ALTICE LABS WHITEPAPER

Cognitive Solutions in the Management of LTE Networks

July 2013

Keywords: LTE, mobile networks, 3GPP, Femto cells, HeNB, Cognitive Networks, context, business model

Altice Labs
Rua Eng. José Ferreira Pinto Basto
3810-106 Aveiro – Portugal
http://www.alticelabs.com
Tel: +351 234 403 200
Fax: +351 234 424 723

Contents

Contents 3
Summary **4**
1. Introduction **5**
2. State of Art **6**
3. New Business Model **7**
4. Mobility and Context Information **8**
5. Cognitive Solution of HeNB Performance **11**
6. System's Assessment **14**
7. Conclusions **16**
8. References **17**

Figure 1: Business Model in HeNB with hybrid access 7
Figure 2: Comparison of HO decision thresholds 9
Figure 3: eNB versus HeNB Performance 10
Figure 4: Functional architecture [8] 12
Figure 5: (a) Initial scenario; (b) Introduction of the new HeNB; (c) Detail of the final scenario 14

Summary

LTE (Long Term Evolution) also called 4G provides a superior maximum speed and more QoS (Quality of Service) than 3G mobile systems. However, the limitation of the available radio spectrum and the need not to increase the number of sites compared to the existing ones, not to increase drastically investment and operational costs, will cause the medium QoS available to users to be far from the real maximum capacities of technology. In this article one suggests the implementation of femto cells (HeNB - Home evolved Node B) of hybrid access managed by cognitive solutions: mobility and configuration of HeNB, framed by a new business model, in which the client is also a partner. With this approach one aims at significant gains in terms of capacity and quality of radio network at limited cost.

1.Introduction

When specifying LTE, 3GPP not only made a mobile system available that provides high speed and QoS, but also granted the technological platform for the evolution of mobile systems based on new concepts.

The evolution of the infrastructures of fixed telecommunications and particularly the availability of optical fibre to home will provide the user with a usage experience that mobile networks will seek to reach. The radio channel is recognised as the bottleneck of the mobile network and main limiter of speed and performance of a system. This constraint derives mainly from the limited bandwidth assigned to every mobile operator. In spite of having the flexibility (multicarrier) to use different bandwidths in different areas of the electrical spectrum, LTE's maximum speed is only reached for the maximum bandwidth (20MHZ), whose availability is limited. Despite the evolution of technology in radio interface through techniques such as the Adaptation Modulation Coding (AMC) and the Multiple Input Multiple Output (MIMO) has got close to theoretical limits; the performance is far from what will be available to the user through the optical fibre. However, other factors such as efficient and timely planning and management play a fundamental role in the overall performance of the radio network.

In the described scenario, the significant improvement of quality of service and network capacity involves the reduction of cells' radius or the increase of sectors per site. As the second option is not effective for most sites already with 3 sectors, the solution involves the increase in the number of sites. The implementation of an increased number of new sites will have additional costs for the mobile operator (CAPEX and OPEX). With the price of the bit falling, and with the current environment of economical crisis, the operators will hardly be able to support the implementation and operation costs (CAPEX and OPEX) of more sites, particularly if they want to increase significantly the quality of service provided with the current technological solutions and business models. So, in this article one suggests a solution based on femtocells, which involves a new business model and a technical solution that addresses the main aspects of its implementation.

2.State of Art

LTE brings substantial improvement to mobile service: higher speeds, best quality of service and usage experience.

However, there is still a great challenge for network operators, which needs to be overcome regarding the coverage of mobile network in indoor environments. Actually, there are situations in which the signal received in the mobile terminal inside a building may be insufficient or inexistent in order to get the desirable quality of service. This makes it impossible to achieve the speed powered by LTE technology. With the purpose to overcome this limitation, there are solutions that can be adopted such as repeaters or pico cells.

However, this type of solution is translated into a financial effort for mobile operators because it involves an increase both in CAPEX and OPEX, harming the future lucrative expectation. As an example, one should highlight the high cost of the rental of the place where these solutions are implemented, which can reach around 20% of the operator's permanent cost (OPEX). In order to surpass this limitation and take advantage of the LTE network, an economical alternative, without any maintenance costs for the operator, has recently arisen, thus allowing to overcome the lack of signal inside buildings. The solution is equipment similar to a WIFI router that is acquired and installed by the consumer himself at his residency only with a broadband connection, which is called HeNB [1] (see References), providing LTE coverage in the area where it is installed.

