

Figure 2. *Customer-End office Allocation* part with C=8 and M=3

1.2. End office-Digital hub Allocation

In this part, we decide which End office is allocated to which Digital hub. This part of the SR could be a $(1\times M)$ matrix that is filled by the numbers n={1,2,...,N}. If the value of the m^{th} cell of the matrix is equal to n, it implies that the m^{th} End office has been allocated to the n^{th} Digital hub. It is noteworthy that, in this part, we consider that all End offices must be allocated to a Digital hub. **Figure 3** depicts the *End office-Digital hub Allocation* part in a network with M=4 End office and N=6 Digital hub; wherein End offices 1 to 4 have been allocated to Digital hubs 3 1, 4, and 5, respectively. It is noteworthy that the Digital hub numbers 2 and 6 have not been selected to be used in the network.

NOTE: It should be noted that ***at least 3 different*** Digital hubs MUST appear in this part to ensure that these Digital hubs will be able to create a ring.

End office	1	2	3	4
Digital hub	**3**	**1**	**4**	**5**

Figure 3. *End office-Digital hub Allocation* part with M=4 and N=6

1.3. Digital hubs Sequence as a Ring

Depending on the selected Digital hubs in the *End office-Digital hub Allocation* part, this part provides the sequence (order) of the Digital hubs as a ring. For having a ring, we need at least three Digital hubs and it has been already ensured in the *End office-Digital hub Allocation* part. This part of the SR is very simple and requires a permutation of the selected Digital hubs. If you well remember from your PyRat course, this problem looks like the Travelling Salesman Problem (TSP). Therefore, this part is represented as a $(1\times N)$ matrix that is filled by the a random permutation of numbers n={1,2,...,N}. Figure 4 shows a ring of N=6 Digital hubs.

Digital hub Number	1	2	3	4	5	6
Digital hub Order	**2**	**1**	**4**	**6**	**3**	**5**

Figure 4. *Digital hubs Sequence* with N=6

In Figure 4, it can be seen that the Digital hubs have been interconnected with the following sequence:

$$2 \rightarrow 1 \rightarrow 4 \rightarrow 6 \rightarrow 3 \rightarrow 5$$

In this sequence, all 6 Digital hubs have participated in the ring; but in Figure 3, only Digital hubs 1, 3, 4 and 5 have been selected. Therefore, we simply eliminate redundant Digital hubs by keeping the original order of Figure 4. Accordingly, by eliminating the Digital hubs 2 and 6 from the sequence of Figure 4, the sequence of the selected Digital hubs is:

$$1 \rightarrow 4 \rightarrow 3 \rightarrow 5$$

2. Local Search 1: *Swap*

This neighborhood search, a randomly selected slice of the SR is swapped. Swap operator leads to a re-allocation in *Customer-End office Allocation* and *End office-Digital hub Allocation* parts; but it leads to a re-ordering of the Digital hubs in *Digital hubs Sequence* part.

3. Local Search 2: *Remove/Replacement*

This neighborhood search could be applied on *Customer-End office Allocation* and *End office-Digital hub Allocation* parts; wherein an existing End office/Digital hub is removed from the SR, then it is replaced either with another existing End office/Digital hub or is replaced with a new one (if possible).

It is upon to you to look for other Local Search operators