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Femtocell : A survey on development in LTE network

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Abstract

Femtocell has been announced as the network mechanism to improve voice and data services in mobile network for indoor and also for limited outdoor geographical coverage. Femtocell also provide supports by offering more capacity to fulfil the increasing demand from indoor mobile users. This study is focused on the challenges on the development of femtocells in LTE Network System and discusses the major factors to optimize the coverage planning for enterprise femtocell deployment. The path loss model used for predicting the signal coverage is the P.1238 model for femtocell user equipment and COST 231 model for macrocell user equipment. In the study 3 enterprise femtocell networks with different coverage area are deployed and the real time measurement is obtained by conducting walk test. The main contribution of this project is the understanding and practical experience gained in deploying femtocell networks. Moreover the area for reliable coverage can be provided by a Home NodeBs (HNBs) and may vary as the density of UE changes. As conclusion, both femtocell and macrocell should be able to use the radio resources more effectively and the femtocell can complement the indoor coverage for the macrocell.

Keywords: Femtocell, Indoor Coverage, Walk Test, Open Access Styling,

Introduction

The rapid development of wireless communication technologies and the electronic gadgets such as smart phones, tablets and laptop equipped with internet access have made it as a vital tool in our daily life regardless of ages. With the increase in number of users, the main goal is to provide excellent user experience. Currently the common complaint towards the cellular system is the imperfect cell coverage especially in the building (Yeh et al. 2008). While the users stay indoors, the signal strength accepted from the base station (BS) outside the building is possibly too small to achieve the satisfactory performance level due to the high loss when the wave propagate through the walls. However the base stations (BS) are not allowed to increase the transmission power beyond the approved limit to increase the received signals in the interruption areas. The conventional approach is to set up new BSs, which is inefficient due to the long and tiresome site survey procedure and the high backhaul and operation expenses.

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As microcell restricts the indoor coverage area whilst at the same time more than 50% of the voice services and 70% of the data traffics occur indoors (Zheng et al. 2013), hence the reason to unload the traffics from the macrocells becomes really necessary. Femtocell deployment is an approach to overcome the indoor coverage limited access as it provides higher quality reciprocity for making calls and data services usage that later gives magnificent subscriber recognition. On the other hand, the service provider gets the advantages from reducing the infrastructure deployment expenses that are then required for network development, including improving the capacity and coverage enhancements. For coverage expansion, femtocells provide advantages during capacity offload by transferring subscribers from macrocell to femtocells, which in turn helps macrocell subscribers to accomplish higher throughputs, since fewer users share the macrocell network resources.

Femtocells, are low-transmit-power (100 mW or less) small-form-factor cellular base stations typically deployed indoors in residential, enterprise, and hotspot settings and are also known as home NodeBs (HNBs) or femto access points (FAPs), Femtocells work on licensed spectrum and are connected to the Internet and operator's core network using a broadband Internet connection (e.g. ADSL, cable) as a backhaul to offer voice/data services to mobile phone subscribers (Atel et al. 2010). Generally the distance of a regular base station may be up to 35 kilometers (22 mi) away and the femtocell access point is in the range of 10 meters (Qasim et al. 2013).

The paper is arranged as follows. Section II illustrates the overview of femtocell deployment in Malaysia and the deployment scenario. In section III, results from walk test are presented. Finally the conclusions are drawn in section IV.

Femtocell deployment in Malaysia

With the deployment of femtocells, it allow a new generation of femtozone appliance that use the benefit of the femtocell's existence and connection to the home network. The connection to the service provider's network can be established through broadband (such as DSL or cable). Latest concept of femtocell designs generally for a residential setting it can accommodate between 2 to 4 active mobile phones usage, while 8 to 16 active mobile phones in enterprise settings at the same time (Lin et al. 2011). Another advantage of femtocell is it will allow operator services to enlarge service coverage indoors or at the cell edge, especially where access would otherwise be limited or unavailable. While for large coverage and densely populated area the issue of Physical Cell ID allocation need to be resolved as it is crucial to distinguish the signal from one Base Station (BS) to the another (Abdullah et al. 2014). Femtocell can be deployed in one of the three access modes, namely closed, open and hybrid access. In Open Access, subscribers are assumed balanced and permitted to connect to either macrocell or femtocells. Closed Access mode permitted solely authorized subscribers to connect to their own femtocells. In hybrid access mode, a restricted quantity of femtocell appliance is accessible for the entire consumer while the rest is used only by femtocell's subscribers.