The HeNB present advantages for the consumer and telecommunications operators, reducing a significant part of acquisition and/or maintenance costs, increasing coverage and overall capacity of LTE [2] network (see References).

The lack of indoor coverage can be substantially reduced through the adoption of this solution. Currently, there are three different types of access associated to HeNB [3] (see References):

1. **Open Access:** Any terminal has permission to connect without any type of restrictions. There is no access control no limitation from the owner of the equipment is allowed;

2. **Closed Access:** The owner has full control over the access through a list (closed subscriber group - CSG) where permission is given only to a restrictive group;

3. **Hybrid Access:** It is defined as a junction of the open access and the closed access. In this type of access any terminal can connect, though there is a preferential list, defined by the owner, with priorities that take over the users outside the list.

Besides the previously mentioned factors, the installation and use of HeNB in residencies may bring another type of advantages to the consumer, given that, inside the HeNB's coverage area, the terminal needs less energy to connect.

3. New Business Model

As described previously, if the use of HeNB, in particular the hybrid ones, is expanded in the telecommunications market, there is the possibility of getting a beneficial business model for both parties (operators and clients). Figure 1 synthesises the business model in which 4 entities are considered:

- user that will connect to HeNB equipment;
- mobile operator;
- HeNB owner;
- broadband provider.

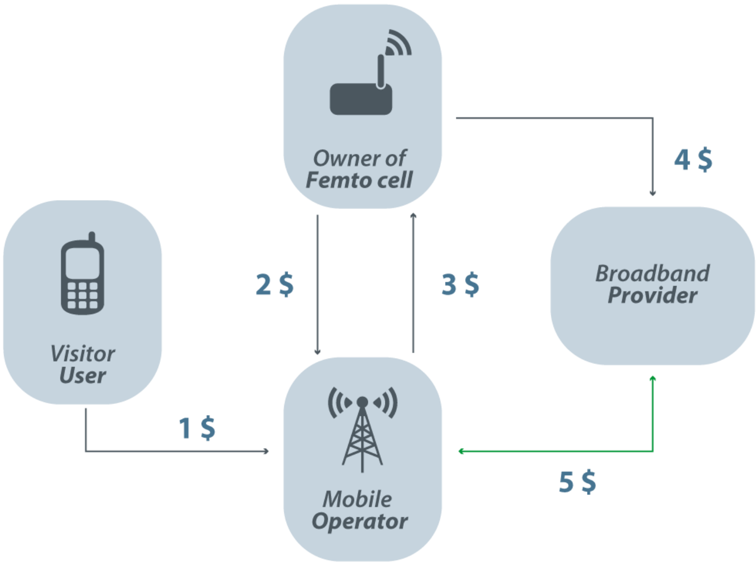

Figure 1: Business Model in HeNB with hybrid access

The price that the user (who will connect to HeNB equipment) pays to get superior quality of service regarding eNB network is basically the same, that is, any user inside the coverage of HeNB can get significant improvements in the quality of service without additional costs (Point 1). After acquiring the HeNB equipment, the owner pays the mobile operator for the service associated to the equipment (Point 2) and the access to ADSL broadband (Point 4). In turn, the mobile operator can, for instance, benefit the owner of the HeNB through the cost reduction of mobile phone calls made in his terminal (Point 3), for providing free access to his hybrid HeNB to other users.

As far as the network operator is concerned, the suggested business model is focused mainly in the segment of consume, where the HeNB is seen as a product that, with a pricing plan, may increase incomes and clients' loyalty.

An effort that can be made to achieve better pricing plans and divide operational costs for operators may be a partnership with the broadband provider, thus presenting to clients a new integrated service (hybrid+ broadband) (Point 5).

4. Mobility and Context Information

In homogeneous and heterogeneous cellular environments a good management of mobility is fundamental for the terminal to move from one cell to another without an interruption of the service.

