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Improving SINR 4G/LTE Femtocell in the Coexisting Network

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***Abstract* - The coexisting of LTE femtocell with existing GSM network is proposed to address the challenge of limitation radio frequency spectrum. SINR femtocells on coexisting networks are highly depend on conditions of distribution of femtocells, including the number and position of femtocells. On previous study have been extensively discussed coexistence of LTE femtocell integrated with GSM network. But it has not been discussed clearly how the strategy for increasing SINR femtocell in this coexisting network. In this study, various factors that affect SINR femtocell performance is analyzed mathematically. Simulation results show that SINR LTE femtocell increase about 0,2dB for every reduction of one femtocell deployed on the GSM network. When m = 2, SINR LTE femtocell reach 48.3dB then improve become 48.5dB when m=1. Meanwhile, when position of femtocell away from GSM base station from x = 0.1R to x = R, SINR LTE femtocell increase about 2.5dB for a single femtocell on each GSM network. So as to increase SINR LTE femtocell can be done by reducing the number of femtocells deployed on GSM network and set LTE femtocell distribution patterns away from GSM base station.**

Keywords—Coexisting, Improving, LTE Femtocell, Network, SINR.

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I. INTRODUCTION

Radio frequency spectrum is a limited natural resource that has important value in telecommunications operations. Spectrum management has an important role in planning radio frequency spectrum usage as efficiently as possible to obtain maximum benefit for all stakeholders, including service providers and users [1]. Most countries set policies related to radio frequency management, such as America, Norway, and China have a framework of radio frequency management [2],[3],[4]. In Indonesia radio frequency spectrum roadmap is prepared every five years to meet the increasing demand of mobile broadband [5].

To overcome spectrum limitation, the development of technology demands a refarming of the frequency spectrum that is very precious resource that can accommodate future development and bring prosperity to the society. Refarming itself is a term used for a spectrum reallocation process by moving the operating frequency to produce contiguous frequency bands. It provides sufficient bandwidth allocation for a broadband system or more than one technology applied in a particular frequency band simultaneously [6]. The benefit of refarming to widen bandwidth has supported the deployment plan of LTE from GSM frequencies and other mobile broadband implementation plans [7], [8].

Spectrum refarming allows different generations of cellular networks to use the same radio spectrum to improve the spectrum utilization. Basically, spectrum sharing is implemented in two ways i.e., overlay spectrum sharing, which allows the secondary users opportunistically access the unused spectrum of the primary users, and underlay spectrum sharing which allows the secondary and primary users co-transmit at the same band. Similarly, there are also two kinds of spectrum refarming models i.e., overlay spectrum refarming model and underlay spectrum refarming model.

Due to the rapid development of telecommunication technology as shown in figure 1 [9], service provider has to find the way to organize limited frequency resources, which of the solutions is finding incumbent operators called GSM refarming. GSM refarming refers to phasing out currently used GSM services and reallocating the frequency bands to more frequency efficient and data optimized technologies such as 4G Long Term evolution (LTE). The LTE system operate in GSM band belongs to an overlay spectrum refarming model, where the Orthogonal Frequency Division Multiple Access (OFDMA) utilizes the sub bands that are not occupied by the GSM. However, the strong need for GSM refarming. It is a time-consuming process as it is complicated for mobile operator to shut down their GSM network immediately due to the existing voice demand and global roaming capability [10].

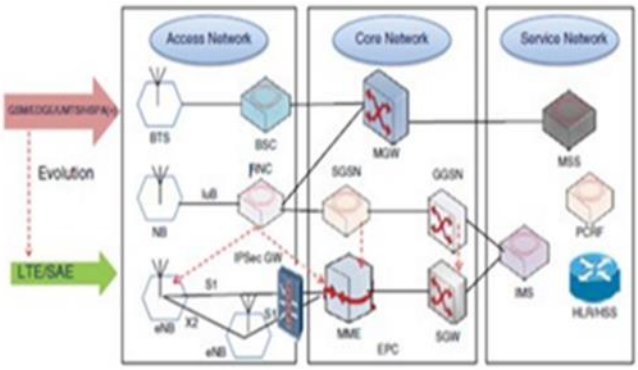

Figure 1. Evolution from 2G/3G/HSPA (+) to LTE [9]

Reviewing the problems and developments related to the allocation of radio frequency spectrum in Indonesia, a comprehensive study is needed on the current conditions of frequency spectrum allocation and the potential for refarming to the future spectrum, for example 4G and beyond. Apart from benefits of spectrum refarming, refarming is risky and exhibiting a high potential of interference regarding migration between fully occupied allocations. This challenge is influenced by various factors, such as the number of service provider and their initial operated spectrums. Problems are also emerging when attempting to determine the allocated frequency and time of the reallocation process to minimize disruptive services to users. Therefore, a careful plan and step by step procedure in the refarming execution is mandatory to make sure a success of coexistence network.

