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Energy Efficiency in Information & Communication Technology (ICT): Directions of Research

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Abstract

Information & Communication Technology (ICT) revolution has resulted in a large number of computer, internet and mobile phone users around the world. This not only imply that a gargantuan number of computing devices like PCs, mobile phones, routers, servers etc. are built and used but also mean that this segment is becoming a significant consumer of energy due to billions of users. With continued development projected for decades to come, energy consumption in this sector will continue to grow. In this paper we show how ICT energy consumption has become considerable and the need of the hour is sustainable development in this sector as well. We discuss the latest areas of research in ICT energy efficiency to give the readers an idea of state of the art research work being done to ensure energy efficiency and saving carbon emissions due to ICT sector.

***Keywords**: Information & Communication Technology, energy efficiency, sustainable networks, data centres, internet, mobile communication.*

1. Introduction

Advances in technology, medicine, agriculture and standard of living have ensured a rapid growth in world population. The inhabitants of our planet are all set to touch 7 billion in 2012, up from 5 billion in 1987. This sustained growth over the last century has put a tremendous pressure on mother earth when it comes to the supply of natural resources. Continued increase in living standards as well as rising needs of developing societies mean more and more energy; raw materials, food and other resources are needed to sustain this growth. Rapid rise of China and India, together having almost 36% of the world's population is putting an additional strain on the resources as these countries strive towards increasing the living standards of their gigantic populations. As the awareness of environmental issues is increasing, more and more people are becoming concerned about the state of the health of our planet. If the humankind has to sustain the growth and to spread the benefits of development across all the societies, the energy security as well as environmental protection is needed at the same time. Today human activity results in an annual production of 31 billion tones of CO2 and there are indications that this number is set to grow despite efforts undertaken by many to restrain carbon emissions [1]. As a result of the continued greenhouse gas emissions, the average temperature of earth's surface has witnessed an increase of approximately 0.8 degree Celsius over the last century. Out of this increase two thirds has occurred only in last three decades.

This continued increase in earth temperature has caused changes in weather patterns further resulting in melting of glaciers, rise in sea levels, desertification, extinction of species, spread of disease and changes in agricultural production. Hence climate change is directly affecting the human population as well as the flora and fauna of our planet. So it becomes abundantly clear from the discussion that if mother earth has so be passed on to the coming generations in a good shape, urgent measures are required from the leaders, scientists and common populace to curtail carbon emissions. If we look at the percentagewise break down of carbon emissions, we see that although electricity is only 13.5% of the global primary energy requirements, its overall contribution to the global carbon emissions are whopping 40% [1]. This is mainly due to the cheap availability and predominant use of coal for generating electricity across the globe. With continued development in China and India, more and more coal fired thermal plants are commissioned

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resulting in increasing contribution of coal to the overall power generation.

Electricity conservation can play a major role in containing greenhouse emissions as electricity contributes to disproportionately higher levels of carbon emissions as discussed above. One major area where electricity consumption is continuously rising is Information and Communications Technology (ICT) sector. ICT combines together the advances in communications engineering, hardware and software and has played a major part in overall development of humanity. Mobile communication and internet have so rapidly and so comprehensively invaded the life of the global population like none other. The extent of this expansion can be judged from the fact that within a short span of two decades, almost 5 billion people have mobile phones and more than 2 billion people are active users of the internet. So ICT revolution has played a stellar role in interpersonal communication, information dissemination, entertainment, commerce and overall development. Its overall influence and penetration is all set to go on increasing in future.

ICT Electricity consumption

Benefits notwithstanding ICT sector has become a significant polluter on the account of its increasing electricity consumption. Energy consumption in the ICT sector can broadly be classified into three main segments:

1. **Personal Devices:**

This segment includes ICT devices like desktop computers, laptops, mobile phones and other such devices like smart phones and PDAs. For everyday use, these devices consume electricity and individual energy consumption of the devices differs depending up on their capabilities. A typical desktop consumes from 100-150W [2], while a laptop consumes from 30-40W [3]. Similarly typical usage of a mobile phone requires around 11 kWh per year [4]. Since there are almost 5 billion users of mobile phones and there are around 1600 million computers in use, hence there is a significant amount of electricity consumption due to the usage of these devices.

2. **Backbone Networks:**

This segment includes the underlying infrastructure which supports the communication and access for the personal devices. Mobile communication infrastructure and internet form this segment. According to a study, the worldwide electricity consumption due to mobile communication infrastructure is estimated to be around 40 million MWh per year [5]. Similarly annual electricity consumption by the internet can be calculated building upon the numbers estimated by [2] and the overall electricity consumption in 2011 was 333 million MWh. As the popularity and pervasiveness of mobile communication and internet is growing, these numbers will continue to rise.