In the case of homogeneous networks (eNB-HeNB), the terminal needs additional information in order to be able to make decisions both regarding the energetic efficiency of the terminal (with impact on the terminal's autonomy) and the quality of service (e.g. excluding connecting to HeNB when moving at high speed, being the loss of connection highly probable). For a correct set of decisions from the terminal, the context information becomes of great importance.

Essential information, such as, the type of network available at the location of the terminal, permissions the terminal has towards a certain network are fundamental to be used in the algorithms of discovery and choice of the most adequate network. This type of mobility management is currently limited where the criterion of cell change is only based on Signal to Noise Ratio (SNR). In the context of the ICT

C2POWER [4] project (see References), an algorithm that uses context information has been developed and assessed to take the most out of the HeNB dissemination, because the increase of HeNB density, in a certain region, makes it possible to reduce the average transmission power of mobile terminals through a good management of the context information .

The algorithm developed for mobility management through the use of context information covers four stages until its final decision, described as follows.

Gathering context information: In this first stage, the algorithm gathers the needed context information. The context information may be gathered in two different ways:

1. Through requests to the network, where the information of all available networks in the area of the terminal are sent to;
2. Through interfaces of the terminal itself, such as for example, GPS readings (to know the location and speed of the terminal), battery charge, used applications, among others.

Process of Assessment of networks and access policies: In the second stage called "Reasoning", the terminal gathers all the information and processes it. At this stage, the list of all the HeNB as well as all the eNB, go through a process of assessment where the networks to which the terminal is not allowed to connect are excluded. Using context information regarding its speed, the terminal may or may not exclude the HeNB, once residence time inside coverage will diminish with the increase of speed. This process makes the process of discovery of networks in the terminal more efficient as it prevents the attempt to connect to networks that are taken to be restrictive or that may reduce the quality of service.

Process of Network Discovery: After the process of network assessment is finished, the terminal owns a filtered list of networks. At this moment the terminal performs the process of discovery, proceeding to the scanning of the previously defined list of networks in order to check their existence. At this stage, if there is any non-detected network, the algorithm automatically excludes it from the list that will be used later on. At the end of this process, only the detected networks to which the terminal has permission to connect will be used in the next stage, that is, in the final decision.

Final Decision: In this last stage the algorithm decides on which network enables bigger energy savings. To proceed to the final decision, the algorithm estimates the amount of energy needed to all the networks individually and selects the most efficient one.

The final decision, unlike current mechanisms of HO (Handover) decision based on SNR, uses an approach based on power estimate, in the Uplink, already implemented in the LTE network to promote the reduction of the interference generated by mobile terminals [5] (see References).

Basically the terminal uses a set of information made available by the network (transmission power and interference of each eNB and HeNB along with PL correction parameters), as well as some parameters measured in the terminal itself (reception power of each eNB and HeNB) in order to estimate the Path Loss (PL) for all the networks available in the previous process. Setting the PL for the differences between eNB and HeNB (e.g. antenna gains), granting the required QoS at the same time (SNR in the Uplink), it is possible to check which network needs less transmission power and thus save energy, being the final decision obtained in the algorithm. The presentation in Figure 2 shows, in outdoor environments, the application of the new concept, where it is possible to visualise the area of energy gain from the use of the suggested algorithm, in comparison to the mechanisms currently used.

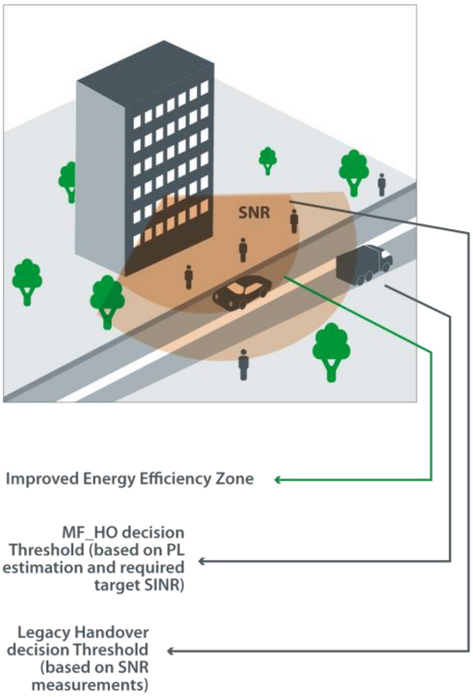

Figure 2: Comparison of HO decision thresholds

In Figure 3, one presents the values obtained in simulation for a terminal when connected to a HeNB compared to an eNB in indoor environments.

