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Research paper

Performance Analysis of Femtocell Deployment in an Indoor LTE Cellular Networks

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Abstract

Wireless communication has become an essential as the technology advanced and this creates a situation where a high capacity cell is needed to accommodate the needs of the public, especially in urban area. The cell that contained heavily loaded users became crowded and hence affected the signal performance. This situation will result in low signal strength received by the users, bad performance of the system and even drop call happened. This paper presents the performance analysis of femtocell deployment in indoor LTE cellular networks. In this study, to support this crowded cell, this research proposes deployment of femtocell which can enhance indoor coverage in Long Term Evolution (LTE) cellular networks. A femtocell is a small, low-power cellular base station, typically designed for use in a home or small business. Several test measurements at 3 different floor levels of shopping mall have been carried out by using Nemo Handy tool to see on signal strength variations. Based on the measurement analysis, a framework with femtocell deployment has been developed by using MATLAB software to improve the signal strength performance. The results demonstrated that femtocell deployment has improved handover successful rate and hence, provides better indoor coverage and network capacity for LTE cellular networks.

Keywords: *Drop Call, Femtocell, Long Term Evolution (LTE), Macrocell and Signal Strength*.

1. Introduction

With the increase of users in a cell, further improving and increasing the capacity of maximum users in a cell is essential as some of the users may not be able to have access to network cell. As a proposed solution, a femtocell can be deployed to increase signal coverage and provided a cell for users' use [4]. A femtocell is a small, low-power cellular base station, typically designed for use in a home or small business as shown in Figure 1. Three-way cooperation between 3GPP, Femto Forum and Broadband Forum has created a new standard enabling operator to deploy the standards-based femtocells. The standard which forms part of 3GPP's Release 8, and interdependent with Broadband Forum extensions to its Technical Report-069 (TR-069) has been completed following close cooperation between 3GPP, the Femto Forum and the Broadband Forum [11].

Several studies in the last decade have shown that by deploying smaller cell site has improved system capacity with higher impact than other options such as deploying more spectrums, improving media access control (MAC) and modulation methods, or coding improvements. Hence, femtocell, being smaller in size than microcell and picocell is suitable to deploy in indoor environment. Other complication that users might have is that the coverage tends to differ in different floors of a building. Lower floor coverage or signal strength might be poor than that of a higher-level floor. In research paper [8], the author carried out an experiment on received signal strength for macrocell and femtocell when the UE is inside and outside house and then proceed with the simulation part on the received signal when the macrocell or femtocell and UE is outside as compared when the UE is inside. The author came to a conclusion that when the femtocell and UE inside the same house, the signal strength shows good performance. The author also concluded that the value of distance between eNodeB (macrocell) and boundary must be adaptive so that the handoff initiation can occur according to the mobile speeds. Although the paper discussed the comparison of macrocell and femtocell in a house, but it didn't explained the effect of having femtocell or macrocell at different floors of the house.

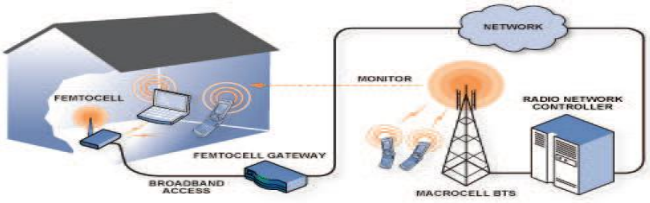

Figure 1 : Femtocell Deployment [9]

