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A study on impact of wired access networks for green Internet

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ABSTRACT

The energy consumption of data network equipment used for the Internet is generally unknown, although such equipment is known to use a substantial amount of energy. In addition, there is a lack of related studies with a special focus on wired networking. This paper aims at analyzing the impact of wired access networks in data network for greening the Internet, and encouraging further research in this field by clearly presenting the significance and reasonability of this endeavor. For this work, we first introduce the background and motivation of green networking. Next, we survey the existing works and describe reasonability of our approach, and then we estimate the overall energy consumption of wired access networks by which the energy consumption of data network is driven, calculate CO_2 emissions and economic costs from the energy consumption and explore savings potential of them. Going a step, we analyze the impact of energy consumption, economy, and environment from the use of wired access network equipment depending on IP traffic types. Finally, we present a new viewpoint on energy efficiency focusing on the quality-of-service with future works related to this issue.

1. Introduction

Along with the continual growth of the Internet, energy consumption and greenhouse gas (GHG) emissions from the Internet use have also increased, which is expected to continue for many years to come. Overcoming these concerns is a real challenge for the world's industries and governments. In this respect, the greening of the Internet began to be studied with the goal of improving the energy efficiency of the current Internet.

The number of current electronics is enormous, and a great number of them provide network connectivity. Today's appliances tend to embed computing and networking functionalities. Thus, network connectivity has become nearly ubiquitous, and the total network energy consumption is expected to increase significantly. Although various approaches to edge devices, such as end-user computers and data centers, exist, which are founded on energy-saving mechanisms and power management criteria, the current trend is moving toward a focus on the significant growth in energy consumption associated with network functionality owing to increasing IP traffic from excessive network connectivity. The issue of energy managing mechanisms exploiting network-specific features, such as in an ad hoc network, that must be added into wired network is referred to as *green networking* (Bianzino et al., 2012).

Network connectivity has become a part of daily life, but the amount of energy used to provide such connectivity is largely unknown. In particular, there is a lake of reliable and practical figures regarding energy consumption or the energy savings potential of data network equipment used for the Internet. The Internet relies strongly on electronics. As the Internet has grown, it will eventually be constrained by energy density limitations rather than by the bandwidth of the physical components (Bolla et al., 2011a). Traditionally, networking systems are designed and dimensioned according to principles that are inherently in opposition with green networking objectives: namely, over-provisioning and redundancy, which cause overall energy consumption (Bianzino et al., 2012). The ultimate goal of networking is to provide services to end-users, the quality of such services and of the user experience is an important point. Therefore a major shift is needed in networking research and development to introduce energy-awareness in the network design, without compromising either the quality of service or the network reliability. Moreover, the Internet services will be increasingly diversified and more subdivided by demands for the sophisticated quality-of-service support. Therefore, energy efficiency must be carefully treated with considering a subtle trade-off between energy savings and quality of service.

Furthermore, the energy efficiency of data network equipment needs to be addressed from a broad view embracing issues of economy, environment, and energy. According to SMARTer 2020 Team (2012), the information and communication technology (ICT)-enabled abatement solutions will help reduce the overall

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GHG emissions and energy consumption from all sectors as well as decrease ICT's own GHG emissions and energy consumption. The total global GHG abatement potential enabled by ICT technologies is between five- and seven-times larger than the ICT's own GHG emissions. Moreover, they not only address climate change and energy savings, but also present an opportunity to drive sustainable economic growth (SMARTer 2020 Team, 2012). ICT's GHG emissions account for only about 2% of global GHG emissions, thus we tend to focus on this 2% rather than on the remaining 98%; however, we have to focus on the remaining 98% of needed reductions, which may be enabled through the use of ICT. Energy-efficient ICT solutions may play an important role in transformative changes and overall reductions, which can be called “the 98% window of opportunity” (Pamlin and Pahlman, 2009). Today's trend is embedding network connectivity in electronics, and the Internet is continually expanding; therefore, GHG emissions by data network equipment are expected to increase rapidly. In addition, network technologies will seep into all aspects of industry and assist in energy monitoring to achieve energy efficiency. To conclude, data network equipment has an important role in establishing not only green Internet but also overall the greening of the world.

