International Journal of Trend in Scientific Research and Development (IJTSRD)
International Open Access Journal
ISSN No: 2456 - 6470 | www.ijtsrd.com | Volume - 2 | Issue – 5

A Review on Green Cellular Network

K Saravanan
Lecturer (Senior Grade)
Department of Electronic Communication Engineering,
Sakthi Polytechnic College, Erode, Tamil Nadu, India

ABSTRACT
Energy efficiency in the cellular network is a growing concern for cellular operators and with the exponential increase in mobile internet traffic driven by a new generation of wireless devices, future cellular networks face a great challenge to meet this overwhelming demand of network capacity. At the same time, the demand for higher data rates and the ever-increasing number of wireless users led to rapid increases in power consumption and operating cost of cellular networks. This emerging trend of achieving energy efficiency in cellular networks is motivating the standardization authorities and network operators to continuously explore future technologies in order to bring improvements in the entire network infrastructure. In this article, we present a brief review and analysis of methods to improve the power efficiency of cellular networks, explore some research issues and challenges and suggest some techniques to enable an energy efficient or "green" cellular network.

Keywords: *Green communication, Base station ON/OFF Switching, Femtocells, Efficiency Analysis, Time Sharing Property, and Heterogeneous Network.*

I. INTRODUCTION

With the ever increasing number of mobile broadband data users and bandwidth-intensive services, the demand for radio resources has increased tremendously. The number of subscribers and the demand for cellular traffic has escalated astronomically. With the introduction of Android and iPhone devices, use of eBook readers such as iPad and Kindle and the success of social networking giants such as Facebook, the demand for cellular data traffic has also grown significantly in recent years. Hence, mobile operators find meeting these new demands in wireless cellular networks inevitable. To do this cost-effectively, a paradigm shift in cellular network infrastructure deployment is occurring away from traditional (expensive) high-power tower-mounted base stations and towards heterogeneous elements. Examples of heterogeneous elements include microcells, pico-cells, femto-cells, and distributed antenna systems (remote radio heads), which are distinguished by their transmit powers/ coverage areas, physical size, backhaul, and propagation characteristics. The resulting network, referred to as heterogeneous network (Het Net), helps in maintaining the quality of service (QoS) for a larger number of users by reusing the spectrum.

However, with the densification of these HetNets, energy consumption. The number of base stations in Developing regions are expected to almost double by 2017 as shown in Figure 1. Information and Communication Technology (ICT) already represents around 2% of total carbon emissions (of which mobile networks represent about 0.2%), and this is expected to increase every year. In addition to the environmental aspects, energy costs also represent a significant portion of network operators' overall expenditures (OPEX).

Figure 1: Growth Forced for Global HSPA & LTE Subscribers 2012-2017

Most of the wireless data usage is in indoor environments such as offices, residential buildings, shopping malls, etc., where the users may face difficulties in achieving high data rates while connecting to the macro cell BSs. This is mainly due to the penetration loss incurred by the wireless signals inside the buildings. This paper describes the effects of energy efficiency in communications networks. Perhaps the two most important reasons to pursue the development of green communications networks are increases in carbon dioxide emissions (CO2) and increases in operational expenditures (OPEX). CO2 emissions are mainly associated with off-grid sites that provide coverage for remote areas. Most such sites are powered by diesel-power generators. According to, in 2002, the amount of CO2 emissions associated with information and communication technology (ICT) was 151 Mt CO2. The mobile communication sector was responsible for 43% of this total, and this proportion is expected to increase to 51% of the total or 349 MtCO2, by 2020. With respect to the economics of the sector, indicates that ICT currently consumes 600 TWh (Terawatt hours) of electrical energy and that this consumption is expected to increase to 1,700 TWh by 2030. Cellular network represents the largest component of the ICT sector.

The above-mentioned statistics have motivated researchers in both academia and industry to develop techniques to reduce the energy consumption of cellular networks, thereby maintaining profitability and making cellular networks “greener". The goals associated with green cellular networks:

1. Improvement of energy efficiency
2. Improvement of the intelligence of the network through tradeoffs between energy consumption and external conditions, that is, traffic load
3. Integrating network infrastructure and network services to enable the network to be more responsive and to require less power to operate
4. Reduced carbon emissions.

