Extensions of the Capacity of Broadband Access Networks

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Abstract—**A main challenge for broadband wired access networks (Hybrid Fiber/Coax or HFC network studied in this paper) is the heavily increasing demand for bandwidth. Several methods can be proposed for enhancing the offered bandwidth of these networks. In this paper, two of them are discussed: node splitting (pushing the fiber closer to the end user) and wireless extensions based on WiMAX.**

Keywords— **Hybrid fiber/Coax networks, wireless broadband access, WiMAX, node splitting**

I. Introduction

DURING the last few years, there has been an increasing demand for broadband network access. The different cable operators deploy today triple-play services, the combination of internet access, video (digital TV and Video on Demand), and telephony services. People use more and more these services, download content, and use peer-to-peer services, causing a heavily increase in the demand for bandwidth.

Our research focuses on determining the most economical way to exploit broadband HFC network access infrastructures in the future to meet the broadband service demands. Improvement of current transmission technology as well as the study of next-generation architecture models (such as Fiber-to-the-Home (FttH) and node splitting (bringing the fiber closer to the home)) and new approaches such as wireless extensions are investigated. In this paper node splitting and wireless extensions based on WiMAX (Worldwide Interoperability for Microwave Access) are presented and analyzed.

II. Hybrid fiber Coax networks

Fig. 1 shows the tree-and-branch architecture of the current HFC access network (typical in Belgium). The hub connects the backbone network to the HFC network. From the hub to the optical node, two fibers are used to transport downlink (DL, traffic from backbone network to home user) and the uplink (UL, traffic from home user to backbone network) signal. From the optical node, the signals are distributed through a thick low-loss trunk coaxial cable. At the bridger amplifier the signal is split in different distribution lines. On the distribution lines, taps are used to connect drop cables to the homes. In most cases four houses are connected to one tap. Trunk and distribution amplifiers are used to compensate for the attenuation of the coaxial cable. Splitters are used to split the signal in equal parts (e.g., a two-way splitter splits the signal of one coaxial cable into two equal signals for two cables).

The combined use of fiber and coaxial cable explains the term

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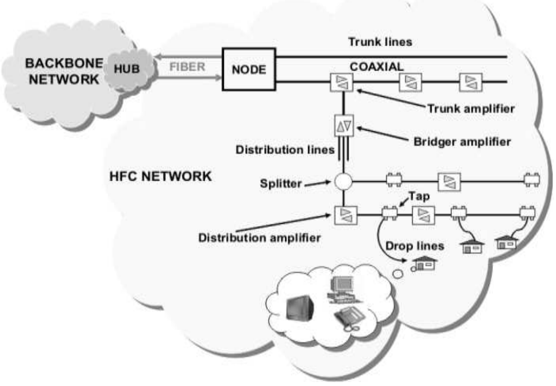

Fig. 1. Architecture of an HFC access network

'Hybrid Fiber/Coax' network. Fig. 1 illustrates that two components can be distinguished in such a branch-and-tree network: the branches and the junctions. The branches represent the coaxial cable with a certain length, which is deployed underground or above ground (on pole or facade of house) and connected to several homes through taps. The junctions represent the initial node, the trunk and distribution amplifiers, and the splitters (above- or underground).

III. Methodology

To meet future bandwidth demands, one can upgrade the current HFC network to a next-generation architecture model (e.g., node splitting) or use new approaches such as wireless extensions in the HFC network (e.g., WiMAX).

A. Node splitting

When applying node splitting, fiber is brought towards selected junctions, which then act as new nodes serving a smaller number of homes than the initial node (so that more bandwidth can be provided per client). The selection of these junctions cannot be done arbitrarily: the most cost-efficient (= cheapest) node splitting architecture has to be determined. Only junctions with amplifiers are considered as potential new nodes because cable operators want to eliminate as much active components as possible. The CapEx as well as the OpEx are high for the active components. The different ranges of houses used to split the networks into smaller parts are 128↔384, 64↔192, 32↔96. These are typical ranges that the cable providers want to apply to their access networks for node splitting (so an average of 256 to 64 HPs per node).

