# Analysis of Handover Based on The Use of Femtocells in LTE Networks

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*Abstract*— One of the key elements in LTE (Long Term Evolution) networks is deployment of multiple femtocells for improvement coverage and data rate. However, arbitrary overlapping coverage of these cells makes the HO (handover) mechanism complex and challenging. In this paper, simulations of deploying LTE femtocells in a scenario were evaluated. With this objective, measure impact and correlation of the use of femtocell parameters of QoS (Quality of Service) and handover are analyzed. Possible limitations of this integration are discussed. Will be the integration of LTE femtocell a panacea? Despite this promising alternative estimates are fraught with uncertainty. The results show that the use of femtocell got worse on indicators of handover, impact on indicators of QoS.

*Keywords*– LTE, handover, femtocell, simulation, OPNET.

## I. INTRODUCTION

Currently, Internet and mobile communications are converging to a new paradigm, the Mobile Internet. The ability to access information and services anytime and from anywhere has been shaping not only new user profiles but also demands for new applications.

With the popularization of the third and fourth generation technologies, mobile communication systems suffer from the addition of new services and functionalities, which also involve critical problems, such as interference, limited coverage, restrictions on the use of triple play applications, among others.

The multimedia services are becoming increasingly popular. These services generate intense traffic on the network, that demand for higher data rates and are sensitive to delay and delay variation, experienced in the network.

In indoor environments, channel quality between the cellular base station and the mobile node may be affected by walls and obstacles. The wireless communication for indoor environments requires more resources, including time, bandwidth, transmission power so that they can ensure the quality of service required by customers.

Thus, it is necessary to investigate access technologies to ensure satisfactory levels of quality of service, taking into consideration the growing demand for data services. In this respect, for a wireless operator, femtocells are an attractive alternative since they are cost-effective to significantly increase the user data rates of their wireless networks at the customer premises. [2]

This growing demand for indoor wireless multimedia and ongoing trends of mobile convergence are paving the way for the installing femtocells industries. Femtocells may be open access or closed access. [3] Open access allows an arbitrary user to use the femtocell, whereas in closed access, the use is restricted to users that are explicitly approved by the owner. While the ultimate goal of femtocell is to improve the efficiency, coverage and services at a reduced cost of operation, the possibility of arbitrary handovers between the existing eNodeB (enhanced NodeB) and HeNB (Home eNodeB), poses new challenges [4].

LTE is a fourth generation cellular network technology that provides improved performance compared to legacy cellular systems. LTE introduces an enhanced air interface as well as a flat, "all-IP" packet data optimized network architecture that provides higher user data rates, reduced latencies and cost efficient operations. Figure 1 illustrates the overall E-UTRAN Architecture.
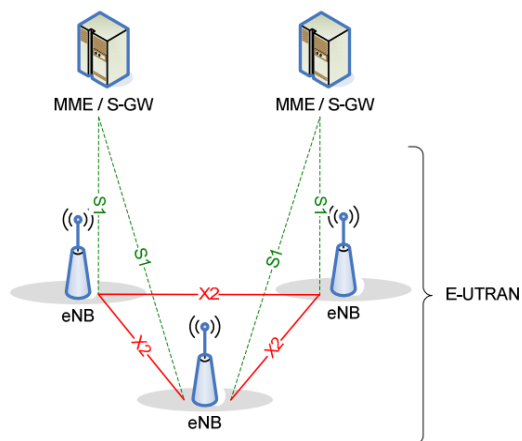
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**Figure 1. Overall E-UTRAN Architecture [5]**

However, even supporting high data rate, LTE frequency can result in poor indoor coverage in some areas. In this case, LTE-based femtocells network could be an alternative to improve the indoor signal and avoid overloading the macrocell. It is still too early to predict the success of LTE femtocell. Factors such as safety, interference and management still need to be studied.

The integration of femtocell LTE network appears to be a promising approach due to its homogeneous nature and characteristics. However, for the mobile unit to provide transparent communication in a change of radio resources, it is necessary to handover the network capacity. The handover is the process that characterizes a cellular network and assures its mobility feature.

