

Energy efficiency in future wireless broadband networks

^{1,2}M. T. Masonta*, ²M. Mzyece and ¹F. Mekuria

¹Council for Scientific and Industrial Research, Meraka Institute, Pretoria, South Africa

²Dept. of Electrical Engineering, Tshwane University of Technology, Pretoria, South Africa

Abstract – Over the past two decades wireless broadband networks have come to be considered the most convenient and reliable means of communications. This has led to an increased number of cellular base stations (BSs) deployed in both urban and rural areas. An increase in the number of BSs is directly proportional to an increase in energy consumption and carbon dioxide (CO₂) emissions. To deal with these challenges, network operators and vendors are embarking on building energy efficient networks to support a greener economy and environment. In this research, we investigate the concept of green radio communications in wireless networks and discuss approaches for energy efficient solutions in wireless broadband network deployments. These solutions include: collaborative networking, cognitive radio (CR) technology, energy harvesting and television white spaces.

Keywords: Cognitive Radio, Energy Consumption, Energy Efficiency, Energy Harvesting, Wireless Networks.

1. Introduction

The need for high-data-rate and faster multimedia applications and services by wireless communications consumers can be translated to higher energy consumption in wireless networks. For instance, recent studies indicated that the information and communications technology (ICT) industry contributes up to 3 per cent of total electric energy consumption worldwide [1]. With the growing demand for broadband wireless communications, these percentages are expected to grow rapidly if nothing is done to address energy efficiency in the ICT sector.

Energy consumption in a typical point-to-multipoint type of network, such as cellular network, can be classified into three different layers: *i*) network management and switching (NMS) layer; *ii*) BS layer; and *iii*) mobile station (MS) layer. The first two layers (NMS and BS layers) directly affect the network operators, while the MS layer mainly concerns the customer or end users. These three layers present different energy consumption issues, and will require unique energy efficient solutions. For instance, an MS may be battery-powered, and the relevant energy efficient solution would include switching-off the display and minimizing signalling overhead (e.g. sleep mode). Meanwhile energy efficient solution for the BS may include the intelligent sleep mode policies when the number of users and the traffic load decreases [3].

Due to the growing demand for advanced broadband wireless technologies and services, research in green radio solutions is gaining more attention globally. Serrano *et al.* [3] presents a comprehensive analysis of the available green radio mechanisms with the aim of understanding their benefits and shortcomings. A review of energy efficiency in both wireless and fixed-line telecommunication networks is presented in [4]. A tutorial and survey on energy efficiency in wireless communication networks is presented in [5]. While these selected references review works around energy efficiency within different communication networks, they do not present energy consumption in a network in a layered form and lack

* Corresponding author – mmasonta@csir.co.za

some of the energy saving solutions presented in this paper. In this research, we investigate the concept of green radio communications in wireless networks in three distinctive layers and then present approaches for low cost and energy efficient solutions for future wireless broadband networks deployments. These solutions include: collaborative networking, cognitive radio (CR) technology, energy harvesting and television white spaces (TVWS).

The remainder of this paper is organised as follows. Section 2 discusses energy consumption in wireless networks, with specific focus on the cellular base stations (BSs) and mobile stations. Section 3 reviews different approaches for addressing energy efficiency in wireless networks, and Section 4 concludes the paper.

2. Energy Consumption in Wireless Networks

Telecommunications networks (i.e. wireless and fixed-line networks) presents different pattern on energy consumption. For instance, in fixed-line networks, over 70 per cent of energy is consumed in the user segment while the remaining 30 per cent is due to the operator's operating expenditure (OPEX) [4]. In contrast, wireless network operators are responsible for the 90 per cent of energy consumption and only 10 per cent of the overall energy consumption corresponds to the users [4]. Thus, energy consumption in broadband wireless networks is becoming significant and its impact includes increased carbon dioxide (CO₂) (or greenhouse gas) emissions and high energy costs for network operators. In this section we assume a typical cellular network consisting of a switching centre (which includes office, retail and other network equipment), a number of base stations (BS), and multiple mobile stations (MS). From the cellular network operator's perspective, a BS consumes more energy than other components as shown in Figure 1. In this section we discuss areas of energy consumption in both the BS and MS. This will assist network engineers to know the key areas of the network which consumes more energy, and in turn enable the design of energy efficient solutions. For example, sleep mode can be used in a MS as one of energy saving scheme, while dynamic frequency selection can be used to save energy at the BS [6].