3. **Auxiliary Infrastructure:**

Today almost a quarter of the global population uses internet. This increasing popularity has resulted in huge bandwidth usage requiring greater amounts of data for audio-video streaming, social networking, e-commerce, e-banking and other web-based applications. In order to meet this bandwidth demand multinational companies like Google, Facebook, Amazon, e-bay, Microsoft and Apple have made huge investments in setting up of data centers which acts as repositories of data to be accessed by the users as well as the companies. The emerging phenomenon of cloud computing is another significant factor boosting the establishment of newer data centers. These data centers in turn require a lot of energy not only for their operation but also for HVAC. According to an extensive study the overall electricity consumption due to data centers in 2010 can be calculated to be 350 million MWh [2]. Based on these numbers the total electricity consumption in 2011 due to this segment can be estimated to be 406 million MWh.Based on the above estimations, the overall electricity consumption due to various ICT segments can be estimated to be 1356 million MWh which is almost 7% of the total electricity consumption. The segment wise electricity consumption in the ICT sector is illustrated in the Figure 1 shown ahead. So from the above discussion it becomes pretty clear that ICT sector is gradually becoming a significant polluter and is already contribution to 3% of the total greenhouse emissions. It is worth mentioning that these numbers do not include the emissions due to the pre-manufacturing, manufacturing and disposal phase of the ICT components.

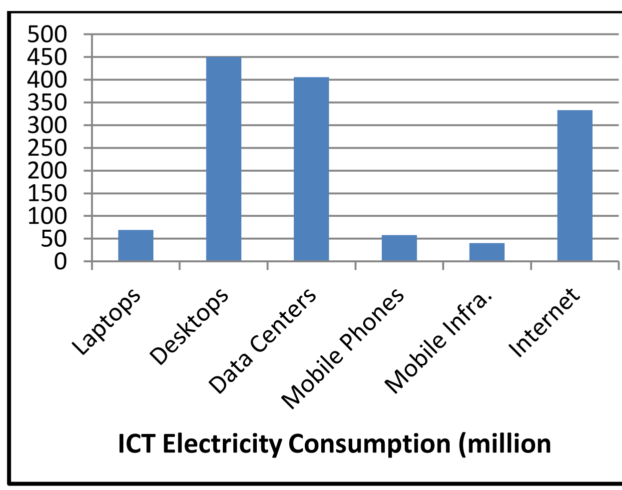

Fig. 1 ICT electricity consumption by sectors [2]

ICT Energy efficiency directions

Therefore from the above discussion it becomes abundantly clear that energy efficiency measures in ICT sector can greatly assist in electric energy savings which in turn has a disproportionately higher potential in terms of curbing greenhouse gas emissions. The rapid expansion in ICT sector means that with the passage of time, the overall electricity consumption in this sector will continue to grow. Hence the need of the hour is to ensure that utmost efforts from the scientific community are directed towards ICT energy research.

As we know that ICT sector incorporates advances in communication technology, semiconductor physics, electrical engineering and software development hence the overall approach for energy efficiency must be holistic one rather than concentrating only in specific directions. Energy efficiency study can be broadly classified into three main domains i.e. at the hardware level, at backbone network level and at level of auxiliary infrastructure. The following discussion covers the state of the art energy efficiency research directions in the mentioned domains.

4. Hardware Level

Energy efficiency research starts from the component level. Developing energy efficient components will be critical for the very survival of the semiconductor industry. Development is multicore technology by Intel is a good example of evolution of energy efficiency solutions at hardware level. The latest Blade and Rack servers incorporate this multicore technology and deliver much higher performances and have lesser carbon footprint. Simplest and most attractive idea for device power management involves temporarily shutting down the equipment when there is less utilization and to slowdown processing when lesser performance is sufficient enough. Some other innovations proposed by Intel include strained silicon technology which increases the transistor performance by 30% for same level of energy consumption. Mobile voltage positioning and Speed Step technologies also minimizes the processor power consumption. Speed Step dynamically scales frequency and voltage depending upon demand while in second case processor voltage is adjusted depending upon the demand [6]. In another study [7] Near Threshold Technology (NTS) has been proposed where the CMOS based digital processors are operated at way below typical supply voltage of 200 mV [8], NTS offers up to 10 times or higher energy efficiency.

Dynamic Voltage Scaling (DVM) and Dynamic Frequency Scaling (DFS) are other attractive solutions for enrgy efficiency at component level. Combined together these are called Dynamic Voltage and Frequency Management (DVFM). Power dissipated in a component is proportional to the square of voltage multiplied by frequency therefore dynamically decreasing these parameters depending upon application can save power in energy restrained environments like laptops and mobile phones. In DVM, the voltage of the component is scaled up or down depending upon the immediate requirements. Lower voltage decreases the power consumption but affects the performance. DFS also known as CPU throttling, is a technique where the microprocessor frequency is varied depending upon the processing requirements. Decreasing the frequency results in lesser number of instructions carried per unit time. The frequency of a processor can be decreased to conserve energy or to decrease the amount of heat generated when the processing requirements are lower. Generally both DVM and DFS are used in a combination to save power when the processing requirements on a component are less. Power supplies convert ac power from the supply into dc power with different voltages required to run computers, servers and various inbuilt systems. Highly efficient power supplies can be designed to save considerable amount of energy. 80 plus certified power supplies ensures 80% or greater conversion efficiency at various loads with a power factor of 0.9 and above.

