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Energy Efficient Networks: A Critical Review

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ABSTRACT

With the alarming increase in energy consumption of the Internet, it is now very important to design, develop and manage Energy-efficient next-generation network architectures. Already existing network infrastructures and technologiesconsumes a whole lot of energy; but as more and more network technologies are introduced, more and more energy is consumed in networks. This paper studies the concept of green networks (Energy Efficient Networks), and outlines its significance in Modern and Future Telecommunication Networks. Furthermore, the techniques for Wireless Network Energy Efficiency are summarized such as OFDMA networks, MIMO techniques, and Relay Transmission.Potential benefits and solutions of Energy efficiency in networks were also discussed.

Keywords: Energy Efficient Networks; Network technologies; OFDMA; MIMO; Relay Transmission; Ethernet; EEE; 802.3az

1.0 INTRODUCTION

Spiralling energy costs and increasing demand for a greener environment have made energy efficiency a hot subject in data networking. Governments and businesses around the world are looking for and promoting a new generation of energy efficient networking equipment. Energy is becoming the issue of the future; Energy consumption is causing dramatic climate changes. We must cope with this and look for ways towards reducing energy consumption at all cost.

Energy Efficient Networking is a method of reducing energy use in Networks through an Ethernet Interface; this will be accomplished by facilitating transitions to and from lower power consumption in response to changes in network demand (Gunaratne et al., 2006). What this means is that a network should be able to change to a lower link speed during periods of low link utilization.

Advances in Information and Communication Technology (ICT) has provided us with diverse opportunities in beautifying our lifestyles, supporting socio-economic development worldwide and in increasing human and business productivity; by providing user and environmental friendly technologies (such as E-Commerce, Sensor Networks, Online Shopping, Remote Communication, etc.). With the explosive growth of this ICT services and infrastructures, there is an increasing number of internet traffic; and this increase will continue over the coming years because of large scale use of the internet. This explosive growth of ICT services and technology has led to the increase greenhouse gas emission and in the level of energy consumption of the ICT sector. ICT sector produces about 3% of total emission of greenhouse gases (Trend CCW, 2011).

It is reported that the total energy consumed by the infrastructure of cellular wireless networks, wired communication networks, and internet takes up more than 3% of the worldwide electric energy consumption nowadays (Fettweiset al., 2008) and the portion is expected to increase rapidly in the future. Leischinget al. (2009) posited that since more computers, Networks and Communication equipment are being deployed every year, 8% of the world’s electricity is consumed by ICT. In Germany alone, Electricity demand of ICT is almost 11% of the total electricity consumption (Trend CCW, 2011).

Telecom networks constitute a significant part of ICT. With the growth of traffic volume in telecom networks, their energy consumption is also increasing rapidly. If energy consumption of the ICT sector continues to grow at an alarming rate, energy shortage will represent an obstacle for future ICT and telecom network expansion. Therefore, it is imperative to develop energy-efficient ("green") network solutions for sustainable ICT growth; to reduce energy consumption and CO_2 emission. Until recently, telecom researchers mainly focused on designing networks with optimized resources (e.g., bandwidth, cost, etc.). With the increasing energy demand of the Internet, it is now imperative to satisfy another design objective – energy efficiency (Pulak, 2011).

1.1 Objective of Study

The general objective of this research is:

1. To Study the meaning and importance of energy efficient networks
2. To outline the environmental and cost effects of ICT in Energy Efficient Networks
3. To understand the techniques of Energy network efficiency

2.0 OVERVIEW OF POWER CONSUMPTION IN NETWORKS

The European Union has targeted a 20% energy consumption reduction by year 2020. A part of this energy reduction scheme concerns the telecommunication industry and ICT that participates in a direct, indirect and systematic way (ITU, 2008). The goal is to deploy telecommunication networks enabling power efficiency, yielding a small ratio of required Watts per Gbps and Watts per user.

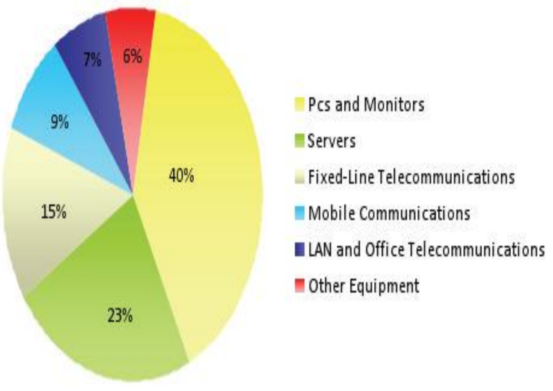

Figure 1: Energy Utilization of ICT subsectors (Source: George et al, 2010)

Figure 1 above outlines different subsectors of ICT and its energy consumption. The nodes in our networks require more energy to power them. The servers and both the fixed-line and Mobile communication consumes about 50% of available power.