The paper is organized as follow. In section II, we introduce state of the art of this research. Section III gives system model used in this study. Evaluation and result are presented in section IV, this section also give discussion of the result. The conclusion is outlined in section V.

II. LITERATURE REVIEW

In the coexisting network, LTE femtocells are deployed on GSM macrocell network, a macrocell in a mobile phone network provides radio coverage served by a high power cellular base station. Usually, macrocells provide coverage larger than any other technology i.e., microcells, femtocells, relay nodes, picocells. This is because, the macrocell base station are mounted on ground-based masts, rooftops and other existing structures, at a height that provides a clear view over the surrounding buildings. It also has a high-power output and its performance can be increased by increasing the efficiency of the transceiver. the locations of the macrocell base station are carefully chosen through network planning, and the base station settings are properly configured to maximize the coverage and control the interference between them. As the traffic demand grows and the radio frequency environment changes, the network relies on cell splitting or additional carriers to overcome limitation of capacity and transmission link. However, this deployment process is complex and inefficient. Furthermore, site acquisition for macrocell base station with towers becomes more difficult in dense urban areas. Another serious issue for macrocells is loss high penetration in indoor environment, which has negative impact on the transmitted and received signals. Therefore, LTE femtocells technology has integrated into the GSM network in order to not only facilitate transition GSM technology to LTE but also to improve user broadband experience in a ubiquitous and cost-effective way. These femtocells are recognized as the future of next generation networks as they are more affordable and cost effective than other technologies.

Femtocell is an economical solution to provide reliable high-speed indoor communications via using the existing broadband Internet connection instead of the conventional macrocell network. It is also known as home BS or home evolved NodeB (Home eNB) which is operating in the licensed spectrum that can integrate mobile and Internet technologies within the home using optical fibre connection or DSL. From the economics point of view, femtocell is a low-cost solution compared to installing higher power macrocell to provide the same quality of service for indoor coverage [11]

Based on this, the use of femtocell can benefit both the service provider and the user. For a service provider, the deployment of femtocells can improve the coverage, especially indoors, capacity and reduce the consumption power. Coverage is improved because femtocell can fill in the gaps and eliminate loss of signal through buildings (i.e., penetration loss) [12]. Capacity on the other hand, is improved by reducing the number of users attempting to use macrocell and by off-loading the traffic through the user equipment network (via the internet) to the operator's infrastructure [13]. Offloading the traffic from the macro base station to the femtocell especially for indoor User equipment who require higher transmission power and resources, saves the base station resources and consumption power. This will increase the network capacity, as the macrocell will be able to serve more outdoor User while the femtocells take care of the indoor user. Where, indoor User can benefit from the improved indoor coverage by having indoor base station i.e., in offices and homes to mitigate the negative impact of the high penetration loss on their performance. As a result, the user achieves the same or higher data rates using less power as the transmission range between the femtocell and its user is short and the battery life is long. Moreover, the authors in [12] show that the user can achieve better voice quality and signal strength via using the indoor femtocell for transmission rather than being connected directly to the macro base station.

The coexisting of LTE femtocell with existing GSM macrocell has been discussed in some studies. In [14] shows that there are only limited opportunities to share frequencies on the downlink network. In doing so, we are going to concern about uplink transmit. In the coexisting network studied in [15], LTE femtocell are deployed on GSM macrocell, yet, it operates on GSM band under certain frequency allocation scheme as a means of facilitating smooth transition to LTE on GSM frequency band. Meanwhile, in [16,17] has been studied that LTE femtocells are able to set off destructive interference to LTE macro network when femtocell use constant frequency channel with macrocell. Study about how to optimize throughput in the coexisting network has been discussed in [18] and impact macrocell size to the coexisting network performance has been investigated in [19]. Before the deployment LTE femto to GSM network, several questions need to be investigated, including the extent to which the GSM network and LTE femtocells deployed for each performance will influence each other, then to what extent the system performance changes due to changes in deployment conditions, namely the impact of dynamic femtocells number and dynamic position of the femtocells deployment to SINR LTE femtocell.

