A Survey of Green Base Stations in Cellular Networks

Chethana R Murthy
Asst Prof, Dept of Information Science & Engineering
R V College of Engineering
Bangalore, India

Dr. C Kavitha
Professor, Dept of Computer Science & Engineering
B.N.M. Institute of Technology
Bangalore, India

***Abstract* - The growing awareness towards energy efficient cellular networks has paved way for new technologies in designing green cellular networks. According to technical analysts, the base stations are the most energy intensive part of a typical cellular network. Saving power in base stations is therefore the primary focus in green cellular networks. The main goal of designing green base stations is for saving energy and reducing power consumption while guaranteeing service and coverage for users and ensuring the capability of base station for evolution. This can be achieved by minimizing the base station energy consumption with energy efficient hardware design, power saving protocols for sleep modes, energy aware cooperative base station power management with self organizing cells, cell zooming, or by using renewable energy sources. This attempts to review possible energy efficient solutions towards green base station.**

***Keywords* - Green base station, green cellular networks, cell zooming, self organizing networks**

I. INTRODUCTION

The exponential growth in the cellular networks market and in the number of subscribers has increased the demand for cellular traffic. These mushrooming networks have pushed the limits of energy consumption in wireless networks and have some impact on the industry's overall carbon footprint. The global greenhouse gas emissions from information and communication technology (ICT) are comparable with those of the aviation industry [1]. Technology analysts estimate that a fraction of the worldwide energy ranging between 2%-10% is consumed by the global ICT industry in manufacturing, using and disposal of ICT equipments [2]. As the use of ICT grows, its emissions are likely to increase despite improvements in efficiency. It is estimated that ICT will be responsible for 3% of global emissions by 2020. So, more and more researchers have focused on improving the energy efficiency of cellular network, wireless sensor network and mobile ad-hoc network, such as the related works in [3-5].

This paper studies the power consumption by a typical base station in a cellular network and attempts to review possible energy efficient solutions towards green base station for a green cellular network. This paper is organized into four sections. Section 1 provides information about "Green cellular networks". Section 2 discusses the energy utilization statistics in a typical wireless network and contribution of base stations emissions towards carbon footprint. Section 3 attempts to review possible solutions to improve energy efficiency in base stations. Section 4 contains concluding remarks.

II. GREEN CELLULAR NETWORKS

Green communication is an innovative research area to find radio networking solutions that can greatly improve energy-efficiency as well as resource-efficiency without compromising the quality of service (QoS) for users. Green Communications not only benefits the global environment but also makes commercial sense for telecommunication operators supporting sustainable and profitable business.

The European Commission has started some projects under seventh Framework Programme (FP7) like "Energy Aware Radio and NeTwork TecHnologies (EARTH)" [6], "Towards Real Energy-efficient Network Design (TREND)" [7] and "Cognitive Radio and Cooperative strategies for Power saving in multi-standard wireless devices (C2POWER)" [8] to address the energy efficiency of mobile communication systems. These are highly ambitious and unique IP projects, investigating the energy efficiency of mobile communication systems by applying a number of paradigm-shifting technical approaches and committed to the development of a new generation of energy efficient equipment, network architecture & protocols, energy-efficient wireless transmission techniques for reduced transmission power & reduced radiation, cross-layer optimization methods, network management solutions and opportunistic spectrum sharing without causing harmful interference pollution.

The aim of Green cellular networks is to represent the trend of Next-Generation Networking - a network that transports all information and services like voice, data, and all sorts of media such as video and to cater people's demand for health and energy savings.

III. WHERE IS THE ENERGY USED?

A cellular network is a radio network distributed over land areas called cells, each served by at least one fixed-location transceiver known as a cell site or base station. When joined together these cells provide radio coverage over a wide geographic area. This enables a large number of portable transceivers (e.g., mobile phones etc.) to communicate with each other and with fixed transceivers and telephones anywhere in the network, via base stations, even if some of the transceivers are moving through more than one cell during transmission.

A typical cellular network consists of three main elements; A core network that takes care of switching; base stations providing radio frequency interface; and the mobile terminals in order to make voice or data connections. The power consumption is distributed across the different functionalities of the network like mobile switching, core transmission, data center etc. [9]. But the base stations are the most energy intensive part of the cellular network. A typical 3G base station which uses 500W of input power to produce 40W of output RF power will consume more than 50GWh a year in a network with 12,000 base stations. This causes a large amount of CO_2 emission as well as contributes to the network's operating costs [10]. Thus base station power consumption is the biggest power issue concerning cellular networks. Saving power in base stations is therefore the primary focus in green cellular network development.