From a technology point of view, a femtocell is not only characterized by short communication range and high throughput, but also by its ability to seamlessly interact with the traditional cellular network at all layers of the network stack, performing tasks like handovers, interference management, billing and authentication. This necessitates substantial support by the appropriate standards bodies [6]. It is observed that the integration of these technologies is a recurrent theme in the academic and scientific community. Femtocells have gained much attention recently due to their advantages in terms of cost savings in infrastructure and improving the experience in indoor environments. However, there are major differences between the full effectiveness of its use.

Faced this paradox, we discuss possible limitations of this integration. Will be LTE femtocell a panacea? Despite this promising alternative estimates are fraught with uncertainty. The results for specific scenarios proposed, show that the use of femtocell got worse on indicators of handover, impact negatively on QoS indicators.

The intention is not exhausting the subject or provides definitive results, but shows important counterpoints, qualifying and contributing for discussion.

This paper aims to conduct a study on handover from the use of femtocells and evaluate the correlation between the indicators of handover and QoS. The study also includes the effectiveness of using LTE femtocell and especially on what will be the impacts, earnings and disadvantages that this combination of technologies offer.

The following sections are organized as follows: section 2 will discuss some concepts of technologies on which this work is based. In section 3 related works will be presented. The description of the methodology used and the results are discussed in section 4. Finally, in Section 5 are final remarks.

## II. THEORETICAL FUNDAMENTS

### A. LTE (Long Term Evolution)

Searching for solutions to make data transmission more efficient, while dealing with more and more volumes of such traffic, LTE has been proposed as the next step in the 4G mobile system, preceded by 2G and 3G. Its development is intended to provide performance improvements, while reducing the cost per bit, allowing for a greater dissemination of mobile services. Its standardization is the responsibility of 3GPP [7].

LTE networks have a new architecture, totally different from what had been used in previous technologies. An example of this is the base station, called eNodeB in which LTE starts processing tasks previously performed in RNC (Radio Network Controller).

Note that the eNodeB will also be responsible for handover decisions through communication between the elements using X2 interface However it is possible that due to the lack of communication over X2 (optional interface), communication between the eNodeB will be accomplished through other alternative, the Access Gateway.

Over the next years, it is expected that billions of devices will be connected to the Internet and cloud-based applications using mobile wireless 3G and LTE networks. So a huge demand for wireless mobility and ubiquitous coverage will definitely be necessary. Global mobile data traffic will increase 26 times between 2010 and 2015, also known as "mobile data tsunami" [8].

### B. OPNET

The OPNET Modeler accelerates the process of research and development enabling the analysis and design of communication networks, devices, protocols and applications.

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It is widely used as a simulator Instrument for modeling telecommunications networks [9].

The software has three main functions: modeling, simulating, and analysis. For modeling, it provides intuitive graphical environment to create all kinds of models of protocols. For simulating, it uses different advanced simulations technologies and can be used to address a wide range of studies. For analysis, the simulation results and data can be analyzed and displayed very easily. User friendly graphs, charts, statistics, and even animation can be generated for users' convenience.

It allows one to create a network from a library of templates and define parameters not only for the environment, but also of each object that makes up, and the impacts of its variations. For educational purposes, its use has also leverage as one of its major advantages is the graphical interface provided to the user to configure settings and to view results.

C. *Handover*

The handover is a difficult procedure because it involves several tasks that may cause interruptions in service delivery and performance degradation of applications. This fact becomes worse if there is an increase in the frequency of migration and transition. As a result, there is a greater number of handovers.

Recently, the concept of handover has not only been linked to continuity of a phone call, but also to the continuity of streaming sessions, maintaining QoS and access to the Internet. One of the research challenges for cellular systems is to improve the call admission system that controls and reduces blocking probability and improves the quality of service.

This extension of the concept of handover occurs due to the popularity of tablets and smartphones, which have allowed the collective experience of users sharing the same coverage area. Recently, the scenario of mobility at different speeds with applications in use has been increasingly common.

As the UE (User Equipment) moves in the network, it may experience different propagation conditions and interference. Can happen to a neighboring cell presents the best conditions (RSRP higher) than the current cell.