In research paper [4], the author stated that by deploying femtocell enables mobile operator to enter a previously unreachable market: the home environment. This is because the femtocell only has a range of few meters that is suitable for home uses. Author also explained that the most efficient way to increase capacity is to shrink the cell size. Although there are other ways of increasing the capacity, those other ways are semi disruptive and cannot compete with a smaller size cell. Although this paper explained the necessity of femtocell in today's life, but it didn't explained all interference that occurred by deploying femtocell especially in house.
The author in paper [12] described the optimal placement of femtocell base station for indoor environment. The author stated that since femtocell is a user deployed base station, random placement of it will affect the performance of associated users. Non – optimal placement of femtocell also resulted in high intra and cross tier interference. The paper also suggested an optimal placement of femtocell based on their research and simulation to increase Quality of Service (QoS) for associated users. The paper simulated the quality and performance of femtocell in a different length and width of an apartment. In addition, it also simulated the interference that users will encounter when randomly place a femtocell for their use. However, this paper didn't exactly mentioned what is the optimal placement for femtocell including placement of femtocell at different floors.
In paper [7], the author explained the benefits of deploying femtocell and how femtocell can optimize the total capacity of mobile network when there is a poor reception. The author emphasized the benefits of femtocell over macrocell in his/her simulation in an indoor setting. However, this paper only compared the quality of performance between femtocell and macrocell but not the actual performance of femtocell alone in a building. It also doesn't involved indoor environment which have different building heights. Another research paper done by Al-Hareth Zyoud [7] explained the challenge of deploying femtocell which is the interference mitigation and management. This paper also includes the techniques that could mitigate the effect of interference caused, received act upon deploying femtocell. Such techniques include aware and non-aware schemes. The advantage of this paper is that it mentioned in detail the techniques that could be used to mitigate the effect of interference. However, it did not mentioned the specific technique that is appropriate in a specific scenario for example in a building or outdoor environment.
From all mentioned papers, most of the researchers focus on the problem of interference. Interference of femtocell utilizing spectrum which was allocated for cellular telecommunication base station, interference between femtocell and interference of User Equipment (UE) which transmitting high power that it is received by more than one base station. Therefore, this research will investigate on current received signal strength performance and then propose of femtocells deployment in order to enhance the received signal strength of UE and hence, reducing interference in an indoor environment of different building heights.
This paper presents the performance analysis of femtocell deployment in an indoor LTE cellular networks. In this study, there are 3 methods of access mode for using femtocell where the first one is a Closed Access Mode (CAM). This method is essentially for users who own a femtocell that is only personal use. The second access mode is called a Hybrid Access Mode (HAM) where non-subscribers can have access during emergency. The third access mode that this research specifically focuses is an Open Access Mode (OAM), where this access is applied in public places and any users can be connected to the femtocell. The limitation of this research is that femtocell LTE is still not available in Malaysia, so providing accurate data based on real experiment is impossible, and therefore only simulation using MATLAB software with few assumptions based on 3GPP parameter is carried out to provide reliable data. This research also only specific in an indoor environment at different height means at different floors. Femtocell deployment is the propose solution as it is the best way to increase capacity.
The rest of this paper is organized as follows. Section II shows the methodology of this research. Section III shows the results for measurement and simulation analysis. Finally, conclusion and the future work recommendations are presented in Section IV.

2. Methodology

This project is divided into two parts which are measurement and simulation. The measurement is carried out to determine the current state of signal strength in the subject place which is Aeon Mall Shah Alam. Signal received was measured at different floors of the mall to differentiate the signal strength of different height. For the measurement, several tests have been done in Aeon Mall Shah Alam at the ground floor (GF), first floor (1F) and second floor (2F). Drive Test (DT) is a test that is perform in a cellular network regardless of the technology. In this carried out research, the measured network is LTE signal. The DT can be used to collect data while moving, either on foot or moving vehicles such as train, car etc. By initiating the DT, it can help identify signal strength, signal quality besides determining the problem such as dropped calls. In addition, the DT is important in the field of work such as Telecommunication and Information technology (IT). Its analysis consists of two phases, which are data collection and data analysis.

