CONTENTS

Telecommunication system for green economy – a survey

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The fast telecommunications development raises the question of power consumption in communication systems, as well as its impact on the environment. Another important issue is the electromagnetic pollution due to the use of these systems. The article is a brief overview of the energy consumption in various types of communication systems - data centers, cloud computing, networks, systems, devices and circuits. The proposed solutions to tackle the problem vary depending on the type of communication system. Most commonly a low-power mode is used when there is absence of traffic in the entire system or parts of it. It is called economical or "sleep mode". Other good practices are developing new algorithms and protocols that improve the energy efficiency of the system.

Телекомуникационни системи за зелена икономика - обзор (Здравка Чобанова, Галя Маринова). *През последните години телекомуникациите се развиват с бързи темпове. Като главен проблем възниква въпросът за консумираната енергия в комуникационните системи, както и въздействието ѝ върху околната среда. Важен въпрос е и електромагнитното замърсяване в следствие използването на тези системи. В статията е направен кратък преглед на консумацията на енергия в различни видове комуникационни системи – центрове за данни, изчислителни облаци, мрежи, системи, устройства и схеми. Предложените решения за справяне с проблема са различни в зависимост от вида на комуникационната система. Най-често се въвежда режим на ниска консумация при липса на трафик на цялата система, или на части от нея, т.нар. икономичен или спящ режим. Други добри практики са разработване на нови алгоритми и протоколи, подобряващи енергийната ефективност на системата.*

Introduction

The strong increase of the number of mobile devices and the services they provide lead to fast development of the Information and Communication Technology (ICT) sector. Globally, the ICT sector contributes with 16% for the increase of Gross Domestic Product (GDP) in the period from 2002 to 2007, and the sector itself has increased its share of GDP from 5.8 to 7.3% and the expectation is to jump further to 8.7% from the growth of the GDP globally for the period from 2007 to 2020 [1]. This economic growth leads to increase of the energy costs and therefore to increase of carbon emissions. Statistical data indicate that the ICT sector consumes 6% of the global energy consumption and 2% of the global carbon emissions [2], as shown on Fig. 1.

For these reasons, it's important to make a decision for decreasing carbon emissions, without affecting with this the quality of services provided. The possibilities for development that ICT give can lead to a decrease of carbon emissions to 7,8 Gt CO_2e (carbon dioxide equivalent) by the year 2020, compared to 0,53 Gt CO_2e in the year 2002. ICT propose solutions for energy monitoring and emissions in real time, they provide the means for process and system optimization with the goal of efficiency. The modification of the means of communication should address all systems and devices in communications.
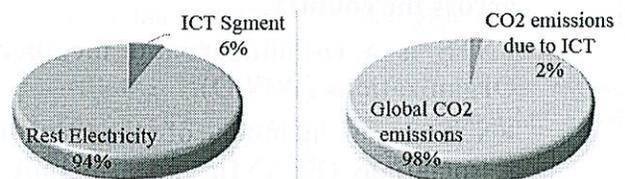

Fig. 1. Energy consumed (a) and carbon emissions (b) of the ICT sector compared with the global energy consumption and carbon emissions [2].

The outline of the paper is: Overview of the energy consumption and the electromagnetic pollution in different communication systems, different solutions existing and proposed in literature for decreasing the

power consumption and an example of power consumption estimation with of Universal Software Radio Peripheral (USRP) model N210 device of Ettus Research.

Power consumption and electromagnetic pollution in different communication systems

Power consumption in the data centers and cloud computing.

An analysis of power consumption and cloud computing is proposed in [3], as shown in Table 1:

Table 1

Power consumption of servers and data centers	53 %
Direct powers consumption	19 %
Power consumption for cooling the infrastructure	23 %
Others	5%

Authors in [4] discuss the power supply usage in big server farms (up to 15000). In the data centres the discrepancy between the maximal power consumption, which is consumed by a big group of machines and the peak value of their consumption in theory can overpass 40%.

In cloud computing the energy consumption assessment includes traffic, processing and data storage. In public cloud, the traffic represents a more significant share of power consumption, than in private cloud services. Cloud computing is more energy efficient compared to conventional computing, especially when the users' computing tasks are of low frequency. However, if each user performs all computing on their own PC, then cloud computing can consume more energy than conventional computing [5].