Control messages are exchanged across the interface between the two X2 eNodeBs and downlink data packets are also forwarded from the source to the target eNodeB through the same X2 interface [10],[11], the handover procedure is illustrate below.
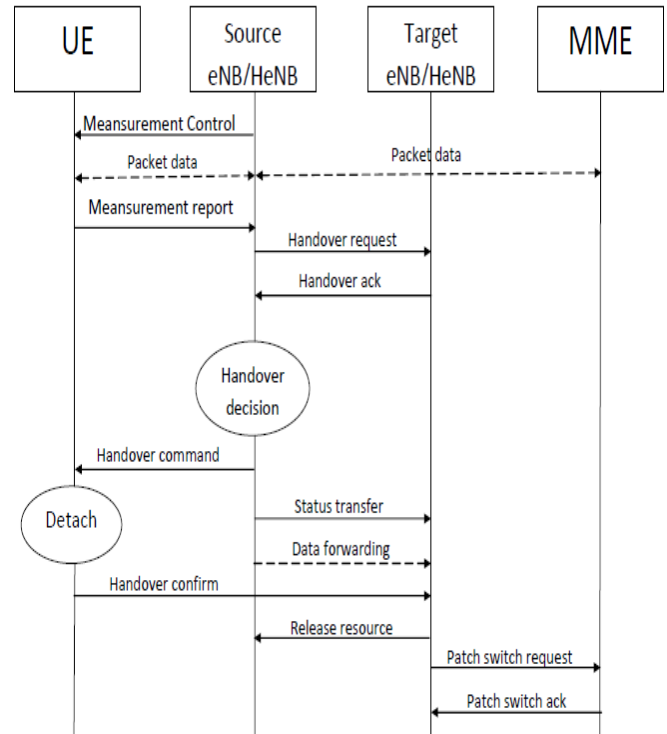


**Figure 2 Handover procedure in LTE [12].**

The neighboring cell RSRP measurement is started when the serving cell signal quality drops below a configured threshold. The measurements are performed periodically from the neighboring cell reference signals. The reference signal slots are spread around in the time-frequency resource slots of the whole system bandwidth so that measurements can be performed on a sub-band level as well as averages for wideband measurements.

RSRP value is calculated as an average from the individual reference signals throughout the entire system bandwidth. The reference signals are cell specific and thus can be differentiated between cells using complex cyclic shift calculations so that the measurements from other cells can be differentiated. [13]

At the time of writing, the used event triggered reports in intra-LTE handovers are A3 for "better cell HO" and A5 for "coverage HO". Out of these two, A3 is more common and basically a given cellular LTE network can provide decent mobility with merely A3 handovers. The A3 handover triggering procedure is illustrated in Figure 3 and explained below.
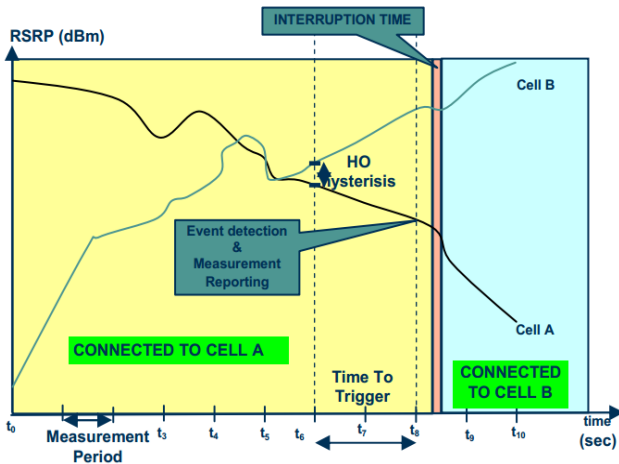
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**Figure 3. Handover triggering procedure [14]**

The starting point of the handover triggering procedure is the measurements performed by the UE. These are done periodically as defined by the measurement period parameter configured at the eNodeB.

When a condition is reached in which the serving cell RSRP drops an amount of the configured HO offset, usually 2-3dB, below the measured neighbor cell, a timer is started. In case this condition lasts the amount of the Time To Trigger (TTT) value, a measurement report is sent to the eNodeB, which initiates the handover by sending a handover command to the UE. In case the reporting conditions change and no longer satisfy the triggering conditions before the timer reaches the TTT value, a measurement report will not be sent and new measurement calculations and timers are started.

