Improving Energy Efficiency of Femtocell Network

LTE Architecture with Energy and Congestion Server (HeNB-ECS)

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***Abstract* —Femtocells are small base stations designed for use as an ideal solution to ensure good radio coverage in the residential and corporate environments. In this paper we review LTE femtocell, LTE HeNB standard architecture and we detail our proposed architecture. It focuses more particularly on the options offered by the HeNB Energy Congestion Server (HeNB-ECS), the proposed server in our solution which manages and administers the HeNB network. We propose more options, in this sense we model the energy managed by HeNB-ECS. We also propose a general algorithm to manage the HeNB network energy and congestion in our architecture.**

Keywords —LTE, Femtocell, HeNB, Power model, Network energy consumption

I. Introduction

Femtocells are small base stations designed for use as an ideal solution to ensure good radio coverage in the residential and corporate environments.

They benefit mobile users with extended capacity enabling them to enjoy the latest services such as high data rate voice, data, internet and new applications.

Femtocells also offer several advantages over solutions like Wi-Fi in particular. They use advanced signal processing techniques to save battery and optimize spectrum usage.

The 3GPP provides a standard for Home eNodeB, LTE (Long Term Evolution) femtocell, which is one of the best approaches to reduce the Operating Expenditures (OPEX) for operators as well as to balance the load from the LTE macrocell networks. Femtocells are low power access points, providing wireless voice and broadband services to customers primarily in the home. 3GPP has carried out the standardization on Home eNodeB (HeNB), while the Home eNodeB applications may also introduce some challenges to the work related to LTE-Advanced [1].

Today, the progress of standardization and the launch of the marketing of femtocells in the residential market in many countries suggest massive deployments soon. Finally, femtocells self-configuration also offers promising prospects for deployment in outdoor environments [2].

Indeed, different publications in the literature dealing with femtocells deployment are using cognitive radio tools for interference management and energy saving. They open new perspectives for the deployment of large scale large coverage low cost energy efficient networks which is the topic of this work.

In this paper we present more detail about our architecture for managing a femtocells network.

This paper is organized as follows. In the first paragraph, we present an introduction and generalities about femtocells. The second paragraph deals with LTE HeNB standard architecture. In the third paragraph we present our architecture for femtocells management, we model the energy managed by HeNB-ECS and we propose a general algorithm to manage the HeNB network energy and congestion in our architecture. In the fourth paragraph we conclude.

II. LTE-HeNB 3GPP Architecture

a) LTE-HeNB Standard Architecture

The Evolved Packet System (EPS) includes the Evolved Packet Core (EPC) and Evolved Universal Terrestrial Radio Access Networks (E-UTRANs). An E-UTRAN includes two types of base stations, named as eNBs and HeNBs. This is pictured in Fig. 1.

The EPC may contain many Mobility Management Entities (MME), Serving Gateways (SGWs) and Packet Data Network Gateways (PDN GWs) together with a Home Subscriber Server (HSS), which, located in the center of the EPC, is in charge of the storage and management of all of users' subscriber information [3].

The MME is responsible for all the functions relevant to the users and the control plane session management. When an UE (User Equipment) connects to the EPC, the MME first contacts the HSS to obtain the corresponding authentication data and then represents the EPC to perform a mutual authentication with the UE. Different MMEs can communicate with each other [3].

b) Functional entities

This section provides a short description of the functional entities associated with the HeNB operation.

