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Engineering View of Green Networking: Design Features

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Abstract: The reduction of energy consumption has become a key issue for industries, because of economical, enviromental and marketing reasons. Data – centers and networking infrastructure involve high – performance and high – availability machines. They therefore rely on powerful devices, which require energy – consuming air conditioning to sustain their operation, and which are organized in a redundant architecture. In recent years, valuable efforts have indeed been dedicated to reducing unnecessary energy expenditure, which is usually nicknamed as a greening of the networking technologies and protocols.

Keywords: Network Devices, Power Consumption, Energy-Efficiency, Green Communications

1. Introduction

Spent of Green House Gases (GHG) increased during the recent years. According to a report published by the Eupopean Union [1], a decrease in emission volume of 15% - 30% is required before year 2020 to keep the global temperature increase below 2 degrees C.

GHG economical effects have been investigated and their financial damage has been put in perspective with the potential economical benefits that would follow GHG reduction. In particular, [2] projected that a 1/3 reduction of the GHG emissions may generate an economical benefit higher than the investment required to reach this goal.

From an enviromental point of view, the objective of green networking is to aim at the minimization of the GHG emissions. The first step could be to enforce as much as possible the use of renewable energy in Information and Communication Technology (ICT). In ICT sector, the volume of CO_2 emissions produced by ICT sector alone has been estimated to an approximate 2% of the total man – made emissions in [3]. In developed countries such as the United Kingdom, this figure rises up to 10% [4]. These studies showed that ICT represents an important source of energy consumption and GHG emissions. So making network devices and protocols aware of the energy they consume should be supporter to the green idea and decisions.

Another track is to design low power components, able to offer the same level of performance. Redesigning the network architecture itself, for instance by de – locating network equipment towards strategic places, may yield subtantial energy savings too for two main reasons. The first reason is related to the losses that appear when energy is transported. The second reason is related to the cooling of electronic devices. Air cooling represents an important share of the energy expenditure in data centers. Furthermore, large ICT companies like Google displaced their server farms to the banks of the Colombia River to take advantage of the energy offered by the hydroelectric power plants nearby. The water flow provided by the river may in addition be used within the cooling systems, as experimented by Google [5], An alternative cooling system, investigated by Microsoft in the Tent and Marlow projects [6] consists in leaving servers in the open air so that heating dissipates more easily.

Geographical delocalization is also a promising approach from an economical point of view. Companies like Amazon explore such geographical delocalization of services, [7] in order to reduce the operational expenditures related to energy supply.

2. Engineering View of Green Networking

From an engineering point of view, green networking may be beter seen as a way to reduce energy required to carry out a given task while maintaining the same level of performance.

For green networking idea, there are four key paradigms that the network infrastructure can exploit this idea. They individuate four classes of solution in [8] namely resource consolidation, virtualization, selective connectedness and proportional computing.

In research consolidation, it is achieved by shutting down some lightly loaded routers and rerouting the traffic on a smaller number of active network equipment.

In selective connectedness of devices, as outlined in [9], [10], it allows instead to turn off unused resources at the edge of the network. For instance, edge nodes can go idle in order to avoid supporting network connectivity tasks. These tasks may have to be taken over by other nodes, such as proxies, so that no fundamental change is required in network protocols.

Virtualization regroups a set of mechanisms allowing more than one service to operate on the same piece of hardware, thus improve the hardware utilization. It results in a lowered energy consumption, as long as a single machine under high load consumes less than several lightly loaded ones. A typical example of virtualization consists in sharing servers in data centers, thus reducing hardware costs, improving energy management and reducing energy and cooling costs, ultimately reducing data center carbon footprint.

Proportional computing was introduced in [11] and may be applied to a system as a whole, to network protocols, as well as to individual devices and components. Dynamic Voltage Scaling and Adaptive Link Rate are typical examples of proportional computing. Dynamic Voltage Scaling [12] reduces the energy state of the CPU as a function of a system load, while Adaptive Link Rate applies a similar concept to network interfaces, reducing their capacity, and thus their consumption, as a function of the link load.

It is necessary to identify where the largest energy consumptions could take place to attempt to reduce the energy consumption. In 2002, [13] analyzed the energy consumption contributions of different categories of equipment in the global internet. It is pointed out that local area networks, through hubs and switches, are responsible for about 80% of the total Internet consumption at that time. More recently, studies have started suggesting an increase of the consumption in the network core: for instance, in 2009 Deutsche Telekom [14] forecasts that by year 2017, the power consumption of the network core will be equal to that of the network access.

In an another work for greening idea [15], it is discussed the impact on network protocols of saving energy by putting network interfaces and other router & switch components to sleep. According to the [16] and [17], the energy consumption of the Internet is too high. The energy consumptions of the internet in recent years of U.S is represented in [18]. According to this study, the expectation of the energy consumption of networking devices will increase by 1 TW – h in the future. In the 2000's a percentage of total energy drawn by the devices in U.S approximately 0.07% of the total.