*Handover Scenario in Femtocell Network*

All mobile systems including the femtocell network implement a handover procedure to support the user's mobility. The handover, in one side allows communication during user's movement in the network.

On the other side, it significantly increases signaling overhead in the network. According to [15], it most likely that the soft handover will not be implemented in femtocell due to limited frequency allocation for femtocells. In addition, due to technological challenges and system operator requirements, the initial 3GPP specification for handover in femtocell focused on one direction only that is from femtocell to macrocell eNodeB [16].

Despite having some constraints, in this paper we consider all possible handover scenarios between femtocell and eNodeB and between femtocells. There are three possible handover scenarios in femtocell:

- Hand-in: this scenario presents the handover where an UE switch out from macrocell eNodeB to femtocell.
- Hand-out: represents the handover that is performed from femtocell to macrocell eNodeB.
- Inter-Femtocells handover: it corresponds to the scenario of handover from one femtocell to another femtocell. In this scenario all femtocells are assumed to be placed at the same location and served by the same service provider.

*D. Femtocell*

This is partly due to the convergence between mobile and Internet since the introduction of third-generation mobile services. With fast and reliable access to the Internet, data volumes have increased far faster than the revenues and this trend is expected to accelerate in the future. In order to be competitive, operators need to find ways to substantially decrease the cost per bit of delivering this data, while not placing limits on customers' appetites for consuming the data.

Besides voice revenues diminishing, a new trend appears regarding wireless usage. Roughly 66% of calls initiated from mobile handset and 90% of data services are occurring indoor [17]. Voice networks are engineered to tolerate low signal quality, since the required data rate for voice signals is very low, on the order of 10 kbps or less, whereas data networks, require much higher signal quality in order to provide the higher (in multi-Mbps) data rates. Hence, operators need to improve indoor coverage without additional macrocell deployment. Femtocell constitutes a promising solution to address indoor coverage with limited cost impact.

The femtocell concept is part of the effort of telecommunication industry to provide communication of high performance, high-quality services for home users. In contrast to conventional types of cells, which are well planned by the operators, the femtocell base stations must be installed by customers themselves, similar to a wireless access point. [18]

The femtocells are small base stations on the same functionality as the macrocells, but they have power to meet only a restricted environment (10-20 meters), are low cost, supporting a small number of users and installed by the user to best reception of voice and data in closed environments. [19]

With almost 60% of the worldwide population equipped with mobile phones, mobile cellular communication is one of the fastest growing technology ever seen. However, recent studies show that voice revenues are declining in favor to data volumes and revenues.

A factor to be taken into consideration, is that the process of installing these femtocells would be up to the user or in other words plug and play, without much consideration when planning, relying only on the skills of self-configuration built to minimize impact on the macrocell through self- provisioning parameters.

The reference femtocell architecture is shown in Figure 4, which has a set of S1 interfaces to connect the HeNB to the EPC.
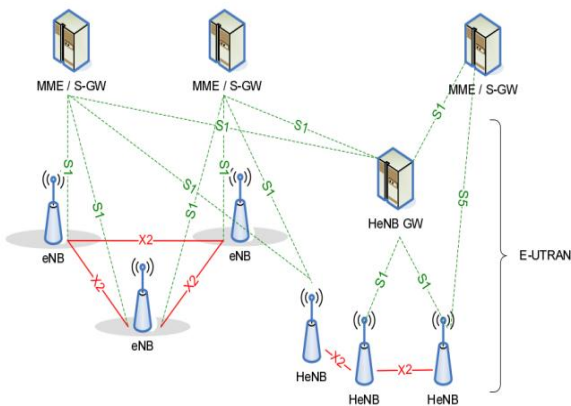


**Figure 4. Overall E-UTRAN Architecture with deployed HeNB GW [20]**

It is noticed that the concern is because despite all the advantages provided deadlocks are not easily solvable due to the following major technical and non-technical challenges still pending. In several studies [21][22][23] it is possible to observe these technical and non technical limitations:

*Technical Challenges*

- Interference Management: will be required to mitigate the performance degradation resulting from the interference between femtocells and macrocell and femtocell between when deployments are dense and without planning.
- Auto-configuration: Ensure femtocells configure and adapt dynamically to change their operating parameters during environmental conditions.
- Management handover: Necessity an effective and clear approach to ensure the proper management of handover between eNodeB and HeNB.
- Techniques for cooperative positioning: Which allow better precision in the placement and management of femtocells before installation.
- Access Control: The mechanisms proposed so far are arbitrary and not optimized and become even more difficult when it comes to areas where different femtocells overlap (massive implementations).

Currently three modes of access were set for a femtocell, mode Open, Closed and Hybrid.

- Femtocells are deployed by the users and can be switched on and off at any time, so the implementation is completely random. The planning tools and classic designs to configure and optimize a network femtocell network unusable. They need to take enough to autonomously integrate network radio access intelligence. [24]
- Security: In case the mode of open access to information privacy must be guaranteed. The femtocell network is prone to many security risks. For example, the private subscriber information travels over the Internet backhaul connection. This information can be intercepted, which would violate the privacy and confidentiality [25]
- Necessity of accurate solutions for scalability, redundancy and traffic particionation.

*Non Technical Challenges*

- The main advantages are concentrated on the side of operators and no business models that include attractive way to purchase femtocells by the end user.
- Operators prefer not to depend on a single supplier, which worries since currently the equipment does not guarantee interoperability.

In this paper, simulations of deploying femtocells in an indoor environment have been carried out to study its effects on the handover and evaluation of quality of service experienced by users.

## III. RELATED WORKS

Some works analyzed are intended to establish the best way of balancing the factors involved in mobile communication and manage users make better use of network resources and thus get a higher efficiency. It self reviews the mechanism for handover in LTE networks has been intensively studied in academia and industry.

Some examples are [26], where the performance is evaluated TCP and UDP when the handover is executed in an LTE system, the TCP throughput is improved by using a small amount of A3-offset, because it effectively suppresses the interference from neighboring cells. Decreasing the value of A3 offset induces more "ping-pong" handover, but this does not affect the performance of TCP significantly.

Into [27] is proposed a strategy for handover between macrocell and femtocell for LTE networks, the paper presents a strategy that tries to avoid the failures of handover and the occurrence of unnecessary handovers.

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In many works [28, 29] if analyzes raise challenging problems on their potential for use in LTE femtocell networks as an alternative for coverage.

Into [30] the handover procedure in LTE femtocells is discussed focusing on the significant increase in the number of femtocells in certain environments. Simulations for the handover between macro and femto between femto were performed and an optimization algorithm was proposed and compared to conventional algorithm.

In other studies, the process of handover between HeNB and LTE eNodeB so modified [31] has been proposed. A new handover algorithm based on the speed of the UE and the QoS three different speed settings were considered in the algorithm, or low mobility (0-15 km/h), medium (15-30 km/h) and high mobility (>30 km/h). The analysis showed that the proposed algorithm has the best performance, and then the algorithm is compared with the traditional algorithm.

Next generation applications require seamless handover. The small coverage individual APs (Access Point) has increased the number of handover occurred. Thus reduce the handover latency has become a burning issue and much work has been done to achieve this goal.

In [32] present a detailed literature review with the main features of femtocell technology and raising technical and regulatory issues. Such networks face a lot of uncertainties as the infrastructure is not preplanned. Moreover, there are technological issues to be considered: Can Femtocells handle unloading data and video streams from conventional networks? Will they create more problems and thus jeopardizing the careful work on installing base stations considering unpredicted interferences?

The following papers show some concerns on the principal aspects for limitation on employing femtocells: [33], [34], [35] concerns are in order in spite of all the advantages. Unfortunately, deadlocks are not easily sorted out due to several technical and non-technical issues that are still pending to be solved.