- HeNB**:** The functions supported by the HeNB are the same as those supported by an eNB (with the possible exception of Non-Access Stratum Node Selection Function or NNSF) and the procedures run between a HeNB and the EPC are the same as those between an eNB and the EPC. The HeNB secures the communication to/from the SeGW [3].
- HeNB GW: HeNB GW serves as a concentrator for the C-Plane, specifically the S1-MME interface. The HeNB GW may optionally terminate the user plane towards the HeNB and towards the S-GW, and provide a relay function for relaying User Plane data between the HeNB and the S-GW. The HeNB GW supports the NNSF [3].
- SeGW**:** The Security Gateway is a mandatory logical function. It may be implemented either as a separate physical entity or co-located with an existing entity. The SeGW secures the communication from to the HeNB [3].
- PDN GW: The PDN GW provides connectivity to the UE to external packet data networks by being the point of exit and entry of traffic for the UE. A UE may have simultaneous connectivity with more than one PDN GW for accessing multiple PDNs. The PDN GW performs policy enforcement, packet filtering for each user, charging support, lawful interception and packet screening [4].
- MME: The MME is considered as the main controlling element which is used to process signaling and control functions between the UE and EPC. The main functions of the MME are to provide network resources and mobility management [5].
- HSS: The HSS is typically a database where user profiles are stored. In the EPC concept of HSS which is not new, the HSS works like the Home Location Register (HLR) and Authentication Center (AuC) and inherits their functionalities from release 99. In the HSS, the HLR functions are used to store and update the database with the user subscription information whereas the AuC functions are used to facilitate the generation of security information from user identity keys [5].

In this architecture, we note the absence of an energy manager. For this reason we propose in our architecture a manager that handles network resources taking into account energy issues.

We also propose a manager of network congestion, whose main role is to reduce network congestion.

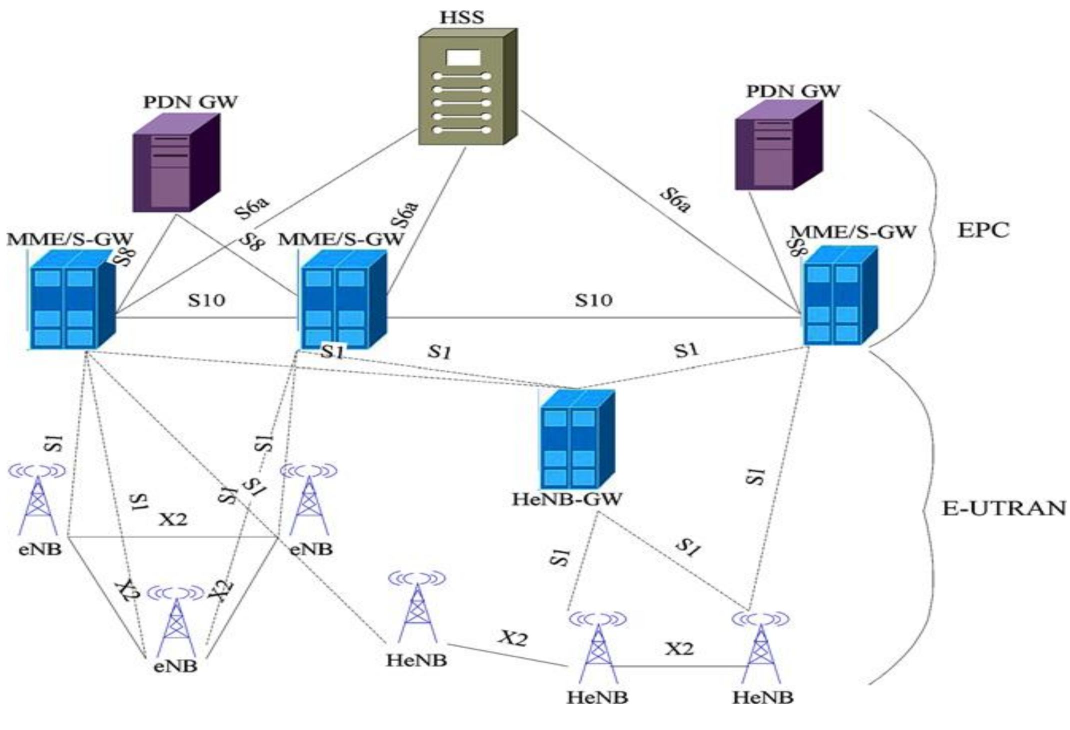

Fig. 1 LTE HeNB Standard Architecture [3]

III. LTE ARCHITECTURE WITH HENB ENERGY AND CONGESTION SERVER (HENB-ECS)

In this section, we detail our solution to manage femtocells network to reduce congestion and energy consumption in the HeNB network presented in [6]. We will focus in particular on the options offered by the HeNB Energy Congestion Server (HeNB-ECS) proposed in our architecture to manage and administer the HeNB network and we propose more options, in this sense we model the energy managed by HeNB-ECS.