The mobile operator in Malaysia have already tested Femtocell, but there have been no major deployment yet. With Femtocell, the mobile operator can offload their network traffic to the Internet and at the same time deploy less indoor base stations. The coexistence and interworking with other 3GPP systems and their respective requirements set the requirement on mobility between LTE and GSM, and between LTE and WCDMA/HSPA for mobile terminals supporting those technologies (Dahlman et al. 2010). While the IP Multimedia Subsystem (IMS) platform standardized by 3GPP will be deployed by the network operator to provide the consumers with mobile multimedia services independent of the network access technologies (Ali et al. 2014). Terminal users can choose for different broadband packages that utilize ADSL with cheaper and more attractive offers and bandwidths of up to 50 Mbps. Above 60% of the population has access to voice and data services utilizing either the cellular network or DSL. Since many popular internet applications, especially streaming voice and video applications have high throughput requirements, the mobile operator in Malaysia is gradually expanding their coverage and improving their capacity to accommodate more users and offer them higher data rates. Yet to fully meet the necessities of the subscribers and advance them to use the cellular networks for information services, the operators have to provide better packages and improve the link budget for indoor environments. In parliamentary law to improve the indoor coverage and signal quality, implementation of femtocell base stations shall prove to be a feasible and low cost solution from the network operator’s perspective.

One of the largest mobile operators in Malaysia is providing the femtocells unit for free to their subscribers (based on their spending per month/ high ARPU-Average Revenue Per User). Besides the objective to upgrade the indoor coverage in building, the signal reception for voice and data access the mobile operator also aims to accommodate wireless data at lower cost in wherever area in Malaysia. The mobile operators claim that the deployment of Femtocells is the best solution to provide better wireless services in indoor environments especially for voice traffic. After execution of Femtocell, high speed wireless data services and applications can be used by indoor consumers where the macrocell network may not provide the same speed. As they attempt to supply users with higher data rates for indoor in order to further increase mobile data usage all the while reducing spectrum usage at cheaper rates, in addition to several other applications. The realization of all this is not possible without a progressive wireless spectrum and strong radio engineering. A walk test is conducted using a mobile phone to check coverage signals as well as to determine the appropriate femtocell placement.

The following are the major factors which affect the coverage planning for enterprise femtocell deployment.

Deployment of the enterprise within the macro network

When deploying enterprise femtocell within the macro network need to determines the level of co-channel interference (indicated by RSSI) that a femtocell must overpower in order to provide the coverage. At a given transmit power the size of the region served by the femtocell will be smaller at a macro cell site (location characterized by a strong dominant macro with large RSSI) than at a macro cell edge location with low level of RSSI. Conversely, the transmit power required to serve a given area will be higher at macro cell site than at macro cell edges.

Variation of macro RSSI within the enterprise

In medium to large enterprises, with floor space of 10000 sq feet or more, there may be significant variation in the macro RSSI within the enterprise. This variation is common and is typically due to the presence of large shadowing obstacles such as surrounding buildings, windows, and internal walls.This RSSI variation also results in potential mismatch between Network Listen Module (NLM) measurements and actual RF conditions as seen by UEs.

Coverage Performance

The goal of the planning process is to have good radio conditions everywhere within the enterprise for UEs to acquire, initiate and sustain voice calls on the serving femtocell. Additionally, the requirements call for excellent radio conditions with high data rates in the desired coverage area. Good coverage performance is addressed by limiting the maximum path loss that needs to be covered by each femtocell in addition to proper femtocell power calibration.

Downlink Interference considerations

The crucial implication of co-channel closed operation for network planning is the need for managing interference to non-allowed users on the downlink. We refer to all non-allowed users as macro UEs (MUEs). This interference appears in the following forms:

(1) Interference to MUEs outside the desired coverage area: this includes interference to adjacent – upper and lower – floors when applicable,

(2) Interference to macro UEs present within the desired coverage area,and

(3) Adjacent channel interference.

Interference of type (1) and (3) is managed by proper power calibration and guidelines for femto placements, while that of type (2) is handled by optimization of handover and reselection parameters. Consideration of interference to non-allowed users also dictates the recommended number of femtocells that need to be deployed.

Uplink interference considerations

There are constraints imposed by UL considerations arising out of maximum path loss served by UE, impact to macrocell uplink, potential DL-UL imbalance due to different DL transmit powers, and UL noise rise levels at adjacent femtocells.

