Reduction of Power Consumption in Cellular Radio Access Network

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Abstract— All over the world, the desire to communicate is known to be peak between 5pm and 9pm which is usually associated with high demand for social calls that account for 16.6% of time in a day. It is within this period that network utilization is at the peak. Network planners dimension their networks by using the peak period normally referred to as the busy hour. The planning which considers only the busy hour of the busy day of the month creates excess capacity in the network. The excess capacity, even when idle, continues to use resources like power and air conditioning. Moreover, emerging trends in cellular communication are shifting from the manual operation and maintenance to more automated ones in the self-organizing networks defined by the Third Generation Partnership Project (3GPP) release 8. This paper is aims at reviewing the methods that have been used to reduce power consumption in the radio network and propose new methods that employ the use of self-organizing networks.

Keywords—Cellular Network, Communication, Power consumption, Self-Organizing Networks.

I. INTRODUCTION

Energy consumption in the Information and Communication Technology (ICT) sector is a major concern of the modern world because of the economic and environmental impact it has. Information and Communication Technology contributes to about 2% of the total Carbon dioxide emission of the world [1]. A quantitative study by Fehske et al. [2] estimated the corresponding figure for cellular networks to be 0.2 and 0.4 percent of the global Carbon emissions in 2007 and 2020 respectively.

In the past decade, the mobile industry has been grown rapidly connecting more than 4 billion people all over the world. In Kenya statistics from the Communication Commission of Kenya [3] indicate that the mobile phone subscriber base is approximately over 30.4 million people.

Base stations are the main power consumers in mobile access networks consuming about 60-80% [4] of the energy in a cellular network. There are currently more than 4 million base stations (BSs) serving mobile users, each consuming an average of 25 MWh per year. According to a report by GSM Association [5], East Africa has a total of 13,225 base station sites as at the third quarter of 2012 with Kenya having the highest number of Base station sites at 5,565 sites followed by Tanzania at 4,593 sites and Uganda at close to 3,067 sites.

This means that the energy consumption is expected to increase more rapidly with current trends of energy use. Under high traffic load, state of the art base stations are power-efficient. But when the traffic demand is low, the base stations still consume a lot of power. From an operator perspective, energy consumption translates directly to operating expenditure (OPEX) with the energy costs per Base Station expected to reach up to $3,200 per annum [4]. This paper provides a brief survey on some of the work that has been done to achieve power efficiency in cellular networks, discusses some research issues and challenges and proposes some power consumption reduction techniques.

II. ARCHITECTURE BASED ENERGY SAVINGS IN BASE STATIONS

The energy consumption of a BS can be reduced by improving the BS hardware design and by including additional software and system features to balance between energy consumption and performance. In the next few subsections, different ways to reduce energy consumption due in base stations based on their architecture will be discussed.

A. Improvements in Power Amplifier:

A Base station has three essential parts: radio, baseband and feeder. The radio consumes more than 80% of a BS’s energy requirement, of which power amplifier (PA) consumes almost 50% as shown in Fig.1. About 80-90% of the energy is wasted as heat in the PA thus creating the need for air-conditioners, adding even more to the energy costs. The total efficiency of a currently deployed amplifier, which is the ratio of AC power input to generated RF output power is in the range from 5% to 20% depending on the standard and the condition of the equipment [6].

Power amplifiers based on special architectures such as digital pre-distorted Doherty-architectures and Aluminum Gallium nitride (GaN) based amplifiers have been employed thus pushing the power efficiency levels to over 50%. Doherty PAs that consist of a carrier and a peak amplifier is advantageous by providing easy additional linearization using...
conventional methods such as feed-forward and envelope elimination and restoration (EER) [7]. The GaN (Aluminum Gallium nitride) based amplifiers can work under higher temperature and higher voltage, they thus providing a higher power output.

