IRACST – International Journal of Computer Networks and Wireless Communications (IJCNWC), ISSN: 2250-3501
Vol. 4, No. 1, February 2014

Towards a Green LTE Architecture

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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, they are low power, low cost and easy to deploy.**

In this paper we review LTE femtocell, LTE HeNB standard architecture and we detail our proposed architecture, the green LTE 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 and techniques to reduce energy and congestion, 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 and we give some numerical results as a graph and a table.

Keywords —LTE, eNodeB, Femtocell, 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 green 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, the green LTE architecture. We model the energy managed by HeNB-ECS, we propose a technique to reduce energy and congestion network, in this sense we propose a general algorithm to manage the HeNB network, particularly energy and congestion in our architecture and we give some numerical results as a graph and a table. 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 energy and network congestion, whose main role is to reduce energy and network congestion.

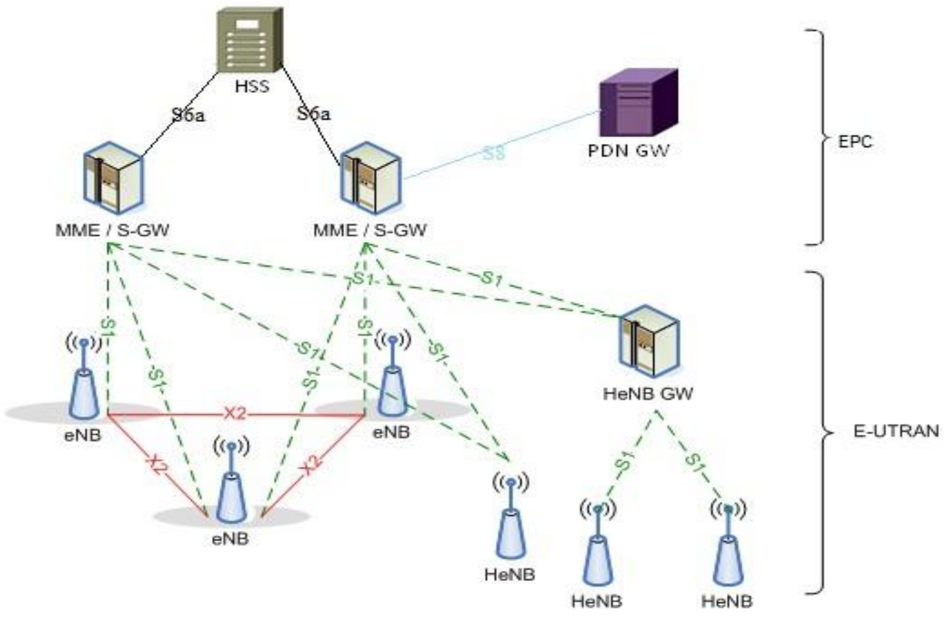

Fig. 1 LTE HeNB Standard Architecture [6]

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

Our architecture (Fig. 2) is based on using a secure Virtual Private Network (VPN) connection with Internet Protocol Security (IPSec) 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 to 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.