In [15], they compared the internet backbone with the wireless link, it shows that the wireless link is almost 1.25x times more efficient. If assuming that the transmitter uses a directional antenna then the difference is more glaring. They ideally get an improvement of 10x over the wired Internet.

As another example, the total energy consumption in India in recent years was approximately 509 TW – h [19]. Using the population based extrapolation for Internet connectivity, it is seen that networking equipment in India would use 6.05 x 1 Billion/250 Million = 24.2 TW – h or 4.75% of the total energy consumed. This is a significant fraction of the total and provides a strong motivation to maket he networking equipment more efficient.

To achieve the goal of energy efficiency, the research must focus on decreasing the amount of energy consumed by the network nodes. Unfortunately, most of the energy savings at the physical layer has already been achieved. Therefore the key to the energy conservation in ICT industry lies within the higher levels of the protocol stack. Various research efforts are being conducted at the data link, network, transport, OS/middleware and application protocol layers to address energy efficiency issues for communication networks.

3. Power Consumption of Wireless Devices

Wireless devices which have limited power supply tend to be used anywhere and anytime. But, unlike the other areas of computer technology, battery technology has not experienced a significant progress in the past decades. [20] states that, unless a breakthrough occurs in the battery technology, it will be difficult to decrease the energy consumed in these nodes. PCs, workstations and mobile computers need to process multimedia information. However, such processing is expensive in terms of both bandwidth and battery power. Thus, conserving bandwidth also means conserving battery life. To reduce power dissipation, the CPUs can be operated at lower speeds [21] by decreasing the supply voltage. [22] presents different page placement algorithms that exploit the new power management features of memory technology. The study considers DRAM chips that support different power modes; active, standby, nap and power down. Trace driven and execution driven simulations show that improvement of 6 % to 55 % in the energy x delay metric.

Although these techniques can result energy savings, other venues should also be explored to improve the energy efficiency. One way to achieve this for the future networks is to design the higher layers of the protocol stack with energy efficient methods. For example, avoiding or eliminating collisions as much as possible within the MAC sublayer can result in significant energy savings as collisions result in retransmissions. The Energy Conserving Medium Access Control (EC–MAC) protocol [23] avoids collisions by broadcasting a schedule that contains data transmission starting times for each mobile node. The EC–MAC studies use fixed length frames. Fixed length frames are more desirable from the energy efficiency perspective; however, variable length frames are better for meeting the demands of the bursty traffic. The energy efficiency of EC–MAC is compared with IEEE 802.11 and other MAC protocols in [24]. While the EC–MAC protocol is designed primarily for infrastructure networks, the Power Aware Multi Access

(PAMAS) [25] protocol is designed for ad hoc networks. PAMAS protocol turns off the transceiver whenever the node determines that it will not be receiving data for a certain period of time. The usage of separate control channel allows for mobiles to determine when and for how long to power off. The results from simulation and analysis show that depending on the topology of the network 10% to 70% power savings can be achieved for fully connected topologies.

In the IEEE 802.11 [26] standard, a mobile that wishes to conserve power may switch to sleep mode and inform the base station of this decision. The base station buffers the packets that are destined to the sleeping mobile and periodically transmits a beacon that contains information about such buffered packets. This approach conserves power but results in additional delays at the mobile that may affect the QoS. A comparison of power saving mechanisms in the IEEE 802.11 and HIPERLAN standards is presented in [27]. [28] illustrates a load sharing method for saving energy in an IEEE 802.11 network. Simulation results indicate total power savings of 5 to 15 % can be achieved.

[29] studies an ARQ strategy that includes an adaptive error control protocol. The energy efficiency of a protocol is defined as the ratio between total amount of data delivered and total energy consumed. If more data is successfully transmitted for a given amount of energy consumption, the energy efficiency of the protocol increases. In [30], using a Markov model based analysis and recursive technique, the ARQ probing protocol is compared to traditional ARQ schemes, and the tradeoff between performance and energy efficiency is investigated. These studies conclude that the energy efficiency of a protocol may be maximized by decreasing the number of transmission attempts and/or transmission power in the wireless environment, without necessarily maximizing the throughput. While, the above schemes include only ARQ strategies, [31] combines ARQ and FEC strategies. This protocol supports that there exists no energy efficient “one – size – fits – all” error control scheme for all traffic types and channel conditions. Therefore, error control schemes should be customized to traffic requirements and channel conditions in order to obtain more optimal energy savings for each different type of connection.

