Impact of Macrocell Size on the Implementation of LTE Femto Integrated with GSM Network

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Abstrak – Pada studi ini diinvestigasi pengaruh ukuran macrocell pada implementasi LTE femto yang terintegrasi dengan jaringan GSM. Karena pada coexistence network ini sangat bergantung pada kondisi sebaran LTE femto diantaranya ukuran macrocell. Pada penelitian sebelumnya mengenai coexistence network, LTE femto tersebar pada GSM macrocell. LTE femto beroperasi pada spektrum GSM dalam suatu skema alokasi frekuensi tertentu yang memfasilitasi transisi dari GSM menuju LTE. Namun demikian, studi sebelumnya belum membahas mengenai pengaruh ukuran macrocell. Studi ini fokus pada GSM Uplink. Kinerja dari kedua sistem yang ditunjukan dengan SINR dan femtocell throughput dianalisis secara matematis. Simulasi dilakukan untuk menganalisa dampak ukuran macrocell pada kinerja coexistence network. Pada studi ini terlihat bahwa bertambahnya ukuran macrocell Akan berdampak pada penurunan SINR GSM BS dan peningkatan SINR dan throughput LTE femto. Karena itulah implementasi LTE femto yang terintegrasi dengan GSM Network sangat dipengaruhi ukuran GSM macrocell.

Kata kunci : GSM Macro; LTE femto; Macrocell size.

***Abstract** – In this study we investigate the impact of macrocell size on the implementation LTE femto Integrated with GSM network since the coexistence network strongly depends on deployment condition, for instance, macrocell size. In the previous study related to the coexistence network, LTE femto are deployed in GSM macrocell. The LTE femto itself operates in GSM band under certain frequency allocation scheme as a means of facilitating smooth transition toward LTE on GSM frequency band. Nevertheless, it does not provide a solution about the impact of macrocell size yet. Uplink of GSM is considered in this study. The performance of both systems are analyzed mathematically in terms of SINR and femtocell throughput. Simulation is employed to support analysis which the result shows that macrocell size will give an impact to the performance of the coexistence system. Parallel to this, the expanding of macrocell size will decrease SINR GSM BS, in spite of that, it will increase SINR LTE femto and femtocell throughput as well. For that reason, the implementation of LTE femto integrated with GSM network can be influenced by macrocell size*

***Keywords** : GSM Macro; LTE femto; Macrocell size.*

I. INTRODUCTION

Since the growth of multimedia applications, mobile network operator observes rapid growth of data traffic load demand in their networks. Some studies show that total wireless network traffic produced from voice and data service will increase ten-times by 2015 compared to 2009 in develop region [1]. Operator have to find the way to increase system capacity with limited frequency resources , one of the solution is finding incumbent operators called GSM refarming. It refers to reallocating frequency GSM bands to more frequency efficient and optimized technologies, for instance, LTE. In other words, GSM refarming is a strong need. Yet, it is a time consuming since it is not simply to do for mobile operator to shut down their GSM network shortly due to the existing voice demand and global roaming capability as well [2]. The coexistence of LTE system with existing GSM cellular network is proposed to address the challenge of growing data demand and maintain GSM service. In [7] studied that deployment cognitive devices in downlink of cellular network which show that only limited opportunity of frequency sharing exists. Thus, we are going to concern on uplink GSM system. In the coexistence system studied in [3], LTE femtocell are deployed on GSM cell. In spite of that, the LTE femto itself operates on GSM band under certain frequency allocation scheme as means of facilitating smooth transition toward LTE on GSM frequency band. It has been studied that LTE femtocell know how to set off a destructive interference to LTE macro network when femtocell uses same frequency channel with macro system [5, 6]. On deployment LTE femto to GSM network, one of questions is need to be investigated; how will the impact of macrocell size to the performance of GSM macro and LTE femto. In [3] does not provide a solution clearly, that is why, we are going to investigate the impact of macrocell size in this study. In view of that, it is needed to evaluate the feasibility of the coexistence network in relation to macrocell size.

The paper is organized as follow. In section II, we introduce system model and formulation. Section III gives the detail of performance metrics used in this study, the evaluation and result are presented in section IV.This section also give discussion of the result. The conclusion and future work plan are outlined in section V.

