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ENERGY EFFICIENT GREEN RADIO TECHNOLOGY

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Abstract: - Recent survey by network operators and manufacturers have shown that current wireless networks are not very energy efficient, particularly the base stations by which terminals access services from the network. Green radio technology describes one of the most promising research directions in reducing the energy consumption as well as the carbon emissions of future base stations. Nowadays, we are facing a number of serious energy related problems, including energy shortages, energy price hikes, and global warming; these problems have a significant negative impact in terms of the environment, global health, and social and economic well being. However, today's mobile communication architectures are not specifically designed to be energy efficient.

Keywords: Energy efficient wireless network, CO2 emission reduction, Green Radio Technology, Power saving in base stations.

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INTRODUCTION

Recent survey by network operators and manufacturers have shown that current wireless networks are not very energy efficient, particularly the base stations by which terminals access services from the network. Green radio technology describes one of the most promising research directions in reducing the energy consumption as well as the carbon emissions of future base stations. Given the worldwide growth in the number of mobile subscribers, the move to higher-data-rate mobile broadband, and the increasing contribution of information technology to the overall energy consumption of the world, there is a need on environmental grounds to reduce the energy requirements of radio access networks [1]. The Green Radio program sets the aspiration of achieving a hundredfold reduction in power consumption over current designs for wireless communication networks. This challenge is rendered nontrivial by the requirement to achieve this reduction without significantly compromising the quality of service Experienced by the Network's users. Our objective is to reduce the energy consumption in base Stations and reduce the amount of CO_2 emission. Mobile communications, which contribute 15–20 percent of the entire information and communications technologies (ICT) energy footprint and 0.3–0.4 percent of global CO_2 emissions [2], the mobile industry faces a great sustainable development problem in energy consumption.

We have to keep controlling system in every base station for switching purpose. Apart from this, the architectural operation of present system is not energy efficient. This leads to enormous amount of fuel wastage. As Shown in Fig. 1 It clearly states that reducing the power usage of the base station will reduce the power consumption as it consumes the maximum power.

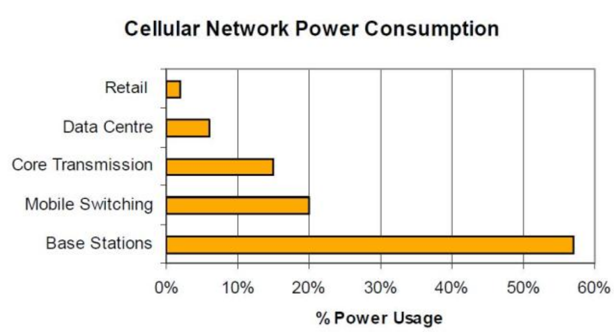

Fig. 1 Power consumption of a typical wireless cellular network.[1]

Fig. 2 shows the CO_2 emissions per subscriber per year for base station and mobile handsets. It is seen that the operational energy for mobile handsets is much less than that of base station. It also shows that the manufacturing or embodied energy is greater in mobile handsets when compared to base station. Now considering one single tower, power is not only used for the signal transmission process, but also for running the cooling unit of generator and light indicator present along with lightning arrestor. Cooling unit consists of an Air-Conditioner and a Fan. Both Air-Conditioner and cooling fan operate throughout the day, irrespective of the climate change and temperature around the generator. Thus, the notion of "green" technology in wireless systems can be made meaningful with a comprehensive evaluation of energy savings and performance in a practical system. This is where energy efficiency metrics play an important role

Fig. 2 Co2 emissions per subscriber per year [3]

As shown in Fig. 3 statistics indicate that the RBS is the main source of energy consumption in the network of a mobile operator [4]. Energy efficient solutions for wireless access networks are mainly concentrated on RBSs. Among all components in an RBS, power amplifiers (PAs) drain the most energy. Energy is also dissipated in alternating current/direct current (AC/DC) converting, cabling, and cooling. Various solutions have been proposed to improve EE of the RBS, such as increasing PA efficiency, using non-active cooling techniques, employing masthead PA to reduce feeder loss, exploiting energy efficient backhaul solutions, applying energy-efficient deployment strategies, and introducing energy-efficient protocols. This article overviews soft methods to improve EE of RBSs, with an emphasis on Long Term Evolution (LTE) systems. Soft methods do not upgrade hardware, but tune parameters in protocols, and apply enhanced architecture and deployment strategies for EE improvement. They enable flexible and cost-efficient solutions with minimum impact on hardware implementation.