Energy consumption in networks

A model is developed in [6] for estimation of the power consumption in the network, depending from the degree of accessibility to the network. The network is divided to network for access, periphery and main network, and the network for access can use different topologies. The analysis which is done presents the power consumed by a user as a function of the access rate, which is made available to the user. The wireless networks for access (WiMax, 3G/UMTS/Universal Mobile Telecommunication System) require more energy than the wired networks. When high rates are requiring, the technology of wired access is more energy efficient.

The total energy consumption at the level of the system cell decreases when the path losses and the size of the cell increase [7]. Since the energy consumption of the base station (BS) and this of the mobile station (MS) decrease, the emissions of CO_2 also decrease. For a year, for a microcell with radius 1 km, for a picocell with radius 100 m and for a femtocell with radius 10 m, the quantity of CO_2 emissions from a BS transmitter are respectively about 181 kg, 1.81 kg and 18.1 g. So, thanks of a topology, based on cell size reduction, the CO_2 emissions can be reduced. The authors of [7] don't consider cells overlapping.

The size of the cells also influence on the electromagnetic pollution. The estimate for each BS and MS can be obtained by the introduction of the electromagnetic pollution index EPI, which is the product of the normalized polluted area and the polluting energy. The normalized polluted area equals the ratio of the sum of the areas of pollution (Packets of Pollution - PoP) and the area of the cell, and the polluting energy is the sum of the energies of all PoP [8].

$$EPI = (\frac{Sum\ of\ area\ of\ all\ PoP}{Area\ of\ cell}) * (Sum\ of\ energy\ of\ all\ PoP)$$

The main issue in wireless sensor networks is the total energy consumption, which includes the energy, necessary for the transfer and the usage of energy in the sensor nodes, working with batteries, which puts a limitation on the lifetime of the network [9]. Attending good energy efficiency needs a solution of the compromise between decrease of energy consumed and the requirements for bandwidth and delay.

In order to achieve a good energy efficiency in the optical networks, a lower limit of the energy consumption is determined, and also the energy characteristics of some switching devices [10]. The lower limit of the energy is limited by the energy consumption in the optical amplifiers and in the optical transmitters and receivers [11]. The criterion for analysis is the energy consumption for bit of data transmitted. The optimal energy per bit in a transport system with a gain depends from the number of followers and from the optimal distance between them.

Energy consumption in devices and systems

For the purposes of characterization of the energy consumption by the mobile devices as notebooks and mobile phones, as a part of the total energy consumption, a definition of the personal computing segment is introduced in [2], which includes the users'

devices as mobile computers, mobile phones, personal computers and devices, used on second stage, as server farms /data centers, internet and mobile infrastructures. Office devices as printers, copy machines, etc. are not included, neither user electronics as TV sets, DVDs, etc. As it can be seen on Fig.2, the share of the energy consumed by mobile devices is 10% from the entire segment of the personal computers and 12% from the total energy sector, but its contribution to the global CO_2 emissions is enormous 40%.
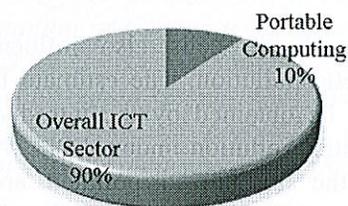

Fig.2. Energy consumed by mobile devices versus the energy consumed in the global ICT sector from [2].

The comparison of UMTS/3G cell system from third generation for mobile networks and GSM/2G second generation for cell networks which is presented in [12] makes estimation for all components, as mobile phones, BSs, antennas and commutation systems, as well as stationary components as cable system and commutation centers. The influence on environment is estimated, taking in consideration all main phases of the life cycle, as raw material extraction, production, use, disassembly and disposal of the product. The CO_2 emissions are caused by the demand for electrical energy, the use of plastics in manufacturing and the energy consumption from fossil fuels. With the exception of the use of copper (wiring), the data transfer of 1 Gbit, from mobile phone to mobile phone requires more resources and causes more emissions compared to the option from mobile phone to fixed network. In the time cycle of mobile phones the production phase has the biggest importance, because of the short exploitation life, and in BSs the exploitation phase has such importance, because of their longer life.

Power consumption in circuits

In advanced technologies with a high number of transistors in a circuit, static power plays an increasing role [13]. By reducing the static energy consumption the type in stand-by mode is optimized, as well as lifetime for batteries.

The chip temperature is an important factor for energy consumption in circuits. Prompt detection of

hot spots gives the opportunity to introduce techniques for temperature management in case of FPGA implementation.