Additional improvements in the efficiency of PA are obtained by shifting from the traditional analog RF-amplifiers to switch-mode PAs. Compared to standard analog PAs, switch-mode PAs tend to run cooler and draw less current. While amplifying a signal, a switch-mode amplifier turns its output transistors on and off with an ultrasonic rate. The switching transistors produce no current when they are switched off, therefore generating very little power as heat resulting in a highly efficient power supply. It is expected that overall component-efficiency of these energy efficient devices could be around 70%. It is worth noting that PAs perform better at maximum output power in order to maintain the required signal quality. However, during the low traffic load conditions, a lot of energy is wasted. Therefore, design of flexible PA architectures that would allow a better adaptation of the amplifier to the required output power needs to be addressed and more efficient modulation schemes, because modulation also affect the PA efficiency [6].

B. Power Saving Protocols

In the current cellular network architecture based on Wideband Code Division Multiple Access (WCDMA)/High Speed Packet Access (HSPA), BSs and mobile terminals are required to continuously transmit pilot signals. Continuous transmission and reception in WCDMA/HSPA consumes significant amount of power even if the transmit powers are far below the maximum levels.

Newer standards such as LTE, LTE-Advanced and WiMAX have evolved to cater for the growing high speed data traffic requirements. The LTE standard introduces power saving protocols such as discontinuous reception (DRX) and discontinuous transmission (DTX) for the mobile handset. DRX and DTX are methods to momentarily power down the devices to save power while remaining connected to the network. The IEEE 802.16e or Mobile WiMAX also has sleep mode mechanisms for mobile stations [8]. The device negotiates with the BS and the BS will not schedule the user for transmission or reception when the radio is off thus saving energy. In future wireless standards, energy saving potential of BSs needs to be exploited by designing protocols to enable sleep modes in BSs.

C. Energy-Aware Cooperative BS Power Management

The traffic load in cellular networks fluctuates in space and time due to a number of factors such as user mobility and behaviour. During the day, traffic load is generally higher in office areas compared to residential areas, while it is the other way round during the night. This results into under utilization of some cells. Hence, a static cell size deployment is not optimal with these fluctuating traffic conditions. Cell-breathing has currently been deployed in CDMA networks whereby a cell under heavy load or interference reduces its size through power control and the mobile user is handed off to the neighbouring cells.

Operating a BS consumes considerable amount of energy thus by selectively letting BSs go to sleep based on their traffic load can lead to significant amount of energy savings. When some cells are switched off or in sleep mode, the radio coverage can be guaranteed by the remaining active cells by filling the gaps created. Such concepts of self-organizing networks (SON) have been proposed in 3GPP standard (3GPP TS 32.521) to add network management and intelligence features so that the network is able to optimize, reconfigure and heal itself in order to reduce costs and improve network performance and flexibility [9].

A new concept called Cell Zooming has been presented [10]. Cell zooming is a technique through which BSs can adjust the cell size according to network or traffic situation, in order to balance the traffic load. It can thus be employed to perform energy savings and help serve the mobile users cooperatively.

D. Using Renewable Energy Resources

Electrical grids are not available or are unreliable in remote locations of the world such as Africa and Northern Canada. Cellular network operators in these off-grid sites rely on diesel powered generators to run Base stations which is not only expensive, but also generates carbon dioxide emissions. A generator can consume an average of 1500 liters of diesel per month. Moreover, this fuel has to be physically brought to the site, which adds further to this cost. In such places, renewable energy resources such as sustainable biofuels, solar and wind energy seem to be more viable options to reduce the overall network expenditure. According to GSM Association [11], by powering 118,000 off-grid Base Stations on renewable energy would save up to 2.5 billion liters of diesel per annum which is 0.35% of global diesel consumption of 700 billion liters per annum and cut annual carbon emissions by up to 6.8 million tonnes.

A program to use renewable energy resources for Base Stations has been started by 25 leading telecoms including MTN Uganda and Zain under the Global Systems for Mobile communications Association (GSMA) [11].

BS equipment manufacturers have begun to offer a number of eco and cost friendly solutions to reduce power demands of BSs and to support off-grid BSs with renewable energy
resources. Nokia Siemens Networks Flexi Multiradio Base Station, Huawei Green Base Station and Flexenclosure Esite solutions are examples of such recent efforts [6], [13], [14].

