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Introducing Variable Factors For Optical Backbone Interconnection Planning

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Summary. This paper contributes to the field of physical network interconnection decision support. This type of problems are very complex to solve for two main reasons: The computational complexity is high due to its combinatorial nature and to the calculation of parameters to evaluate the solutions. Usually, these parameters are related to the deployment investment, or performance and reliability. Geographical and statistical factors are used for their calculation and are normally considered as constant regardless of the specific deployment place. The main contribution of this work is to consider these factors as variable, and to evaluate their effect. A case study is presented and vectorized maps and image processing is used in order to provide the proper scenario for the evaluation. The objective can be defined as a simple question: Is the interconnection decision different when these factors are constant or variable?

1 Introduction

Physical network interconnection decision is a complex problem. The number of combinations to interconnect N nodes is very large, and it grows exponentially with N. For example, even if these N nodes can only be interconnected forming a ring, theoretically, this can be done in $N-1!$ different ways [1].

On top of this complexity, each individual potential solution must be evaluated. The simplest approach is to design the interconnection by minimizing the total networks length, this type of problem has been solved even before computers were used in optimization problems [2]. In addition, more complete approaches have been developed by minimizing the number of wavelengths required for a specific demand [3], or maximizing the average connection availability [4].

There are some factors that must be taken into account that affect these objective functions, and these factors are usually taken as constant approximations to reduce the complexity of the problem.

For example, the physical distance of a link between two cities can be approximated as the Euclidean distance, between them, and a weight, with no need to determine the exact roads used to deploy that link. This factor is usually considered as constant in the whole geographical area where the network has to be deployed, regardless of the landscape, country, region, or type of roads [5].

The main objective of this work is to introduce the concept of variable factors when dealing with physical network interconnection. These factors are for example, variable trenching cost when working with deployment investment, or variable failure rates when working with connection availability. In this way, the factors reflect the reality in a more accurate way.

A case study is presented in order to explain and apply these concepts. The goal is to determine if the solution provided by an interconnection decision algorithm varies if constant or variable parameters are used. If the solution is different, then there is potential benefit of applying the variable factor to solve such problems.

This type of networks are very expensive to deploy compared to wireless or other access network due to the large areas covered and the large civilian engineering costs. Therefore, these should be properly planned at the first attempt as good as possible in order to economize the project. For this reason, any small improvement could imply large benefits/savings [6].

Vectorized maps are used in order to provide the variable factors, where the value of each factor depends on the specific type of landscape in specific points. Three types of landscape are considered: Flat lands, Sea, and Mountains.

The overall contribution of the paper is to improve the accuracy of network planning models by considering the factors variable, which can be used for better decision support.

The rest of the document is organized as follows: Section 2 covers the background and definitions of the topic. Section 3 presents the methodology to use the vectorized maps and to apply the information about the different factors. Section 4 illustrates the concepts with a case study and Section 5 summarizes the main conclusions of this work.

2 Definitions and Complementary Work

This section summaries the concept of factors and parameters. Also, as this work is a small part of a larger system, the work in relation to the overall decision support mechanisms is briefly presented.

2.1 Factors and Parameters

The factors are the characteristic and attributes used to calculate the parameters. For example, in relation to the trenching cost when deploying a network, the cost per km of trench is a factor. Any variable that is required and influences each of the parameters can be considered as a factor. In this work, factors are given as a weight plus a constant base value. Consequently, a factor is variable if the assigned weight is variable.

The three main parameters when dealing with physical network interconnection and the effect of using variable factors for their calculation are the following:

Physical length: The ratio Euclidean-real distance is not constant, it is dependent on the type of relief crossed by the lines. It is not the same to deploy submarine cables and underground cables.

Deployment cost: Depending on the country, area or landscape the cost of digging (manpower), and the cost of letting/buy the land to lay down the fibre might vary.