2.1. Measurement

For this study, a set of Nemo Handy Device was used to measure the received signal strength of UE. With this device, the Received Signal Strength Indicator (RSSI) and serving cell locations can be monitored, recorded and saved. Nemo Handy is an effective tool for tracing digital networks as shown in Figure 2 and 3. Nemo Handy collects measurement results and stores them on a memory card. Measurement results provide useful information for network optimization, verification and maintenance purposes. Results can be efficiently and easily viewed with the Nemo analysis tool Nemo Analyze for Windows.
Figure 2 shows the start-up of the Nemo Handy device. From Figure 3, it shows the interface and status the phone is currently on, and it also shows what system you are using (LTE, GSM, WCDMA), currently use script status and logging status. Nemo Handy Device application indicates a trail of color when UE is moving around the mall. Measurement was done from starting point, going around in a circle at a fixed speed and back to the starting point. With a Nemo Handy Device, the signal strength of each floor is being measured. From the Nemo interface, there is indication of the signal quality during measurements which are red for bad signal, orange for fair signal, yellow for good signal and green for excellent signal as shown in Figure 4 and 5. From the measurement analysis, if the signal shows bad performance, a femtocell framework is propose to be developed by using MATLAB software. Then, comparison will be done to determine whether the strength of the signal becomes better or poorer.

2.2. Simulation

Figure 6 shows the developed framework by using MATLAB software for the handover process in macrocell-femtocell network. The yellow dotted line represents the femtocell placement and the black line indicates the movement of UE. Initially, UE will be connected to

the strongest signal. If the signal is low, UE will move towards the femtocell and handover will occur. In this research, femtocells are deployed in area which has bad signals to improve its performance. The blue dot represents base stations and the red dot represents the centered base station of the cluster.

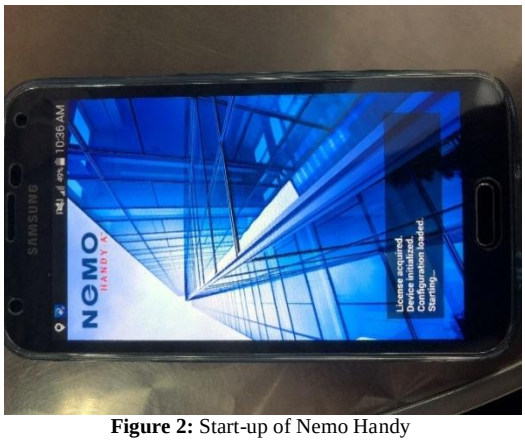

Figure 2: Start-up of Nemo Handy

Figure 3: Interface and Status of Nemo Handy

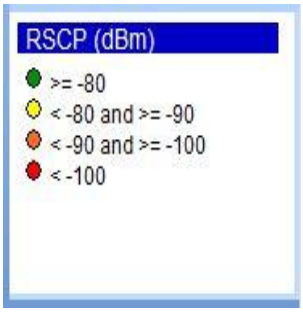

Figure 4: RSCP standard readings from Nemo Handy Device

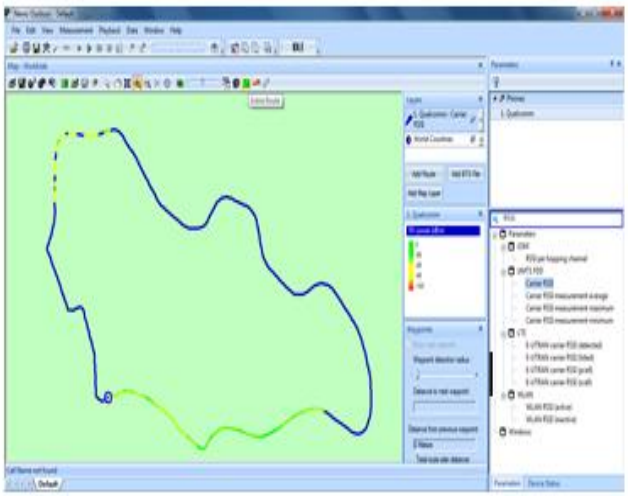

Figure 5: Color indication showing signal strength performance along the measured route