PSC planning considerations

Primary Scrambling Codes (PSCs) allocated to femtocells are typically restricted to a much smaller set (of size 4-10) than the total available (512) of PSCs. This can potentially cause PSC collisions. Self-configuration of PSCs based on NLM measurements of surrounding PSCs alleviates this problem to a certain extent. Yet self-configuration may suffer from the hidden node problem (a UE sees colliding PSCs but NLM at the femtocells do not). In enterprise deployments, due to presence of potentially many femtocells in the same enterprise, careful PSC assignment is needed to ensure that PSCs of neighboring femtocells do not collide with each other. During the walk test, we assume that PSCs of neighboring femtocells do not collide with each other.

Other considerations

Placement of the femtocells in the enterprise may also be constrained by the availability of GPS drop, ports for backhaul, electrical power outlets and concerns for the physical safety and security of the device. We assume that these requirements are met.

Deployment Scenarios

The benefits of enterprise femtocells have broadly the same deployment benefits as their resident cousins which include easy installation and utilization of standard IP broadband backhaul. All the same, they also differ in various ways. This admits the greatest number of users and coverage area; RF interactions between femtocells; mobility and handover from one femtocell to another; and potentially large RF variations inside buildings. This has contributed to some concerns surrounding potential interference, handover and installation challenges.

Table 1 :
Macrocell base station (MBS) parameters

Parameter	Value
Frequency operation	2100 MHz
Power Transmit	41-43 dBm
Bandwidth	15 MHz
Transmit Antenna Height	30 m
Coverage	1000m

Table 2 :
Macrocell User Equipment (MUE) and Femtocell User Equipment (FUE) Parameters

Parameter	Value	
Receiver antenna height	1,5 m	
Thermal Noise	-104,5 dBm	
Noise Figure	7 dB	
Model Pathloss	FUE:	MUE:

	P.1238	COST 231

Tabel 3:
Femtocell Base Station (FBS) Parameters

Parameter	Value
Frequency Operation	2100MHZ
Power Transmit	13dBm
Bandwidth	1,4MHz
Transmit Antenna Height	3m
Coverage	25m

Result and Analysis

Besides the femtocell deployment in LTE environment, we still need to consider the UMTS network and GSM network as both are still being used and the User Equipment (UE) also plays the important role to choose the specific network based on Received Signal Strength Indicator (RSSI) or Quality and capacity measuring matrix (Ec/No).

During walk test, the researcher uses the color scheme with reference to Table 2: RSSI color scheme as a representative to the received signal. RSSI is the relative received signal intensity in a wireless environment, in arbitrary units. RSSI is an indication of the power level being received by the antenna. Thus, the higher the RSSI number, the stronger the signal. To describe the total power received in milliwatts, the value is normally shown in dB logarithmic scale and typical value are -100dbm for low signal level to -60 dB for very strong signal level.