4. Energy-Efficiency in Transport Layer

There are also various studies in the transport layer. In [32] the energy efficiency of TCP is discussed. Results of this study show that error correction significantly affects the energy performance of TCP and that congestion control algorithms of TCP actually allow for greater energy savings by backing off and waiting during error bursts. Simulation results presented in [33] point out that TCP probing achieves higher throughput values while spending less energy. An experimental transport protocol, called Wave and Wait protocol (WWP) [34], is developed specifically for a wireless environment with limited power.

Conserving energy in the application layer has also been considered. The summary of software strategies for energy efficiency is presented in [35]. In [36, 37] APIs such as Advanced Configuration and power interface and power management analysis tools such as power monitor is developed to assist software developers in creating programs that are power conserving. PowerScope [38] is a power management tool developed at the Carnegie Mellon University. PowerScope maps energy consumption to program structure, producing a profile of energy usage by process and procedure. The authors report a 46 % reduction in energy consumption of an adaptive video playing application by taking advantages of the information provided by PowerScope. [39] considers the impact of energy efficiency on database systems. Energy efficiency in database design by minimizing power consumed per transaction through embedded indexing has been addressed in this study. [40] discusses energy efficient query optimization for a database system. In [41], research on processing encoded video for transmission under low battery power conditions is presented. The basic idea of this work is to decrease the number of bits transmitted over the wireless link in response to low-power situations. Decreasing the number of transmitted bits reduces the energy consumption due to reduced transmitter usage.

5. Conclusion

Nowadays, especially 4G and 5G mobile wireless networks use large amount of data interchange and rate. Due to this huge data usage of these technologies energy-efficiency and greening ideas become so significant. This paper aims to give a general view to power consumption of networks and network devices. This paper also aims to underline the engineering point of view of green networking solutions to improve the existing networking hardwares and softwares to provide suitable infrastructure to 4G and 5G systems.

References

[1] D. Pamlin and K. Szomol´anyi, “Saving the Climate @ the Speed of Light–First Roadmap for Reduced CO2 Emissions in the EU and Beyond.” World Wildlife Fund and European Telecommunications Network Operators’ Association, April 2007.

[2] W. D. Nordhaus, “To Slow or Not to Slow: the Economics of the Greenhouse Effect,”The Economic Journal, vol. 101, pp. 920–937, July 1991.

[3] Global Action Plan, “An Inefficient Truth.” Global Action Plan Report, http://globalactionplan.org.uk, Dec. 2007.

[4] M. Webb, “SMART 2020: Enabling the Low Carbon Economy in the Information Age.” The Climate Group. London, June 2008.

[5] R. H. Katz, “Tech Titans Building Boom,”IEEE Spectrum, vol. 46,pp. 40–54, Feb. 2009.

[6] R. Barga, “Cloud Computing – A Microsoft Research Perspective.” Keynote Speech at IEEE P2P 2009 (Seattle, WA, USA).

[7] A. Qureshi, R. Weber, H. Balakrishnan, J. Guttag, and B. Maggs, “Cut-ting the Electric Bill for Internet-Scale Systems,” in Proceedings of the ACM Conference on Applications, Technologies, Architectures, and Pro-tocols for Computer Communications (SIGCOMM 2009), (Barcelona, Spain), Aug. 2009.

[8] A. P. Bianzino, C. Chaudet, D. Rossi, J.L. Rougier “A Survey of Green Networking Research.” Communications Surveys & Tutorials, IEEE Volume:14 , Issue: 1.

[9] K. Christensen, C. Gunaratne, B. Nordman, and A. D. George, “The Next Frontier for Communications Networks: Power Management,” Computer Communications, vol. 27, pp. 1758–1770, Dec. 2004.

[10] M. Allman, K. Christensen, B. Nordman, and V. Paxson, “Enabling an Energy-Efficient Future Internet Through Selectively Connected End Systems,” inProceedings of the Sixth ACM Workshop on Hot Topics in Networks (HotNets-VI), (Atlanta, Georgia, USA), Nov. 2007.

[11] L. A. Barroso and U. H¨ olzle, “The Case for Energy-Proportional Computing,”IEEE Computer, vol. 40, pp. 33 – 37, Dec. 2007.

[12] M. Weiser, B. Welch, A. Demers, and S. Shenker, “Scheduling for Reduced CPU Energy,” inProceedings of the 1st USENIX Conference on Operating Systems Design and Implementation (OSDI 1994), (Monterey, California), Nov. 1994.

[13] K. W. Roth, F. Goldstein, and J. Kleinman, “Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings Volume I: Energy Consumption Baseline,” Tech. Rep., National Tech-nical Information Service (NTIS), US Department of Commerce, Jan. 2002.

[14] C. Lange, “Energy-related aspects in backbone networks,” inProceed-ings of 35th European Conference on Optical Communication (ECOC 2009), (Wien, AU), September 2009.