In Figure 3 it is possible to see that in a situation in which a terminal is connected to a macro network (eNB) inside its home, where the quality of signal is weak, it presents energy consumption that reaches approximately the maximum supported by the terminal (194,2mW). This situation may improve significantly if you acquire and install HeNB equipment. Therefore the energy consumption in the uplink of the terminal is reduced by about 97%. Besides this improvement, the QoS increases significantly (about 91%), since the terminal goes from a data rate of 1,7Mbit/s to 19,6Mbit/s. The figure also shows that the number of lost telephone calls caused by lack of indoor coverage can be substantially reduced through the adoption of this solution.

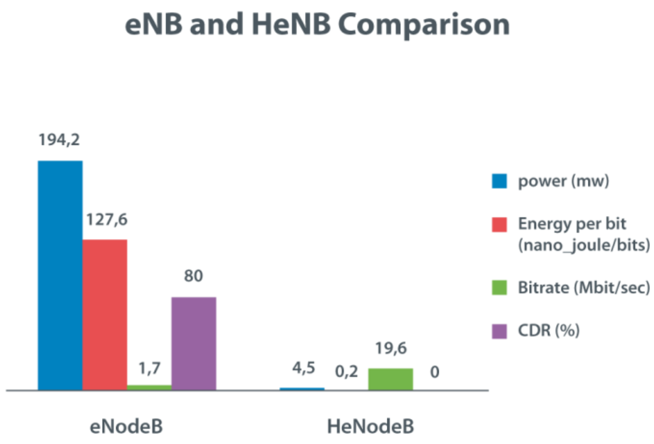

Figure 3: eNB versus HeNB Performance

5. Cognitive Solution of HeNB Performance

In spite of the restrictions regarding the transmission power limit applied to HeNB, either for physical reasons (reduced dimensions), or for the functioning principle (local coverage), they may even so cause serious interference effects with the other entities in the network, in particular the BS (Base Station) of the operator. Since it is impossible to take precautions against these effects, when planning the network, because the HeNB installation is not planned "a priori", it is therefore imperative provide the network with means to prevent that from happening, making the process automatic and resettable.

The resetting process of a HeNB should take into consideration that this cell should degrade to a minimum the entities already present in the network, either BS, MT (Mobile Terminal), or other HeNB; this involves a careful choice of the bearer to be used and the maximum power it can emit with.

During the European project WHERE2 [6][7] (Wireless Hybrid Enhanced Mobile Radio Estimators – Phase 2) (see References), a cognitive system to set the HeNB was developed, taking into account the radio environment around the location of the cell to set.

In the beginning, the configuration of this type of cells was made taking in consideration only a short proximity around the cell, which in spite of working in some situations, revealed some flaws that could go on leading to a loss of QoS from the user, leading to an accentuated degradation in the services provided by the operator. This need (for a maintenance or improvement of quality of services) was the reason for the development of the suggested system.

The information on position has vital importance to the functioning principle of the system presented in the diagram of Figure 4. While macros are fixed cells, with practically inexistent mobility, because after being installed they hardly suffer any position changes, HeNB are small devices with a high degree of mobility, because they were designed exactly for that purpose – to be easy to move and install. On the other hand, while macros are devices with high levels of power, HeNB are low-power devices, because its use is restricted to short neighbours; this causes the exact location of a HeNB to have more relevance than in the case of a macro. So, whereas in a macro the distribution of signal is hardly affected by a small difference in its position, a HeNB is strongly influenced by the place where it is installed. So, the use of a tracking system is needed (whether it is a GPS or one of the systems to be developed under the scope of the project WHERE2 [10]). This information (1) will be used for two different tasks: knowing where the new HeNB will be placed; and from that location, getting the information on the network disposition in the neighbourhood of that cell.

