

# Chapter 11

## Energy Optimizations in Broadband Access Networks

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### ABSTRACT

*Despite the increased interest in competitive technologies, access network operators are keen to deploy a Digital Subscriber Line (DSL) that uses the existing copper-based telephony infrastructure. This is because of its low deployment cost compared to fiber user based access networks and relatively high bandwidth compared to wireless access networks. As power costs and sustainable business operations become key concerns, energy-efficient access networks including DSL is gaining traction. In this book chapter, the authors study different ways to save energy in access networks: spectral optimization at the physical layer and deployment practices. While they focus on DSL technology, the concepts as described can be readily applied to other access technologies such as fiber, cable, or wireless.*

*Traditionally, communication systems are focused on the rate maximization as an end-user utility and hence do not care about the energy consumption. The authors show that they can trade-off power against data rate, as long as this does not impact the required service by taking into account the power cost to achieve certain user's social utility, e.g. data rate. The potential energy gains depend on both the hardware technology and the aggregate transmit power.*

*The second part of this chapter focuses on deployment practices and describes how different access network architectures can improve the energy consumption, when considering both the telecom equipment and its supporting functions. The authors show that introducing an access network architecture that distributes more functions in the outside plant does not negatively impact energy consumption of the access network. A use case for the Benelux is worked out and a related innovation in the Swisscom access network shows that also in the more centralized architectures further optimizations are possible.<sup>1</sup>*

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## INTRODUCTION

Access nodes such as Digital Subscriber Line Access Multiplexers (DSLAMs) are widely used to offer reliable and affordable network access for a growing base of Internet and triple play users. The Smart2020 report (GeSI, 2008) expects that by 2020 the worldwide carbon emissions due to Information and Communication Technology (ICT) will triple compared to 2002. More specifically, the carbon emissions related to broadband access were projected to increase with a factor of 12 over the same period. On the other hand, the availability of broadband access enables new technologies such as tele- and homeworking, Internet shopping, tele-health, etc., which help to reduce the number of CO<sub>2</sub> emitting transports. While currently the wired access technology is mostly based on DSL, in the future we will also experience a major shift from copper-based access towards fiber access technology such as Passive Optical Network (PON) and Point-to-Point access networks. Although the clear shift towards fiber-based access will help to bring the total number of broadband users connected with a wired connection to exceed 800 Million households by 2013, it is expected that up to 60% of the broadband users will still remain connected with copper twisted pairs, which previously were used for voice communication only (plain old telephony service, or PSTN) but are now extensively used to offer broadband data access too. The main enabling technologies are Asymmetric Digital Subscriber Line (ADSL) and Very high bitrate Digital Subscriber Line (VDSL2) which offer, depending on the flavour, theoretical speeds of up to 100 Mb/s downstream (towards the user) and 50 Mb/s upstream (towards the network). The continuous improvements of DSL based access technologies remain useful as several hundred millions of lines remain candidates for further energy optimizations until fiber based access has replaced all copper-based access.

Energy optimization in access networks is becoming an important and active research area due to economical (the increasing cost of energy) and ecological (the carbon footprint of the service) reasons. A European code of conduct (JRC, 2011, February) sets limits for the use of power consumption per port in the access nodes, e.g. DSLAMs, but also for the end-user equipment, e.g. DSL modems. Similar initiatives are taken in other regions such as by the China Communications Standards Association (CCSA, 2011) and in the USA by the Alliance for Telecommunications Industry Solutions (ATIS, 2011). In our quest to improve the energy efficiency of access networks, we follow different approaches to provide a broad view on solutions to this energy efficiency problem.

First, we provide some insights on the topology of the access network in the end-to-end connectivity. We describe the DSLAM and identify the major contributors to the energy consumption of the broadband line.

Based on this power breakdown, we focus initially on one specific building block of the access node. Without loss of generality, we focus on the Line Driver (LD) in the DSLAM physical layer as it is responsible for up to 50% of the total energy consumption of the DSLAM. We show that 1) using energy efficient hardware technology, e.g. class G or H amplifiers rather than class AB amplifiers, 2) tuning the line driver supply voltages to deliver certain Aggregate Transmit Power (ATP) and 3) minimizing the ATP put on the lines, all these optimizations will significantly reduce the energy consumption of the line driver.

With the appropriate models of the line driver and the physical layer technology, we optimize different settings to achieve certain user's social utility, e.g. rate, at the minimum required power consumption. In the DSL case, the discrete multi-tone modulation is used and the total used ATP is simply sum of the power per carrier and the data rate sum of the bit loading per ton. Within the optimization framework, the spectral optimization trades off the rate and the power. For more

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