II. SYSTEM MODEL & FORMULATION

2.1 Coexistence Model

The coexistence network should be acceptable of both GSM and LTE systems. In the meaning that the deployment of LTE femtocells should not degrade the performance of GSM networks, meanwhile provide proper service in the newly deployed LTE femtocell [8]

In the coexistence network, the LTE femtocells operate on orthogonal frequency division multiplexing (OFDM) technology so they are able to utilize several fractions of radio frequency without interfering with other parts of the frequency lying in between. In the study of frequency allocation between GSM and LTE femtocell, the scheme proposed in [3] is adopted in which LTE femtocell can utilize all the channels except those are used by the GSM macrocell where the femtocells are located.

For example, supposing GSM cell employs reuse cluster f_1. LTE femtocells located in this GSM cell may not use f_1 in order to prevent severe interference to the GSM BS. Each of them possibly will utilize remain clusters $f_2 f_3 f_4$ by a means of OFDM as depicted in Fig.1

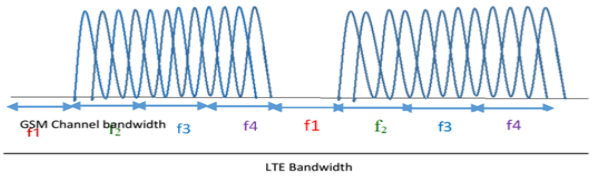

Fig.1 Channel alocation scheme for LTE femtocells located in a GSM cell using reuse cluster f1 [3]

In this frequency allocation scheme, each LTE femtocell is enabled to operate on all GSM channels except those utilized by its master GSM macrocell.

Uplink interference received by GSM BS and LTE femtocell are illustrated as below.

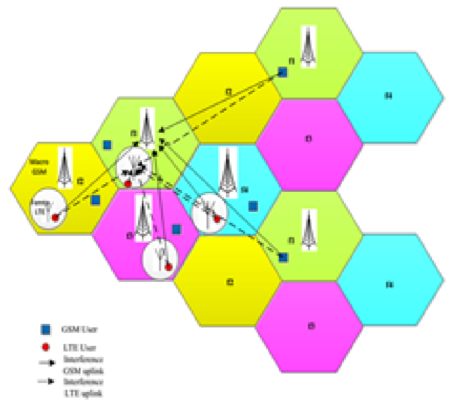

Fig.2 Uplink Interference Model

In Fig.2 macrocell GSM base station in f_1 to be the victim inter-cell interference, it receives interference from GSM MS connected to cells ∈ Ψ (f_1) and interfered by LTE femtocells located in GSM cell ∉ Ψ (f_1). Meanwhile for LTE femtocell in f_1, it receives interference from GSM MS connected to ∈ Ψ (f_1), femtocell in other GSM cells ∉ Ψ (f_1) and femtocell in the same cell.

2.2 GSM network model.

GSM operates in various frequency bands, in this study 1.8GHz is considered. As a technology based on time division multiple access (TDMA), GSM employs frequency reuse and cluster formation to utilize the frequency resources. Frequency allocated to an operator can be divided into *K* groups and shared by each reuse cluster. The *K* is name as reuse factor. In this study we focus on GSM Uplink.We consider hexagonal cell model having an Omni-directional base station in the center with cell radius R. Mobile stations (MSs) are generated and it moves towards random directions in the system.

If $P^g(r)$ be the transmission power of a GSM MS which distance from the serving BS is *r*. Also, If Q^g be the received signal power at the BS. Hence [3],

$$Q^g = P^g(r)\, L(r) = P^g(R)\, L(R) \qquad (1)$$

Which *L (d)* denotes the propagation loss for the distance *d*.From (1), we get [3]

$$Pg(r) = \frac{L(R)}{L(r)} P^g(R) \qquad (2)$$

Which $P^g(R)$ is considered to be the maximum transmission power of the GSM MS.

For the propagation model, COST231 Hata model with the center frequency of 1.8GHz is adopted, with BS antenna height as 30m, and MS height as 1.5m, *L (d)* in dB scale is given as follows [3]:

$$L(d) = 136.2 + 35.2\log_{10}(d[km]) \qquad (3)$$

2.3 LTE Indoor femtocell model

LTE femtocells are assumed to be used in indoor environment, and Motley-Keenan formula is used to the model indoor propagation.We assume that a femtocell where a BS and a MS located in the same floor of a building. Propagation loss at 1.8GHz is described as below [3].

$$L(d) = 37.5 + 20\log_{10}(d\,[m]) \qquad (4)$$

Distance between MS and BS in the femtocell is assumed to be 20m. Wall penetration loss 5dB is considered for propagation between indoor and outdoor entities. In time division duplex (TDD) mode of LTE such that the BS and the MS of the femtocell use the same frequency band. If P^l denotes the transmission power of the femtocell BS, the MS is also assumed to have the same transmission power. It occurs because bandwidth of LTE is spread over a number of GSM channels, we define effective transmission power of LTE femtocell which is the portion of transmission power affecting a single GSM frequency channel, denoted by $P^l eff$. The received signal power corresponding to $P^l eff$ is denoted by $Q^l eff$ [3]

We suppose that the BS and MS of a femtocell are not distinguished by GSM system for the reason that the separation between the femto BS and MS is negligible compared to the size of GSM cell. As a result, it can be believed that a LTE femtocell as a single entity in the calculation of interference.