Among all the promising energy saving techniques, cognitive radio and cooperative relaying, although already getting matured in many aspects, but still are in their infancy when it comes to the deployment issues in cellular networks. Therefore, it is crucial to promote the potentials of these techniques in cellular wireless networks. Moreover, it is necessary to be aware that still many energy concerns in cognitive and cooperative networks have remained as unanswered challenges. Small cell BSs provide increased coverage and network capacity during peak times, however, they might not be very useful under light traffic load scenarios. Instead, they might be under-utilized or completely redundant leading to inefficient use of energy and communication resources. Hence, during periods of low traffic, it is appropriate to turn off the small cell BSs and offload the users to a nearby macro cell BS. The presence of FAPs provides additional flexibility in this regard, since the small cell users can be offloaded to the FAPs, if it is permitted. Also, the impact of such energy saving is high since cooperation may allow some small cell BSs, which consume higher energy than FAPs, to be turned off that would otherwise be on. In addition, the mobile operator can use a portion of its energy savings, achieved from cooperation, as well as excess resources, e.g., renewable energy, to provide incentives to the FAP operator.

In this paper, we provide a brief survey on some of the work that has already been done to achieve power efficiency in cellular networks, discuss some research issues and challenges and suggest some techniques to enable an energy efficient or “green” cellular network. We also put a special emphasis on cognitive and cooperative techniques, in order to bring attention to the benefits cellular systems can gain through employing such techniques, and also highlight the research avenues in making these techniques green. A taxonomy graph of our approach towards the design of green cellular networks, we identify four important aspects of a green networking where we would like to focus: defining green metrics, bringing architectural changes in base stations, network planning, and efficient system design. In addition, some broader perspectives must also be considered. In the following sections we elaborate on each such aspect and discuss the related issues and challenges. Then a brief overview of the techniques that have been considered in previous studies for use in saving energy, including a discussion of the principles of operation, the advantages, and the shortcomings of each technique. we study how to minimize energy consumption of BS employing improvements in power amplifier, designing power saving protocols, implementing cooperative BS power management, using renewable energy resources and bringing some simple architectural changes. Section IV addresses the energy efficiency from a network planning perspective where we discuss how different types of network deployments based on smaller cells can be used to increase the energy efficiency of a wireless system. Regarding the system design, we first explain the use of modern communication technologies such as cognitive radio and cooperative relays to enable green communication in cellular systems.

II. Related Work

Now a day many technologies have advance to increase the energy efficiency of cellular HetNets using dynamic BS ON/OFF switching technique. The dynamic small-cell ON/OFF operation while serving the offloaded traffic using the macro cell BS to minimize the total power consumption of the HetNet. Two algorithms are proposed to make ON/OFF switching decision. The first one is an optimal location-based operation algorithm applied in the case of uniformly distributed users. The second algorithm is a suboptimal approach proposed for non-uniformly distributed users. It has been shown that power saving is achieved thanks to the proposed dynamic ON/OFF switching operation. The 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. 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. Energy efficiency metrics provide information that can be used to assess and compare the energy consumption of various components of a cellular network and of the network as a whole. These metrics also help us to set long-term research goals for reducing energy consumption