In [14] the energy consumption of digital optical and electronic circuits for signal processing is compared, including the energy consumption of the converters from optical to electrical part and from electrical to optical part of the circuit, and the demultiplexers and multiplexers necessary for electronic circuits for high speed optical signal processing. The analysis shows that, the optical signal processing is concurrent to electronics in very high speed networks, only in case of simple operations, when there is a small number of operations for each bit of information. in case of more complicated processing, the electronics provides a better energy efficiency.

Methods for power consumption reduction in communications

Energy efficient hardware

Energy efficient hardware is one of the energy efficient solutions for reducing the energy consumed. The change of hardware devices with new generation devices, with similar functionality and lower energy consumption. For example, hard disc drives from the data centers are changed with Solid-state-discs with lower energy consumption as described in [3].

Power supply monitoring

The power consumption reduction can be achieved through the introduction of the low power mode („sleeping" mode). Different network components are switched into sleeping mode when traffic is missing [15], [16], [17], [18], [19] for a certain time (timer-driven sleeping) or they are woken-up when data arrive (wake-on-arrival). If the network switches to a sleeping mode for a determined time and data packages arrive at the input, they will be lost. In case of waking-up on data arrival (wake-on-arrival) the circuit recognizes the packages and the line stays powered, even in sleeping mode. This leads to the approach of traffic forming in case of small overloads at the ends of the network. The end devices transmit the packages to clusters and routers, until the network wakes up for processing the series of packages and then falls again asleep, until the next series arrive.

An adaptation scheme of the network rate is introduced in [6], where the operative frequency of the device is reduced. This leads to reduction of energy costs. The first reason is that the Ethernet connections, operating at frequency of 100 Mbps ÷ 1Gbps dissipate 2÷4 W versus 10÷20W in case of 1Gbps. The second

reason for cost reduction is that, operating at lower frequency permits the application of dynamic voltage scaling – DVS, which reduces the operating voltage

In M2M communication (machine-to-machine) the energy efficiency can be increased through regulation of the power transmitted (to the minimal required level) [19]. The efficiency can be improved additionally through the introduction of a schedule, with the aim to switch some nodes in low power state ("sleeping") mode, in a way that only the subset of the nodes connected stays active, and in the same time the functionality (the observation and the data collection) in the original network stays intact, as illustrated on Fig.3. The circuit includes local communication only and it generates a very low number of control messages, thus making it energy efficient.
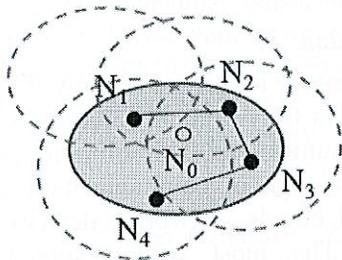

Fig. 3. Node N0 can switch in sleeping mode, because the range of its sensor coincides completely by the neighbors connected N1 ... N4.[19].

One of the recommendations in [2] for power supply monitoring in the mobile devices is that the users implement more frequently the power supply monitoring. In notebooks, the tuning for power supply monitoring is switched off by default.

Different techniques are used for switching off the processor in the computer (SpeedStep, PowerNow, Cool'nQuiet, Demand-Based Switching), through reducing the clock frequency of the processor or through switching-off different parts of the chip [3].

Energy efficient planning

When designing a network in cooperation, the protocols and the algorithms for reducing the total energy consumption as an index should be designed, instead of the individual nodes of the network [2].

Multiple tasks are planned in real time in multiprocessor systems which support DVS. A probabilistic planning of processing time for the tasks is done in [3], in order to divide the volume of the processing and thus to reduce the energy consumption.

The energy efficiency can be increased based on the consolidation of the servers through virtualization of service. The virtualization divides the computing resources and permits to share the hardware. Different levels of virtualization can exist, as well as different forms, for example full virtualization at the level of the operational system or virtualization of Sensor Node as Service SNaaS of the sensor cloud in IoT [20].

The energy efficient planning can be done at the level of the circuit, as in [21], [22]. Through planning and modification of the mapping style, the power is reduced, as well as the number of elements, used for the realization, which leads to more efficient design of the FPGA area.

System development, algorithms and protocols for multiradio transmission

The multiradio system, proposed in [23], which combines different systems – based on standards and others not based on standards. The multiradio concept shows how, switching between the bandwidths 2.4GHz and 868MHz, a connection between remote clusters can be realized on ZigBee nodes, disposed on different places or separated by overloaded communication. A solution is proposed in case of network overload in areas like Home Area Networking HAN and commercial buildings.