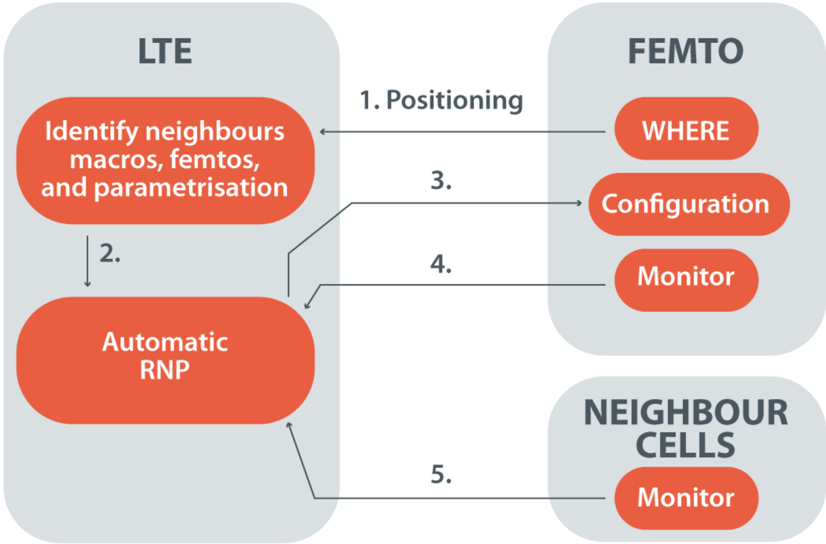

Figure 4: Functional architecture [8]

The information needed for the configuration process is known by the network, and obtained from the determined location (1).

So, a list of the neighbour cells and their corresponding parameters is collected.

Among the collected parameters one should highlight: the used bearer(s), the levels of power, and their location.

The gathered information (1) and (2) is used for computing recreation of the scenario on a RNP (Radio Network Planning) tool, which uses real information to test the real recreated scenario with the introduction of the mew cell. The parameters to be set in the cell are related to the used bearer and to the transmission power. The estimate of the bearer is based on the highest average SNR value for the installation scenario of the new HeNB. So in that location a cell is placed, and consecutively a bearer will be assigned and the average SINR of the scenario will be measured, taking into account the several entities displayed in it that share the available spectrum for the use of HeNB. Since the choice of the bearer falls upon the highest average value of SINR of the scenario, the interference effects on the neighbours are guaranteed to be minimised. As a careful planning of the bearer may not be enough to minimise the interferences in order to grant the correct functioning of the network, a transmission power control is imposed, to minimise even more those problems. In this process, some guarantees regarding the QoS of the users (HeNB) present in the network, but also new clients that intend to install their HeNB in the network, are established.

So:

- Existing users cannot see their quality of service deteriorate significantly by the abrupt introduction of new users;
- New users have to take significant advantage out of the installation of a new HeNB, otherwise the introduction of a new cell in the network is not justified.

After defining the parameters that meet the two former needs, the RNP tool checks if it can grant the use of minimum power without significantly affecting the system, or is it has to reduce any of the neighbour cells. In any case, the system always looks for using the maximum power available to guarantee the maximum coverage possible from the HeNB. The parameters may however depend on the area (rural, urban or suburban) surrounding the place where the installation is being.

After obtaining the data to be set in the new HeNB, they are sent to the cell for their configuration (3). Although the whole scenario is based on the reality of the displayed network, phenomena may occur that make the correct functioning impossible, or at least according to what was planned, therefore it is necessary to gauge the validity of the results obtained in the process. So, the new cell (4), as well as the existing ones (5) monitor the spectrum to check the network functioning, after the new cell starts working. This information is reported to the network that assesses its functioning and determines if it is working according to what was planned o, or if it is necessary to unleash a new configuration process. If, for any reason, a reorganisation or reconfiguration of the network is necessary (especially regarding HeNB), the operator may freely request the execution of a new configuration process, which will happen in a continuous act and in real time without affecting significantly the network and the users connected to it.

It is important to refer that the whole communication process between operator's network and HeNB is performed according to the specifications of the 3GPP [8][9] (see References) for the configuration parameters of a HeNB, to easily provide the practical adoption of this system.

6. System's Assessment

Figure 5 (a) shows the results obtained for the developed assessment scenario. The scenario is made up of a BS and nine HeNB, and the maximum transmission power of the BS is set for 33dBm and the HeNB's for up to 20dBm.