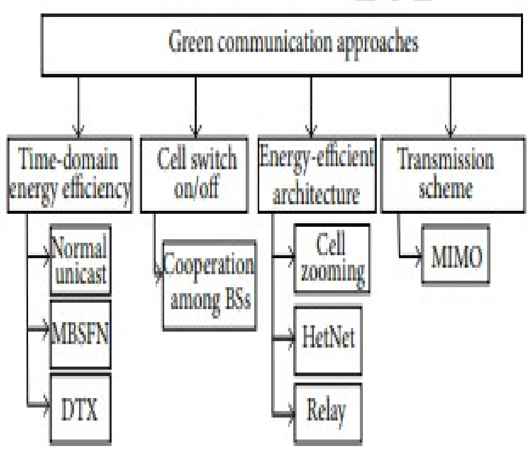

Figure 2: Classification of energy saving technique

Therefore, to quantify efficiency at the equipment level, a measure of the ratio of the energy consumption to the performance of a communication system would be more appropriate. Facility-level metrics assess initial power usage but do not reflect the energy efficiency of individual pieces of equipment. Thus, equipment-level metric, such as power amplifier efficiency metric, which quantify the performance of individual pieces of equipment, are required. The ATIS has introduced the telecommunications energy efficiency ratio (TEER), which is the ratio of useful work to power consumption and is measured in units of Gbps/Watt. Another method to counter cross-tier interference in HetNets is to use power control. A self-optimized coverage coordination framework between macrocell and femtocell is proposed based on the distributed power control by the femtocell BSs. In [20], a power control approach forfemtocell networks is introduced to reduce the transmit power levels of the strongest femtocell interferers.

In addition to energy conservation methods, the use of renewable energy to power cellular HetNets is also considered in literature. . Availability of locally generated renewable energy helps in reducing the carbon footprint of the BSs by limiting the required fossil fuel based energy. For instance in [22], a HetNet with hybrid energy supplies, i.e., the small cell BSs are powered by either the traditional electricity grid or green energy sources, has been used to minimize energy costs of the network. Some specific metrics have been used to measure the performance of computing processing associated with energy consumption, in units such as millions of instructions per second per watt (MIPS/W) and millions of floating-point operations per second per watt (MFLOPS/W).

This metric relates energy consumption to the number of transferred bits and the area of coverage. This is equivalent to analysing the average power usage with respect to the average rate and the area of coverage (W/bps/m2). A rich set of metrics exists at the access node level. The ECR quantifies the energy used to transmit a piece of information (Joules/bit). Some other metrics quantify the utility of various resources with respect to existing tradeoffs, such as the spectral efficiency (b/s/Hz) and the power efficiency (b/s/Hz/W). One metric intended to cover all the aspects in a more general way is the radio efficiency ((b·m)/s/Hz/W) [15], which reflects the data transmission rate and the transmission distance that is attainable for a given bandwidth and level of power supplied. The review detailzed the tradeoffs among several different energy efficiency metrics, such as deployment efficiency versus energy efficiency, spectrum efficiency versus energy efficiency, bandwidth versus power, and delay versus power. However, the most popular metric for measuring the performance of the system is “bits per Joule,” which is the number of bits transmitted per Joule of energy. Interested readers can find a more comprehensive taxonomy of green metrics. While power per user can be a useful metric for a network provider to evaluate economic tradeoffs, network planning etc., metrics such as ECR provide the manufacturers a better insight into performance of hardware components. However, even the busiest networks do not always operate on full load conditions, therefore it would be useful to complement metrics such as ECR to incorporate the dynamic network conditions such as energy consumption under full-load, half-load and idle cases. In this regard, other metrics such as ECRW (ECR-weighted), ECR-VL (energy efficiency metric over a variable-load cycle), ECR-EX (energy efficiency metric over extended-idle load cycle), telecommunications energy efficiency ratio (TEER) by ATIS, Telecommunication Equipment Energy Efficiency Rating (TEEER) by Verizon’s Networks and Building Systems consider total energy consumption as weighted sum of energy consumption of the equipment at different load conditions.

Shockingly, 80-90% of that is wasted as heat in the PA, and which in turn requires 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 generally in anywhere in the range from 5% to 20% (depending on the standard viz. GSM, UMTS, CDMA and the equipment’s condition) [29]. Modern BSs are terribly inefficient because of their need for PA linearity and high peak-to-average power ratios (PAPR). The modulation schemes that are used in communication standards such as WCDMA/HSPA and LTE are characterized by strongly varying signal envelopes with PAPR that exceeds 10dB. To obtain high linearity of the PAs in order to maintain the quality of radio signals, PAs have to operate well below saturation, resulting in poor power efficiency [3]. Depending on their technology (e.g Class-AB with digital pre-distortion) and implementation, the component level efficiency of modern amplifiers for CDMA and UMTS systems is in the order of approximately 30% to 40% [29]. Since these technologies have reached their limits, PAs based on special architectures such as digital pre-distorted Doherty-architectures and GaN (Aluminum Gallium nitride) based amplifiers seem to be more promising by pushing the power efficiency levels to over 50% [29]. 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)[30]. Since GaN structures can work under higher temperature and higher voltage, they can potentially provide a higher power output.