Site 1

Table 1:
Existing macrocell coverage

MCC : xx2	MNC: xx9	LAC:xx3x
RNC: 1xx	CELL ID: xxx11A	TYPE : HSPA

Table 2:
RSSI colour scheme

Range RSSI (-dBm)	colour

-65	Green
-75	Blue
-85	Yellow
-95	Red
-105	Black

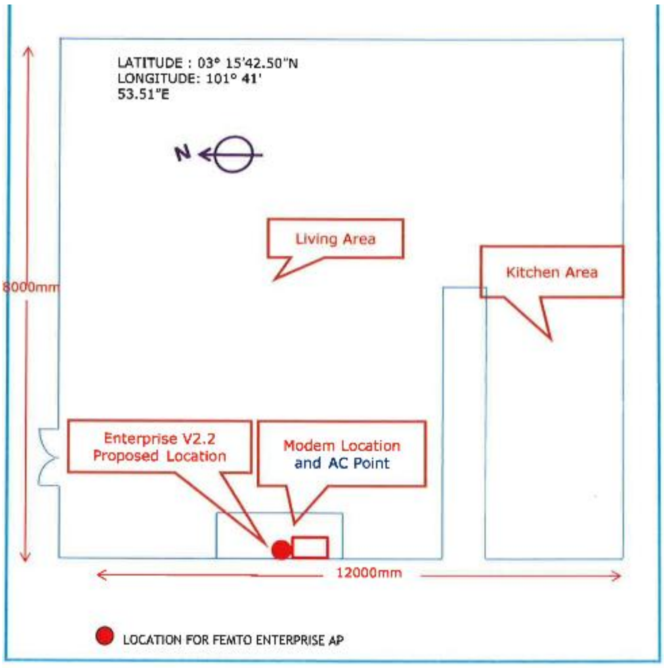


Diagram 1 : Floor plan for site 1

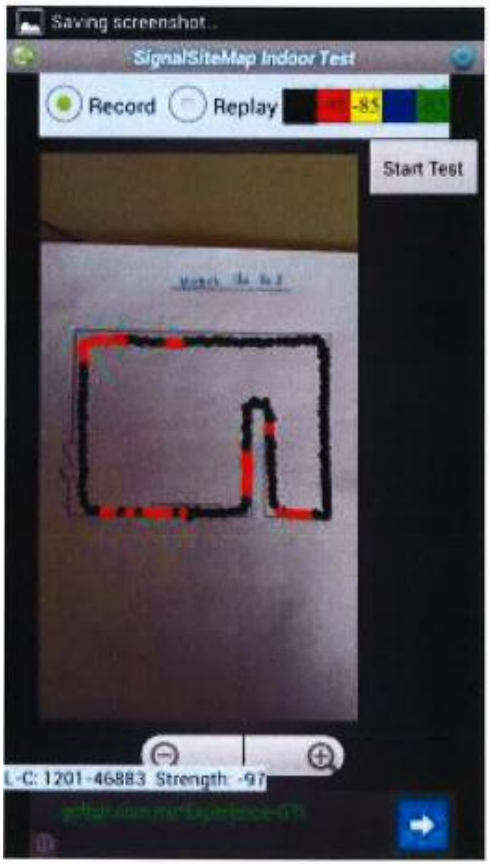


Diagram 2: RSSI reading before femtocell deployment

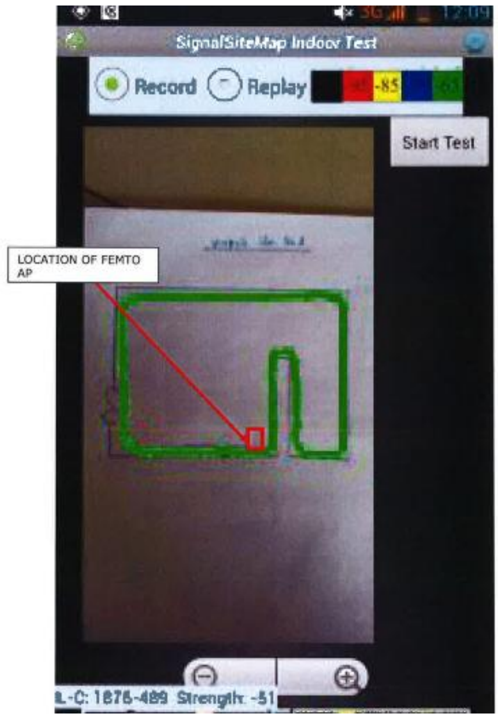
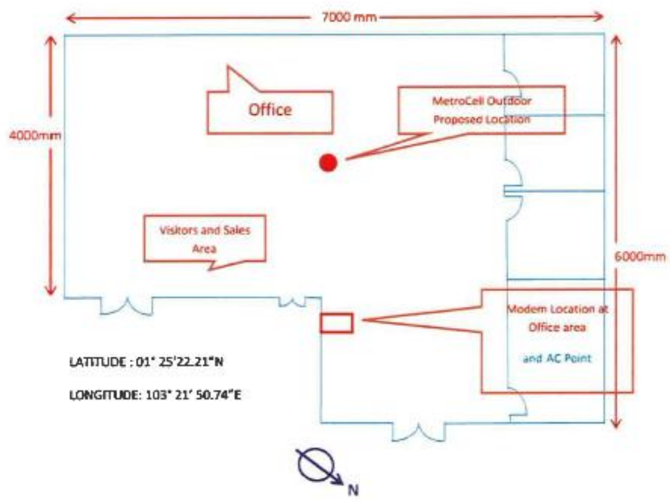