III. PERFORMANCE METRICS

3.1 SINR GSM BS and LTE Femtocell in uplink

The purpose of our study is to investigate the impact of LTE femtocell to the performance of GSM system. In Fig.2 if $\Psi(f_1)$ denotes a set of GSM cells that use reuse cluster f_1. In the coexistence network, to GSM radio link in a cell that belongs to $\Psi(f_1)$, the interference comes from two groups of sources, i.e other GSM MS connected to cells $\in \Psi(f_1)$ and LTE femtocell locates in the GSM cells $\notin \Psi(f_1)$.

If Q^g denotes received signal power at the BS, I_j^{gg} is the expected value of interference from a GSM MS in cells $\in \Psi(f_1)$ to the considered GSM BS given as [3].

$$I_j^{gg}=\int_0^R\int_0^{2\pi} P^g(r)\, L\left(\sqrt{r_j^2 + D_{js}^2 - 2\, r_j\, D_{js}\cos\theta_j}\right)\frac{r}{\pi R2}\, d\theta_j\, dr_j \quad (5)$$

$I_k^{lg}(x)$ denote the expected value of interference from a LTE femtocell in GSM cells $\notin \Psi(f_1)$ to the considered BS is given as [3];

$$I_k^{lg}(x) = \int_0^{2\pi} P_{eff}^l\, L\left(\sqrt{x^2 + D_{ks}^2 - 2xD_{ks}\cos\beta_k}\right)\frac{1}{2\pi}\, d\beta_k \quad (6)$$

Background noise at the GSM BS is denoted by N_b^g and equals to $N_0W^gN^g_F$. Let $\gamma^g(x, M)$ be the expected value of SINR of the GSM BS given that there are M femtocells in each GSM cell with the distance of x from the nearest GSM BS [3]:

$$\gamma^g(x,M)= \frac{Q^g}{\sum_{j\in\Psi(f1)} I_j^{gg} + M\sum_{k\in\Psi(f1)} I_k^{lg}(x) + N_b^g} \quad (7)$$

Meanwhile, like shown in Fig.2 SINR of LTE femtocell located in cell $\in \Psi(f_1)$, the interference of the LTE femtocell come from GSM MS that employ f_1, femtocells in other GSM cells $\notin \Psi(f_1)$, and femtocells in the same cell.

If $Q^l eff$ denotes effective received power at GSM channel, $I_j^{gl}(x)$ be the expected value of interference from a GSM MS that employ f_1 is given as [3],

$$I_j^{gl}(x) = \int_0^R\int_0^{2\pi}\int_0^{2\pi} P^g(r_j)\, L\sqrt{(r_j\cos\theta_j - D_{js} - x\cos\beta_s)^2 + (r_j\sin\theta_j - x\cos\beta_s)^2}\ \frac{r_j}{2\pi^2 R^2}\, d\beta_s\, d\theta_j\, dr_j \quad (8)$$

$I_k^{ll}(x)$ denotes interference from femtocell in other GSM cells $\notin \Psi(f_1)$ is given by (9),

$$I_k^{ll}(x)= \int_0^{2\pi}\int_0^{2\pi} P_{eff}^l\, L\left(\sqrt{(x\cos\beta_k - D_{js} - x\cos\beta_s)^2 + (x\sin\beta_k - x\sin\beta_s)^2}\right)\frac{1}{4\pi^2}\, d\beta_s\, d\beta_k \quad (9)$$

Interference value from another femtocells in the same GSM cell is denoted by $I_s^{ll}(x)$ [3];

$$I_s^{ll}(x) = \int_0^{2\pi} P_{eff}^l\left(\sqrt{2x^2(1-\cos\beta_s)}\right)\frac{1}{2\pi}\, d\beta_s \quad (10)$$