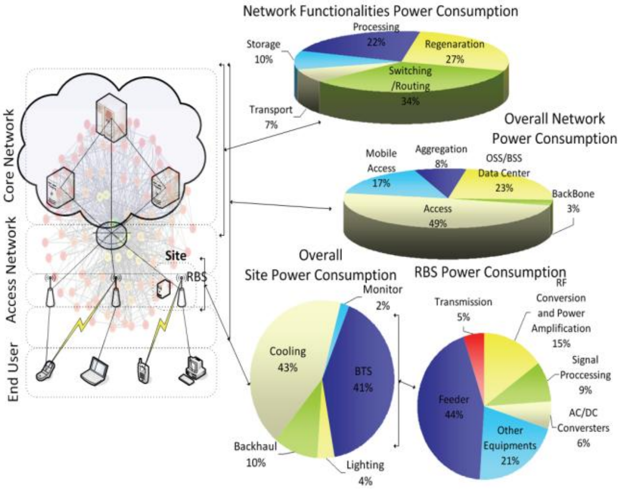

Figure 2: Power Consumption in different network layers (Source: George et al, 2010)

Considering the overall performance and functionality of a network in figure 2, energy consumption is higher in the Access part of the network, and in the operation of data centres that provides computations, storage, applications and data transfer in a network (Gladisch et al, 2008). The main functionalities of a network can be summarized as the process of regeneration, transportation, storage, routing, switching and processing of data (Vukovic, 2003). In Figure 2 the power consumption patterns of these processes are presented and it can be observed that the largest part of energy is consumed for routing/switching, regeneration and processing of data. Both communication protocols and electronic devices are responsible for this consumption and this imposes challenges for more sophisticated transport techniques, thermal removal from switches or the servers and less redundant data transfers. A characteristic example of energy efficiency in electronic equipments for these functionalities is shown in Table 1 below:

Table 1: Power Efficiency of Network Equipments (Source: Vukovic, 2003)

EQUIPMENTS	POWER EFFICIENCY (W/Gbps)
Router	40
IP Switch	25
Transport TDM	80
ATM Switch	80

For mobile networks, a crucial factor affecting network power consumption is the site operation that incorporates base station equipments (GreenPower, 2009), (Ericsson, 2007). In the last part of Figure 2 the power within the overall site and the base station (BTS base transceiver station) itself is presented. It is obvious that the greatest portion of energy is consumed for cooling of equipments and base station operation. Monitor operation and lighting requires the minimum of energy.

3.0 TRADITIONAL ENERGY EFFICIENT NETWORK

To address the increasing power consumption, the IEEE came out with an Ethernet 802.3az standard, a.k.a. Energy-Efficient Ethernet (EEE) standard, that implements low-power idle (LPI) modes for Ethernet BASE-T transceivers (100Mb, 1GbE, and 10GbE) as well as the backplane physical layer. The main EEN idea is to power links down in periods of low utilization (or completely idle) and to power links back up when they need to transmit data again. This idea based on a well known fact that typical server/client Ethernet link in typical network environment is idle most of the time while traffic bursts occur only occasionally.

The IEEE 802.3az specifies the protocol of LPI signaling for both sides of the physical link, enables rapid adjustments of power saving modes of the connected devices, and allows powering down transmitting and receiving functions while no data is sent.

3.1 Power Over Ethernet (PoE) as a Power Savings Mechanism

A major reason for utilizing PoE to power devices instead of using AC supply bricks is the capability to remotely shutdown devices and to reduce cable instalment. By controlling when devices are on and off, a dramatic amount of power can be saved. For example, night-time cameras can be shutdown during the day (and vice-versa) from a centralized point, IEEE802.11 WLAN access points can be turned on to increase coverage/bandwidth or off at times of low utilization, and IP phones can be turned off during evenings or weekends. In multi-port installations, statistics also play in PoE’s favour. While a single AC power brick needs to support a device in all of its operating modes with a shared power supply by multiple POE devices, the power supply can be sized according to the average power utilization in the same manner employed for years in POTS (Plain Old Telephone System) telephony. This represents a great reduction of idle switching power supply losses which typically amount to 10% to 20% of the maximum power supply load. When more power is necessary, it is in many cases possible to add an additional power supply to a PoE switch or Midspan while making sure that the power is sized according to the growing necessities of a business.