IV. How to reduce base station power consumption?

Energy efficiency with respect to base stations can be considered in all stages of cellular networks. There are several solutions towards green base stations such as improving base station hardware design, employing energy aware techniques, additional software and system features for network planning to balance between energy consumption and performance etc [11]. In this paper we have attempted to review few solutions among them.

A. Base station hardware design

A number of efforts have focused on hardware improvements. For instance, next-generation base stations are designed to be substantially more energy efficient. The base station equipment manufacturers have begun to offer a number of eco and cost friendly solutions to reduce power demands of base stations and to support off-grid base stations with renewable energy resources.

The Flexi base station (BTS) - an industry-leading, cost and energy-efficient multi-radio base station for Single Radio Access Network (RAN) advanced mobile broadband networks is an example of efficient site design and management by Nokia Siemens Networks [12]. The Flexi base station acts as a software-defined base station for technologies like Global System for Mobile Communications (GSM)/ Enhanced Data rates for GSM Evolution(EDGE), Wideband Code Division Multiple Access(WCDMA)/ Evolved High-Speed Packet Access(HSPA+), and 3rd Generation Partnership Project(3GPP) - Long Term Evolution(LTE) (i.e Frequency-division duplex(FDD)/ Time-division duplex(TDD) systems). The benefits of a Flexi base station are as follows: reduced installation time and materials costs, compact size and reduced weight - only 20% of a conventional cabinet base station, up to 70% reduction in site power consumption, flexible location either indoor or outdoor without the need for air conditioning, shorten antenna feeders. The Flexi base station carbon footprint is further diminished by its software-based capacity to remotely manage tuning the running capacity, upgrade, canceling the need for site visiting. Its upgrading capability enables flexibility for sites to upgrade and adapt to future radio technologies with maximum re-use of legacy site infrastructure. Flexi base station is also ready for using renewable energy such as solar or wind power [13].

The Ericsson's Tower Tube- Tower Tube is an award winning solution by Ericsson with latest technology and innovative design to reduce construction cost, decrease carbon emission, energy optimization and for pleasant look [14]. Tower tube has its radio base station positioned at height for increased network's coverage, capacity and low feeder loss. It is space efficient with all slim designed equipments encapsulated in the tower. It does not require cooling. Thus with cutting edge design and building materials like concrete with post-tension reinforcement technology, the Tower tube lowers the amount of carbon dioxide in the manufacturing process also

B. Power saving protocols for sleep modes

Energy consumption in base stations can be minimized without affecting the quality of service by developing energy-efficient, radio resource management schemes. Sleep mode mechanisms for base station operations is one of the promising approaches to reduce energy consumption.

The authors in [15] propose two sleep mechanisms for 2G and HSPA base station to shut down a number of system resources in light traffic scenarios: dynamic way and semi-static way. In dynamic way resources are activated/deactivated in real-time as a function of the instantaneous load of the system. In a semi-static way resources are kept unchanged during longer time intervals, in the order of one hour. The authors show that the dynamic one achieves larger energy reductions while the semi-static one has an acceptable performance with low complexity.

The authors in [16] discuss a sleep mode mechanism for base stations in Orthogonal Frequency-Division Multiple Access (OFDMA) cellular networks where the lightly loaded base stations are turned off randomly achieving explicit expressions for the impact of switching off base

stations on the total expected power consumption, on the coverage, and on the amount of radiation to the human's body. The authors assume base station distribution to form a homogeneous Poisson point process and the radio interference to be negligible.

The authors in [17] propose a complimentary method to switch off the low utilization level base stations based on the store-carry and forward relaying paradigm. This scheme formulates a joint routing and scheduling problem and exploits the mobility of relay nodes to migrate traffic from base stations of very low utilization to neighbor base stations, allowing in that respect these sites to be switched off. The authors conclude from their numerical investigations that significant energy gains are attained using this scheme for switching off base stations.

C. Network self organizing techniques

Self-organizing networks (SON) is one of the promising areas of the latest 3rd Generation Partnership Project technology- Long Term Evolution (LTE) for next-generation radio access networks that save operational expenditures. The SON can be applied to achieve objectives like self configuration for load balancing, self optimization and self healing, cell outage management, and management of relays and repeaters, etc.