## IV. METHODOLOGY

First of all, it was necessary to elaborate the methodology to consider same modeling for both the scenarios to be simulated. Figure 5 shows a flowchart that describes the sequence of activities to be conducted. This methodology may be generalized for several other real world problems that can be modeled and simulated.
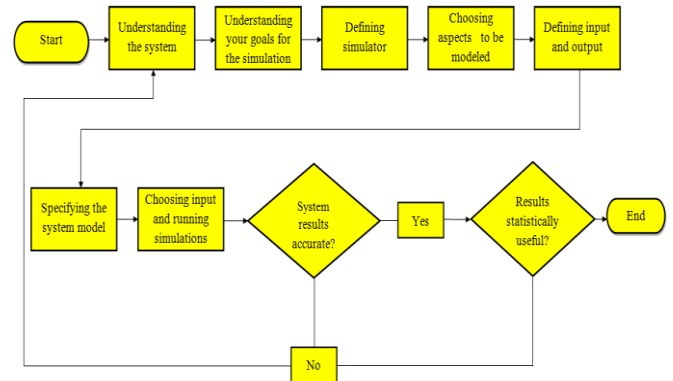


**Figure 5. Flowchart**

The handover process is related to access, radio resource and network control, having a significant impact on the capacity and performance of the system. In this paper, the modeling of scenarios of interest was performed using the Opnet Modeler 17.5 (release 8).

In the analysis conducted for this study, two identical scenarios were created, but one without the use of femtocell and the other with the insertion of 9 femtocells per cell. The Figure 6 shows the modeling of the simulation scenario and the configuration and parameterization of femtocell radios are contained in Table III.

In both scenarios, the network consists of 5 eNodeB, parameterized according to Table I. Concerning mobility, it was assumed for all 100 network users the random waypoint mobility model [36]. The structure also includes elements EPC (Evolved Packet Core) and gateway that will communicate with the application server.
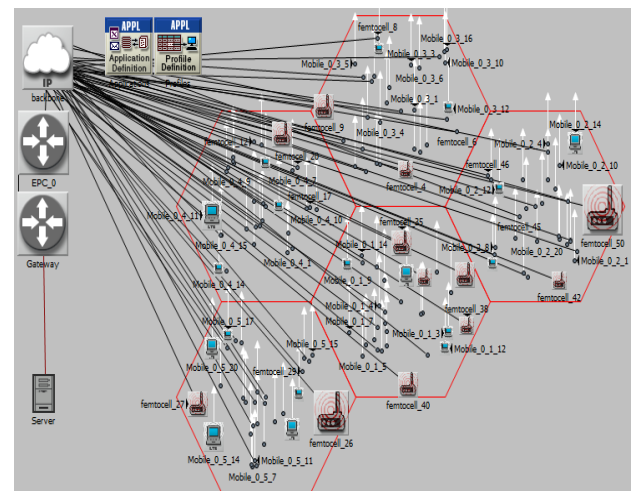


**Figure 6.Scenario modeled in OPNET tool.**

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*A. The simulation Parameters*

The parameters and settings of the antennas are described in Table II. To generate traffic on the network, made use of a VoIP (Voice over Internet Protocol) application.

The VoIP application is used to represent the class of inelastic applications, real-time, interactive, which is sensitive to delay end-to-end, but can tolerate packet loss. Today, the emergence of real-time application requires more resources, so it is necessary ensure rapid and reliable voice communication for a large number of users on the network.

All users have been configured to establish a VoIP call to an external server. In Table I, we list the most relevant parameters used for configuring the application.

**TABLE I**
**CONFIGURATION OF VoIP APPLICATION**

| | |
|---|---|
| Silence Length (s) | Exponentially distributed, mean 0.65 |
| Talk Spurt Length (s) | Exponentially distributed, mean 0.352 |
| Encoder Scheme | GSM FR |
| Voice Frames per Packet | 1 |
| Type of Service | Best effort (0) |
| De-Compression Delay (s) | 0.02 |

**TABLE II**
**CONFIGURATION OF LTE ANTENNAS**

| Parameter | Value |
|---|---|
| Transmission Power | 26 dBm |
| SC-FDMA (UL) Frequency | 1920 MHz |
| OFDMA (DL) Frequency | 2110 MHz |
| Bandwidth | 10 MHz |
| Gain Antenna | 17 dBi |
| Antenna Height | 40m |
| Radius Coverage | 7 Km |
| Propagation Model | Urban Macrocell |
| Duration of simulation | 900s |

**TABLE III**
**CONFIGURATION OF FEMTOCELLS**

| Parameter | Value |
|---|---|
| Transmission Power | 23 dBm |
| Gain Antenna | 2 dBi |
| Propagation Model | Indoor Environment |
| Antenna Height | 1m |

*B. Handover Performance Indicator (HPI)*

In this section the main evaluation metrics used as performance indicators handover will be described. The metrics are described below.