To resolve the inquiry, much work must be done. In [11],[12],[13],[14],[15],[16] does not provide a clear and comprehensive solution, so more metrics need to be defined and compared in different scenarios. In view of that, we are going to investigate various deployment condition, for instance, dynamic femtocell count and dynamic deployment position to improve SINR femtocell

III. METHOD AND MODEL SYSTEM

The coexisting network must be suitable for both GSM and LTE systems. In the meaning that the deployment of LTE femtocells does not reduce the performance of GSM networks, besides, the coexisting will provide proper service in the newly deployed LTE femtocell [20]

In the coexisting network, the LTE femtocells operate on orthogonal frequency division multiplexing (OFDM) technology so they are able to use several fractions of radio frequency without interfering with other parts of the frequency lying in between. LTE femtocell can use whole channels except those are used by the GSM network where the femtocells are located. The 4G/LTE system operate in GSM band belongs to an overlay spectrum refarming mode

As we consider regularly located on GSM cells and assume uniformly distributed GSM MSs and LTE femtocells, each reuse cluster has the constant expected value of received interference. Thus, we analyze the SINR of femtocell for a frequency channel in the cluster f_1 without loss of generality. The interference of the LTE femtocell comes from GSM MSs that employ f_1, femtocells on other GSM cells $\notin\Psi(f_1)$, and femtocells in the constant cell s

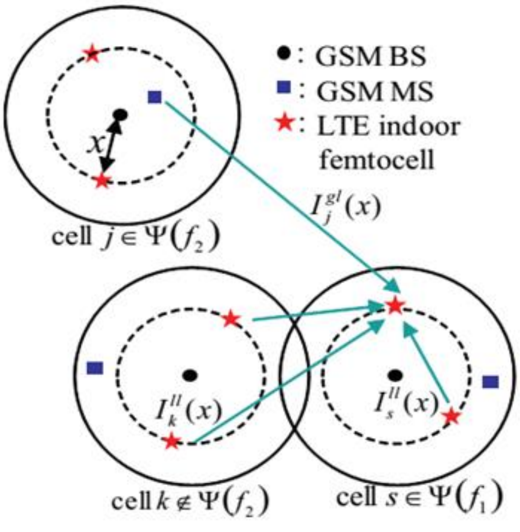

Figure 2. Interference LTE femtocell received in cell s

If $I_j^{gl}(x)$ be the expected value of interference from a GSM MS in cell j provided that the distance between BS s and the femtocell is x. As illustrated in Figure 2, the location of the GSM MS relative to BS j is (r_j, θ_j), and that of the femtocell relative to BS s is $(x, \beta s)$. Then, by employing a polar coordinate where the BS j is at (0, 0) and the BS k is at (D_{js}, 0), I_j^{gl} (x) is provided as;

$$I_j^{gl}(x) = \int_0^R \int_0^2 \int_0^{2\pi} P^g(r_j) \, L\sqrt{(r_j cos\theta_j - D_{js} - xcos\,\beta_s)^2 + (r_j sin\theta_j - xcos\,\beta_s)^2} \, \frac{r_j}{2\pi^2 R^2} d\beta_s \, d\theta_j dr_j \quad (1)$$

Similarly, the average interference from a femtocell on GSM cell k, which is denoted by I_k^{ll}(x), is provided as;

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

The interference value from another femtocell in the constant GSM cell s is denoted by $I_s^{ll}(x)$. In the polar coordinate BS s is located at origin point then;

$$I_s^{ll}(x) = \int_0^{2\pi} P_{eff}^l \left(\sqrt{2x^2(1-cos\beta_s)}\right) \frac{1}{2\pi} \, d\beta_s \quad (3)$$

Background noise at the femto BS and MS, $N_b^l = N_0 W^g N_F^l$ where N_F^l is the noise figure of LTE BS and MS. The expected value SINR of the femtocell provided M and x as follow;

$$\gamma^l(x, M) = \frac{Q_{eff}^l}{\sum_{j\epsilon\Psi(f2)} I_j^{gl} + M \sum_{k\notin\,\Psi(f2)} I_k^{ll}(x) + (M-1)\, I_S^{ll}(x) + N_b^g} \quad (4)$$

IV. Result And Evaluation

This study observes how SINR LTE femtocell is affected by dynamic femtocell number and deploy position. Simulation is employed to get clear view the relationship between change of femtocell number and deployment position on SINR LTE femtocell. In table 1 parameters study are listed. Parameter used for the experiments based on standard GSM and LTE parameter.

