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Published in:
11th International Conference on Advanced Communication Technology, 2009. ICACT 2009

Publication date:
2009

Document Version
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

Citation for published version (APA):
Labeaga, S., Pedersen, J. M., Gutierrez Lopez, J. M., Riaz, M. T., & Madsen, O. B. (2009). Multi-perspective guidelines for the design of new network planning tools – a case study. In *11th International Conference on Advanced Communication Technology, 2009. ICACT 2009* (pp. 778-781). IEEE.

Multi-perspective guidelines for the design of new network planning tools – a case study

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***Abstract* — The aim of this paper is to introduce a theoretical and practical perspective of the network planning process that could help future algorithm programmers to have a global perspective of the problem in such a way that their algorithms could become more complex, able to tackle multi-optimization. Guidelines have been extracted from a case study: Design of a new IT infrastructure for the Region of Nordjylland [1].**

***Keywords* — guidelines, network planning tool, design, backbone.**

1. Introduction

Network planning is not a trivial task due to the high number of parameters involved in the process and their mutual dependencies. Using informatics tools to assist in the task has become essential in recent days. However, due the quantity and relation of the parameters, normally the network planning process is divided in parts, trying to find appropriate solutions to each one and then assemble them achieving a final result [2].

Nevertheless, this solution is far from a global optimization. The necessity of creating complex algorithms able to reach multi-compromises between all the involved parameters would imply an important step ahead in the obtaining of more economical and efficient solutions.

The aim of this document is to introduce a theoretical and practical perspective of the network planning process that could help future algorithm programmers to have a global perspective of the problem in such a way that their algorithms could become more complex and able to tackle multi-optimization problems. Apart from being a basis for the creation of more complex and effective algorithms, the document provides as well effective solutions to adapt the theoretical results to the real world, which is mainly influenced by economical aspects [3].

These guidelines have been created by using the results and experiences obtained in the design of a new IT Infrastructure for the region of Nordjylland, Denmark [1]. In this project, different kinds of well known regular topologies (Single Ring, Double Ring, N2R and 4-Regular Grid) were compared in terms of average distance, degree and economical cost. Further information about ring and grid topologies can be found in [4] and [5] respectively.

The paper has been divided into eight sections. In section 2 the complexity of network planning is introduced. Then, the case study is explained in section 3. Its methodology and results are exposed in the next two chapters. After that, sections 6 and 7 comment the results from a technical and practical perspective respectively. Section 8 contents the conclusion and finally, in section 9 future investigation lines can be found.

2. The Network Planning Process

Network planning and design is an iterative process that encompasses different stages (Figure 1). It begins with the acquisition of external information. This includes: forecasts about population distribution, services and network capabilities. After studying the population and determining the needs of the users it is necessary to define a method in order to place the nodes. This method should achieve both economical and technical requirements that are usually in conflict.