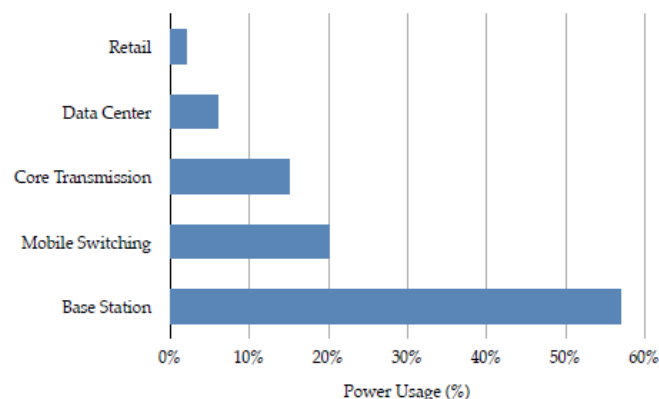


Figure 1: Power consumption distribution for cellular operator [8] (Source, Vodafone)

2.1. Energy Consumption at the BS

In a cellular network, the BS is the main contributor of energy consumption and CO₂ emission when compared to the switching centre and mobile stations [7]. Figure 2 depicts the breakdown of energy consumption per component within the BS. Power amplifiers are the most energy hungry components, followed by the cooling systems. Power amplifiers (PAs) are mainly used to amplify the transmit signals to higher power level in order to allow

reliable over-the-air transmissions [9]. One major reason for higher energy consumption in the PAs is their lower (or poor) efficiency. For instance, most PAs in BSs exhibit efficiencies of around 15 per cent, of which the remaining 85 per cent of energy is generally manifested as heat [8]. It is for this reason that power-hungry and complicated cooling solutions are used in most BSs [8].

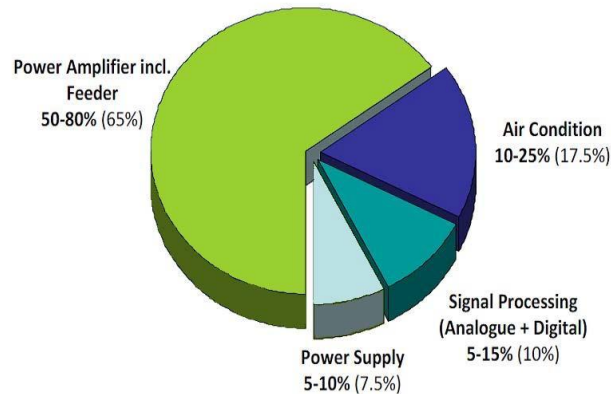


Figure 2: Energy consumption in cellular base station [9]

The use of larger (or macro) cell BSs (in order to increase the coverage area) also leads to higher energy consumption in the network. This is due to the fact that a BS has to serve some users who are located at the edge of the cell. Thus more energy is required from the serving BS to cover these users [6]. Another area of concern on the BS is the coverage in central business district which experiences dense population during working hours. These areas require very good cellular coverage during the working hours (i.e. between 08:00 to 17:00 weekdays), but the same network is almost in the idle state at night [6]. However, the main BS components (such as cooling systems, air conditioning and power supply) operate the same for both cases (i.e. peak and off-peak hours), and leads to more energy wastage.

2.2. Energy Consumption by the MS

The global number of mobile stations (MSs) or user equipment is seen as another driver of the overall CO₂ footprint in the ICT. The statistical surveys expect the number of GSM subscribers to grow to 6 billion while the number of wireless broadband subscribers is expected to be over 2 billion by 2014 [10]. As the demand for data traffic (broadband services) exceeded the voice traffic, MS are becoming energy hungry and they require to be recharged almost every 24 hours. To maintain reliable communication between the serving BS and the MS, there are lots of overheads in data transfer which in turn increases the ratio of required power per bits [4]. Figure 3 shows a typical example of energy profile in MS in the active (transmit) state and idle (sleep) state. Normally, when a MS is in the transmit state, it incurs both circuit (P_c) and transmit power (P_{Tx}) [2]. Circuit power is relatively independent of the transmission rate and it increases with the transmission duration [2]. The total energy consumption at the MS is dependent on its current state, which is either active or idle. Just like in the BS, the high energy consumption during the transmit state is due to the RF power from the PA, which is important to reliably transmit the signal over the air from the MS to the BS. Thus energy efficient schemes are very important design criterion for MS

due to the limited battery life of mobile devices, high data transmission rates, high electricity cost and lack of electricity supply in most African rural areas [11].

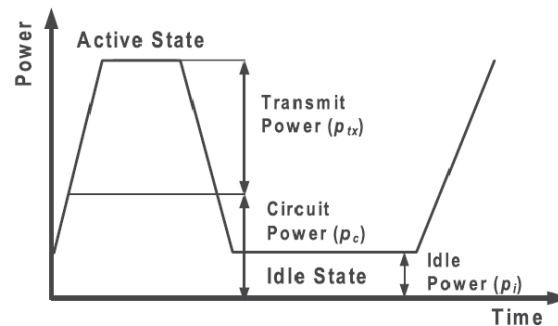


Figure 3: Example of energy profile in mobile station [2]

3. Towards Green Radio Networks Communications

The emergence of the global green economy and the need to lower CO₂ emissions has seen many countries and the telecommunication industry embarking on building energy-efficient networks (also known as green radio or networks). For instance, the European Commission (EC) has reached an agreement to cut greenhouse gas emissions by 20% by 2020 and to improve energy efficiency by 20% [12]. In order to realize these, several initiatives and approaches are being carried out globally to tackle energy efficiency of communication networks and the ICT industry in general. The green radio initiatives promise to increase the wireless network lifetime, reduce operational expenditures, and also improve the ecological footprint of wireless networks. In this section we discuss selected approaches proposed in different literature for improving energy efficiency and reducing CO₂ in future wireless networks.

