Using Regular Topologies for WiMAX Backbone

A Case Study

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Using Regular Topologies for WiMAX Backbone. A case Study - IPC 2009

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Summary. The aim of this paper is to study the applicability of regular topologies in the backbone of WiMAX networks. The study is focused on a large-scale WiMAX network. Different regular topological solutions as single ring, double ring or 4-Regular Grid are applied to the network and compared in terms of degree, diameter, average distance and estimated economical cost. Furthermore, other non-quantitative parameters as expandability, embedability and algoritmic support are introduced.

1 Introduction

The use of regular topologies in backbone networks has been studied in detail in the past with satisfactory results [1]. Furthermore, year after year, users and companies demand more and more bandwidth, lower delay and higher network reliability [2] [3].

Even though protocols are being developed to ensure reliability [4], the physical network structures limit the level of reliability that can be offered: two nodes can only communicate if there is a physical link between them. Traditionally, rings have been used as alternatives to tree structures. Rings offer connectivity in case of any single failure. However, given the expected demands of reliability, this is likely to become insufficient in near future. More information about redundancy in ring topologies can be found in [5] and [6].

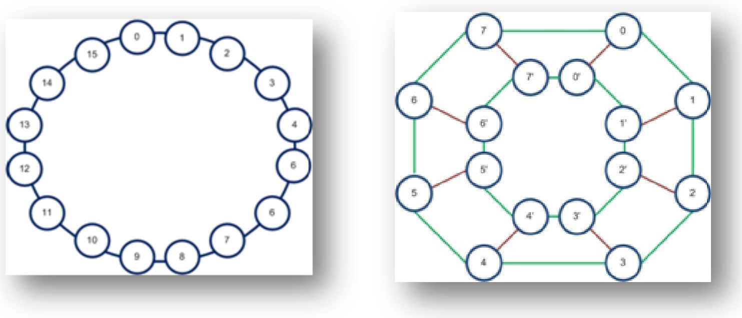
This paper studies the applicability of regular topologies as backbone in a WiMAX scenario. It has been created by using the results and experiences obtained in the design of a new IT Infrastructure for the region of Nordjylland, Denmark [14]. In this project, different kinds of well-known regular topologies (Single Ring, Double Ring, N2R[1] and 4-Regular Grid -Fig. 1 and Fig. 2-) were

[1] The N2R topology (Fig. 3b) is a type of generalized Double Ring (DR) topology. It consists of two rings denoted inner ring and outer ring. Hence, the number of nodes in the N2R structure is any positive even integer larger or equal to 6. These rings each contain the same number of nodes (p). The inner ring links

compared in terms of average distance, degree and economical cost. Further information about ring and grid topologies can be found in [7] and [1]. The three main reasons for analyzing regular topologies are:

1. It is possible to define and document well-known parameters and metrics which ease the network characterization. Besides, based on well-known metrics it is easy to compare different topology designs in a proper way.
2. Topological routing. Based on regular topologies it is possible to define topological routing techniques which allow faster communications, faster restoration and the reduction of routing overhead within the network. [8]
3. Expandability and upgradability. It is easier to add links to improve the network performance or to add nodes in order to expand it (in an organized way). [9]

The organization of the paper is as follows: Section 2 introduces the WiMAX technology. Section 3 presents the case study and briefly explains the current situation of the IT infrastructure in the Denmark. Then, in section 5 the methodology is described. Finally, section 6 and 7 contain the conclusion and future work lines respectively.



(a) Single Ring (b) Double Ring

Fig. 1. Classical Regular Topologies

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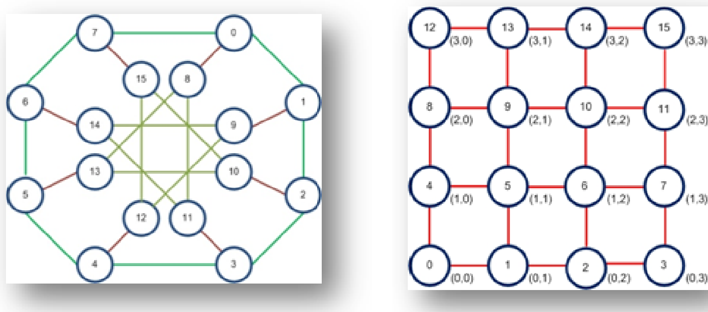
do not interconnect physically neighbor nodes. The links in the outer ring and the links interconnecting the two rings can be described in the same way as the DR structure, but links in the inner ring are interconnecting node Ii and node I(i+p)modq, where q is a positive integer. To avoid forming two separated networks in the inner ring, q must fulfil gcd(p,q)=1 (Greatest Common Divisor), also q is evaluated from 1 to p/2. [7]