We also propose a general algorithm to manage the HeNB network energy and congestion in our architecture.

A. Motivation

The rapid evolution of the use of femtocells to improve radio coverage in the residential environment and in the small businesses raises a problem of management and administration of network HeNB.

Contrary to the standard architecture already presented, we want to:

- Connect HeNB outside radio coverage in a geographical area already fixed by a secure link
- Manage energy resources HeNB networks
- Reduce network congestion

B. LTE Architecture with energy and congestion server (HeNB-ECS)

Our architecture (Fig. 2) is based on using a secure VPN (Virtual Private Network) connection with IPSec Protocol (Internet Protocol Security) with self configuration between the HeNB and the HeNB-ECS (HeNB Energy and Congestion Server).

The role of HeNB-ECS is that of HeNB-GW, Se-GW and it manages energy and network congestion. It chooses the HeNB where the UE can connect according to its availability and energy.

To the difference of the existing architecture, it allows manage energy resources by a collective and collaborative approach; each HeNB contributes to the reduction of network congestion and energy consumption.

To connect HeNB outside radio coverage in a geographical area already fixed by a secure link, we need to determine a geographical area to manage and administer network resources.

We also integrate a database DB in the HeNB-ECS to record all necessary data for the transfer of communications from busy HeNB to another available and it helps to manage the network energy.

The HeNB-ECS manages the connection between UE and HeNB according to several criteria inter alia:

- State energy of each HeNB
- State Network (Number of UE connected to each HeNB)
- Geographical area