E. Other ways to reduce BS power consumption

Another way to improve power efficiency of a BS is to bring some architectural changes to the Base stations. Currently, the connection between the RF-transmitter and antenna is done by long coaxial cables that add almost 3dB to the losses in power transmission and therefore, low power RF-cables should be used and RF-amplifier has to be kept closer to the antenna [6]. Fiber optic has been employed to replace RF-cables. Site level solutions can also be used to save energy. For example, outdoor sites can be used over wider level of temperatures, and thus less cooling would be required. Another solution is to use more fresh air-cooling rather than power consuming air conditioners for indoor sites. In addition, RF heads and modular Base Station design can be implemented to reduce power loss in feeder cables.

III. NETWORK PLANNING BASED ON HETEROGENEOUS NETWORK DEPLOYMENT

With the exponential growth in demand for higher data rates and other services in wireless networks requires a more dense deployment of base stations within network cells. Macrocells are not efficient in providing high data rates because they are designed to provide large coverage. A way to make the cellular networks more power efficient in order to sustain high speed data-traffic is by decreasing the propagation distance between nodes, hence reducing the transmission power. Hence cellular network deployment solutions based on smaller cells such as micro, pico and femtocells as shown in Fig.2 comes in handy to solve this problem.

A miro/picocell is a cell in a mobile phone network served by a low power cellular BS that covers a small area with dense traffic such as a shopping mall, residential areas, a hotel. The range of a micro/picocell is in the order of few hundred meters. Femtocells are designed to serve much smaller areas such as private homes or indoor areas with a range of a few meters. Simulations show that with only 20% of customers with picocells, a joint deployment of macrocell and picocell in a network can reduce the energy consumption of the network by up to 60% compared to a network with macrocells only [14]. In addition by reducing the number of base stations needed through optimal placement of sites and sharing of base stations by service providers can go a long way in reducing the overall power consumption.

IV. USE OF COGNITIVE RADIO AND COOPERATIVE RELAYING TECHNOLOGIES

Recently, the research on technologies such as cognitive radio and cooperative relaying has received a significant attention by both industry and academia. Cognitive radio is an intelligent and adaptive wireless communication system that enables utilization of the radio spectrum in a more efficient manner. The main purpose of cognitive radio is to collect information on the spectrum usage and to try to access the unused frequency bands intelligently, in order to compensate for this spectrum underutilization [15]. From Shannon’s theorem, the capacity of a channel is given as:

\[ C = B \log_2 \left(1 + \frac{S}{N}\right) \]  

Where:
C: channel capacity (maximum data-rate) (bps)
B: RF bandwidth
S/N: signal-to-noise ratio

In equation (1) it is seen that the capacity increases linearly with bandwidth, but only logarithmically with power. This means that in order to reduce power consumption, we should seek for more bandwidth by managing the spectrum optimally and dynamically, and this falls into the scope of cognitive radio. It has been shown in that up to 50% of power can be saved if the operator dynamically manages its spectrum by activities such as dynamically moving users into particularly active bands from other bands, or the sharing of spectrum to allow channel bandwidths to be increased [16]. Cooperative relays provide a lot of improvement in throughput and coverage for futuristic wireless networks. Developments in these technologies will solve the problem of energy efficiency via smart radio transmission and distributed signal processing.

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<th>Description Reported saving</th>
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<td>Improvements in Power Amplifier - up to 50% with Aluminum Gallium nitride (GaN) -based amplifiers and Doherty architecture - up to 70% with switch-mode power amplifiers</td>
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<td>Network self-organizing techniques Between 20-40%</td>
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V. CONCLUSION

In this paper we have addressed various methods that have been employed or proposed so as to reduce power consumption in the cellular radio access network. Energy efficiency of cellular communication systems is becoming a major concern for network operators to not only reduce the operational costs, but also to reduce their environmental effects. Table 1 gives a summary of the power savings obtained by some of the discussed techniques.

With the cellular network technology moving towards self Configuration and Self Optimization networks cell zooming concept and use of renewable sources of energy seem to be the most promising techniques to reduce power consumption so as to save on operational costs and reduce environmental effects.

ACKNOWLEDGEMENT

The authors gratefully acknowledge JKUAT for their support.

REFERENCES