Availability: Usually, availability is calculated based on statistical factors, Mean Time To Fail, $MTTF$, and Mean Failure Time, MFT, for example [7]. These might vary depending on the resources assigned to maintenance task, or the placement of the fiber ducts. For example, submarine cables take a much longer time to fix than underground cables. Also, availability may vary to maintain the trade-off between $MTTF$ and cost of deployment.

2.2 Complementary Work

This work can be considered as a module of a larger system for networks physical interconnection decision support. This module focuses in the part of the process of predefining the factors to be used to calculate the relevant network parameters. Fig. 1 shows the whole problem solving scheme, highlighting the specific contribution of this work (within the dotted rectangle).

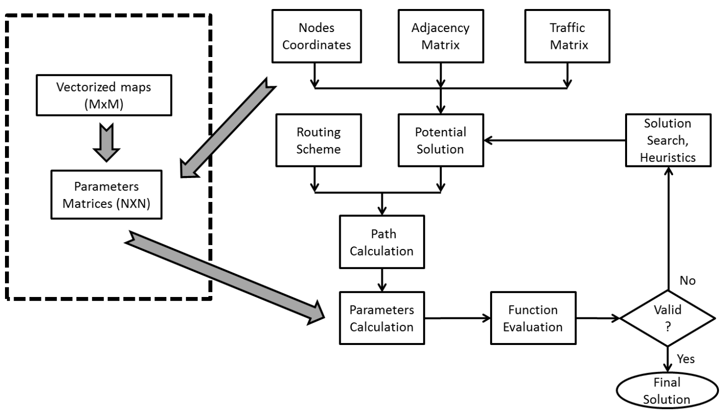


Fig. 1. System Scheme

This is a one time process, and the resources spent to calculate the factors can be considered as insignificant compared to the resources spent on the solution search iterations. The resulting factors are accessed to evaluate each of the individual potential solutions provided in each of the interaction in the solving process.

3 Methodology

Usually, the input of this kind of problems is related to the nodes: coordinates, population, etc. Then, the interconnection is planned based on this information and some predefined factors that affect the network parameters such as trenching cost per km or failure rate per km. These factors are commonly assumed as constant.

The proposal is to use variable factors, and their specific value at a specific geographical location is dependent on the kind of terrain. Therefore, the factors become vectors or matrices, and they are calculated by vectorizing the planning area. Basically, this vectorization consists in dividing the region into cells, and assigning a specific "class" to each cell. For example, in this work, this assignment is based on the relief of the cell, and three classes are considered: Flat Land, Sea, and Mountain.

The result is a $(M\text{x}M)$ matrix, M being the dimension of the division and each cell having its assigned class. Consequently, if each of the different classes are assigned different factor values, then factors become matrices. Fig. 2(a) illustrates an example of an area division.

The factor matrices are used in order to calculate the parameters matrices. These are $N\text{x}N$ matrices, and contain the information about all the possible links that can be part of the network, $N \cdot (N-1)$.

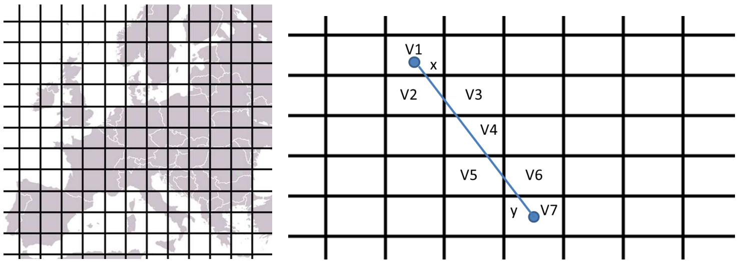
Let V be the $M\text{x}M$ matrix containing the information about the factor of each division. In our specific case, three factors are associated to each cell, Vij: FL_{ij} for length, FC_{ij} for cost, and FA_{ij} for availability.

Then, the three NxN matrices with the links information are: L for length, C for cost and A for availability. This process is followed to determine each link's parameters. The same procedure is followed for each pair of nodes (x and y), this process is iterated $N \cdot (N-1)$ times:

- Determine the straight line equation that connects x and y.
- Determine the cells of V that the line crosses.
- Compute this information to calculate the length (L_{xy}), cost (C_{xy}), and availability (V_{xy}) associated to the link.