III. Contributions

In contrast to literature, we develop a unified framework that aims to reduce energy consumption using efficient resource allocation transmit power allocation, and BS ON/OFF switching. We also incorporate the availability of renewable energy sources in the proposed framework. Additionally, we investigate the cooperative scenario between cellular Het Nets and private femto cell networks to form a virtual network, which contributes significantly in the resource allocation and BS ON/OFF decision. Another way to improve power efficiency of a BS is to bring some architectural changes to the BS. 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. This will improve the efficiency and reliability of the BS. In the authors suggest all-digital transmitter architecture for green BS that usesa combination of EER and pulse width modulation (PWM)/pulse position modulation.

In several remote locations of the world such as Africa and Northern Canada, electrical grids are not available or are unreliable. Cellular network operators in these off-grid sites constantly rely on diesel powered generators to run BSs which is not only expensive, but also generates CO2 emissions. One such generator consumes an average of 1500 litres of diesel per month, resulting in a cost of approximately $30,000 per year to the network operator. Moreover, this fuel has to be physically brought to the site and sometimes it is even transported by helicopter in remote places, which adds further to this cost. In such places, renewable energy resources such as sustainable bio fuels, solar and wind energy seem to be more viable options to reduce the overall network expenditure. Hence, adopting renewable energy resources could save cellular companies such recurrent costs, since they are capital intensive and cheaper to maintain. Also, since renewable energy is derived from resources that are regenerative, renewable energy resources do not generate greenhouse gases such as CO2. Recently, a program called "Green Power for Mobile" to use renewable energy resources for BSs has been started by 25 leading telecoms including MTN Uganda and Zain, united under the Global Systems for Mobile communications Association (GSMA). This program is meant to aid the mobile industry to deploy solar, wind, or sustainable bio fuels technologies to power 118,000 new and existing off-grid BSs in developing countries by 2012. Powering that many BSs on renewable energy would save up to 2.5 billion litres of diesel per annum (0.35% of global diesel consumption of 700 billion litres per annum) and cut annual carbon emissions by up to 6.8 million tones.

Despite many efforts, hardware technologies for reducing energy consumption at the base station have not been able to achieve significant energy savings. Moreover, one cannot ignore the amount of energy that is wasted by inefficient utilization of resources. These factors have led to a solution that utilizes both equipment-level and network-level approaches. The network-level approaches seek to tune network-related parameters based on the sensing of external conditions, which enables the determination of the optimal transmission strategies for energy savings. The philosophy behind all the proposed methods is the same, reducing energy consumption based on the traffic load. In the following section, we will review how network-level approaches can help to improve the energy efficiency.

Regarding the employed algorithms, we can notice that the iterative algorithm is able to achieve a close performance to that of the optimal solution obtained using the dual decomposition method for all considered scenarios. The small difference is because the low complexity method does not achieve the optimal solution during the resource allocation process and the ON/OFF switching operation. Indeed, a different active small cell BSs combination in the ON/OFF switching using the iterative algorithm might lead to an increase of the energy consumption compared to the optimal combination.

IV. Network Planning-Heterogeneous Network Deployment

Macro cells 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 femto cells are very promising in this context. A micro/Pico cell 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/Pico cell 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, atypical femtocell might only have a 100mW PA, and draw5W 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.