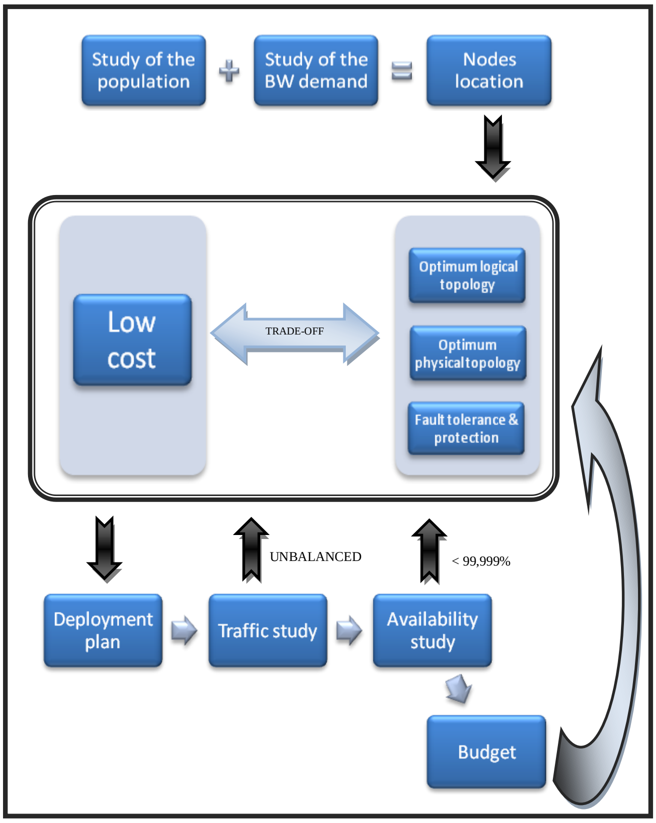


Figure 1: Network Planning Stages

Once the nodes are placed, the following step is to decide how to connect them. This stage also involves tradeoffs between economical cost and network performance. Economical cost is not easy to calculate because it involves running costs such as well as one-time costs such fiber deployment. The deployment plan can be seen as an effective time-tool in order to deal with the performance-cost tradeoffs. Finally, traffic, availability and other studies must be done in order to check that the final result fulfils all the requirements.

3. Case study

Nordjylland is the northern region of Denmark and it is also the less populated one. Its largest city (and also the capital) is Aalborg, the fourth largest one in Denmark, which population was 100.731 inhabitants (2007).

Nordjylland covers an area of 8.020 km2, which means that its population density is about 72 inhabitants per km2, the lowest one in the country [6].

The current situation of the IT Infrastructure in Denmark is quite similar to the situation in other developed countries in terms of speed. Despite Denmark is leading (in Europe) with respect to broadband availability and penetration, the main technology used in the last mile is xDSL, being quite far from other developed countries in FTTH deployment. Important backbone networks are already deployed but there exist a bottle neck in the access networks (last mile) which connect the final users till the aggregation nodes [7].

This bottle neck is due the bandwidth limit of the traditional copper lines. The replacement of the old access network based on copper wires from POTS (Plain Old Telephone Service) to new generation technologies (such as FTTH) able to provide higher transfer rates is a really expensive task, especially in areas with low population density such as Nordjylland.

Statistics prove that this replacement has already started in recent years, with FTTH subscriptions increasing more than 100% in 2006 and 2007 (Figure 2). However, despite this increasing, only 2% of the subscriber lines were using FTTH technologies in 2007 [7] which proves that there is still a long way ahead.

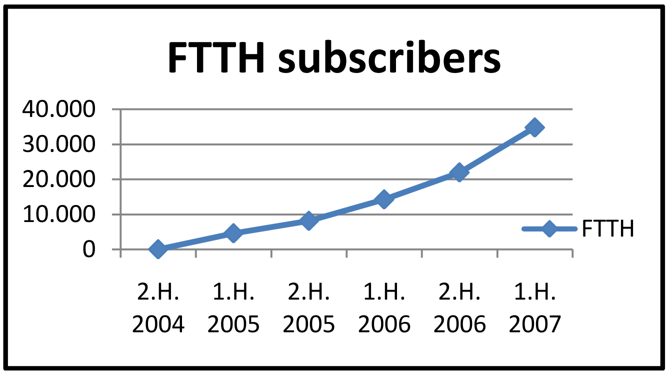


Figure 2: FTTH subscribers in Denmark

4. Methodology

The aim of this section is to study deeply the methodology applied to the case study, specifically the nodes location process and the topology study.

A. Nodes location process

The nodes location process was divided in three different stages:

The first one consisted of placing the nodes in the most densely populated areas of the map. This way we make sure that fiber optic costs will be reduced because the distance between the COs (Central Offices) and the nodes will be reduced. This initial approach is computer assisted by using GIS (Geographic Information Systems) Data (Figure 3) and MapInfo® thematic map tools. Once we knew the most densely cells, we placed physically the nodes in the COs closest to the selected cells. Using this method money is saved because of the creation of a new infrastructure for the nodes would not be cost-effective.