3.1. Collaborative Networking

Recent studies have projected the demand for advanced broadband wireless technologies and services to triple by 2020 [2]. To supply this demand, wireless operators are facing a challenge of expanding their networks while reducing the total energy consumption and CO₂ emissions. Collaborative networking is one of the effective tools to reduce both cost of infrastructure deployment and energy consumption.

3.2. Cognitive Radio Technology

Cognitive radio (CR) technology is promising to address energy efficiency in smart wireless networks by using their cognition and reconfiguration capabilities [6]. This cognition capability allows CR networks to be aware of their radio frequency environment, the user demands, and operating conditions. Once a CR is aware of its environment and user demands, it can reconfigure its radio parameters to operate in energy saving modes.

3.3. Energy Harvesting

Energy harvesting technologies can take advantage of different sources of power, including RF waves, solar radiation, vibration, and thermal energy. Although harvested power may be

small to power a BS, high capacity storage can be used to store enough energy to recharge a mobile phone.

3.4. Television White Space Spectrum

Currently cellular networks operate at 900 MHz and higher frequency bands. At these bands, typical macro cell BS can provide a reliable cellular coverage for about 20-30 KM radius. As a result, more BSs are deployed to ensure maximum cellular coverage in every country. However, if lower frequencies, for instance in the 400 to 700 MHz (or in the TV white spaces –TVWS) are used, fewer BSs will be deployed. This is due to the fact that TVWS spectrum offers favourable propagation characteristics than higher frequencies [13]. Therefore, operating in the TVWS spectrum will lead to fewer BS deployments, which can be translated to lower energy consumption and CO₂ emissions.

4. Conclusions

In this paper we start by discussing energy consumption in cellular networks, mainly due to the BSs and MSs. We then present different solutions that can be used by wireless communication operators to contribute towards reducing energy consumption, cost and CO₂ emissions in order to achieve the goals of green radio networks and environmental sustainability. The aim of this paper is to highlight the efforts and contributions by the ICT community towards addressing energy efficiency and protecting the environment.

References

- [1] B. Badic, T. O'Farrell, P. Loskot, and J. He, "Energy efficient radio access architectures for green radio: large versus small cell size deployment", *Proc. IEEE VTC*, Anchorage, Alaska, 20-23 September 2009.
- [2] S. Andreev, P. Gonchukov, N. Himayat, Y. Koucheryavy, and A. Turlikov, "Energy efficient communications for future broadband cellular networks", *Computer Comm.*, Vol. 3, pp. 1662-1671, 2012.
- [3] P. Serrano, A. de la Oliva, P. Patras, V. Mancuso and A. Banchs, "Greening wireless communications: Status and future directions", *Computer Communications*, Vol.3, pp.1651-1661, 2012.
- [4] G. Koutitas and P. Demestichas, "A review of energy efficiency in telecommunication networks", *Telfor Journal*, vol. 2, no. 1, 2010.
- [5] G. Y. Li, Z. Xu, C. Xiong, C. Yang, S. Zhang, Y. Chen and S. Xu, "Energy efficient wireless communications: tutorial, survey and open issues", *IEEE Wireless Comms.*, pp. 28-35, Dec. 2012.
- [6] M.T. Masonta, Y. Haddad, L. De Nardis, A. Kliks, and O. Holland, "Energy Efficiency in Future Wireless Networks: Cognitive Radio Standardization Requirements", *Proc. of IEEE Int. Workshop on CAMAD*, Barcelona, Spain, 17-19 Sep. 2012.
- [7] O. Blume, D. Zeller and U. Barth, "Approaches to energy efficient wireless access networks", *Proc. of Int. Symposium on Communications, Control and Signal Processing*, Limassol, Cyprus, 3-5 March 2010.
- [8] O. Holland, V. Frederikos and A. H. Aghvami, "Green mobile communications", In *Encyclopedia of wireless and mobile communications*, B. Furht (Ed.), Taylor and Francis, Mar. 2010.
- [9] Alcatel-Lucent and Vodafone Chair on Mobile Communication Systems, "Study on Energy Efficient Radio Access Network (EERAN) Technologies," Project Report, Tech. University of Dresden, Germany, 2009.
- [10] A. Fehske and G. Fettweis, "The global footprint of mobile communications: the ecological and economic perspective", *IEEE Communication Magazine*, Vol. 49, no. 8, pp. 55-62, 2011.
- [11] M. T. Masonta, M. Mzyece and N. Ntlatlapa, "Towards energy efficient mobile communications", *Proc. of ACM SA/CSIT*, Bela Bela, South Africa, 11-13 October 2010.
- [12] European Commission, "Climate change: Commission welcomes final adoption of Europe's climate and energy package" Press Release, Brussels, December 2008, Available from: <http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/1998>
- [13] M.T. Masonta, D. Johnson and M. Mzyece, "The White Space Opportunity in Southern Africa: Measurements with Meraka Cognitive Radio Platform," *Springer Lecture Notes*, R. Popescu-Zeletin *et al.* (Eds.), vol. 92, Part 1, pp. 64-73, Feb. 2012.