4.0 THE PROBLEMS AND POTENTIAL SAVINGS FROM ENERGY EFFICIENT NETWORKS (ASSUME 100% ADOPTION)

4.1 The Problems

Baseline (2002) stated that in the United States, Office equipment, Network equipments and servers consumes 97 TWh/year of energy; which translates into $8billion/year being expended. While a typical switch with 24 ports, running at 1Gbp/s, consumes an average of 20Watts power. All Electronics – IT equipment (PCs, Monitors, Printers, servers e.t.c.) consumer electronics, and telephony; for Residential, commercial, industrial areas consumes at least 250 TWh/year which is roughly $20 billion/year (*Based on .08$/kWh; rates are rising*). Over 180 million tonsof $CO_2$is emitted per year, which is roughly equivalent to the amount emitted by 35 million cars!

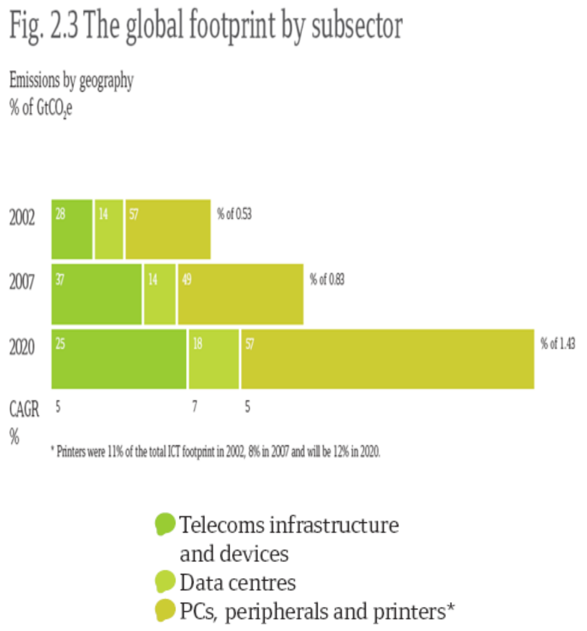

Figure 3: Major CO_2 contribution among Telecoms devices, Data centers and PCs respectively (Source: SMART 2020 REPORT)

From figure 3 above, Personal Computers and not Industrial Data centres are major contributor of CO_2.

4.2 Potential Savings

4.2.1 Residential

Personal Computers, Network equipment, Monitors and other equipment in residential areas will only consume between 1.73 and 2.60 TWh/year; which is estimated to be about $139 to $208 million/year

4.2.2 Commercial

Commercial areas include both small and large scale offices and buildings. PCs, switches, printers and other equipments will consume between 1.47 and 2.21 TWh/year, which is estimated to be about $118 to $177 million/year

4.2.3 Data Centres

Data centres include Internet Service providers (ISPs) and other large Network Infrastructural industries. Servers, storage, switches and routers in Data centres are expected to consume between 0.53 and 1.05 TWh/year, which is estimated to be about $42 to $84 million/year.

There is a reduced power and cooling burden in data centers.

Bottom line is that Energy Efficient Networks provides real economic benefit through substantial energy savings.

In summary, if an Energy Efficient network is properly designed and implemented, a total of about $298 to $469 million/year will only be expended, as against a total of $8billion originally expended (Baseline, 2002).

4.2.4 Energy savings: Impact on National Economy

Countries of the world where ICT is implemented are seeking better ways to reduce their energy requirements. Daily energy needs are increasing and there should be a way of reducing the energy consumption rate as this has a direct impact on a nation's Economy.

The budget of the United States of America in the year 2014 is 18.23 trillion dollars (Wikipedia 2014). And with an estimated 310.6 million PCs available in the USA, and each one having at least one Ethernet Port. A traditional Ethernet port consumes about 1.34wh of energy, and if the system is powered on for at least 16 hours in a day, the energy consumed in a day would be 1.34wh * 16 hours = 21.44 watt-hours * 900 million = 6,659,000,000 watt hours / day.