N_b^l is back ground noise N_b^g and equals to $N_0W^gN^g_F$. $\gamma^l(x,M)$, expected value SINR of the femtocell given M and x as follow [3];

$$\gamma^l(x,M)=\frac{Q_{eff}^l}{\sum_{j\in\Psi(f2)} I_j^{gl} + M\sum_{k\in\Psi(f2)} I_k^{ll}(x) + (M-1)\, I_s^{ll}(x) + N_b^g} \quad (11)$$

3.2 Femtocell throughput

To measure throughput capacity on each channel for each LTE femtocell is calculated by using Shannon equation as follow [4];

$$C = B\log_2(1 + \gamma^l(x, M)) \quad (12)$$

Where B is channel bandwidth of LTE femtocell, $\gamma^l(x, M)$ is SINR of the LTE femtocell system

IV. EVALUATION AND RESULTS

The impact of macrocell size to the performance of GSM network and LTE femto are investigated by numerical experiments. Parameters used in this study is shown in table 1.

Table 1. Parameters used for experiment

Parameter	Value
K	4,7
Macrocell Radius [km]	(0.5, 0.2,...2) km
Number femtocell	6
P^g (R)	30 dB
P^l_{eff}	6 dB
N_o	-174 dB
W^g	200 kHz
N_F^g	5dB
N_F^l	5dB

4.1 Impact of macrocell size to the SINR of GSM

Macrocell size will give a great impact to the received signal power and inter-cell interference. Simulation is employed to get relationship between macrocell size and SINR of GSM. The impact of expanding macrocell size to the SINR of GSM as shown below.

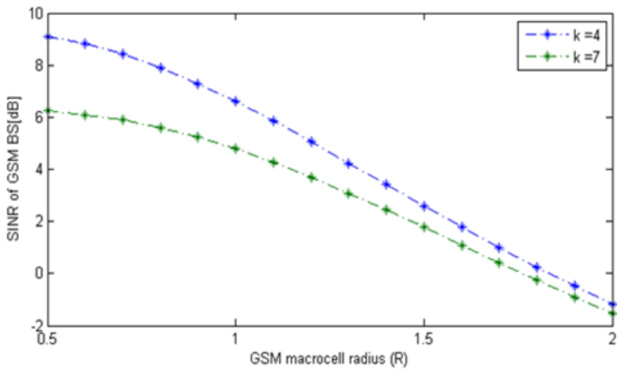

Fig. 3 SINR of GSM versus GSM macrocell size

In Fig.3 shows that SINR of GSM decrease as the increasing macrocell size for two different reuse factors. As long as macrocell size expand from *R = 0.5 km* until *R = 2 km* for the reuse factor *K = 4*, SINR of GSM tends to decrease siginificantly about 10 dB. For K = 7 decreases about 8dB. This trend occurs due to the impact of macrocell size to the received signal power and path loss. The greater macrocell size will increase path loss from GSM MS to GSM BS and reduce received signal power, consequently it decreases SINR of GSM. Besides that we can observe that among the two reuse factors used in our study, reuse factor *K = 4* gives the highest SINR of GSM when all parameters are same. When macrocell size *R = 0.5 km*, SINR GSM reaches 9dB for *K = 4* and 6 dB for *K = 7*. Afterward, SINR decreases as the increasing macrocell size. The trend that smaller reuse factor has highest SINR can be ascribed to the decrease interference from another femtocell in smaller reuse factor.

4.2 Impact of macrocell size to the SINR of LTE femtocell

Macrocell size gives an impact to inter-cell interference. Simulation is conducted to get relationship between macrocell size and the SINR of LTE femtocell.