The mutual supplementary saving concepts comprise component, link and network levels. At the component level the power amplifier complemented by a transceiver and a digital platform supporting advanced power management are key to efficient radio implementations. Discontinuous transmissions by base stations, where hardware components are switched off, facilitate energy efficient operation at the link level. At the network level, the potential for reducing energy consumption is in the layout of networks and their management, that take into account slowly changing daily load patterns, as well as highly dynamic traffic fluctuations. The algorithms that were proposed for homogeneous networks cannot be easily implemented in a HetNet because of the random and non uniform deployment of the BSs especially the LPBs. Sleep algorithm for HetNet needs to consider the random deployment of the small cells, the non-uniform traffic demand distribution user behaviour, and the delivered QoS after making sleep decision. A dynamic sleep algorithm using artificial neural networks (ANN) to predict future traffic demand for a Femto Access Point (FAP), sleep/wake function was categorized into node controlled, UE controlled and core controlled. Sleep command was sent to the FAP using the core controller interfaces. A HetNet deployment model was proposed in to determine the optimal macro/micro BSs density. This model has an added advantage of choosing which BS should be powered off during off-peak traffic periods. Factors such as path loss and transmit power are to be considered for BS switch off. A social spider algorithm was adopted in to decide on which BS to be switched off, while groups BSs into clusters where switching is applied per cluster.

Depending on the voice traffic model, this mechanism can provide an average power saving of 37.5% and for a high traffic scenario; it can achieve five times reduction in the occurrence of mobility events, compared to a fixed pilot transmission. A rather radial approach to create a link between fully centralized (cellular) and decentralized (ad hoc) networks in order to achieve more efficient network deployment is a paradigm shift towards self-organizing small-cell networks (SCNs). However, coverage and performance prediction, interference and mobility management together with security issues are some of the many issues that must be dealt while designing such networks. 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 macro cell may reduce the overall efficiency of the macro cell 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. It provided insight into possible architectures/scenarios for joint deployments of macro and femto cells with an analysis framework for quantifying potential macro-offloading benefits in realistic network scenarios.

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.

V. Recent Technologies

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. The optimization problems formulated are non-convex ones due to the existence of the binary matrix as a decision variable. In this section, we propose two approaches to solve these problems: A complex dual decomposition based method developed to find the optimum solution of the problem, and a practical but low complexity iterative algorithm that achieves sub-optimal results. In the sequel and without loss of generality, we develop the steps for each of the proposed approaches to solve the optimization problem for the MS and MSF-closed scenario. It is worth to note that the same steps can be followed to find the solutions corresponding to scenario by considering the corresponding FAPs' power budgets and the available FAPs' carriers.

It is expected that neighboring BSs will provide coverage to the switched off region. Cell zooming and Coordinated Multi Point (CoMP) is some of the techniques that have been proposed in literature to extend coverage. These techniques require some level of cooperation among the BSs to enhance network performance. For example, transmit power needs to be increased systematically in order to avoid interference. In addition, less power is required per BS to extend coverage to a given region. HetNets deployment can be made more intelligent by the use of the cognitive radio techniques. This will give rise to a cognitive HetNet. Effective integration of these can lead to an EE Het Net configuration. Cognitive capabilities were used in to reduce cost and power consumption from the smart grid. A topological control mechanism which will allocate spectrum space to the secondary user when the spectrum slot is not being utilized by the primary used. This provides the added capability of eliminating interference between BS cells in the network. A combination of BS cooperation and cognitive capabilities will give rise to a new generation of self-organized HetNets. These networks will have the capability to reconfigure, reorganize and decide on opportunistic spectrum usage and traffic demand. They will further have the capability maintaining and enhanced performance. However, MT mobility, interference, traffic demand are some of the issues that will still need to be dealt with during network design stage. BS deployment also has to be done in such a way that users do not have to oscillate their association too frequently.