This figure though scary when really analysed, gives us the amount of power consumed in a year by only consumer PCs.

According to Baseline (2002), in the United States alone, Office equipment, Network equipments and servers consumes 97 TWh/year of energy; which translates into $8billion/year being expended. While a typical switch with 24 ports, running at 1Gbp/s, consumes an average of 20Watts power. All Electronics – IT equipment (PCs, Monitors, Printers, servers e.t.c.) consumer electronics, and telephony; for Residential, commercial, industrial areas consumes at least 250 TWh/year which is roughly $20 billion/year (*Based on .08$/kWh; rates are rising*).

Summing up these data, cost of powering IT equipmentsis an average of 20 billion/year at 250 TWh/year. The cost of powering Network equipment and servers is about $8billion/year.

Commercial areas, which include both small and large scale offices and buildings PCs, switches, printers and other equipments will consume between 1.47 and 2.21 TWh/year, which is estimated to be about $118 to $177 million/year

Data centres consume between 0.53 and 1.05 TWh /year, which is estimated to be about $42 to $84 million/year.

The total of these cost approximations will give us as sum total of
$84 million/year +
$177 million/year +
$20 billion/year +
$8billion/year
= 28.261 billion dollars / year

Relating this to the Budget for the Year 2014, $18.23 trillion, $ 28.261 billion dollars is 0.15% of the whole budget spent on powering PCs.80% of the cost is saved, when we fully implement EEN, these numbers can be greatly reduced so the cost savings can be diverted to another sector of the economy for Infrastructural development.So instead of spending 28.261 billion dollars we save $22.6088 billion and spend about $5.6522 billion*.

** This is a reflective estimate of savings possible in the USA, other countries may vary as their power consumption and power generation varies*

5.0 ENERGY EFFICIENT SOLUTIONS FOR NETWORKS

The benefits of adopting an Energy Efficient Network are so enormous. Some of them include:

1. Enhanced Power Optimization
2. In some organizations, saving energy helps save operating cost
3. An EEN accelerates deployment of new applications due to customers increased demand
4. Enables Use of Incentives by energy industry
5. Enables optimal link utilization
6. Reduced Carbon dioxide (CO_2) emission

In lieu of these benefits, it is important to theoretically analyse some Energy Efficient Solutions for Networks;

1. Low Power Electronics should be used in our networks, and damaged electronics should be properly recycled.
2. Efficient Battery Technology should be used
3. “Always on” devices should not be deployed in our network, as keeping always on connection without the need for data transfer reduces power efficiency of the network
4. For Wireless Networks, an optimized connection and access technique (modulation and coding schemes) be incorporated. For wired networks, there is need for an efficient power management; hence Optical fibre cables (FTTH PONS) are preferable over coaxial cables.
5. For Access Networks, the importance of Network planning and dimensioning as well as remote monitoring cannot be over-emphasized. There must also be adequate source of renewable energy.
6. For Core networks, Eco server (Green Data centers) is preferable; while there is need also for virtualization. (George et al., 2010)

6.0 ENERGY EFFICIENT WIRELESS NETWORKS AND TECHNIQUES

With explosive growth of high-data-rate applications and as a result of high network throughput, more and more energy is consumed in wireless networks to guarantee *quality-of-service* (QoS); which is sometimes unaffordable for energy-aware networks or energy-limited devices. It is therefore of urgent importance to reduce energy consumption while meeting throughput requirements in such networks and devices.

6.1 Techniques for Energy Efficiency in Wireless Networks

6.1.1 OFDMA Networks

In OFDMA, system resource, such as subcarriers and transmit power, needs to be properly allocated to different users to achieve high performance. Worldwide Interoperability for Microwave Access (WiMAX) and the Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) are two major wireless systems where OFDMA networks have been deployed. Energy-efficient Orthogonal Frequency Division Multiplexing (OFDM) systems, a special case of OFDMA, have shown a higher degree of Energy-efficiency than the conventional OFDMA networks. This new scheme maximizes the overall EE by adjusting both the total transmit power and its distribution among subcarriers. It is demonstrated that there is at least a

15% reduction in energy consumption when frequency diversity is exploited (Geoffrey et al., 2011).