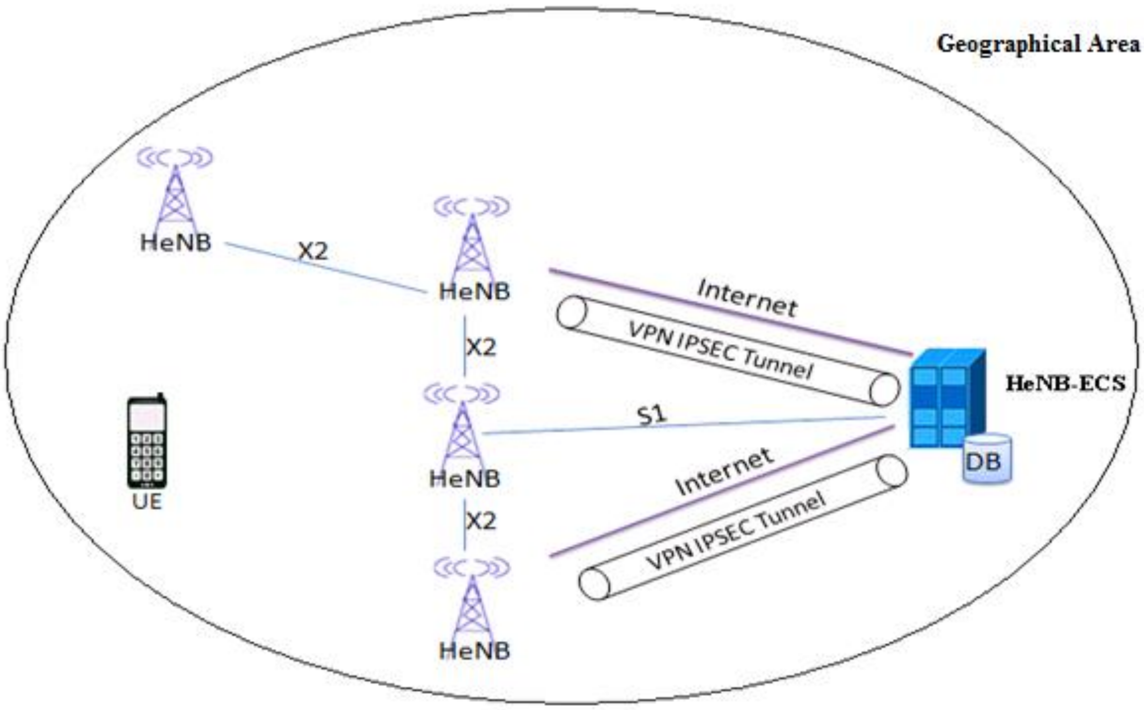

Fig. 2 Architecture with HeNB-ECS

C. Connection between HeNB and HeNB-ECS

The data (State energy, State Network, geographical area …) is transferred from HeNB to HeNB-ECS and is saved in the DB of HeNB-ECS.

In this section we talk about three types of connection:

- HeNB outside radio coverage with VPN support:

We propose a tunnel VPN IPSec connecting HeNB with HeNB-ECS.

- HeNB outside radio coverage without VPN support:

HeNB connects to HeNB-ECS via another HeNB by a support equipped VPN.

- HeNB inside of coverage zone:

HeNB connects to HeNB-ECS via a radio link.

D. Problem formulation

In this section of the paper, we present the different problematic situations modeled mathematically, for this raison we use the general mathematical formula of energy:
$E = P * T$ With P: Femtocell power and T: Time

1- Energy wasted by HeNB in idle mode

In Fig. 3, we note some HeNB in idle mode; however, a number of UE attempts to connect to one of the HeNB.

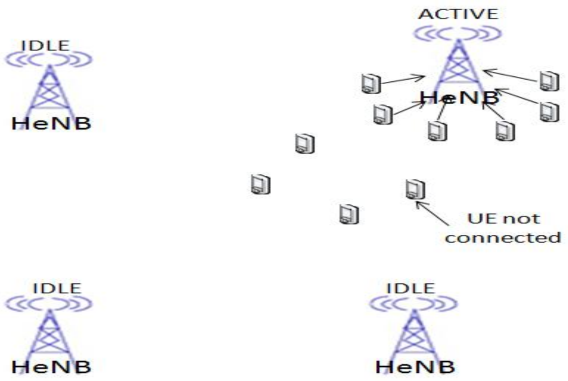

Fig. 3 Energy wasted by HeNB in idle mode

Total energy of HeNB Network is:

$$E = \sum_{i=1}^{N} P * T \quad (1)$$

This situation illustrated in Fig. 3 can be modeled by:

$$E = \sum_{i=1}^{Na} P_{Factive} * T + \sum_{i=1}^{Ni} P_{Fidle} * T \quad (2)$$

Na: Number of HeNB in active mode
Ni: Number of HeNB in idle mode
N : Total number of HeNB

So, from this last equation 2, we note during a period T energy was wasted:

$$E_{idle} = \sum_{i=1}^{Ni} P_{Fidle} * T \quad (3)$$

We note also, the UEs not connected to HeNB, even if it was available HeNB, the number of UE not connected N_{NC} is:

$$N_{NC} = N_T - N_C$$

N_T :Total number of UE
N_c :Number of UE connected
N_N :Total Number of UE supported by HeNB network
N_{Fe} :Number of UE supported by each HeNB.

With $N_N \geq N_T \geq N_C$

So, the total network capacity is not exploited, for this reason we propose a management of HeNB and UE according to network state, we put HeNB in idle mode or in active mode depending on the number of UE. We obtain:

$$N_T = N_C \ (4) \quad \text{With } N_{NC} = 0$$

2. Wasted energy exceeds the energy needed

In this situation Fig. 4, we observe, all HeNB in active mode but the number of UE may be supported, only by one HeNB, so, we see that the energy used exceeds the energy needed.