An improvement in network throughput can be achieved by finding an optimal combination between user association and resource allocation. A joint user association and resource allocation condition. A logarithmic network utility maximization with a constraint of equal resource allocation was proposed i.e. maximization of user association with equal resource allocation. The proposed model, however, is restricted to low mobility network environments. The delay encountered as traffic traverses a network was considered in to propose a delay cell association. Real world policies were considered in for achieving user association decision. The objectives included balancing load distribution for minimum bit rate users, maximizing throughout for best effort user and minimizing transmission cost for the entire network. User association was modelled as a stationary point process model. The access points (AP) were assumed to be distributed according to a stationary point process. A relationship between the association area of the cell containing origin to a typical association area was derived. It was shown that the association area of an AP decreases with path-loss exponent and increases with channel gain variance.

Future research will focus on EE resource allocation given power allocation constraint to achieve a maximum data rate requirement. These future works should consider other factors such as interference, QoS, transmission impairments, etc. The optimality of resource allocation algorithms is another area of future research, along with mobility which hasn't been given much attention in resource allocation. In our opinion, it will bring to light a whole new dimension for resource allocation. The fact future of user association in Het Nets will have to focus on improving EEy while maintaining a minimum threshold. Some areas still require further research efforts. These include interference mitigation, bandwidth, transmission power, and cell edge user association and user mobility. MTs should also be able to associate with more than one BS to maximize throughput and minimize interference. Another area requiring further research is the frequency of dissociation of the MT with its associated BS for mobile users. This will go a long way in stabilizing the network by eliminating increased oscillation.

VI. Conclusion

In this paper we had reviewed the energy efficiency of cellular communication systems, which is becoming a major concern for network operators to not only reduce the operational costs, but also to reduce their environmental effects. We began our discussion with green metrics or energy efficiency metrics. Here, we presented a brief survey of current efforts for the standardization of the metrics and the challenges that lay ahead. Regarding architecture, since BSs represent a major chunk of energy consumed in a cellular network, we then presented an exhaustive survey of methods that have been currently adopted or will be adopted in future in order to obtain energy savings from BSs. In particular, we discussed the recent improvements in power amplifier technology that can be used to bring energy savings in BSs. Improvements in the power amplifier will not only decrease the power consumption of the hardware system, but will also make the BS less dependent on air-conditioning. We also discussed the power saving protocols such as sleep modes that have been suggested for next generation wireless standards. Such power saving protocols at the BS side still needs to be explored in future wireless systems. Three possible network scenarios, based on the participation of private FAPs (absent, closed, hybrid), are studied. A joint strategy for radio resource and power management and BS ON/OFF switching is employed to efficiently utilize the radio access infrastructure and minimize energy consumption. The availability of locally generated renewable energy is also incorporated in the developed framework. A dual decomposition based method is proposed to achieve the optimal results. In addition, a low complexity iterative solution is proposed to achieve a near optimal solution of the non convex problem. Results show that the cooperation between the mobile operator and the FAPs can lead to significant gains in terms of energy consumption, as compared to the non-cooperative scenario. We also developed a framework for cooperation agreements between the mobile operator and private FAPs based on monetary incentives.

In summary, 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.

VII. References

1. C. H. Tang, C. E. Wu, C. W. Lin, and C. Y. Liao, "Network energy efficiency for deployment architectures with base station site model," in 2012 1st IEEE International Conference on Communications in China Workshops, ICCC 2012, 2012, no. 99, pp. 85–90.
2. C. Khirallah, J. S. Thompson, and D. Vukobratovic, "Energy efficiency of heterogeneous networks in LTE-advanced," in 2012 IEEE Wireless Communications and Networking Conference Workshops, WCNCW 2012, 2012, pp. 53–58.
3. D. Chee, M. S. Kang, H. Lee, and B. C. Jung, "A study on the green cellular network with femtocells," in ICUFN 2011 - 3rd International Conference on Ubiquitous and Future Networks, 2011, pp. 235–240.
4. G. Auer et al., "Energy efficiency analysis of the reference systems, areas of improvement and target breakdown," tech. rep., INFSO-ICT-247733 EARTH (Energy Aware Radio and Network Technologies), 2012.
5. W. Yu and R. Lui, "Dual methods for non convex spectrum optimization of multicarrier systems," IEEE Trans. vol. 54, no. 7, pp. 1310– 1322, Jul. 2006.