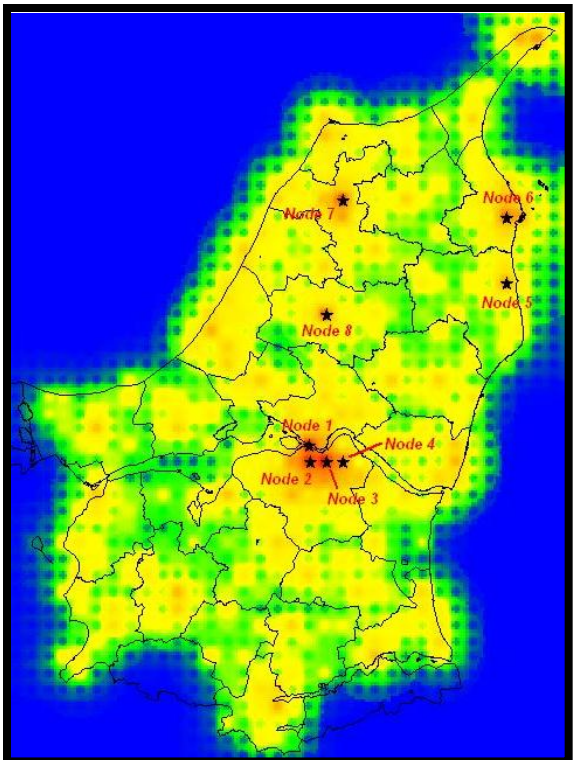


Figure 3: Network Terminals Density

Secondly, the integration with other Access technologies as WiMAX has been tackled. It has been checked that the distance between the WiMAX Base Stations and the nodes is short. In the cases of antennas far away from nodes, new nodes have been projected. This is an important stage in order to take advantage of the backbone investment.

Finally, the aim of the third stage was balancing the load of the nodes, in such a way that each one covered a similar number of subscribers.

All of the commented stages have been informatics assisted by MapInfo software, and can be easily automatized by using MapInfo queries.

B. Network topology

Different topological models have been adapted to the case study and compared. Next parameters have been used for the comparison:

- Diameter. The maximum distance (number of hops in a shorter path) between two nodes in the network.
    - Average distance. The average number of hops between two nodes.
    - Connectivity number (Degree). The number of neighbors of each node.
    - Economical cost. An estimation of the overall fiber deployment cost.

Some extra qualitative parameters defined in the Structural Quality of Service (SQoS) evaluation framework [8] have been taken into account.

- Algorithmic support. For example, topological routing [9] support.
- Embeddability. This parameter is important when implementing graph structures in the real world. Some structures are easier to embed than others, this depends highly on physical conditions. Planar structures are relatively easier to embed.
- Expandability. The graph structures have different properties with respect to support SQoS parameters. An expansion of these structures can degrade these properties if not expanded correctly. Some structures, especially planar ones, are easier to expand than the non planar ones.

5. Case study results

Next, Table 1 shows the final results of the comparison between the 4 introduced topologies:

Table 1: Topological comparison

	Degree	Diameter		Average distance		Economical cost
		1st Path	2nd Path	1st Path	2nd Path	
Single Ring	2	8	8	4,27	11,73	14.315.448
Double Ring	3	5	5	2,66	3,66	31.393.699
N2R (8,3)	**3**	**4**	**5**	**2,3**	**3,9**	**31.012.200**
4-Regular Grid	**4**	**6**	**6**	**2,33**	**2,46**	**31.085.600**

Ring topology is a really economical solution, but it is also the most limited one in all the studied features. Its large diameter and its longer average distance makes it non-recommendable for next generation networks.

Focusing on degree 3 topologies, it has been proved that N2R is clearly much more powerful (in terms of average distances and diameter) than standard double ring. Also in this particular case N2R has a lower economical cost. On the other hand embeddability and expandability are better for double rings [8]. In spite of these problems N2R, it is still recommendable in front of standard double ring.

4-Regular Grid offers a similar prize to N2R. Its diameter is longer than in N2R, but on the other hand, the average distance for the second independent path is favorable to it. Also the scalability (it is easy to change the 4-Regular mesh into a triangular one), the possibility of using topological routing and good expandability are valued but also difficult to quantify.

Figure 4 shows the final nodes location and 4-regular grid topology selection:

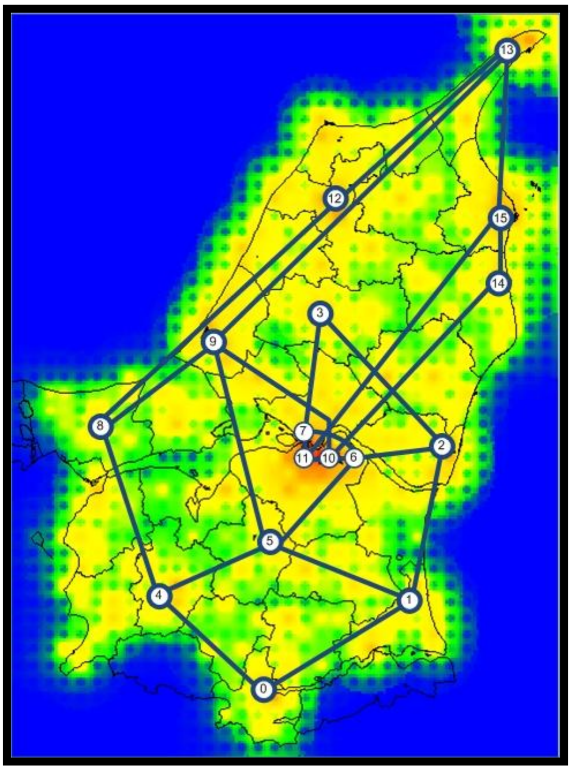


Figure 4: Final results

6. Results analysis: Technical Perspective

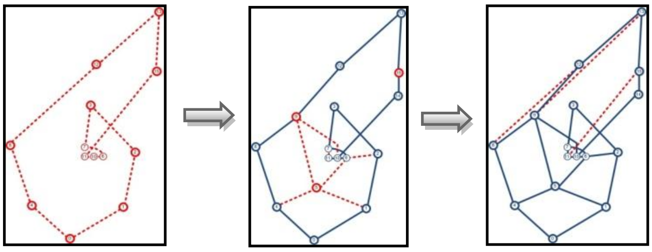
According to the stages shown in Figure 1, the next step after designing the topology is the traffic study. The traffic study consisted of analyzing the expected traffic in Mbps in each of the links. Despite the effort applied in the nodes location methodology to achieve similar traffic in all the links (by placing the nodes in such a ways that they covered similar number of subscribers), final results proved that traffic was not balanced at all.

These results highlighted the importance of taking into account the services that the network subscribers are going to use. With Special emphasis to the study of the services that require more bandwidth as P2P services or IPTV [1].

After all, it was proved that methodology for the nodes location process had minimal influence on the traffic distribution compared to the influence of the services: location of the IPTV servers/gateways that affects the IPTV and P2P traffic fluxes respectively.

7. Results analysis: Practical Perspective

In most of network planning cases the technical solution is obtained as described above not compatible with the real world mainly influenced by economic factors. In other words, usually theoretical results are not feasible because of the necessary initial investment. The deployment plan can be used as solution to convert the theoretical unaffordable plan into a profitable one by deploying the network gradually based on a strategic plan (Figure 5).



Stage 1: Single Ring

Stage 2: Logical 4-Regular Grid

Stage 3: Physical 4-Regular Grid

Figure 5: Strategic deployment plan

Furthermore, a gradual deployment plan is a key point in the financing of the projects because it allows generating profits in a relative short term using them in future stages. Obtained results (Figure 6) proved that it is possible to create a strategic deployment plan in which up to 30% of the initial project investment is reduced and in which 100% of the structure is recycled in future stages [1].

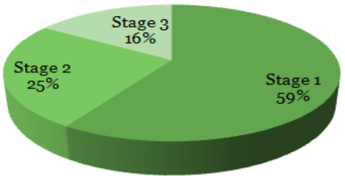


Figure 6: Backbone deployment cost

8. Conclusion

From a technical perspective, it has been shown the importance of having a global point of view before focusing on the optimization of the network planning stages (Figure 1). This convenience has been illustrated with a network planning example in which the advanced optimized method to place the nodes had a reduced relevance -in the traffic results- compared to other external parameters as the location of the servers of different kind of services as IPTV.

From a practical perspective, the importance of a strategic deployment plan has been emphasized as a very effective tool in the convergence of the practical world and the theoretical one. Interesting results have been achieved in which the initial investment is reduced up to 30% (Figure 6), keeping the availability acceptable since the first stage and recycling the initial infrastructure in future stages.

9. Future work

Once the topologies have been studied, it is possible to find more than one interesting solution. Focusing on our case we arrived to some similar results for the topologies: 4-regular grid and N2R. Both require very similar economical cost, 4-regular grid has better degree and average distances, but on the other hand worst diameter.

A possible solution could consist of creating an objective evaluation framework, in which each parameter had a scale to be evaluated. The solution with higher average ranking would be selected. Networks could be classified so that a framework could be constructed based on a combination of technical and business-model parameters.

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