Energy Savings in Mobile Networks: Case Study on Femtocells

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INTRODUCTION

Mobile networks do not have considerable share in the overall energy consumption of the ICT (Information and Communication Technology) sector, which itself is responsible for 2% to 10 % of the world energy consumption. However, reduction in energy consumption of mobile networks is of great importance from economical (cost reduction) and environmental (decreased CO_2 emissions) perspective.
This paper presents first a discussion on different energy saving aspects in mobile networks. Then a case study on the impact of femtocells to the energy efficiency of WCDMA networks is given.

ENERGY SAVING ASPECTS IN MOBILE NETWORKS: PREVIOUS STUDIES

A. *Background*

Recently, the mobile communication community has become aware of large and ever-growing energy usage of mobile networks [1]. Besides industry the awareness of ever-increasing energy consumption has been growing also on academic research [2],[3],[4],[5],[6],[7].
A typical mobile network consists of three main elements: core network, base stations, and mobile terminals. Base stations contribute 60% to 80% of the whole network energy consumption. Thus the efforts in the reduction of energy consumption focus on the BS equipment, which includes the minimization of BS energy consumption, minimization of BS density and use of renewable energy sources [8].
The ways to minimize the BS energy consumption includes improvement in BS energy efficiency through better performance of BS hardware, usage of system level and software features, and usage of BS site solutions like fresh air cooling systems for indoor networks. One of the main energy saving approaches is the system level feature in which underutilized cells (BS's) are switched off whenever traffic load is small.
When cells are switched off, it is assumed that the radio coverage and feasible service conditions can be guaranteed by the remaining active cells (BS's), probably with some increment in the BS transmitting power. This increase in transmission power in remaining active BSs, however, can be small when compared to the savings achieved by switching off some BS sites.

B. *BS switching in conventional macrocell topology*

Energy saving through BS switching was used in [5] where proposed power saving algorithms can be centralized (when all the channel information and traffic requirements are known) or decentralized (no such information required). Energy savings are higher in

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centralized approach because BS density becomes lower, while coverage guarantee is better in decentralized approach because more BS's stay active. In [5] the focus was on the relation between BS energy saving and load balancing. Through examination it was found out in [5] that load balancing appears to be important BS energy saving algorithm due to its decentralized and dynamic nature.

Similar approach was applied in [4] where focus was in cell layout. To achieve optimal energy saving it was discovered that in real networks only a small fraction of cells need to remain on during the night time. In [4] few typical cellular network configurations (Manhattan/linear; Manhattan/squared; Hexagonal; Hexagonal/squared; Crossroad) had been compared assuming two different daily traffic patterns. Comparison indicates that the best solution is not to switch off the largest possible number of cells; rather it is important to make tradeoff between the low traffic period and the number of cells that are switched off. According to this paper for example, the best performing scheme is switching off 4 cells out of 5 with crossroad configuration.

C. *Impact of femtocells to the network energy efficiency*

We continue part of the study of [7] in this paper. It is shown that femtocells may reasonably decrease the network energy consumption but only if femtocells are deactivated when indoor traffic is nonexistent. Thus, femtocell should be capable of sensing the traffic and adjusting its mode (activate or deactivate) following the traffic conditions. Along with this feature femtocell can enter sleep mode when there is no indoor traffic. The importance of this feature is obvious from the fact that if a number of femtocells remain active when traffic is nonexistent, then network energy consumption increases accordingly.

CASE STUDY: IMPACT OF FEMTOCELLS TO THE WCDMA NETWORK ENERGY EFFICIENCY

A. *Modeling and comparison scenario*

We recall a simple model that was proposed in [7] to describe the daily energy consumption per square kilometer in the network:

$$(E/A)_{Ntw} = \frac{N_{Site}^{New} \cdot N_{Cell} \cdot \left(P_{Oper} + \lambda^{New} \cdot P_{Tx}\right)}{N_{Site} \cdot A_{Site}} \cdot 24h + \frac{N_{Cell} \cdot N_F \cdot P_F}{A_{Site}} \cdot 24h \quad (1)$$

Thus, dimension for the performance is the kWh/km^2 .The area covered by a three-sector site is given by $A_{Site} = 9/4 \cdot R^2 = ISD^2$. Here we present only one comparison scenario that offers more energy saving in network than the other scenario as in [7]. In the above equation, number of sites in new deployment and corresponding load λ^{New} refer to the new parametric values of the modified network with respect to the old parametric values of the reference network. Either of these changes is expected to take place in one of the two compared networks as in [7] depending upon the scenario. In order to make calculations more concrete we adopt from [4] the UMTS macrocell base station specific values P_{oper}=137W and P_{TX}=57W, which will be then used in comparison. For femto BS input power we use two values, 2W and 5W. The former value is optimistic but reachable in future while latter value is already reality in products [9].