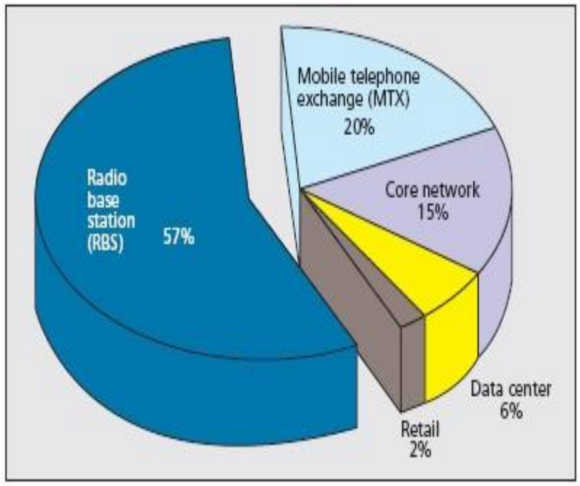

Fig. 3 Energy consumption composition of a mobile operator.[4]

Energy Consumption in the Base Station

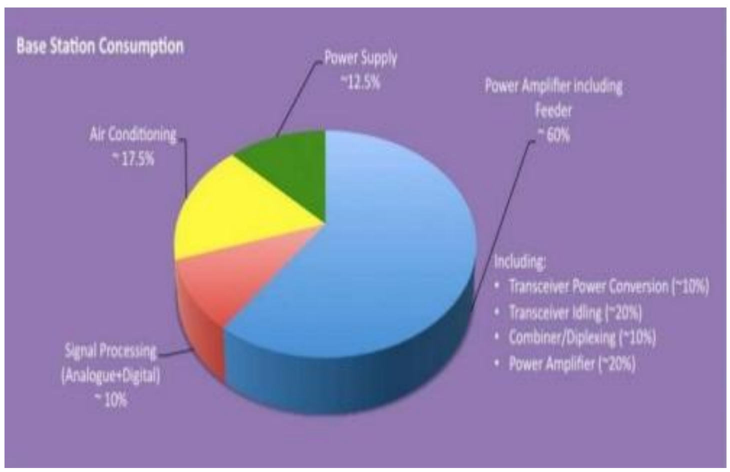

Fig. 4 Energy consumption in base station

In Figure 4, we present a synthesis we made of different sources that shows the consumption contribution from different components. The second reason is the fact that traffic in the real world cannot be considered uniform, neither geographically nor temporally speaking, wasting therefore an important percentage of energy due to unnecessary active BSs. It is mentioned that for a typical radio access deployment, only 10% of BSs are responsible for nearly a half of the traffic, whereas 50% of the BSs handle 5% of total traffic. Taking into account this panorama, researchers around the world are looking for ideas to solve or at least mitigate such problematic. These ideas include new architectures and mechanisms at different levels (i.e. internal components, BS, RAN), some of them conceived into the core of the already important list of international projects working on wireless network energy efficiency.

All efficiency of the base station, in terms of the power drawn from its supply in relation to its radio frequency (RF) power output, is governed by the power consumption of its various constituent parts, including the core radio devices

Power Amplifiers : This devices amplifies the transmit signals from the Transceiver to a high enough power level for transmission, typically around 5-10 W.

Radio transceivers: The equipment for generating transmit signals to and decoding signals from mobile terminals.

Transmit antennas: The antennas are responsible for physically radiating the signals, and are typically highly directional to deliver the signal to users without radiating the signal into the ground or sky. Base stations also contain other ancillary equipment, providing facilities such as connection to the service provider's network and climate control. A major opportunity to achieve the power reduction targets of the program lies in developing techniques to improve the efficiency of base station hardware. Target power consumption figures allow future overall base station efficiencies to be predicted.

BASE STATION ARCHITECTURE

The current base station architecture is not energy efficient. The important drawback of the current system is that it is dependent on electrical grid power. In rural and remote areas, these base stations are not able to access a reliable electrical grid power. These base stations are powered by diesel generators, fuelled by oil. A huge amount of diesel is required by the diesel generator to generate power.

The target system for the base station efficiency analysis is the Long Term Evolution (LTE) system with support for four transmits antennas. This system can exploit the space domain to achieve high data throughputs through multiple input multiple output (MIMO) techniques. In the case of the antenna, the 90 percent efficiency target is to be achieved by exploiting highly efficient dual-polarized patch antenna elements.

In times of steadily increasing energy costs and with the vanishing resources of the classic, non-regenerative energy sources, we see the challenge of finding new solutions for the uninterruptable power supply of mobile radio base stations (BTS). A growing environmental consciousness and the demand for reduction of the emission of greenhouse gases like C02 increase the motivation to develop alternative power supply concepts.