*Handover Delay*: From this statistic is possible to identify the number of handover performed, as well as the position in time where the delay for the handover is successfully occurred.

*Handover Failure*: The ratio of handover failure (HF) is the ratio between the number of failed handovers (NHfail) on the number of attempts made. Where the number of handover attempts is given by the sum of the number of failed handover (NHfail) plus the number of successful handovers (NHsuc).

$$HPI_{HF} = \frac{NHfail}{(NHfail + NHsuc)} \qquad (1)$$

*Blocking Probability*: The blocking probability is the ratio of the number of failures (Nfail) on the total number of failures (failure of handover + failures radio ) added to the total number of handover (TH).

$$HPI_{BP} = \frac{Nfail}{((RadioFail - NHfail) + TH)} \qquad (2)$$

*C. Simulation Results*

The simulation was conducted through a survey of the initial configurations carried out in OPNET. The simulation time was 900 seconds, long enough for the environment present a stable behavior and test users could navigate the trajectory established.

In Figure 7, the graph extracted directly from OPNET. This chart expresses a joint display of two key metrics for analyzing the handover performance indicators. Membership lets you view the eNodeB in that moment of time and in which eNodeB, the user has joined.

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In the same figure and the same instant of time, the handover delay is reported, identifying delays in handovers performed successfully.
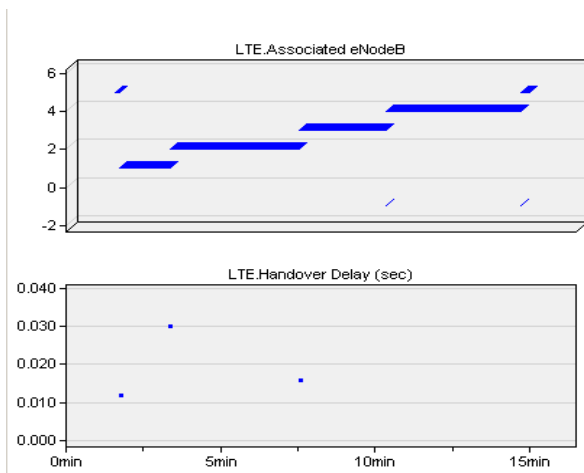


**Figure 7. Associated eNodeB e Handover delay.**

The results and trends are indicative of the mechanisms that actually impact on system performance. Some of the variable parameters include the speed of the user, the type of traffic, application, etc.

In the analysis, the 100 mobile users were initially observed individually, since each user traveled a random trajectory, which guaranteed numbers of failures and specific to each handovers.

The results presented here demonstrate a comparison of both simulated environments, ie with and without setting femtocell. The analysis allows us to infer that since deployment of femtocells in the network, users are conducting a much larger number of unnecessary handovers, which impacts heavily on indicators of handover performance. The comparison can be seen in Table IV.

The rate of handover failure suffers an additional 61%. Have the blocking probability increased by rejecting approximately 50% more using femtocells.

**TABLE IV**
**INDICATORS OF HANDOVER PERFORMANCE**

| Statistic | LTE scenario | LTE scenario + *Femtocell* |
|---|---|---|
| Handover Failure | 0.1 | 0.71 |
| Blocking Probability | 0.259 | 0.764 |

Some indicators were collected to evaluate QoS experienced by the users' behavior. We notice that the deployment of femtocells did not represent a significant improvement over the parameters of QoS.