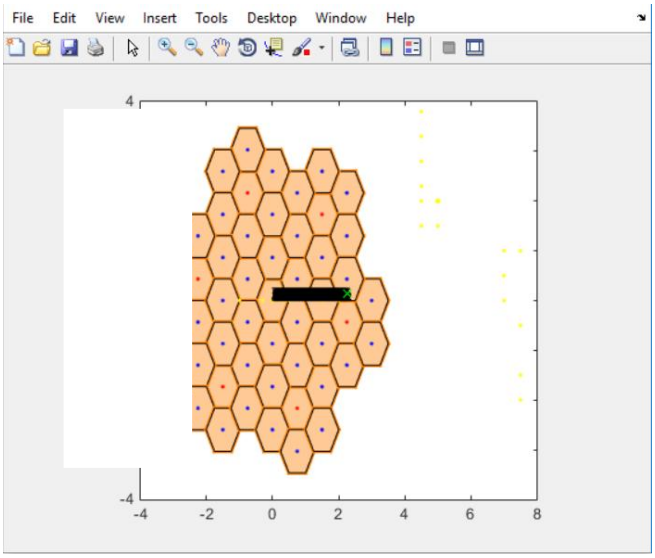

Figure 6: Framework of macrocell-femtocell network

3. Results Analysis and Discussion

Figures 7, 8 and 9 show the route taken for the test measurement at three different floors.

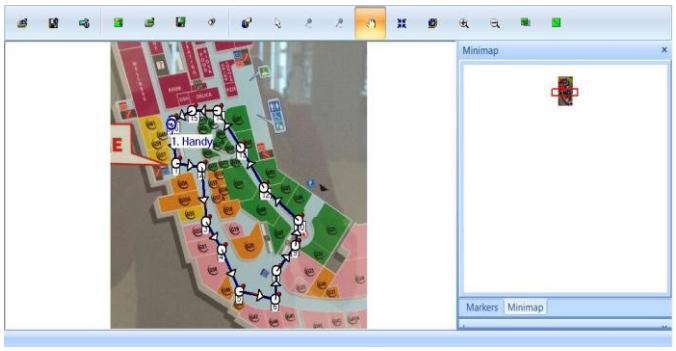

Figure 7: Measurement of Handy Device at GF

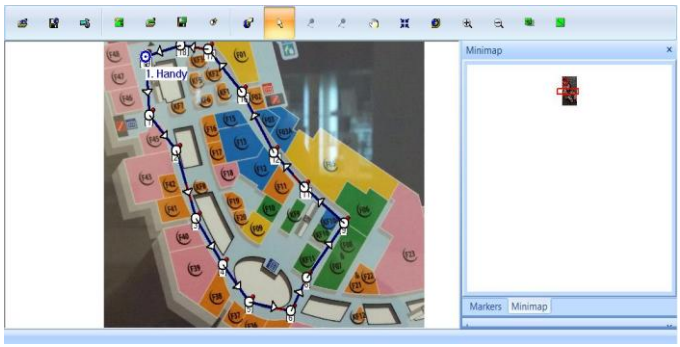

Figure 8: Measurement of Handy Device at 1F

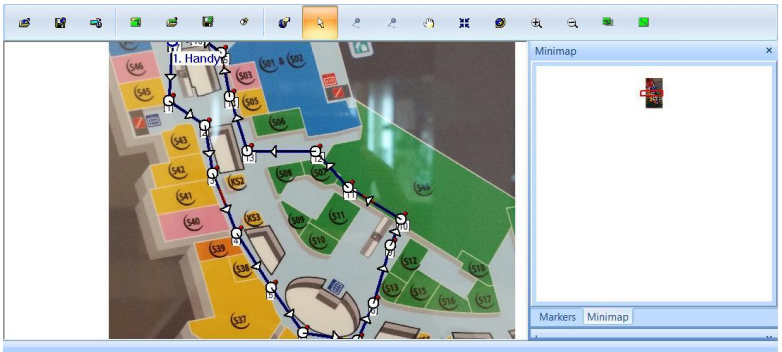

Figure 9: Measurement of Handy Device at 2F

Figures 10 and 12 show the RSRP signal behavior that has been measured in the mall. Before calls were initiated, the readings of RSRP were detected. Every time a new call is made, the RSRP signal is then changes to RSCP signal which indicated the 3G network. This can be seen as in Figure 13, 14 and 15 where once the voice call is established, the LTE signal is fall back to RSCP signal.