Architecture for Green Radio Technology

Before starting any discussion on “green” networks, the first question naturally comes to mind is that what actually is “green”? How do we measure and define the degree of “greenness” in telecommunication networks? Although carbon footprint or CO2 emissions would actually be considered a measure of “greenness”, but the share of carbon emissions for telecommunication networks is fairly low (less than 1%). However, please note that other motivations to obtain “green” wireless technology also include economic benefits (lower energy costs) and better practical usage (increased battery life in mobile devices), hence evaluation of energy savings or measuring energy efficiency seems to be a more apt choice for measuring “greenness”. Thus, the notion of “green” technology in wireless systems can be made meaningful with a comprehensive evaluation of energy savings and performance in a practical system. Energy saving can be viewed as an optimization function that reduces power consumption by adapting the provided network capacity.

Architecture:

1. Minimizing BS energy consumption

2. Using Renewable Energy Resources

3. Energy-Aware Cooperative BSs

Measuring Greenness: Green Metrics

1. Facility-level Metrics

2. Equipment-level Metrics

3. Network-level Metrics

Network Planning:

1. Macro-cells

2. Micro-cells

3. Pico-cells

System Design:

1. Green Comm. via Cognitive Radio

2. Green Comm. Via. Cooperative Relays

3. Low Energy Spectrum Sensing

4. Energy-Efficient Resource Management

5. Cross-Layer Design & Optimization

6. Cross-Layer Design & Optimization

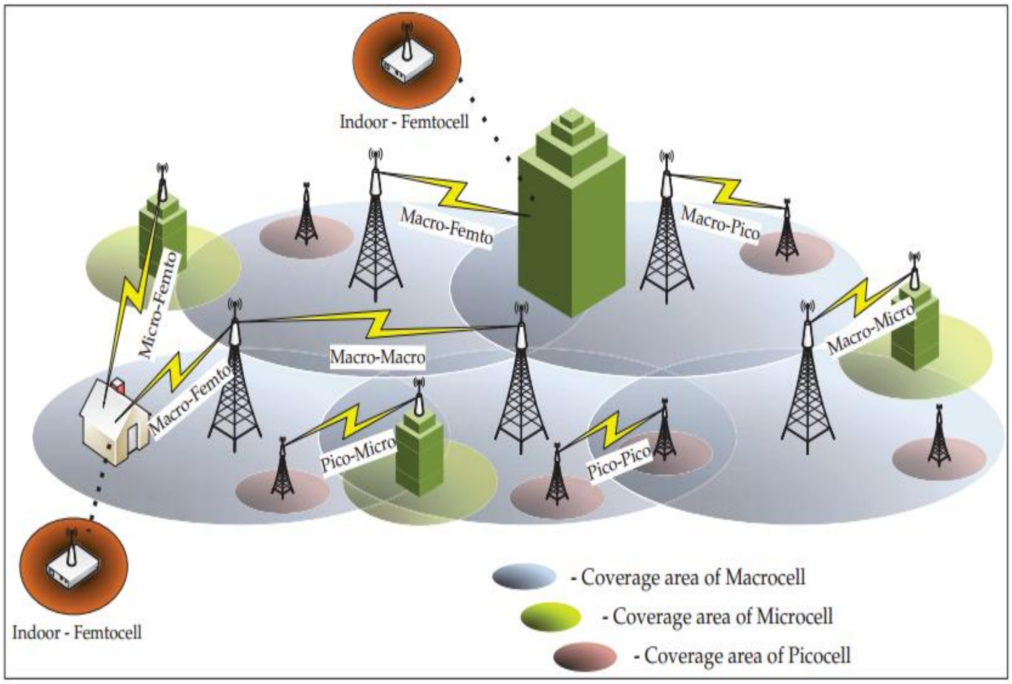

Fig. 5 A typical heterogeneous network deployment

“Green” technology in wireless systems can be made meaningful with a comprehensive evaluation of energy savings and performance in a practical system. This is where energy efficiency metrics play an important role. These metrics provide information in order to directly compare and assess the energy consumption of various components and the overall network. In addition, they also help us to set long term research goals of reducing energy consumption. With the increase in research activities pertaining to green communications and hence in number of diverse energy efficiency metrics, standards organizations such as European Technical Standards Institute (ETSI) and Alliance for Telecommunications Industry Solutions (ATIS) are currently making efforts to define energy efficiency metrics for wireless networks. Generally speaking, energy efficiency metrics of telecommunication systems can be classified into three main categories: facility-level, equipment-level and network-level metrics. The Green Grid (TGG) association of IT professionals first proposed facility-level efficiency metrics called PUE (Power Usage Efficiency) and its reciprocal DCE (Data Center Efficiency) in [5] to evaluate the performance of power hogging datacenters. PUE which is defined as the ratio of total facility power consumption to total equipment power consumption is although a good metric to quickly assess the performance of datacenters at a macro level, it fails to account for energy efficiency of individual equipments. Therefore, in order to quantify efficiency at the equipment level, ratio of energy consumption to some performance measure of a communication system would be more appropriate. However, grading the performance of a communication system is more challenging than it actually first appears, because the performance comes in a variety of different forms (spectral efficiency, number of calls supported in block of time, etc.) and each such performance measure affects this efficiency metric very differently. Some suggested metrics including power per user (ratio of total facility power to number of users) measured in [Watt/user], and energy consumption rating (ECR) which is the ratio of normalized energy consumption to effective.