An assessment of the general behavior of 100 users was carried out. The figure below shows the delay in both scenarios. We notice that there was not great variation, both had behavior around 200 milliseconds.
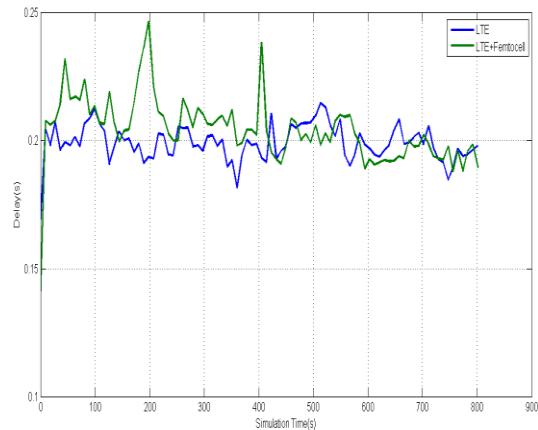


**Figure 8. Delay of VoIP application.**

Figures 9 and 10 show the values of MOS (Mean Opinion Score) and jitter obtained. The MOS is rated at calculate the mean of results of the test subjects. Using a scale from 1 to 5, where a score of average equal to or greater than 4 is considered toll-quality. The MOS achieved was considered poor, as had average behavior around 1.5 even after the addition of femtocells.
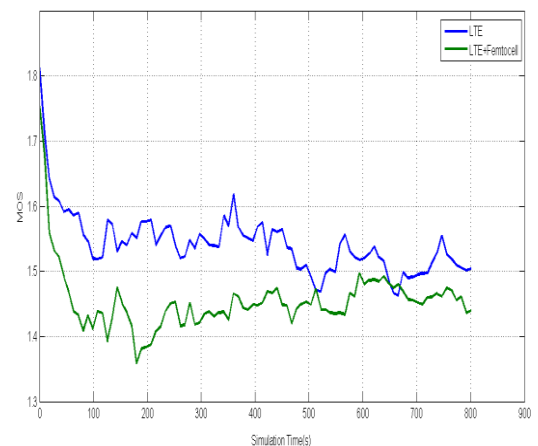


**Figure 9. MOS of the VoIP application.**

Have watched the last graph obtained, but not the least important, the jitter is illustrated below. The graph shows the maximum difference in one way delay of packets over a particular time interval. As shown in fig. 10, time average of jitters rate for voice in both scenarios are similar.
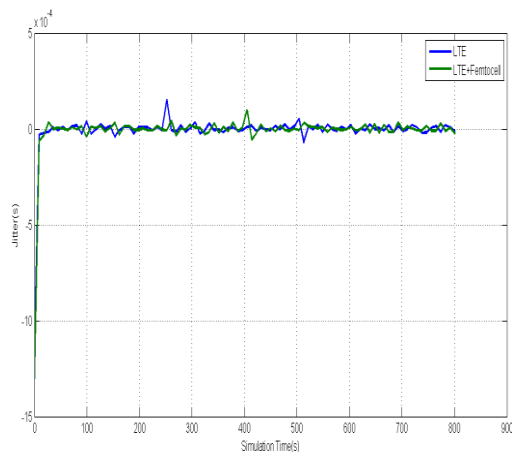
**Figure 10. Jitter of VoIP application**.

## V. CONCLUSIONS

With the evolution of mobile communications and the emergence of Based on the preliminary analyses, one can note that integrating LTE and femtocells was not a good option as expected.

For the considered parameters and scenarios, inclusion of femtocells would improve QoS. The results stress the necessity of self-configuration for proper functioning of femtocells. It is also important to mitigate the degradation of the performance due to the interference between macrocell and femtocell as well as among femtocells, especially when installations are conducted without proper planning. Without these issues, it is impracticable and there is a significant impact on QoS, on handover and on the overhead of signaling associated to mobility procedures.

In spite of some of the aspects mentioned, use of these small cells, at least for the considered scenarios, did not turn into a panacea. Management of handover mechanism, interference and self-configuration still poses a major challenge and it is relevant for the success of integration of LTE and femtocells. Finally, it is important to point out that the study conducted in the paper should not be considered as conclusive and other parameters must be taken into consideration. Besides, there must be a forum to discuss the employing of femtocells.

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