The tool to calculate the most cost-efficient node splitting of an area is implemented in Visio$^{\text{TM}}$ using the macro-extension (Visual Basic). The user can easily draw a network in Visio, define the range, and execute the macro on the network to obtain the

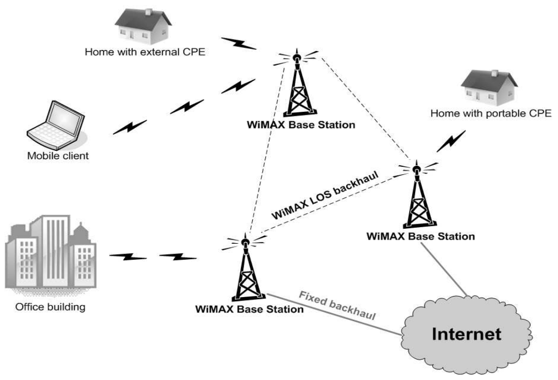

Fig. 2. WiMAX Network

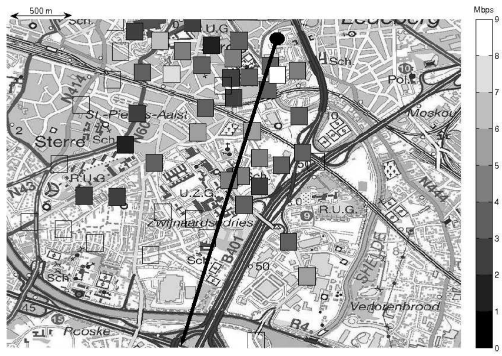

Fig. 3. DL throughput at different locations (● = location of BS)

desired new topology. Two different heuristic techniques are used for the node splitting. The new nodes selected by heuristic 1 and 2 are based on the maximum number of served homes and minimum relative cost, respectively.

B. *Wireless extensions: WiMAX*

Wireless broadband connections may be a complement for 'last mile' fixed access. They can be installed within days at relative low costs, which make them faster to deploy and cheaper in comparison with their wired equivalents. WiMAX (Worldwide Interoperability for Microwave Access) based on the standards IEEE 802.16 [1] and HiperMAN [2] promises an interoperable system and high data rates.
Fig. 2 shows a typical setup for a WiMAX network. Different base station (BS) antennas can be positioned in an urban environment and act as a WiMAX Line-Of-Sight (LOS) backhaul network. These BS are connected to the Internet through a fixed backhaul network. The CPE (Customer Premises Equipment) at the end-user (e.g., Office building, residential houses, mobile client) is connected to the BS, enabling communication with the Internet.

IV. RESULTS

A. *Node splitting*

TABLE I
RESULTS OF NODE SPLITTING FOR ALL RANGES FOR AN URBAN AREA IN BELGIUM

Area	**Range**	**Both Heuristics**	
		New Nodes	**Cost [u]**
Urban	1: 128↔384	5	1180.64
	2: 64↔192	9	2237.64
	3: 32↔96	22	6278.76

Table I summarizes the results of the heuristic techniques applied to an urban environment in Belgium for all ranges (with the cost expressed in units [u]).
When the ranges are divided by two, the cost almost doubles. The cost even increases with a factor 3 comparing range 2 with range 3 (especially due to the larger distances between initial node and new nodes, where the fiber has to be deployed).

B. *Wireless broadband access: WiMAX*

Fig. 3 shows the observed throughput in DL, measured at 50 different locations in an urban environment with the BS height $h_{BS} = 45$ m. The BS is indicated using a black circle. The black line shows the direction of the main beam of the BS. Empty squares indicate locations where no connection was possible. The maximum distance where connection is obtained, is about 2.21 km. However, permanent connection with the BS is only guaranteed within a range of 1 km. A low correlation between DL throughput and distance can be observed, which illustrates that the throughput is more related to environmental conditions than to distance. In DL and UL, a maximum throughput of 8.19 Mbps and 11.8 Mbps are obtained, respectively.

V. CONCLUSIONS

In this paper, two methods are proposed to extend current HFC access networks for future bandwidth demands. By using node splitting, the initial HFC access network is split into smaller parts by deploying fiber closer to the end-user, while WiMAX can be used as a wireless extension to the broadband wired network. Both methods can deliver additional bandwidth to the end-user to meet future broadband demands, each with a certain cost. In the future, the network performance and expenditures of these and other methods (which deliver the required additional bandwidth to the current HFC network) will be investigated and compared to each other.

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REFERENCES

[1] IEEE Standard Std. 802.16-2004, *IEEE Standard for Local and Metropolitan Area Networks, "Part 16: Air interface for fixed broadband wireless access systems"*, 2004.
[2] ETSI, *"ETSI Broadband Radio Access Networks (BRAN) HIPERMAN, Physical (PHY) layer, Standards TS 102 177"*, 2003.

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