This paper aims at analyzing the impact of wired access networks in data network for greening the Internet and at encouraging work in this field by clearly presenting the significance and reasonability of this issue. In this paper, we estimate the energy use and savings potential in today's wired access networks, and provide a comprehensive view on green networking using a top-down approach. The remainder of this paper is organized as follows. Section 2 provides the background and motivation of greening the Internet. Section 3 surveys the related works and presents reasonability of our approach. Section 4 includes an estimate of the overall energy consumption, CO_2 emissions and economic costs of wired access networks which drives the energy consumption of data network and explores savings potential of them. Section 5 provides the study on impact of wired access network equipment depending on the traffic type in terms of greening. Section 6 presents the new viewpoint of energy efficiency focused on QoS for green Internet and future works related to this issue. Finally, some concluding remarks are given in Section 7.

2. Background and motivation

The world is being confronted with the twin challenges of ensuring reliable and affordable energy supplies and dealing with climate change, and energy efficiency has been consistently identified as an essential means of moving toward a more sustainable energy future. Energy efficiency improvements can deliver a vast amount of energy savings, and thus CO_2 emissions caused by energy use and production can be reduced. In buildings sector, the huge potential of improvements in energy efficiency remains untapped, and will have the largest impact on energy savings and the mitigation of CO_2 emissions through energy-efficient technologies. According to IEA (2012), residential and commercial buildings account for approximately 32% of the global energy use and almost 10% of the total direct energy-related CO_2 emissions. Energy demands from the buildings sector will more than double by 2050. Much of this growth is fueled by the rising number of residential and commercial buildings. By the international energy agency (IEA) 2DS (2 °C scenario) (IEA, 2014), which assumes the policy action consistent with limiting the long-term global temperature increase to 2 °C, buildings sector can make a 24% contribution to world CO_2 emissions reductions to contribution to 2025.

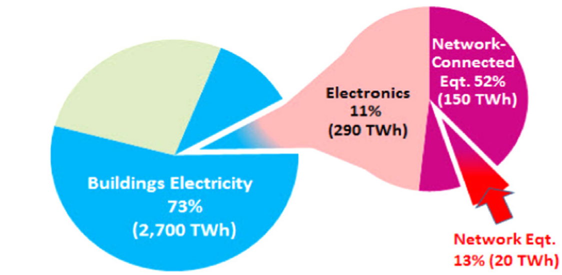

Fig. 1. Electricity consumption of the USA (2006).
Source: Nordman (2009).

Globally, network connectivity is being added to electronics that did not support such functionality in the past, and the demand for network equipment is also increasing. As shown in Fig. 1, buildings in the USA account for over 70% of the total electricity consumption in 2006, and electronics account for almost 11% of building electricity use. Network-connected equipment takes up 52% of all electronic energy consumption.

BIO Intelligence Service (2011) presented the global energy consumption of network-connected equipment used in buildings (e.g., PC, printer, phone, TV, game console, media player, STB, router, and gateway) in Business-As-Usual (BAU) and ECO scenarios. The BAU scenario assumed that continuity is maintained considering the current situation and trends that there is no significant effort to reduce the energy consumption. The ECO scenario assumed that energy saving is possible through implementing power management and power-level reduction policies. This report stated that current network-connected equipment wastes around 20–65% of its energy use owing to inefficiency. In other words, this means that there is about 20–65% energy savings potential through the market penetration of energy efficiency technologies. Here, the figure of 20% was calculated assuming mandatory implementation of a power-down sequence in all network-connected equipment, activated by default when the equipment remains “idle” for a defined period of time, and the figure of 65% was in the hypothetical case of all the products featuring non-operating mode power consumption of 1 W of less.

The wasted energy by network-connected equipment is caused by the absence of an effective power management of network-connected equipment. Greater quantities of new network-connected products are entering the market, and such products are spending more time in higher power modes owing to network-related requirements and a lack of effective power management strategies (BIO Intelligence Service, 2011).

It is useful to distinguish between network-connected edge devices and network equipment (where the main function is to maintain network links) because their function and energy-saving potential are different. Thus far, edge devices have become an object of attention in terms of energy efficiency, and many related researches have been carried out; however, the energy consumption and savings potential of network equipment have been relatively unknown, and therefore need to be discussed in depth. The reasons for conserving energy in wired data network equipment for the Internet are as follows. First, inefficiency exists in networking system of the current Internet.

By Bianzino et al. (2012), Networking infrastructure involves high-performance and high-availability machines. Due to the lack of quality of service (QoS) support of Internet architecture, they rely on powerful devices, which are organized in an over-provisioned and redundant architecture. As a result, during low traffic periods, over-provisioned networks are also over energy consuming. For resiliency and fault tolerance, networks are also designed in a redundant manner. Devices are added to the