We can model it by:

$$\sum_{i=1}^{N} P_{Factive} * T \quad (5)$$

Our solution can keep the following energy:

$$E_{Seving} = \sum_{i=1}^{Ni} P_{Factive} * T - \sum_{i=1}^{Ni} P_{Fidle} * T \quad (6)$$

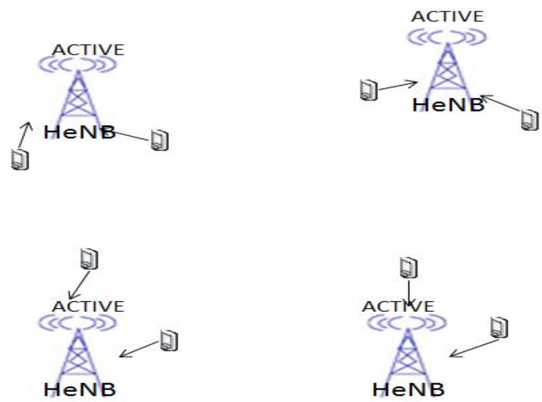

Fig. 4 Energy used exceeds the energy needed

E. Algorithm description

To resolve the problems already mentioned by equations 2, 3 and 5, to gain energy mentioned by the equation 6 and to reduce the network congestion equation 4. Our architecture by HeNB-ECS manages total energy of HeNB network according to general flow chart pictured in Fig. 5 and Fig. 6

Fig. 5, present the flow chart of the HeNB or UE connection to HeNB-ECS. It puts HeNB in idle or active mode network as needed.

Fig. 6, present the flow chart of the HeNB or UE disconnection for HeNB-ECS. The two flow charts are complementary.

We exploit with this solution the total energy of HeNB network we use energy, only when needed. In this way we minimize the energy used in HeNB network, therefore we can reduce CO_2 emissions. With overall management of the entire network managed by HeNB-ECS, we also reduce the congestion of network.