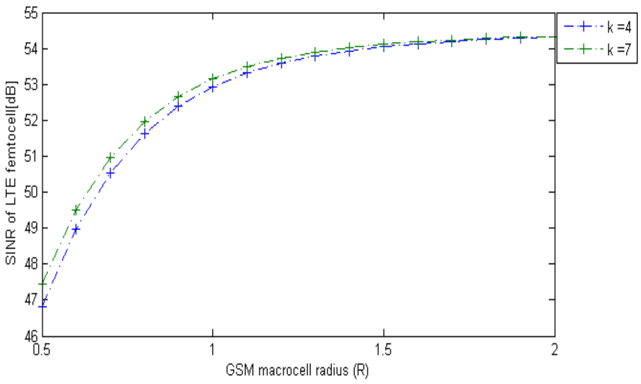

Fig .4 SINR of LTE femtocell versus GSM Macrocell size

Fig.4 shows that SINR LTE femtocell increase as the increasing of macrocell size for two different reuse factors. As long as expand of macrocell size from *R = 0.5 km* until *R = 2 km* for reuse factor *K = 4*, SINR LTE femtocell tends to increase about 8.5 dB.For *K = 7* SINR of GSM increase about 8 dB. It possibly occurs since in network with larger macrocell size, LTE femtocells are deployed in more extensively manner within GSM macrocell and distance among femtocells will be farther. It will reduce inter-femtocell interference, so it increases SINR of LTE femtocell. Meanwhile, we can observe that in the scenario deployment 6 femtocells per GSM cell, SINR LTE femtocell for reuse factor *K = 7* is higher than *K = 4*. It occurs since before accomodating more LTE femtocell in each GSM cell, network with bigger reuse factor receives less interference from GSM MS in co-channel cell. On the other hand, when deployed femtocell number increasing i.e accomodating 7 or more femtocell per GSM cell, it is possible that SINR for *K = 4* is higher than SINR for *K = 7*.This trend occurs because inter-interference femtocell for smaller reuse factor is less than bigger reuse factor. Hence, it increases SINR LTE femtocell.

4.3 Impact of macrocell size to the femtocell throughput

Macrocell size gives a great impact to the inter-cell interference and SINR femtocell, thus it affects throughput. Simulation is conducted to get relationship between GSM macrocell size and femtocell throughput.

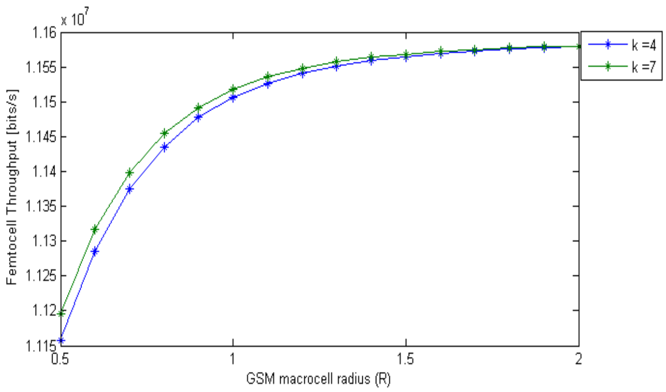

Fig.5 Femtocell throughput versus GSM macrocell size

Fig.5 shows that femtocell throughput increase as the increasing of macrocell size for two different reuse factor. As long as expand of macrocell size from *R = 0.5 km* until *R = 2 km*, for reuse factor *K = 4*, femtocell throughput tends to increase about 4.3×10^2 kbits/s, and for *K = 7* femtocell throughput increase about 3.8×10^2 kbits/s.It occurs since in network with larger macrocell size, LTE femtocell deployed more extensively manner within GSM macrocell and distance among femtocells will be farther. It will reduce inter-femtocell interference, so increases SINR and femtocell throughput. More to the point, it can be seen in the scenario deployment 6 femtocells per GSM cell, femtocell throughput for reuse factor *K = 7* is higher than *K = 4*. It occurs since before accomodating more LTE femtocell in each GSM cells, network with bigger reuse factor receives less interference from GSM MS in co-channel cell. Conversely, when number deployed femtocell increase i.e accomodating 7 or more femtocell per GSM cell, it is likely that femtocell throughput for *K = 4* is higher than throughput for *K = 7*. The trend that smaller reuse factor has higher throughput can be ascribed to the decrease interference from another femtocell in smaller reuse factor.

V. CONCLUSION

In the study of macrocell size impact, we find that SINR GSM tends to decrease due to the increasing of macrocell size. It possibly occurs as the greater macrocell size will increase path loss from GSM MS to GSM BS and reduce received signal power, thus it decreases SINR of GSM. Opposite to GSM case, SINR LTE femtocell tends to increase due to the increasing of macrocell size.This trend occurs as in network with larger macrocell size, LTE femtocells deployed are deployed in more extensively manner within GSM macrocell and distance among femtocell will be farther so it reduces inter-femtocell interference. As well as femtocell throughput will increase if the SINR femtocell increase. Henceforth, it is recommended to deploy LTE femtocell in larger GSM cell when SINR and femtocell throughput are the major concerns. When protection of GSM system we are concern about, it is recommended to deploy LTE femtocell in smaller GSM cell.

As a final point, implementation LTE femto integrated with GSM network highly depends on deployment conditions.In the future research, various deployment condition is required for further study. Additionaly, the advance interference management scheme for the coexistence network is similarly an attractive field for future research.

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