(a) N2R (b) Grid

Fig. 2. Regular Topologies

2 WiMAX Outlook

WiMAX is an IEEE 802.16 standard-based technology responsible for bringing the Broadband Wireless Access BWA to the world as an alternative to wired broadband. [10]

In most of scenarios, WiMAX costs less to deploy than any other broadband technology. Berkeley University tried to quantify that difference by an interesting study (published in 2008) with an estimated cost[2] per home passed in function of the techonolgy used. (Fig. 3) [11]

Broadband technology	Cost per home passed
xDSL	30-50 $
Cable	1.200 $
3G	50 $
FTTH	1.250 $
WiMAX	8 $

Fig. 3. Access technology deployment cost

Another important advantage of WiMAX technology is the envisioned cooperation with 3.5G technologies. Cooperation between heterogeneous radio access networks is an important feature in future wireless networks. Interworking between 3G and WLAN has been well investigated [12].

New works and standardization activities start to focus on cooperation issues between WiMAX and HSDPA. Indeed, both mobile WiMAX and HSDPA

[2] Notice that the xDSL cost is low compared to the Cable. This is because it has been considered that the copper infrastructure (last mile) is already deployed.

offer a high bandwidth, a continuous coverage and user mobility. Therefore, it is profitable to make these Radio Access Networks (RANs) cooperate in order to benefit from their joint resources. [12]

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 [13]. The current situation of the IT Infrastructure in Denmark is quite similar to the situation in other developed countries in terms of speed and FTTH deployment [14] [13]. Despite Denmark is leading (in Europe) with respect to broadband availability and penetration, the main technology used in the last mile is still xDSL.

Important backbone networks are already deployed but there exists a bottle neck in the access networks of those users located far from their central offices (local loop) [13].

This bottleneck is due to 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 wired 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. Precisely, it is in this kind of scenarios where WiMAX could play a key role as new access technology due to its main advantages: quick deployment, lower cost and mobility.

4 Methodology

The aim of this section is to study the methodology applied to the case study. The methodology can be divided in two main stages: the location of the nodes and the selection of the topology.

The first stage, in which the nodes are located in the scenario, consists of a computer assisted process that require several iterations due the high number of parameters to optimize (e.g. economical cost, users distribution, network balance, etc.). The details of this stage is out of the goals of the document. Further information can be found in [14].

The second stage, in which this paper is focussed, consists of comparing regular topologies as WiMAX backbone. Each topological model is adapted to the number of nodes defined in the stage 1 (16 nodes for this studied scenario). Then, the following parameters are used for the comparison:

I. Diameter. The maximum distance (number of hops) between 2 nodes in the network. This parameter is important because it has direct influence on the maximum delay.

II. Average distance. The average number of hops between 2 nodes. This parameter is important because has direct influence on the average delay. The average distance for the secondary independent path[3] has also been calculated.

III. Connectivity number (Degree). The number of neighbors of each node. This parameter is important because has direct influence on the reliability of the network.

IV. Economical cost. An estimation of the overall fiber deployment cost. This estimation has been realized using GIS Data and Map Info software. Distances between nodes have been calculated using (Geographic Information System) GIS data and multiplied by the approximate cost of deploying 1 meter of fiber [14]. This is usually the main factor to consider.

Furthermore, some extra qualitative parameters defined in the SQoS evaluation framework presented at the Information Technology and Telecommunication Conference 2004 (ITT 04) [16] have been taken into account:

V. Algorithmic support. For example, topological routing support.

VI. 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. Fig. 4 shows an example of embeddability: the N2R topology embedded in the considered scenario.

VII. 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 Results

Fig.5 summarizes the results obtained after applying the selected topologies to the WiMAX scenario. The first column shows the degree of each topology. In the single ring, double ring and N2R cases it is simple to obtain the degree because they are completely regular topologies. However, in the case of 4 regular Grid it is not so trivial because the topology is not completely regular. Internal nodes have degree 4, whereas the nodes in the sides have degree 3 and the ones at the corners only degree 2.