Fig. 2(b) illustrates a graphical example of how parameter L_{xy} is calculated for the link between node x and node y. The link can be divided in S segments, and each segment is associated to l_{Vn}, Euclidean length, Vn being each of the V cells crossed by the link. L_{xy} is mathematically defined in Eq. (1).

$$L_{xy} = \sum_{n=1}^{S} l_{Vn} \cdot FL_{Vn} \tag{1}$$



(a) Area Division (b) Vector Example

Fig. 2.

In the case of cost or availability the variables c_{Vn} and a_{Vn} can be used as base values, and then are multiplied by their corresponding factor from FC_{Vn} or FA_{Vn}.

4 Case Study

This case study presents an interconnection problem to be solved. In order to illustrate the consequences of using variable factors, it is solved following two procedures: using the classical constant factors and the newly introduced variable factors. The objective is to interconnect 16 capitals in Europe, minimizing the networks total length and following a Double Ring topology [8]. The question to answer is simply if there is any difference in the results using the two approaches.

A matrix V is required in order to solve the problem with variable factors. Ideally, this information would be an input to the problem, but unfortunately, such information does not exist yet. Instead, we propose to use a map of the region and use image processing to extract the information. This procedure has been used, for example, in [9] to extract information to be used to compute distances or find shortest paths.

As previously mentioned, three types of relief classes are considered in this work that can be easily extracted form colored physical maps: Sea in blue tones, the Flat Lands in green tones, and the Mountains in brown/red tones.

In order to illustrate the image processing output, Fig. 3 show the map used to extract the information, and Fig. 4 presents the class of each cell as Sea in blue, Flat Land in green, and mountain in red; the black cells are the nodes[3].

For each cell, the algorithm determines the color of each pixel, and the most *seen* color in each cell is the selected one. In this way, for example, if the cell is at the sea that cell will be given a class "B" (of Blue). The area

[3] For black and white prints, sea corresponds to the darkest tone, mountains to the intermediate tone, and flat lands to the lighter tone

is divided in 10.000 cells, $M = 100$, and depending on the class of each cell, these are the assigned factors:

- Class B, Sea: $FL_{ij} = 1$.
- Class G, Flat Land: $FL_{ij} = \sqrt{2}$.
- Class R, Mountain: $FL_{ij} = 2$.

Fig. 3. Input Map

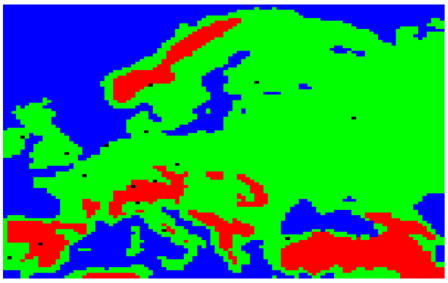


Fig. 4. Output Map

Having all the required information ready, it is processed and used as input for the solution search algorithm (GA in this case). Figs. 5 and 6 show the two approaches results, being different from each other. Table 1 presents the total length for both networks, $NT1$ being the optimization result for constant factors and $NT2$ the optimization results for variable factors.

Therefore, it is possible to conclude that using variable parameters affects the final solution. Furthermore, this difference combined with other cost or availability factors may be become more significant.

This case study can be extended as desired by associating other factors to each of the three classes such as manpower cost, tensing cost, mean failure time, and similar. The procedure would be exactly the same, making it rather simple to implement improvements and extensions of the method.