Authors of [9] propose the development of MIMO systems, which have good spectral efficiency for radio-applications in sensor networks. These individual MIMO systems can act also in cooperation. Thus, through cooperative transmission and reception of information expenses for energy transmission can be saved.

The development of the algorithm Dynamic Coverage Management (DCM) for energy saving in different wireless networks with two basic structures, proposed in [24] can contribute up to 50% reduction of energy consumption. The first structure uses the mechanism for redirection of calls, and the other requires the introduction of a threshold value, through which the microcell is activated, to take calls and to reduce the traffic of the macrocell.

Reduction of energy consumption and increasing lifetime of the sensor network is achieved through the development of different protocols as for example density-aware multihop clustering (DAMC) for non-uniformly distributed Wireless Sensor Networks (WSNs) in [16], routing protocols in the architecture of M2M communication [19], standards as 802.15.4 ZigBee Smart Energy in smart networks [25] or new generation devices as energy efficient sensor for mobile device for tracking and playback of motion, which is proposed in [26].

Estimation of the power consumption in a software radio system

The power consumption estimation of the USRP can be done from datasheets. Usually these data are intended to show the maximum power consumption. Their main purpose is to inform the user of the safe supply of USRP. The assessment of manufacturer was made taking into values at worst case and at full load / all components operate at full power /.

The datasheet values are the same for the full series N2x0, although USRP N210 is with a larger FPGA - Xilinx Spartan 3A DSP - XC3SD3400A FPGA than the USRP N200 which is with Xilinx Spartan 3A DSP1800 FPGA. Based on the given values of the voltage applied and the resulting current, the power can be calculated through the Ohm law.

Tools for system monitoring can be used for estimating the real energy consumption, since such tools give information for the loading of the PC components in percent or they provide data for the energy consumed by different components.

In order to observe the functionality of the USRP, a simple flowgraph of a receiver block with USRP is designed as shown on Fig.4, the USRP block receives the signal and the block FFT Sink, and visualizes the signal.
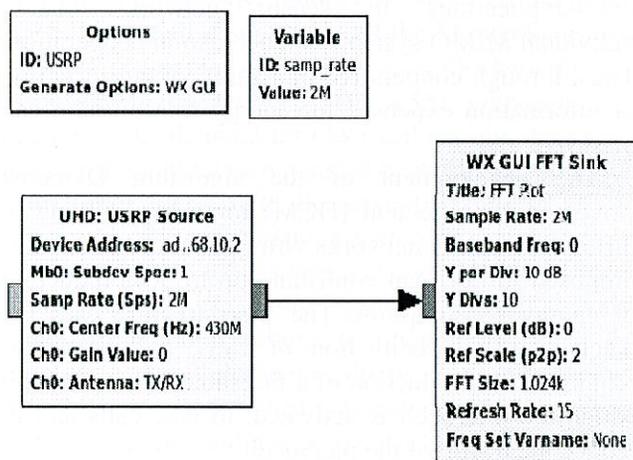
Fig. 4. Flowgraph of receiver with USRP.

The processing of the flowgraph in GNU Radio Companion (development of source code in Python, describing the behavior of the flowgraph) takes 44 % of the resources of the CPU. The tool Gnome System Monitor gives information about the busy resources in the system. The tool can be installed and then started as an application.

Fig. 5. Estimation of the resources used by the CPU for the processing of the flowgraph.

Conclusion

The overview in this paper shows the large interest of researchers for searching solutions, connected with green communications. The solutions are searched for the concrete type of communication system – data centers and clouds, networks, devices, systems and circuits. The most widely spread method for reduction of the energy consumption consists in the introduction of a kind of sleeping mode, but other more concrete proposals also exist. There are several references, that recommend different policies for green communications, but this overview is focused on the engineering and technical aspects of the problems and solutions, like energy efficient hardware, power supply monitoring, energy efficient planning and system development and algorithms and protocols for multiradio transmission. The concrete energy consumption estimation in a designed communication system is barely mentioned and a deeper study on that topic is published in [27]. On the other hand, a large study of communication system designs to be implemented on FPGA platforms and on USRP devices is planned in the goal to determine more efficient algorithms for system realization with minimization of energy consumption and electromagnetic emissions.

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