A new user intends to use a new HeNB (H13) of Figure 5 (b) – which is placed in the scenario position where the user wants to install it. On this location there are already some signs from neighbour HeNB, among which from the nearest HeNB (H12) working in the same bearer. This case originates a severe interference effect, making both HeNB (H12 e H13) unused. In the neighbourhood of these cells the levels of SINR are relatively low, leading to the assurance of network coverage in those places by other HeNB and/or by BS, as it is clear by the light shades of signal distribution (synonymous with low SINR).

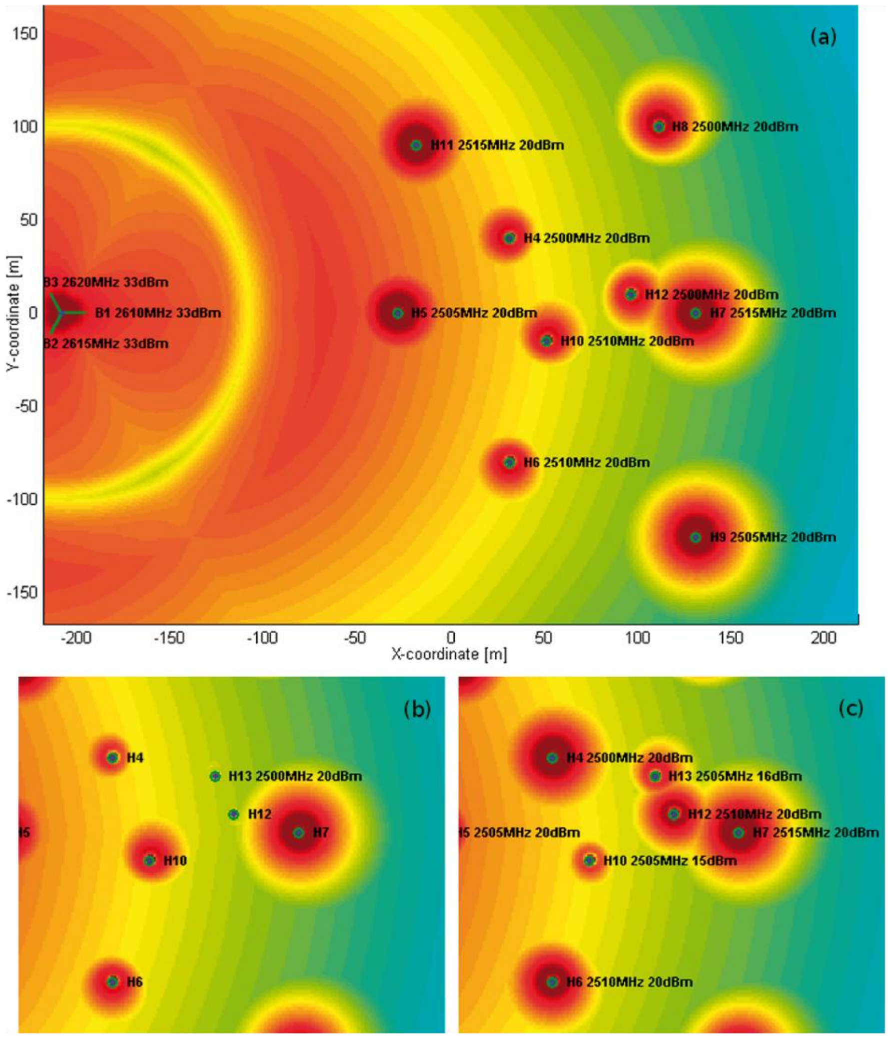

Figure 5: (a) Initial scenario; (b) Introduction of the new HeNB; (c) Detail of the final scenario

By introducing the presented configuration system, not only the use of bearers by very close neighbour cells is avoided, but also, as one can see in Figure 5 (c), H12 and H13 stop sharing the same bearer and the new HeNB starts using the bearer with more quality of signal (that is, higher average SNR). For this configuration both HeNB, which in the previous case were unused, present now a distribution of signal with a much higher quality – as you can see by the darker shade (synonymous with a higher average SNR).