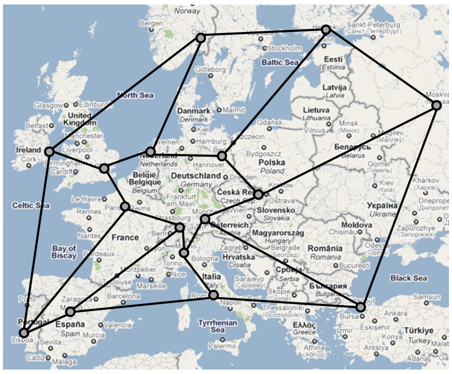


Fig. 5. Constant Factor Solution, $FL_{ij} = \sqrt{2}$, NT 1

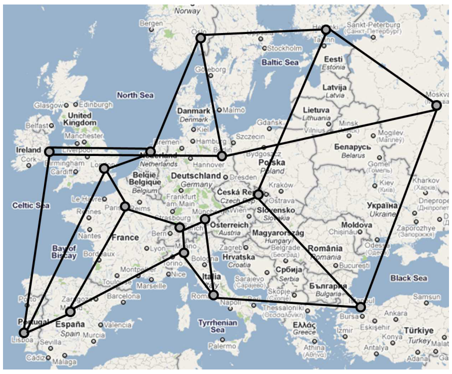


Fig. 6. Variable Factor Solution, FL_{ij} Variable, NT 2

Factors	**Cte**	**Variable**
NT 1	30155	30265
NT 2	30736	30206

Table 1. Total Network Length [km]

5 Conclusion

This work presents an improvement over existing interconnection decision support systems for optical physical networks. Usually, network parameters are calculated using constant factor regardless of the geographical location of the links.

This paper introduces the concept of variable factors in order to reflect more accurately the reality in the models used for interconnection decision support. This addition does not imply a significant increment on the complexity of the system.

A case study is presented to illustrate the idea and concepts behind this new contribution. Image processing of colored maps is used extract geographical information to define the factors as vectors. These are variable dependent on the type of landscape: flat land, sea, or mountains.

The results show that variable parameters can influence the final interconnection solution. The difference in the network's length depicted in Table 1 combine with other variable factors may have a significant influence on the obtained solutions. In general, regardless of what the specific numerical values, the addition of variable factors can improve the decision support system of optical network interconnection.

Future work on this topic could be to perform case studies, using constant and variable factors, minimizing the deployment cost, maximizing the connection availability, or using real road distances. Also, further research on how the different factors can be vectorized, depending on the relief, will be an important complement to the ideas presented in this paper.

References

1. Cheng, Maggie Xiaoyan; Li, Yingshu; Du, Ding-Zhu (2006). Combinatorial Optimization in Communication Networks, Springer, 658 pages.
2. Miehle, William (1958). Link-Length Minimization in Networks, Operations Research, Vol. 6, No. 2, March-April 1958, pp. 232-243.
3. Liu,Huan; Tobagi, Fouad A. (2006). Physical Topology Design for All-Optical Networks, Broadband Communications, Networks and Systems, 2006. BROADNETS 2006. 3rd International Conference on pp.1-10, 1-5 Oct. 2006.
4. Tornatore, Massimo ; Maier, Guido A.; Achille, Pattavina; Villa, Marco; Righetti, Aldo; Clemente, Roberto; Martinelli, Mario (2003). Availability Optimization of Static Path-Protected WDM Networks. Optical Fiber Communication Conference 2003, Optical Society of America.
5. J. Gutierrez; M. Imine; O. B. Madsen,(2008) Network planning using GA for regular topologies, Proceedings of IEEE International Conference on Communications, ICC 2008, China, pp. 5258–5262.
6. Grover, Wayne D. (2003). Mesh-Based Survivable Networks, Options and Strategies for Optical, MPLS, SONET and ATM Network. Prentice Hall PTR, 1st edition.
7. Rados, Ivan (2007). Availability Analysis and Comparison of Different WDM Systems, Journal of Telecommunications and Information Technology, vol. 1, pages: 114-119
8. T. Joergensen; L.Pedersen; J.M. Pedersen (2005)
Reliability in single, double and N2R ring network structures, CIC'05 Las Vegas, USA, Pag. 2-4.
9. Kasturi, R.; Alemany, J. (1988). Information Extraction from Images of Paper-Based Maps, IEEE Transactions on Software Engineering. Vol. 14, pages: 671-675, IEEE Computer Society.