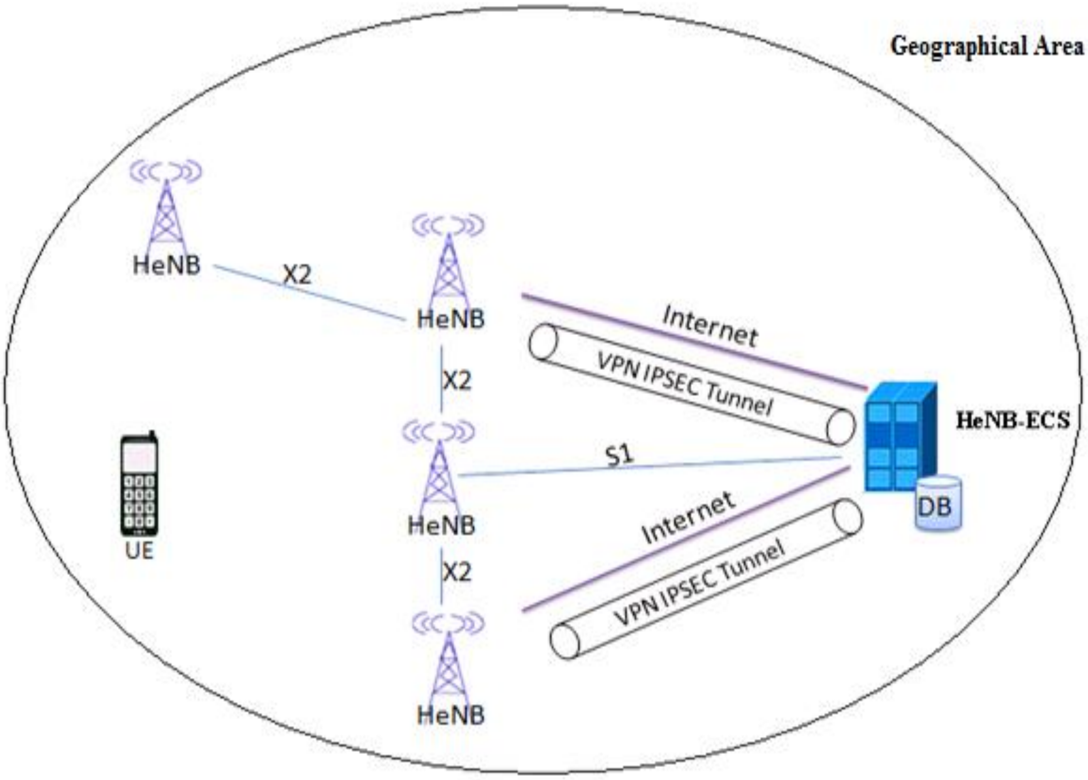

Fig. 2 Architecture with HeNB-ECS

C. Connection between HeNB and HeNB-ECS

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.

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

D. Problem formulation

In this section of the paper, we present the different problematic situations modeled mathematically, for this reason 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 UEs attempt to connect to one of the HeNB.

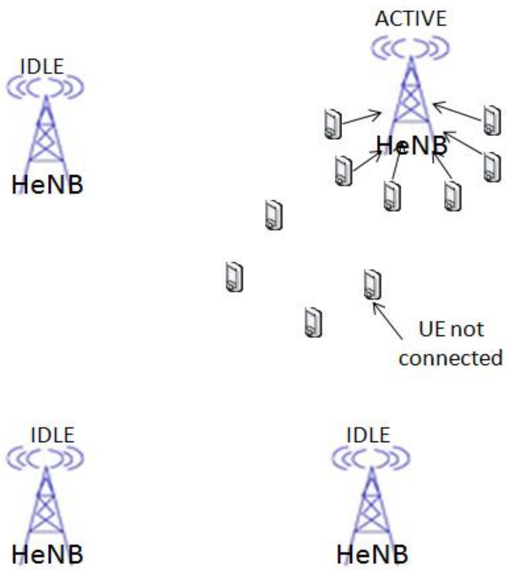

Fig. 3 Energy wasted by HeNB in idle mode

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 UEs attempting to connect to HeNB
N_c :Number of UEs connected
N_N :Total Number of UEs supported by HeNB network

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:

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

Our solution can save the following energy:

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

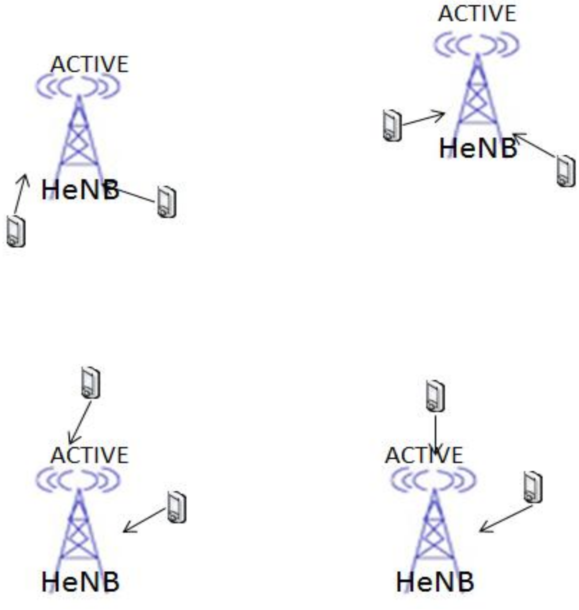

Fig. 4 Energy used exceeds the energy needed

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 algorithm 1 pictured in Fig. 5 and algorithm 2 pictured in Fig. 6

Fig. 5 presents the algorithm of the HeNB or UE connection to HeNB-ECS. It puts HeNB in idle or active mode network when as needed.