Diagram 3: RSSI reading after femtocell deployment

Site 2

Diagram 4 : Floor plan for site 2



PROPOSE METROCELL OUTDOOR COMPLETED WITH CABLE RJ45

Diagram 5: RSSI reading before femtocell deployment

Diagram 6: RSSI reading after femtocell deployment

Site 3

Diagram 7 : Floor plan for site 3

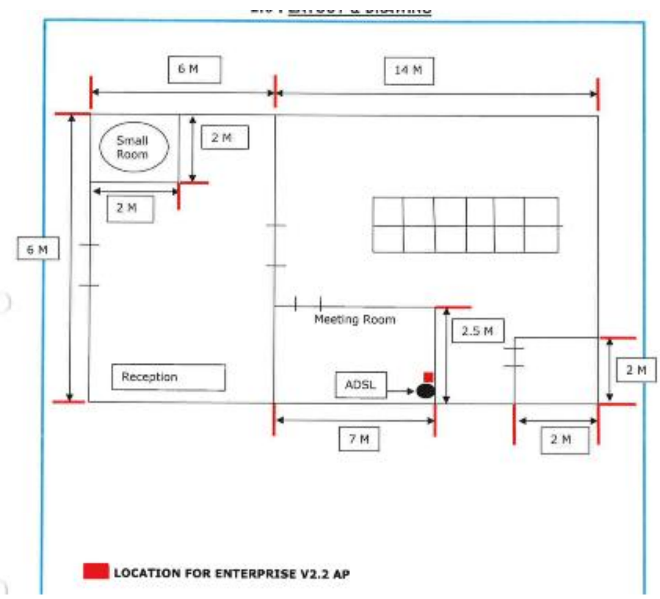


Diagram 8: RSSI reading before femtocell deployment

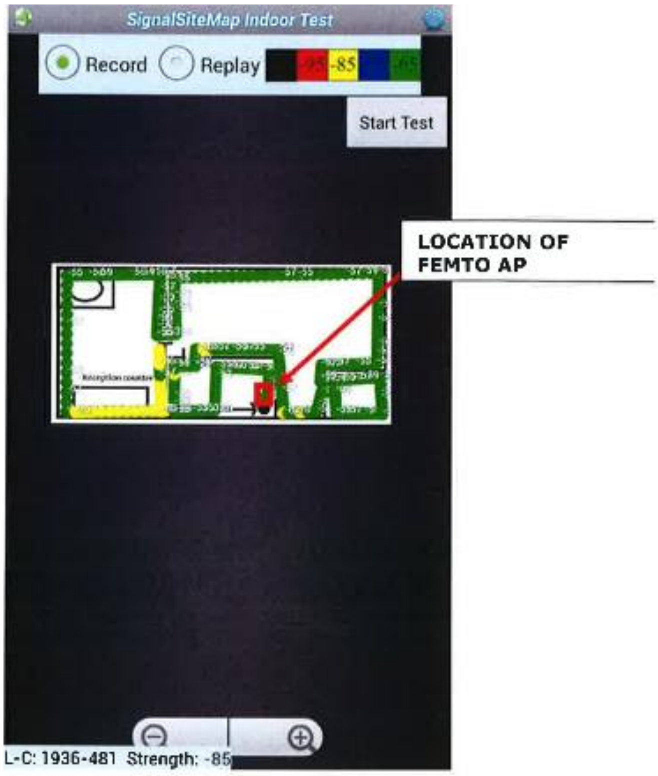


Diagram 9: RSSI reading after femtocell deployment

The result from the walk test, we can compare the RSSI reading before and after the deployment of femtocell. For site 1, before the deployment of femtocell the RSSI reading was -97dBm and was improved to -51 dB after we placed a femtocell in the area. For site 2, after using the femtocell we can see there are several places in yellow colour which mean the RSSI reading is -85 dBm. This may occur due to the distance with the femtocell unit and wall penetration loss. We also can see the same thing happens inside Site 3 where certain places still in the range of -85 dBm .

Discussion and Conclusion

This finding highlights the benefits from femtocell deployment which have proven to solve the indoor coverage limited access as it provides excellent user experience through wider coverage and high data throughputs for voice. Some important observations are noticed and summarized below:

1.Even though the study was conducted to do a survey on LTE environment, researchers should also consider the UMTS and GSM network as those networks still being deployed.
2.Good coverage performance is addressed by setting the maximum path loss that needs to be handled by each femtocell in addition to proper femtocell power calibration.
3.By considering the interference to non-allowed users also dictates the recommended number of femtocells that need to be deployed.

As conclusion this study has contributed to our knowledge about the field experience on femtocell deployment and the technical challenges that have to be overcome for optimum enterprose femtocell and macrocell networks. At the end, both femtocell and macrocell should be capable to use the radio resources more effectively as the femtocell will compliment the macrocell indoor coverage.

Further study will include identifying the matters that touch on mitigating the interference issues and the user mobility management in the coexistence of enterprise femtocell with macrocell networks.

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