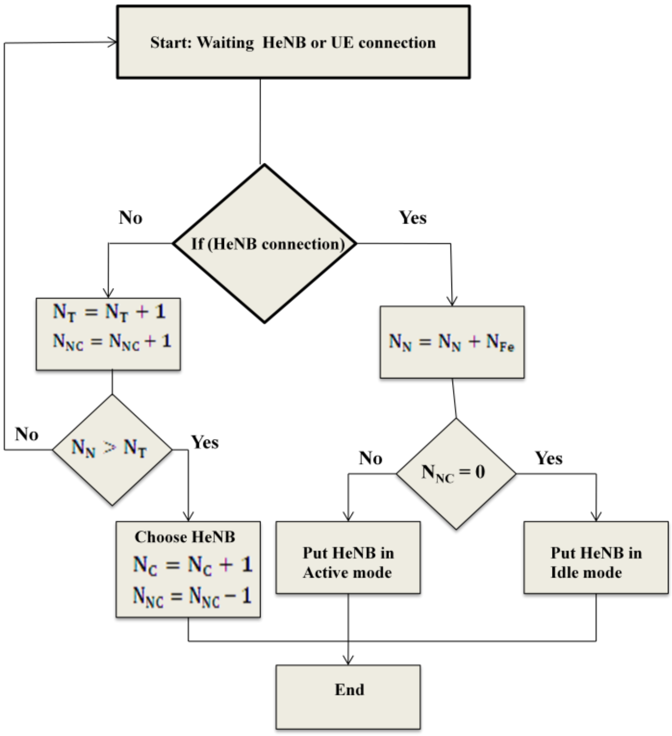

Fig. 5 Flow chart of the HeNB or UE connection to HeNB-ECS

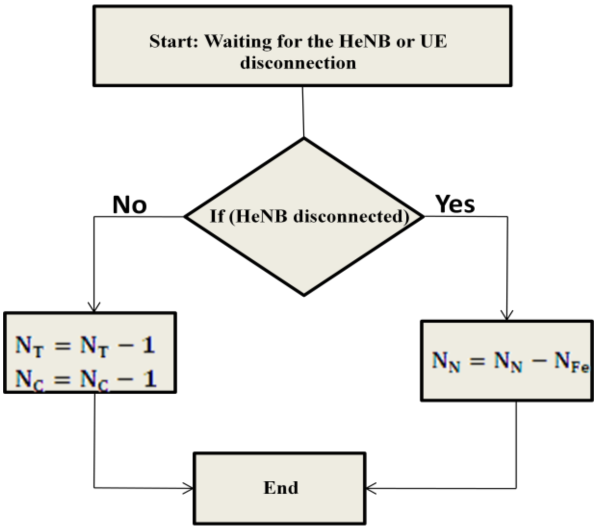

Fig. 6 Flow chart of the HeNB or UE disconnection for HeNB-ECS

F. Numerical results

In this sub-section of the paper, we give a concrete case to better explain our work and we present the results as a graph and a table, for this reason, we use a network of 5 femtocells and 4 UE to compare between the situation modeled by equation 5 and our solution. Here, we suppose that the four UE supported by a single femtocell. Also we use the results obtained in [7-8], especially femtocell power in idle or in active mode (show table 1). In this example Fig. 7, we observe the energy consumed by our solution is lower with respect to the energy modeled by equation 5.

According to the table 2, during 4 seconds we can keep $48\,\text{J}$, $(163{,}2 - 115{,}2 = 48)$, which exhibits a percentage 29,41%, $\left(\frac{48}{163{,}2} * 100 = 29{,}41\right)$, in the case where 4 HeNB in active mode.

TABLE 1: POWER CONSUMPTION OF FEMTOCELL [7-8]

Femtocell	**Active mode**	**Idle mode**
Power (W)	10,2 (W)	6 (W)

Table 1 provides the femtocell power consumption of data transmission between femtocell and UE. The femtocell in active mode consume 10, 2 (W) and in idle mode it consume 6 (W).

TABLE 2: ENERGY CONSUMPTION OF FOUR FEMTOCELLS

Time (S)	**1**	**2**	**3**	**4**
Energy of our solution (J)	28,8	57,6	86,4	115,2
Energy modeled by equation 5 (J)	40,8	81,6	122,4	163,2

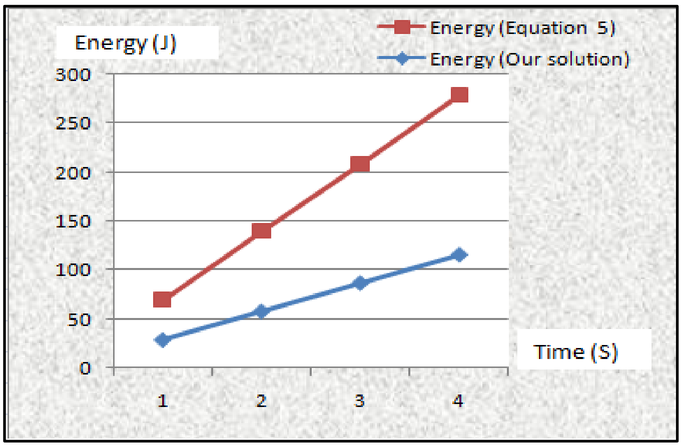

Fig. 7 Example shows the energy consumed by our solution

IV. CONCLUSION

In this paper we have presented an overview of femtocells. We have given standard architectures and in the last section, we have proposed our new architecture for femtocells management using VPN IPSec and HeNB-ECS. It has several options including optimization of security, congestion and energy consumption in the network. We gave a general algorithm of the HeNB or UE connection/disconnection for HeNB-ECS with that objective.

To the difference of the existing standard architecture, our solution allows to manage energy resources by a collective and collaborative approach. It also helps improve the efficiency and reliability of the entire network and it can reduce CO_2 emissions by reducing energy consumption.

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