[15] M. Gupta and S. Singh, Green ing of the internet. In Proceedings of the 2003 Conference on Applications, Technologies, Architectures, and Protocols for Computer Communications, ser. SIGCOMM’03 , ACM, New York, 2003, pp. 19–26.

[16] International Energy Agency workshop on The Future Impact of Information and Communication Technologies on the Energy System, Feb 21 – 22, 2002, Paris, France. http://www.iea.org/weo/ict/agenda.htm.

[17] Gilbert Held, “Emerging Technology: The Price of Power Consumption”, Network Magazine, Sep.5, 2001.

[18] Kurt W. Roth, Fred Goldstein, and Jonathan Kleinman, “Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings Volume I: Energy Consumption Baseline”, National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA 22161, NTIS Number: PB2002-101438.

[19] 2002 CIA World Factbook, http://www.cia.gov/cia/publications/factbook (2003).

[20] P. Lettieri and M. Srivastava, Advances in wireless terminals, IEEE Personal Communications 6(1) (1999) 6–18.

[21] A. Chandrakasan and R.W. Brodersen, Low Power Digital CMOS De-sign (Kluwer Academic, Norwell, MA, 1995).

[22] A.R. Lebeck, X. Fan, H. Zeng and C. Ellis, Power-aware page allocation, in: Proc. of Ninth ACM ASPLOS (2000) pp. 105–116.

[23] K.M. Sivalingam, J.-C. Chen, P. Agrawal and M. Srivastava, Design and analysis of low-power access protocols for wireless and mobile ATM networks, Wireless Networks 6(1) (2000) 73–87.

[24] J.-C. Chen, K.M. Sivalingam and P. Agrawal, Performance comparison of battery power consumption in wireless multiple access proto-cols, Wireless Networks 5(6) (1999) 445–460.

[25] S. Singh and C.S. Raghavendra, PAMAS: Power aware multi-access protocol with signalling for ad hoc networks, Computer Communication Review 28(3) (1998) 5–26.

[26] IEEE, Wireless LAN medium access control (MAC) and physical layer (PHY) Spec, IEEE 802.11 standard (1998).

[27] H. Woesner, J.-P. Ebert, M. Schlager and A. Wolisz, Power-saving mechanisms in emerging standards for wireless LANs: the MAC level perspective, IEEE Personal Communications 5(3) (1998) 40–48.

[28] I.B. Dhaou, A novel load-sharing algorithm for energy efficient MAC protocol compliant with 802.11 WLAN, in: Proc. IEEE Vehicular Technology Conference, Amsterdam, Holland (1999).

[29] M. Zorzi and R. Rao, Energy constrained error control for wireless channels, IEEE Personal Communications (1997).

[30] M. Zorzi and R.R. Rao, Error control and energy consumption in communications for nomadic computing, IEEE Transactions on Computers 46(3) (1997) 279–289.

[31] P. Lettieri, C. Fragouli and M.B. Srivastava, Low power error control for wireless links, in: Proc. ACM MobiCom, Budapest, Hungary (1997).

[32] M. Zorzi and R.R. Rao, Energy efficiency of TCP in a local wireless environment, Mobile Networks and Applications (2000) accepted.

[33] V. Tsaoussidis and H. Badr, TCP-probing: towards an error control schema with energy and throughput performance gain, in: International Conference on Network Protocols, Osaka, Japan (2000).

[34] V. Tsaoussidis, A. Lahanas and H. Badr, Wave & Wait protocol (WWP): low energy, high throughput for mobile IP-devices, in: Proc. of 8th IEEE Conference on Networks (ICON) 2000, Singapore (2000).

[35] J.R. Lorch and A.J. Smith, Software strategies for portable computer energy management, IEEE Personal Communications 5(3) (1998) 60–73.

[36] Intel Corporation, Intel Power Measurement Tools (2000), http:// developer.intel.com/design/mobile/intelpower/tools/.

[37] Intel Corporation, Microsoft and Toshiba Corporation, Advanced Configuration & Power Interface (2000), http://www.teleport.com/˜acpi/.

[38] J. Flinn and M. Satyanarayanan, PowerScope: A tool for profiling the energy usage of mobile applications, in: Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications (1999), http://www.cs.cmu.edu/user/jflinn/www/pscope.html.

[39] T. Imielinski, S. Vishwanathan and B.R. Badrinath, Energy efficient indexing on air, in: Proceedings of the International Conference on Management of Data (ACM-SIGMOD) (1994).

[40] R. Alonso and S. Ganguly, Energy efficient query optimization, Technical report MITL-TR-33-92, Matsushita Info Tech Lab, Princeton, NJ (1993).

[41] International Energy Agency workshop on The Future Impact of Information and Communication Technologies on the Energy System, Feb 21 – 22, 2002, Paris, France.