Towards Energy Efficient Wireline Networks, An Update From GreenTouch

P. Vetter[1], T. Ayhan[2], K. Kanonakis[3], B. Lannoo[4], K.L. Lee[5], L. Lefevre[6], C. Monney[7], F. Saliou[8], X. Yin[9]
[1]Bell Labs, Alcatel-Lucent, Murray Hill, NJ, USA; [2]Stanford University, Stanford, CA, USA
[3]AIT, Athens, Greece; [4]Ghent University -IBBT, Ghent, Belgium; [5]CEET, Melbourne, Australia;
[6]Inria, Lyon, France; [7]Swisscom, Bern, Switzerland; [8]Orange Lab, Lannion, France; [9]IMEC, Ghent, Belgium

Abstract

The paper describes how a combination of different innovations can improve the power consumption per subscriber of a wireline access and aggregation network by 50x and the energy efficiency per transferred bit by 400x.)

I. INTRODUCTION

Energy consumption has emerged as a major requirement of communication systems in recent years [1]. The goal of the international Greentouch consortium is to demonstrate disruptive research concepts that drastically improve the energy efficiency of the network [2][3]. The present paper provides an overview of GreenTouch projects related to the wireline access network, but similar efforts are on-going for mobile and core.

The next section discusses the economic drivers for a green access and metro aggregation network. The third section describes various approaches to reduce its power consumption. We conclude with an estimation of the total possible efficiency improvement and measure the current progress of the wireline access activities in GreenTouch towards this goal.

II. DRIVERS FOR A MORE ENERGY EFFICIENT NETWORK

Without any efficiency improvements of equipment, the energy consumption of the network would proportionally increase with the traffic volume. Though the industry achieves efficiency improvements, they happen at a slower pace than the traffic growth [4]. As revenues per subscriber will approximately stay flat, the energy becomes an increasing expense, which may diminish any profits in the long term. In addition to this general concern about the sustainability of the business case, there are other economic incentives for better energy efficiency in specific parts of the network.

In central offices, better energy efficiency allows for a higher equipment density, hence reducing cost associated with floor space. Building requirements, as e.g. in [5] limit the maximum power consumption per floor space or per rack. As the power consumption of optical line terminations (OLT) and edge routers increases, bays have to be kept empty or shelves of a rack cannot efficiently be filled in order to meet these requirements. Thermal limits also prevent higher throughput in future integrated circuits and higher density on blades in order to improve the performance and reduce the cost of equipment. The secondary energy, which is mainly related to cooling of central office buildings and accounts for up to half of the total energy consumption, can also be reduced. A smaller size of power supply back-up systems, e.g. batteries or generators, can further improve the cost.

In remote nodes, better energy efficiency reduces the cost related to the supply of electricity to cabinets, curb units, or base stations. Alternatives such as power supply from the home via the twisted pair copper in case of digital subscriber line (DSL) [6] or solar cells at base stations become viable options to reduce operational expenditures. Smaller heat dissipation facilitates simple cooling by convection, instead of forced air or even air conditioning at units in the field.

At the customer premises equipment (CPE), a drastic reduction of the power consumption, which becomes possible with GreenTouch approaches on the long term, could allow for replaceable commercial AA type batteries as back-up in a fiber to the home (FTTH) optical network unit (ONU), instead of the conventional lead acid battery to ensure service availability. A low power ONU could also be powered from the battery of a laptop e.g. via a universal serial bus (USB) cable.

Through tax incentives and regulation of the maximum power consumption of network equipment, cf. e.g. [7], governments pursue energy goals that are beyond any immediate business benefit for the industry, e.g. in order to enable an exit strategy from nuclear power, or to mitigate the carbon impact on global climate change and its consequent cost to the society.

III. POWER REDUCTIONS FOR WIRELINE ACCESS

Figure 1 shows the average power consumption per subscriber and possible improvements. We used the same format as in [3], but updated the data with more accurate values from experiments and simulations, included the effect of power shedding, used more accurate predictions for the traffic growth [8], and added the contribution of a metro aggregation switch (AS) and edge router (ER). GreenTouch evaluates the efficiency improvements against a Gigabit Passive Optical Network (GPON) based FTTH reference architecture in year 2010, which is the starting year of GreenTouch. In order to assess the effect of different saving approaches, the power consumption is broken down per subsystem: opto-electronic transceivers (OE) on the PON, digital electronics of the PON, wireline Ethernet interfaces to the local area network (LAN), home gateway (HGW) processor, OLT, reach extender in case of long reach PON, AS and ER. For completeness, we also show the contribution of wireless LAN (WLAN), though it is not within the scope of the wireline activities in GreenTouch and hence not included in the total efficiency improvement numbers reported in this paper.