5. Backbone Networks

The need for energy efficiency in the internet was stressed way back in 2003 [9]. Incorporating energy efficiency in backbone networks provides twin benefits, firstly increasing power bills are forcing telecom companies to seek energy efficient solutions for cutting expenditure and secondly to reduce the carbon footprint of the networks. In addition to these there are legitimate concerns about the future networks being able to handle the increasing bandwidth requirements in an energy efficient manner. In the network core, one solution to achieve energy efficiency is to selectively switch off the idle network elements when the network utilization is low (during night time) while at the same time retaining the ability to traffic the remaining data [10]. According to [11] the telecommunications industry is migrating to a single unified IP-based next generation network (NGN) which will significantly decrease the number of switching centers. The switching devices will be more tolerant to climatic conditions thereby removing the necessity of air conditioning. Also the NGNs will use latest standards like VDSL2 (ITU-T G.993.2) which has provisions for three different power modes (full, low-power and sleep) while the older VDSL had only full power mode. By introducing these innovations, ITU indents to decrease the carbon footprint of the telecom sector in future networks.

Mobile Communications sector provides a different sort of challenge when it comes to energy efficiency. With more than three fourth of the global population already the users of mobile phones and additional millions becoming subscribers every year in countries like China and India, this sector is becoming a major consumer of electrical energy. Traditionally energy efficiency issues were neglected in access networks and in typical mobile environment, BTS or Base Stations are major consumers of energy [12]. With mobile communication penetrating into traditionally underdeveloped areas, more and more BTSs have to be installed away from the power grids where diesel generators and alternate sources are required. Therefore additional costs are incurred by the service providers motivating them to seek energy efficiency in access networks. In typical off-grid sites, energy provisioning may cost up to 50% of total operational costs [13]. Hence access networks are the biggest culprits in the mobile communication as they have minimal provisioning for energy efficiency. A good example is DC power consumption of a typical three sector site which consumes about 50% of the peak power even under zero load conditions [14]. Mobile networks normally have slowly changing load pattern as well as highly dynamic fluctuations whereas the systems are configured rather statically [15]. This means there is a good scope of network energy efficiency with energy efficient radio resource management (RRM).

6. Auxilliary Infrastructure

Rising popularity of internet applications, online multimedia sharing, e-commerce, e-banking and demand for online video has resulted in huge investments by multinational companies in data centers. Estimates predict that by 2014, 91% of all the internet traffic will consist of video data in form of internet TV, video on demand, internet and P2P [16]. Rising popularity of cloud computing is in part based up on massive computing and storage capacity provided by such data centers. As a result of this increased data demand, data centers have become a major contributor to greenhouse emissions worldwide. The number of servers in a data center has reached the order of 10,000 and much larger data centers with up to 150,000 servers are in the line [17]. Not only the numbers of the data centers and the servers have gone up, the power density per rack has also exploded over last few years. In 2004 the power density per rack was about 10 kW/rack [17] which increased to 55 kW/rack within a short span of 2-3 years [18]. However with various efficiency measures in place, the current consumption is between 25-30 KW/rack. Hence from the above discussion, it becomes clear that when it comes to the energy efficiency in ICT, Data Centers will have to be treated with utmost care.

With the density of the servers increasing day by day, their power density has also increased and therefore there are ever present chances of thermal failures. Therefore there is a need of constantly cooling the server racks which results in higher energy consumption in their cooling systems. Variable speed fans have been proposed to ensure that these are started and their speed can be controlled according to the requirements of dissipation of heat from the racks. In blade architecture, a number of fans are employed in a single rack and each fan is controlled according to the area specific thermal condition [19]. Water based cooling method is much better than the air based cooling but it has not gained much popularity due to complexity. AC to DC power conversion is employed in the data centers as servers need DC power for their operation. This conversion also causes significant power losses. These losses can be reduced by improving the efficiency of power provisioning. Since the implementation of energy efficient states is less effective in components other than CPU, experts are calling for radical redesign in memory and disk subsystems [20].

Conclusions

In 2011, ICT sector consumed almost 7% of the global electric energy which was approximately 1356 million MWh. As electricity generation is a very energy intensive process and results in almost 40% of the overall carbon emissions, it is important that special consideration must be given to the electricity saving measures. ICT sector is already contributing 3% of the global carbon emissions and this number is set to grow in future aided by rapid proliferation of ICT related technologies. One must also keep in mind that these numbers include only the usage phase of the ICT devices. Energy consumed during the manufacturing and disposal of billions of devices and components is not included in the numbers. Need of the hour is urgent attention of the scientific community to ensure energy efficient development in computing sector as well. This work covers some of the latest direction of research to give the reader an idea of the proposed solutions. As energy consumption in ICT sector is spread across computing devices, backbone networks and auxiliary infrastructure, a holistic approach is required to ensure sustainable development is ICT sector.

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