Fig. 6 presents the algorithm of the HeNB or UE disconnection for HeNB-ECS. The two algorithms are complementary.

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Algorithm 1: HeNB or UE connection to HeNB-ECS

start: waiting HeNB or UE connection
    if (HeNB connection)
        N_N ← N_N + N_Fe
        if (N_NC = 0)
            Put HeNB in idle mode
        else
            Put HeNB in active mode
        end if
    else
        N_T ← N_T + 1
        N_NC ← N_NC + 1
        if (N_N > N_T)
            Choose HeNB
            N_C ← N_C + 1
            N_NC ← N_NC − 1
        else
            Waiting HeNB or UE connection
        end if
    end if
end
```

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

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Algorithm 2: HeNB or UE disconnection to HeNB-ECS

start: waiting HeNB or UE disconnection
    if (HeNB disconnected)
        N_N ← N_N − N_Fe
    else
        N_T ← N_T − 1
        N_C ← N_C − 1
    end if
end
```

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

Here, we describe briefly the algorithm 1 of the HeNB or UE connection to HeNB-ECS Fig. 5.

In the beginning, the server HeNB-ECS waits the UEs or HeNB connection, then if HeNB tries to connect (if HeNB connection). The server HeNB-ECS performs the following operation:

$$N_N \leftarrow N_N + N_{Fe}$$

With N_{Fe} : Number of UEs supported by each HeNB.

Afterwards, if $N_{NC} = 0$ (the number of UE not connected), the server puts the HeNB in idle mode else it puts the HeNB in active mode.

In the case, where UE attempts to connect, the server performs the following operations:

$$N_T \leftarrow N_T + 1$$
$$N_{NC} \leftarrow N_{NC} + 1$$

Finally, if $N_N > N_T$, the server chooses a HeNB to connect UE and it performs the following operations:

$$N_C \leftarrow N_C + 1$$
$$N_{NC} \leftarrow N_{NC} - 1$$

In the contrary case, the server waits HeNB or UE connection

We also describe the algorithm 2 of the HeNB or UE disconnection for HeNB-ECS Fig. 6.

In the beginning, the server HeNB-ECS waits the UEs or HeNB disconnection and then if HeNB attempt to connect, the server performs the following operation:

$$N_N \leftarrow N_N - N_{Fe}$$

In the contrary case, the server performs the following operations:

$$N_T \leftarrow N_T - 1$$
$$N_C \leftarrow N_C - 1$$

These algorithms can efficiently manage the network especially; the network congestion and energy consumption.

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

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.

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 1: POWER CONSUMPTION OF FEMTOCELL

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

According to the Figure 4, during 4 seconds we can save 67 J,$(204 - 136{,}8 = 67)$, which exhibits a percentage 33%, $\left(\frac{67}{204} * 100 = 33\right)$, in the case where 5 HeNB in active mode.

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

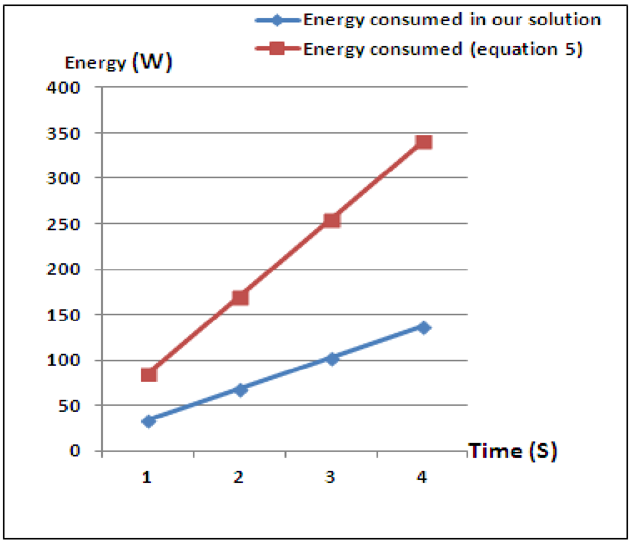

Fig. 7 Example shows the energy consumed by our solution

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 green 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 and we have presented the numerical results as a graph and a table.

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

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