The authors in [18] discuss dynamic operations to switch off the redundant base stations during periods of low traffic such as at night to provide significant energy savings. The authors quantitatively estimate the percentage of power savings through a first-order analysis based on real cellular traffic traces and found promising potential savings. They also have identified a number of open issues pertinent to implementation of energy- efficient dynamic base station operation schemes, such as various approaches to ensure coverage, and inter-operator coordination.

The authors in [19] discuss the base station handover optimization in self organized networks. The role of self-organized handover optimization in the overall radio network performance is significant. From the results obtained by simulations of handover optimization procedure characterized by heterogeneous radio conditions between neighboring cells, the authors show that their procedure is stable and efficient from initial suboptimal parameter settings towards optimum values of the handover key performance indicators.

The authors in [20] introduce algorithms for partitioning energy in coordination with network elements to power on and power off base stations and save energy with the objective of matching offered capacity with the traffic demand in a flexible manner. These algorithms achieve network-level energy saving and are based on shared knowledge of load and coverage information to enable an appropriate cell reconfiguration. The authors analyze the performance of centralized and distributed algorithms under different network topologies and traffic conditions through simulation evaluation.

Cell zooming is a technique to adaptively adjusts the cell size according to traffic conditions. It has the potential to balance the traffic load and reduce the energy consumption. When a cell is congested, the cell can zoom in to reduce the cell size and therefore release from the congestion and the neighboring cell zooms out to avoid any possible coverage hole. Cell zooming can be implemented by adjusting the physical parameters such as the transmit power of base stations, or by base station cooperation and relaying.

The authors in [21] discuss cell zooming to balance the traffic load, while reducing the energy consumption. The authors have implemented two cell zooming algorithms centralized and distributed algorithm. In the centralized algorithm resource allocation and cell zooming operations are performed in a centralized way depending on all the channel conditions and user requirements in the network collected by the central system. In the distributed algorithm each mobile unit itself selects the base station to be associated with, based on the broadcasted information by the base stations. The simulation results show that with cell zooming the energy consumption can be greatly reduced.

D. Using renewable energy resource like sustainable bio-fuels, Solar – Wind energy

Renewable energy resources are the upcoming energy supply sources to power the base stations in the areas where there is no public and stable power supply, inhospitable terrain, neglected infrastructure, remote areas, deserts, islands etc.

One of the leading telecom solutions providers – Huawei, has developed the renewable energy solutions for base stations to solve the power problems in China, Africa and the Middle East region. The energy source includes solar energy, wind and solar hybrid power, solar and diesel hybrid power. These Huawei Green Base Stations with energy-efficient equipments, optimized hardware design and environmental friendly materials has reduced power consumption up to 60 percent. Huawei Green Base Stations have minimum environmental impact, low maintenance rate and the benefits of higher reliability and customization. [22-23].

Flexenclosure Esite for off-grid sites is yet another extremely power efficient solution specially designed to generate energy from renewable energy sources like wind and solar radiation. Esite also conserves power in a battery bank with an additional back-up source to secure redundancy and uninterrupted operation [24]. Esite is a low life-cycle cost system with the focus on trouble-free operation supporting

V. CONCLUSION

In a wireless network base station power consumption is the biggest issue. With global warming and energy crises becoming the most compelling challenges for the environment, green solutions is a common issue to be handled. Hence the primary focus of the "Green cellular network" is saving power in base stations to "care for planet and operator's valet". In this paper we reviewed few techniques for saving power consumption and improve energy efficiency in base stations. However, there are still many technical challenges for base station architecture redesign, heterogeneous network deployment, radio resource management etc that need to be addressed for energy efficient base stations.

REFERENCES

[1] Postnote – ICT and CO2 emissions, December 2008 Number 319 Parliamentary Office of Science & Technology

[2] Ziaul Hasan, Hamidreza Boostanimehr, Vijay K. Bhargava, "Green Cellular Networks: A Survey, Some Research Issues and Challenges" Communications Surveys & Tutorials, IEEE, 2011

[3] "A Survey of Green Mobile Networks: Opportunities and Challenges" Springer Science-Business Media, Mobile Netw Appl, LLC 2011

[4] C. Han et al., "Green radio: radio techniques to enable energy-efficient wireless networks," IEEE IEEE Commun. Mag., vol. 49, no. 6, pp. 46-54, 2011

[5] Chen Yan, S. Zhang, S. Xu, and G. Y. Li, "Fundamental trade-offs on green wireless networks," IEEE Communications Magazine, vol. 49, no. 6, pp. 3037, 2011.