Table 1. Parameters of SINR LTE femtocell

Parameter	Value
K	4
macrocell radius [km]	0.6km
femtocell position	(0.1R, 0.2R, R)
femtocell number	(1,2, 3...15)
P^g (R)	30 dB
P^l_{eff}	6 dB
N_o	-174 dB
W^g	200 kHz
N_F^g	5 dB
N_F^i	5 dB

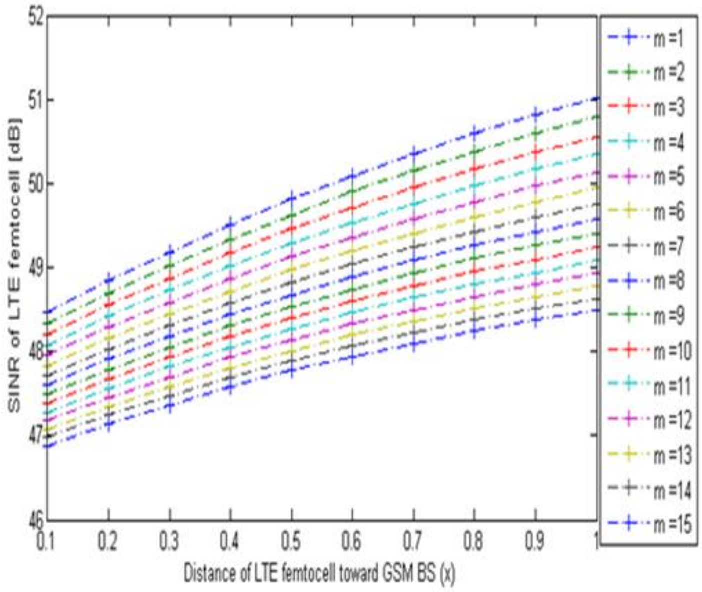

Figure 3. SINR LTE femtocell improve with dynamic femtocell number and dynamic deployment position

The result in figure. 3 shows when femtocells are deployed near to the GSM base station, *i.e.*, $x = 0.1R$, accommodating one and more LTE femtocells per GSM network cause decrease in SINR femtocell about 0.2dB, i.e., when $M = 1$, SINR LTE femtocell reach 48.5dB then decrease become 48.3dB when $M=2$, and the SINR LTE femtocell continue to decline due to the increase of number deployed femtocell in each GSM network. This trend occurs due to more femtocells number accommodated on each GSM cell will be more inter- femtocell interference, thus it decreases SINR LTE femtocell. Meanwhile, SINR LTE femtocell increase as the farther distance femtocell toward GSM base station (x). When change from $x = 0.1R$ to $x = R$, SINR LTE femtocell increase about 2.5dB for a single femtocell on each GSM network. The strengthening of SINR LTE femtocell is caused by less inter-femtocell interference because of farther distance. The farther distance will increase path loss of interfering femtocell and reduce inter-femtocell interference strength, hence it increases the SINR LTE femtocell.

V. Conclusion

SINR LTE femtocell is highly dependent on number and deployment position of LTE femtocells. On this study, SINR LTE femtocell increase about 0,2dB for every reduction of one femtocell deployed on the GSM network. Meanwhile when the distance of femtocell away from GSM BS from x = 0.1R to x = R, SINR LTE femtocell increase about 2.5dB for a single femtocell on each GSM network. So as to improve SINR LTE femtocell can be done by reducing the number of femtocells deployed on GSM network and set LTE femtocell distribution patterns away from GSM base station.

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References

[1] T. Wang, G. Li, J. Ding, Q. Miao, J. Li, and Y. Wang, “5G Spectrum: is china ready?,” *IEEE Communications Magazine*, vol. 53, no. 7, pp. 58–65, Jul. 2015, doi: https://doi.org/10.1109/mcom.2015.7158266.