Figure 10: RSRP readings at GF

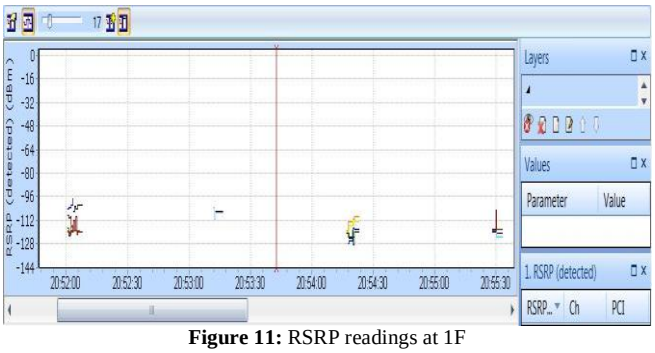

Figure 11: RSRP readings at 1F

Figure 12: RSRP readings at 2F

Figure 13: RSCP readings at GF

Figure 14: RSCP readings at 1F

Figure 15: RSCP readings at 2F

Figures 13 to 15 show the difference of RSRP values of measurement done at ground floor, first floor and second floor of Aeon Mall Shah Alam. The value in the figures shows a fair to poor connection of RSCP readings. The readings show better signal performance at higher floor as compared to lower floor level. This case occurs on higher floor because most operators have installed antennas on building roof and this cause relatively low signal strength to reach users on the ground. Therefore, this research is proposed to deploy femtocell at the bad signal area which can improve the signal performance, and hence provide higher capacity in the building at urban area.

Figure 16 shows the simulation result showing the number of handover when the femtocells are deployed. From the result, it can be seen that number of handover increases as the UE increases. It is because femtocell can only provide limited capacity for number of user. As can be seen from the graph, after 60 UEs the number of handover decreased as no more femtocells can be connected and only macrocells available which has very low signal strength.

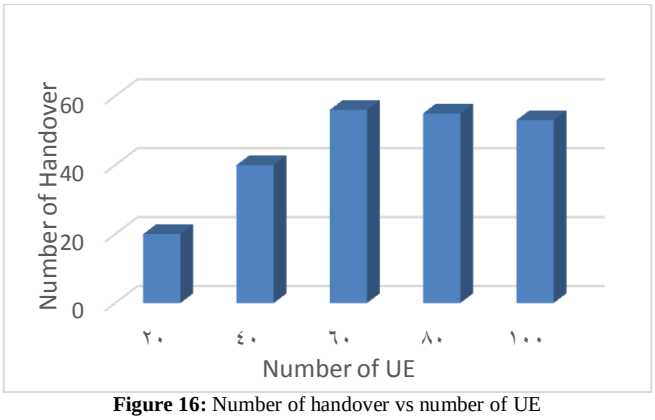

Figure 16: Number of handover vs number of UE

Therefore, from this result, it can be concluded that femtocell is the best solution to be deployed at area which has low signal strength level. However, the other concern is the femtocell placement also important so that coverage can be enhanced strategically.

4. Conclusion

This paper has presented the performance analysis of femtocell deployment in an indoor LTE cellular networks. The coverage of macrocell is limited for the in-building and insufficient capacity for wireless users as the traffic growth especially from indoor locations. Hence, the higher capacity is needed for users to have a good quality of services. However, since the capacity of macrocell is overloaded, some of the users may not be able to communicate over it or keep dropping calls when connected to the macrocell. The femtocell handover is studied in this project to provide a better signal performance for users. During measurement, signal strengths were measured at Aeon Mall Shah Alam at different floors to measure the signal strength performance. The weak measured signal is then become the point of interest where to deploy femtocell in order to improve user's coverage at that area. Placing or deploying femtocell does improves signal coverage, however, placement of femtocell without planning can gives more devastating outcome than good ones. Therefore, a good placement of femtocell needs to be strategically planning as to minimize the bad outcome of misplacing femtocell. For the future work, femtocell placement can be considered to improve the signal strength performance and hence, reducing the interference between macrocell and femtocell base stations.

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