Comparison scenario: Assume that the macrocell ISD is not fixed but instead, we fix the target load in macrocells. Since femtocells offload part of the traffic, the required number of macrocell BS's is decreasing due to cell breathing [3] and we have,

$$(E/A)_{Ntw} = \frac{N_{Site}^{New} \cdot N_{Cell} \cdot (P_{Oper} + \lambda \cdot P_{Tx})}{N_{Site} \cdot A_{Site}} \cdot 24h + \frac{N_{Cell} \cdot N_F \cdot P_F}{A_{Site}} \cdot 24h \quad (2)$$

B. *Numerical comparison*

For comparisons we first carry out dimensioning of the network without femtocells and calculate daily energy consumption per square kilometer. When N_F femtocells are added to the system they take a certain portion of the users, say (R_{femto}·100) % of users (R_{femto} is the ratio between femtocell and macrocell connections). Then number of macrocell sites is decreasing, thus reducing the energy consumption of the network. When comparison scenario is analyzed in case of the femtocells deployment that do not possess power save feature, we assume any fixed number of femtocells that remain active throughout the R_{femto} scale. We consider 64kbps service and initial system load 0.9. Other information besides service rate and load in (1) can be obtained from link budget in [7].

Utilizing equation (2), results regarding comparison scenario has been plotted in Fig.1 from energy saving perspective for both types of femtocells (with and without power save feature) having input power of 2W and 5W. Plotted curves show that total energy saving is more when deployed femtocell possess power save feature in comparison to the situation when they do not have such feature. In Fig.1 different symbols are used to diferentiate the variuos plots depicting total energy saving in different conditions. For the case with N_F=N_{users} we have used; Circle for the condition when femtocells with 2W input power possess power save feature, Triangle (Up) when femtocells with 2W input power do not possess power save feature, Asterisk (*) when femtocells with 5W input power possess power save feature, Traingle (Down) when femtocells with 5W input power do not possess power save feature. Similarly in case of N_F=*2.3 x* N_{users} we have used; Square when femtocells with 2W input power possess power save feature.

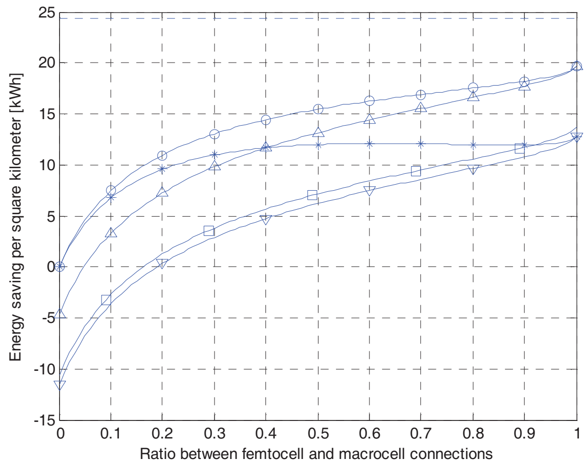

Figure 1: Daily energy saving per square kilometer in the network for comparison scenario .

We observe from plots of both input powers of femto BS; when more load out of full load gets shifted from macrocell to femtocell, approximately same amount of energy can be saved from both types of femtocell deployment (with and without power save feature). This figure explains that femtocells without power save feature would be more unfavourable when not much load of the macrocell is shifted to femtocell i-e during situation when there is not much indoor traffic existing in the network.

With input power of 2W, when femtocells that do not possess power save feature are deployed in the network, there will be extra energy consumed (no energy saving) by the network until R_{femto} reaches 0.05 since femto base station energy consumption is easily overtaking the achieved savings on the macrocell side. Whereas in case of the 5W femto BS, extra energy is consumed by the network until R_{femto} reaches 0.2, and this extra energy will be more than the extra energy consumed in case of 2W femto BS.

Therefore in case of 2W input power, the deployment of femtocells that do not possess power save feature could be acceptable if femtocells possessing this feature are unavailable. However in case of 5W input power, this femtocell feature is necessarily required.

Moreover, we vary the number of active femtocells (2W) in the network as for example $N_F = 2.3 \times N_{users}$, then the energy saving gets reduced. It is concluded through analysis that number of femtocells should be limited and upper bound to it is the number of users in the macrocell i-e N_F *(Upper bound)*= N_{users} , for both types of femtocells (with and without power save feature). Thus the maximum gain in energy saving will be achieved with $N_F = N_{users}$.

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