As it was commented in Sec. 4, the degree has a direct influence on the network reliability because it limits the number of independent physical paths. The grid topology turns out to be the most robust in this field with degree 4 for all the internal nodes, 2 for the corner nodes and 3 for the rest.

[3] In network planning, secondary independent path applies to the possibility of a node A to send data to a node B by using an alternative path phisicaly independent from the primary path.

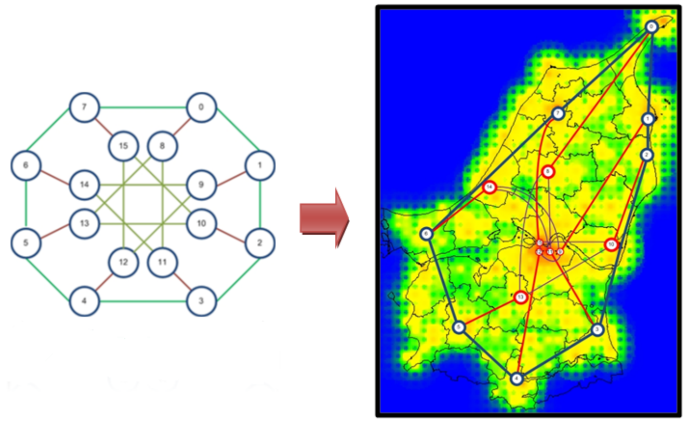


Fig. 4. N2R Physical Topology

Regarding the diameter, as it was expected, single ring shows the worst results due to its structure: To reach an opposite node in a single ring it is necessary to cover half of it. The most valuable technology in this area is N2R. With a diameter of 4 for the first independent path and 5 for the secondary one shows up as the most advanced solution. Notice that despite Grid has degree 4, this has no direct influence in the diameter. Even the double ring presents better results in this aspect. One possible solution to improve the results of the Grid is upgrading it to a "Torus" network. This has been studied in [14].

The average distance is the parameter that most emphasizes the difference between the topologies. Thus, we see that the simplest topology has very low results compared to the rest. 11,73 is the average distance for the secondary path using single ring while the worst secondary path average distance result among the rest of topologies corresponds to N2R and is only 3,9. N2R is the most favorable topology taking into account the first independent path. However, if we also take into account the second one, Grid is the referable solution.

Finally, the economic cost is favorable to the single ring. As reflected in the last column, the economic cost is similar in all the advance topologies. Single ring shows up as the most economic topology but also with the worse properties.

Regarding the non-quantitative parameters, 4 regular grid is the most interesting topology because of its well-known properties to support topological routing and expandability.

Since all the studied topologies presented are based on planar structures, all of them have similar degree of embeddability. Only the 4 regular Grid, upgraded to "Torus" could have some kind of problem.

	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

Fig. 5. Final results (Euros)

6 Conclusion

This paper has proposed WiMAX as Access Network solution for low dense populated areas. The main advantage of this technology is its low deployment cost compared to other new technologies as FTTH.

About the backbone, a comparison framework has been shown. With it, high reliable regular topologies has been compared to traditional solutions as single ring. New topological solutions could be compared in future to the studied ones. Finally, the results of the study have been analyzed achieving the following conclusions:

1. Single ring topology is a really economical solution, but it is also the most limited one in all the studied features. Its large diameter, its lower average distance, and mainly its low degree (that limits the availability) may force it to be non-recommendable for next generation networks.
2. Focusing on degree 3 topologies, it has been proved that N2R obtains better results (in terms of average distances and diameter) than standard double ring.
3. 4-Regular Grid presents a similar cost than N2R. Its diameter is longer than in N2R, but on the other hand, the average distance for the second independent path is shorter. Also the scalability -it is easy to change the 4-Regular mesh into a triangular one or to expand it as showed in [8]- and the possibility of using topological routing are valued but also difficult to quantify.

7 Future Work

Creating an objective evaluation framework, in which each parameter had a scale to be evaluated (including the non-quantitative ones). 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.

Other proposed future work, could consists of comparing (for a given network) the necessary economical investement to achieve a fixed reliability target value by upgrading hardware and by upgrading the network topology.

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