Cells H10 and H13 also stop transmitting the maximum power, allowing the continuation of a very good quality of signal while minimizing the interference effects between both.

For the effects of this process's demonstration we chose the confine the use of bearers to a low number (four) to force the processes of choice of bearer and transmission power with a small number of HeNB.

To assess the importance of this research work it is also interesting to verify that one of the leading manufacturers in the HeNM trading market – Qualcomm – abandoned the configuration process, based only on sensing, to start using solutions that are more effective and close to what is presented in this article.

7. Conclusions

The increase of complexity of mobile systems allied to the need to optimise the use of such a scarce resource as the radio spectrum has led to the adoption of cognitive solutions in the management of radio resources. In this article the general use of hybrid access femtocells, as a way of increasing the network capacity and the quality of service provided without significant costs for the operator, s suggested. The integration of femtocells in current systems, manually planned and managed, is supported by two cognitive solutions: one guarantees the configuration of the HeNB according to its location and the other one the user's mobility in the network. The assessment performed and presented in this article proves the viability of this type of solutions that also addresses aspects of energy science in the mobile terminal. More efficiency obtained through the suggested solution not only reduces the environmental impact, but also increases significantly the autonomy of the mobile terminal.

8.References

[1] GB_921_Getting_Started_with_eTOM_R9-0 – The Business Process Framework (eTOM) Suite, versão 9.0, Agosto 2010, TeleManagement Forum.

[2] GB921_D_Release_9.0_v9.1.doc – The Business Process Framework (eTOM), Addendum D: Process Decompositions and Descriptions, versão 9.1, Agosto 2010, TeleManagement Forum.

[3] GB921_E_Release_9.0_v9.1.doc – Business Process Framework (eTOM), Addendum E: End-to-End Business Flows, versão 9.1, Agosto 2010, TeleManagement Forum.

[4] GB_929_Application_Framework_(TAM)_Release_4.5 – Application Framework (TAM), versão 4.3, Maio 2011, TeleManagement Forum.

[5] TM Forum Business IQ, May 2012, (TM Forum Business Benchmarking 2012)

[6] Assessing TCO for Best-of-Suite Versus Best-of-Breed Architectures in Communications Service Industry, Raul Katz and Juan Pereira, Abril 2007

[7] NOSSIS_Overview_2012_v1.1, versão 1.1, Jun 2012, PT Inovação

[1] 3GPP TR 23.830 3rd Generation Partnership Project; Technical Speci cation Group Services and System Aspects; Architecture aspects of Home NodeB and Home eNodeB (Release 9), 2009

[2] Stüttgen. H, “femtocells femtocell a promise for mobile users and operators”, NEC Europe LTD., 2010

[3] 3GPP TS 22.220, V11.0.0: Service requirements for Home Node B (HNB) and Home eNode B (HeNB) (Release 11), 2011

[4] FP7 project - C2POWER, “www.ict-c2power.eu”, 2011.

[5] 3GPP, R1-074850, “Uplink Power Control for E-UTRA – Range and Representation of P0”, Ericsson. 2007

[6] FP7 Project – WHERE2, “www.ict-where2.eu”, 2012.

[7] FP7 Project – WHERE2, “Description of Work”, Annex I, May 2011

[8] FP7 Project - WHERE2, “Intermediate: Coordination and Cooperation between Network Nodes”, Deliverable 3.1, July 2012.

[9] The Femto Forum, “LTE network monitor mode speci cation v1.01”, Technical report, October 2010.

[10] Qualcomm, “UltraSON™ Uplink Interference Management Suite”, http://www.qualcomm.com/about/research/projects/femtocells/private-femtocells/uplink-ultrason, 2012

The research work here presented was developed in the context of the following projects: ICT Where2 (http://www.kn-s.dlr.de/where2/index.php) and C2POWER (http://www.ict-c2power.eu/).

Rua Eng. José Ferreira Pinto Basto
3810-106 Aveiro
Portugal

Tel.: +351 234 403 200
Fax: +351 234 424 723

EMPRESA CERTIFICADA apcer ISO 9001 ISO 14001 OHSAS18001 NP 4457 - IDI

CERTIFIED IQNet MANAGEMENT SYSTEM

www.alticelabs.com