6.1.2 MIMO Techniques

MIMO techniques have been widely adopted in wireless networks nowadays. As shown in Figure 4 below, single input single-output (SISO), single-input multiple-output (SIMO), and multiple-input single-output (MISO)can be regarded as special cases of multiple-input multiple-output (MIMO). MIMO can also be used with single user or multiple users to form single-user MIMO (SU-MIMO), multi-user MIMO (MU-MIMO), and coordinated multipoint transmission (CoMP). It has been demonstrated in these specifications that spatial DOF from configuration of multiple antennas enhances both reliability and capacity

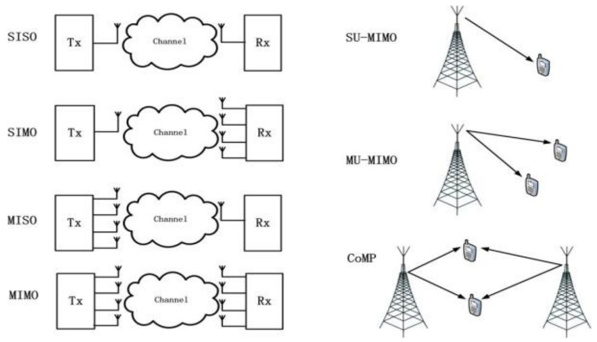

Figure 4: MIMO Techniques (Source: Geoffrey et al., 2011)

6.1.3 Relay Transmission

Broadcasting and Multiple Access are the two phases in the transmission period of a relay system. During the broadcasting phase, data sent in the air by the source node may be received by the relay nodes or both the relay and the destination nodes. During the multi-access phase, the relay nodes or both the source and relay nodes transmit data to the destination nodes.

Relay transmissionprovides another way of improving reliability and save energy. By deploying relay nodes, more connections between the source node and the destination node are built and data from the source node can be delivered through multiple wireless links. Therefore, the time to transmit a fixed amount of data reduces and so does the consumed energy.

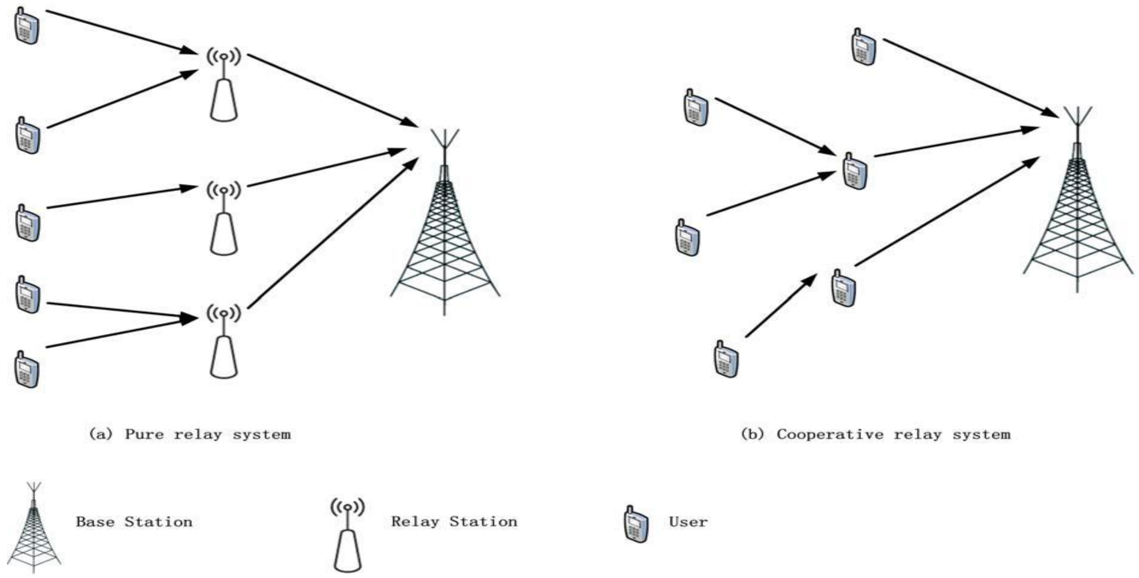
(a) Pure relay system
(b) Cooperative relay system

Figure 5: Relay Transmission system (Source: Geoffrey et al., 2011)

7.0 CONCLUSION

In this research work, the authors have comprehensively studied Energy Efficient Network (EEN) – The Problems and solutions of EEN, Environmental and cost benefits of implementing an Energy Efficient Network, as well as a brief summary of the techniques for Wireless Networks Energy efficiency. Efforts should be made as regards further investigation on some of the topics listed in this research.

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