The energy consumption of a typical 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 order to improve hardware design of a BS for energy consumption, we need to address the energy efficiency of the power amplifier (PA). A PA dominates the energy consumption of a BS and its energy efficiency depends on the frequency band, modulation and operating environment. Some typical system features to improve BS energy efficiency are to shut down BS during low traffic or cell zooming. Besides hardware redesign and new system level features, there are various site level solutions that can be used in order 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 BS design can be implemented to reduce power loss in feeder cables. One more significant setback in increasing power efficiency with PAs is that they perform better at maximum output power in order to maintain the required signal quality. However, during the low traffic load conditions (e.g night time), lot of energy is routinely 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. In addition to this, we need to investigate more efficient modulation schemes, because modulation also affects the PA efficiency. As an example, by focusing more on higher modulation schemes that require additional filtering in order to prioritize data over voice, linearity of PA is more desirable because of the non-constant envelope of the signal. Using different linearization techniques such as Cartesian feedback, digital pre-distortion and feed-forward along with different kind of DSP methods that reduces the requirement on the linear area of PA have also been suggested.

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. Whereas conventional macro-cellular network deployments are less efficient, it may not be economically feasible to modify the current network architectures. Macrocells are generally designed to provide large coverage and are not efficient in providing high data rates. One obvious 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. Therefore, cellular network deployment solutions based on smaller cells such as micro, pico and femtocells are very promising in this context. A typical heterogeneous network deployment is shown in Fig. 5. A micro/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, or a train station. While a typical 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. The range of femtocells is typically only a few metres and they are generally wired to a private owners' cable broadband connection or a home digital subscriber line (DSL). Smaller cells because of their size are much more power efficient in providing broadband coverage. As an example, a typical femtocell might only have a 100mW PA, and draw 5W total compared to a 5KW that would be needed to support macrocell. An analysis by OFCOM (UK regulator) and Plextek concluded that femtocell deployment could have a 7:1 operational energy advantage ratio over the expansion of the macrocell network to provide approximately similar indoor coverage [6]. 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 macro-cells only [7]. Another advantage of smaller cells is that they can use higher frequency bands suitable to provide high data rates and also offer localization of radio transmissions. However, deploying too many smaller cells within a macrocell may reduce the overall efficiency of the macrocell BS, since it will have to operate under low load conditions. Therefore, careful investigation of various deployment strategies should be done in order to find how to best deploy such smaller cells. In [8], Calin et al. provided insight into possible architectures/scenarios for joint deployments of macro and femtocells with an analysis framework for quantifying potential macro-offloading benefits in realistic network scenarios. Richter et al. in , investigate the impact of different deployment strategies on the power consumption of mobile communication network. Considering layouts with different number of micro BSs in a cell, in addition to macro sites, the authors introduce the concept of area power consumption as a system performance metric. Simulation results suggest that under full traffic load scenarios, the use of micro BSs has a rather moderate effect on the area power consumption of a cellular network and strongly depends on the offset power consumption of both the macro and micro sites. In, the authors investigate the potential improvements of the same metric achievable in network layouts with different numbers of micro BSs together with macro sites for a given system performance targets under full load conditions.

Recently, the research on technologies such as cognitive radio and cooperative relaying has received a significant attention by both industry and academia. While cognitive radio is an intelligent and adaptive wireless communication system that enables us to utilize the radio spectrum in a more efficient manner, cooperative relays can provide a lot of improvement in throughput and coverage for futuristic wireless networks. However, developments in both these technologies also enable us to solve the problem of energy efficiency via smart radio transmission and distributed signal processing. In the following subsections, we will discuss how we can enable green communication in cellular systems using cognitive radio and cooperative relaying.

CONCLUSION

This paper addresses the energy efficiency of cellular communication systems. It can be seen that increase in mobile users leads to increase in power consumption, which in turn leads to emission of more and more CO2. This leads to global warming as CO2 is considered to be one of the green house gases. In order to control this effect, the major area to be controlled is to reduce power consumption. Research on energy efficient or “green” cellular network is quite broad and a number of research issues and challenges lay ahead. Nevertheless, it is in favor of both the network operators and the society to swiftly address these challenges to minimize the environmental and financial impact of such a fast growing and widely adopted technology. This article attempts to briefly explore the current technology with respect to some aspects related to green communications and we discuss future research that may prove beneficial in pursuing this vision.

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