[2] 5G Americas Whitepaper, "5G Spectrum Vision", America, February 2019

[3] Norwegian Communication Authority, "Spectrum Roadmap for Mobile Communication in Norway", Norway, February 2019

[4] I. F. Akyildiz, "Spectrum management in cognitive radio networks," NOMS 2008 - *2008 IEEE Network Operations and Management Symposium*, Salvador, Brazil, 2008, pp. xxix-xxix, doi: 10.1109/NOMS.2008.4575104.

[5] Ministry of Communication and Informatics, Peraturan Menkominfo Nomor 22 Tahun 2015 tentang Rencana Strategis Kementerian Kominfo Tahun 2015-2019, 2015. Available: https://ppid.kominfo.go.id/jenis-informasi/inf-setiap-saat/renstra/

[6] S. Han, Y. -C. Liang and B. -H. Soong, "Spectrum Refarming: A New Paradigm of Spectrum Sharing for Cellular Networks," *in IEEE Transactions on Communications*, vol. 63, no. 5, pp. 1895-1906, May 2015, doi: 10.1109/TCOMM.2015.2418196.

[7] S. Lasek, D. Tomeczko, J. T. J. Penttinen, D. Valerdi and I. Güemes, "GSM refarming analysis based on Orthogonal Sub Channel and interference optimization," *2012 8th International Symposium on Communication Systems, Networks & Digital Signal Processing (CSNDSP)*, Poznan, Poland, 2012, pp. 1-6, doi: 10.1109/CSNDSP.2012.6292715.

[8] R. D. Vieira et al., "GSM Evolution Importance in Re-Farming 900 MHz Band," 2010 IEEE 72nd Vehicular Technology Conference - Fall, Ottawa, ON, Canada, 2010, pp. 1-5, doi: 10.1109/VETECF.2010.5594534.

[9] ElNashar, A., El-saidny, M., & Sherif, M. Design, Deployment and Performance of 4G-LTE Networks : A Practical Approach. Wiley. 2014

[10] Motorola Inc., “Frequency Analysis for Future LTE Deployments,” White Paper, 2007

[11] Germano A. and Chairman V., Femto Forum, “The Impact of Femtocells on Next Generation LTE Mobile Networks”, 3GPP, 2010.

[12] Akinladi O. A., Paul B. S., Joseph M.K. and Ferreira H.C, “Indoor Communication: Femtocell Behavior in an Indoor Environment”, in proc. of the International MultiConference of Engineers and Computer Scientists (IMECS) conference, Hong Kong, 2015.

[13] S. S. Das, P. Chandhar, S. Mitra and P. Ghosh, "Issues in Femtocell Deployments in Broadband OFDMA Networks: 3GPP-LTE a Case Study," 2011 IEEE Vehicular Technology Conference (VTC Fall), San Francisco, CA, USA, 2011, pp. 1-5, doi: 10.1109/VETECF.2011.6093191.

[14] E. G. Larsson and M. Skoglund, "Cognitive radio in a frequency-planned environment: some basic limits," in IEEE Transactions on Wireless Communications, vol. 7, no. 12, pp. 4800-4806, December 2008, doi: 10.1109/T-WC.2008.070928.

[15] KW Sung, Lei Shi, J Zander, “Coexistance of LTE Femtocell with GSM Cellular Network”, Personal Indoor and mobile radio communication (PIRMC), IEEE 21st International symposium, September, 2010

[16] [Z. Bharucha, H. Haas, A. Saul, and G. Auer, “Throughput enhancement through femto-cell deployment,” *European Transactions on Telecommunications*, vol. 21, no. 5, pp. 469–477, Jul. 2010, doi: https://doi.org/10.1002/ett.1428.

[17] J. Espino and J. Markendahl, "Analysis of macro — femtocell interference and implications for spectrum allocation," *2009 IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications*, Tokyo, Japan, 2009, pp. 2208-2212, doi: 10.1109/PIMRC.2009.5449849.

[18] M. Yaser, “Optimalisasi Throughput LTE Femtocell Pada Jaringan Koeksistensi LTE-GSM”.Jetri: Jurnal Ilmiah Teknik Elektro Vol. 20, No. 2, Februari 2023

[19] M. Yaser, “Impact of Macrocell Size on the Implementation of LTE Femto Integrated with GSM Network,” *SETRUM (Sistem-KEndali-Tenaga-elektRonika-telekomUnikasi-koMputer)*, Dec. 2016, doi: https://doi.org/10.36055/setrum.v5i2.965.

[20] Penttinen Jyrki T.J. The LTE – Advanced deployment handbook. 2016