[6] "Energy Aware Radio and NeTwork TecHnologies (EARTH)" : https://www.ict-earth.eu/

[7] "Towards Real Energy-efficient Network Design (TREND)" : http://www.fp7-trend.eu/

[8] "Cognitive Radio and Cooperative strategies for Power saving in multi-standard wireless devices (C2POWER)" : http://www.ict-c2power.eu/

[9] M. Deruyck, et. Al., "Power consumption in wireless access networks", in Proceedings-European Wireless Conference, April 2010

[10] White paper – Green Radio "NEC's Approach towards Energy-efficient Radio Access Networks" February 2010, NEC Corporation

[11] Yuli Song, Dongxiao Li, and Zhansheng Wu, "Discussion on smart power saving technology of BTS", Designing Techniques of Posts and Telecommunications, vol. 31, no. 3, pp. 70-73, 2010

[12] "Multiradio Base Station makes network evolution easier and greener than ever", Press Release Feb 5 2009, Nokia Siemens Networks. Available at: http://www.nokiasiemensnetworks.com/sites/default/files/document/NokiaSiemensNetworks 2009 02 05 enFlexiMultiradioBTS.pdf

[13] http://www.nokiasiemensnetworks.com/portfolio/products/mobile-broadband/single-ran-advanced/flexi-multiradio-base-station

[14] http://www.ericsson.com/ourportfolio/products/ericsson-tower-tube

[15] Saker, L. Elayoubi, S.-E. Chahed, T, "Minimizing Energy Consumption via Sleep Mode in Green Base Station" , Wireless Communications and Networking Conference (WCNC), 2010 IEEE

[16] Eitan Altman, Manjesh K. Hanawal, Rachid El-Azouzi, "Tradeoffs in Green Cellular Networks" , ACM SIGMETRICS Performance Evaluation Review Volume 39 Issue 3, December 2011

[17] Kolios, P, Friderikos, V, Papadaki, K, "Switching off low utilization base stations via store carry and forward relaying" Personal, Indoor and Mobile Radio Communications Workshops (PIMRC Workshops), 2010 IEEE 21st International Symposium

[18] Eunsung Oh, Krishnamachari, B, Xin Liu, Zhisheng Niu, "Toward Dynamic Energy-Efficient Operation of Cellular Network Infrastructure", Communications Magazine, 2011 IEEE

[19] Ewe L, Bakker H, "Base station distributed handover optimization in LTE self-organizing networks", Personal Indoor and Mobile Radio Communications (PIMRC), 2011 IEEE 22nd International Symposium

[20] K. Samdanis, D. Kutscher, and M. Brunner, "Self-organized energy efficient cellular networks," Proc. Of IEEE PIMRC'10, pp. 1665-1670, 2010.

[21] Zhisheng Niu, Yiqun Wu, Jie Gong, and Zexi Yang, "Cell zooming for cost-efficient green cellular networks," IEEE Communications Magazine, vol.48, no.11, pp.74-79, November 2010

[22] "The green CDMA base station", Huawei Communicate, Issue 45, 2009. Available: http://www.huawei.com/ilink/en/download/HW 082746

[23] http://www.greenhuawei.com/green/greenenergy.html

[24] Flexenclosure E-site Case Study, Available: http://www.flexenclosure.com/Esite.aspx

AUTHOR'S PROFILE

Chethana R Murthy received her B.E. and M.Tech degree in Computer Science & Engineering from Visvesvaraya Technological University, Belgaum, Karnataka – India in 2003 and 2007 respectively. She has more than seven years of industry and teaching experience. Her research interests include wireless networks & communications, green cellular networks, next generation technologies

Dr. Kavitha C received her B.E. and M.E degree in Computer Science & Engineering from Bangalore University, Karnataka – India in 1992 and 1998 respectively and her Ph.D from Visvesvaraya Technological University, Belgaum, Karnataka – India in 2010. She has more than fourteen years of teaching experience. Her research interests include wireless networks, sensor networks.