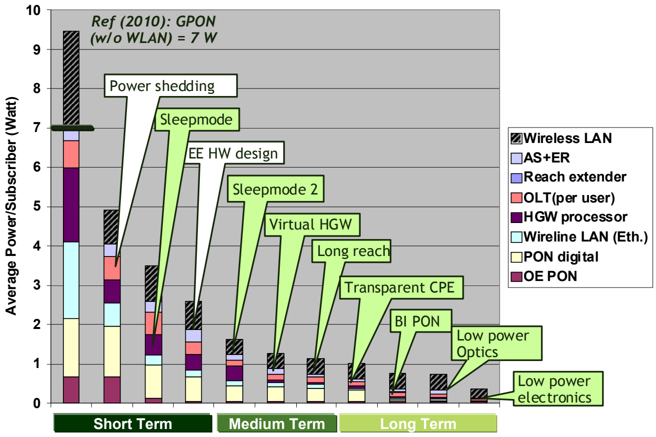

Figure 1. Evolution of average power consumption per user (update of [3]).

On the short term, it is already possible to save energy by power shedding of functional blocks (e.g. a specific LAN interface) that are not in use and only turned on when a session is established. With periodic sleep mode, the average energy consumption of the fiber interfaces of an ONU (cf. ITU-T G.987.3) and the Ethernet LAN (cf. IEEE802.3az) can be reduced. Energy Efficient Hardware (EE HW) design refers to engineering optimizations, such as reduced transfers of data across input/output (I/O) of integrated circuits thanks to further integration, more efficient interconnection techniques, critical review of required memory accesses, and use of clock gating or power switching for parts of an integrated circuit that are not in use. EE HW also includes more efficient cooling techniques in central offices.

On the medium term, we can achieve additional improvements with an advanced sleep mode (labeled "sleep mode 2" in Figure 1) in an ONU, thanks to dedicated hardware designs that feature a smaller sleep power and allow for a faster wake-up, or with load concentration in an OLT. A virtual HGW runs the typical home gateway functions, such as routing, OAM (operations, administration, and maintenance), and security, on a central server in the network instead of a processor on the CPE. GreenTouch demonstrated up to a thousand virtual HGW on a single server [9], which results in a 5x saving of processing power despite a penalty for air-conditioning in the server location. Long reach PON achieves lower power consumption thanks to a better sharing of the line termination, which is moved to the edge router location, and a reach extender, which simpler than the bypassed AS [10].

On the long term, more disruptive concepts are investigated by GreenTouch. A transparent, quasi-passive CPE minimizes connectivity between the first mile and the home network to a simple repeater, or in its ultimate form, even a fully passive device [11]. The functions of a conventional CPE can be moved to a virtual HGW server as described above.

Bit Interleaving PON (Bi-PON) is a new time division multiplexing transfer protocol that reduces the power consumption of the digital electronics for the protocol processing by more than an order, as GreenTouch demonstrated in [12][13]. In a conventional packet based PON system, every ONU processes all downstream data until it is able to extract the incoming packets destined for the local area network and drop the rest of the data. Much power is consumed in the processing of this high throughput, most of which is unnecessary. Bit interleaving allows for selecting the relevant bits immediately behind the clock and data recovery. Further processing is done at the user rate instead of the aggregate line rate, which results in significant power savings.

In addition to PON architectures, GreenTouch is also exploring the fundamental limits of point-to-point optical access technologies [14]. Progress in optical components and electronic circuit technology will further aid energy efficiency.

IV. Summary and Outlook

Thanks to a combination of the described approaches and considering Moore's law for improvements in semiconductors by 2020, it is possible to reduce the average power consumption per subscriber of a wireline access and aggregation network by more than 50x. Considering an annual traffic growth of 8x per subscriber in a mature market between 2010 and 2020 [8], this results in an energy efficiency per transferred bit improvement by 400x over a decade.

As a measure of the progress towards this identified opportunity for wireline access since the start of GreenTouch in 2010, we can report proof of more than 10x gain per subscriber and 100x in efficiency per bit, thanks to the demonstration of sleep mode, Bi-PON, and virtual HGW. The goal is to evaluate additional improvements in on-going projects during the remainder of the GreenTouch program until 2015.

Acknowledgment

The authors would like to thank their colleagues and partners in GreenTouch for valuable contributions.

References

[1] J. Kani, Tutorial at OFC, p. NM2K.1, Los Angeles, March 2012.
[2] GreenTouch consortium: www.greentouch.org
[3] P. Vetter, et al., IEEE ICC, Ottawa, pp. 5941 – 5945, June 2012.
[4] D.C. Kilper, et al., IEEE J. Sel. Quantum. Electronics, vol. 17, no. 2, pp. 275-284, March/April 2011.
[5] NEBS GR63-CORE, Issue 4, April 2012.
[6] J. Maes, et al., IEEE ICC, Ottawa, pp. 3149 – 3153, June 2012.
[7] European Commission, Joint Research Centre, "Code of Conduct on Energy Consumption of Broadband Equipment", Version 4, 2011.
[8] S. Korotky, OFC, Los Angeles, 4-8 March 2012.
[9] J.P. Gelas, Electronic Goes Green Conference (EGG 2012), Berlin, Germany, September 9-12, 2012.
[10] F. Saliou et al, OFC, Los Angeles, p. OThB2, March 2011.
[11] L.G. Kazovsky, et al., ICTON, Stockholm, June 2011.
[12] D. Suvakovic, et al., GreenCom, November 2012.
[13] H.K. Chow, et al. ECOC, Amsterdam, p. Mo.2.B.1, September 2012.
[14] K.L. Lee, et al., IEEE JOCN, Vol. 4 Issue 9, pp.A59-A68, 2012.