Coexistence LTE with GSM and UMTS - Performance Analysis using SEAMCAT Simulation

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Abstract— **The LTE (Long Term Evolution) technology is expected to offer a number of distinct advantages over other wireless technologies. Scarcity of spectrum had encouraged regulator and provider to refarmed the spectrum. Spectrum refarming for LTE in 900MHz, 1800 MHz or 2100 MHz frequencies band is considered to trigger the potential degradation of existing services such as GSM and UMTS. The simulation's results decribe that in those frequencies band options, LTE can well coexist with other technologies in the ecosystem such as GSM and UMTS. Overall simulation results show that at 1800 MHz while LTE is interfered by LTE and others such as GSM and UMTS, the performance is lower than other frequencies, so the best option is at 900 MHz or 2100 MHz of the frequencies**.

Index Terms—**Refarning, Coexistence, Throughput, SINR, Performance**

I. INTRODUCTION

Radio frequency spectrum is a limited natural resource that has strategic value in telecommunications operations and dominated by the state.

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 based on national needs.

Along with the rapid development of telecommunication technology as presents in Figure 1.1 [1]., especially mobile broadband technology is now starting to move collectively from 3G to 4G. Long Term Evolution Advanced (LTE-A) is a mobile communication standard and a major enhancement of the LTE standard. Long Term Evolution (LTE) is a step toward the 4th generation (4G) of radio technologies designed to increase the capacity and speed of mobile telephone networks, it can be seen from the LTE architecture that is simpler than previous technology, the use of OFDM, smart antennas (MIMO), and several other supporting technologies.

Adoption of LTE depends on how many new mobile operators can obtain spectrum in the digital dividend and the IMT band - as well as the extension of the spectrum 2G / 3G that there may be a re-ordering for 4G service.

Regulators and governments play an important role in the implementation of LTE networks as a maker of network capacity solutions can be available. However, the uncertainty surrounding the decision rules and complex fragmentation of LTE frequency spectrum at the national and regional levels continue to negatively impact the development of LTE consumer devices compatible. Meanwhile, the frequency spectrum of the spectrum arrangement scenario accounts for 38 percent of the current global LTE market, where more than 50% associated with the 1800 MHz band (Purohit, 2013). The development of this refarming allows operators to introduce LTE before the allocation of additional spectrum by the regulator.
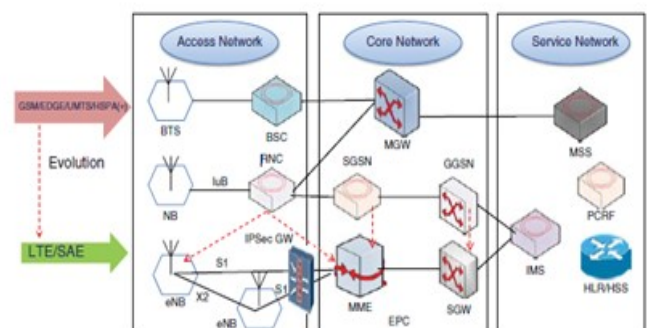

Figure 1.1 Evolution from 2G/3G/HSPA(+) to LTE [1]

By looking at some of the issues and developments related to the spectrum allocation of radio frequency spectrum in Indonesia, needed a comprehensive identification and analysis on the condition of allocated frequency spectrum of current and potential refarming to the frequency spectrum in the future. This study will further analyze technically on several scenarios, especially analyze from the minimization of interference in the view of throughput and SINR to examine the coexistence LTE to GSM and UMTS. Based on previous research and technology that used now in Indonesia, so this research will take 3 alternatives frequency : 900 MHz, 1800 MHz and 2100 MHz, while the interferer is GSM 850MHz, GSM 900MHz, GSM 1800MHz and UMTS 2100 MHz.

This study will use a Monte Carlo simulation is a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results; usually a simulation runs repeatedly to obtain the probabilistic distribution of the unknown entity. Simulation modeling is done by using the Advanced SEAMCAT (Spectrum Engineering Monte Carlo Analysis Tool) to show the level of interference with the OFDM DL (Down Link).

II. REFARMING AND COEXISTENCE

Refarming is a concept of rearrangement of previously used frequency for new technologies to make it more optimal. Refarming of the spectrum associated with the reuse of existing 3G spectrum licenses to launch new technologies such as LTE. The costs associated with this approach is significantly lower than obtaining new spectrum licenses LTE. By adopting this approach, release the operator part of the spectrum and use it to support LTE services.

The purpose of refarming is to ensure LTE systems can coexist with other mobile systems operating in the same geographical area [2]. In 3GPP RAN Working Group 4, coexistence of LTE with other mobile systems has been studied using system scenarios, together with implementation issues, that reflect the environments in which LTE is expected to operate, and the LTE radio transmission and reception characteristics have been specified accordingly to facilitate LTE coexistence with other mobile systems [3]

III. SIMULATION AND SCENARIO

The flexibility frequencies to be used in LTE services has been carried out several options to implement it. In this study will analyze the frequency that used in 2G and 3G/UMTS, for 3 options frequncies such as 900MHz, 1800 MHz and 2100 MHz. An inteferer link will be simulated at GSM 850 MHz, GSM 900 MHz, GSM 1800 MHz and UMTS 2100 MHz.

LTE's scalability bandwidth have make some benefit for the limited resources, in this study will see in four options bandwidth : 5 MHz, 10 MHz, 15 MHz and 20 MHz.

Link budget for LTE, GSM and UMTS is the basic for the parameter input value in the SEAMCAT tools, such as SINR

minimum, Minimum Coupling Loss, Antenna Propagation, etc.

Despite, 3GPP TS 36.101 standards [4] on LTE's implentation is used to get the value of the parameters which is depend on the bandwidth such as :
a. Channel bandwidth
b. Adjacent Channel Selectivity (ACS). ACS is the ratio of the receive filter attenuation on the assigned channel frequency to the receive filter attenuation on the adjacent channel(s).

Table 2.1 Adjacent channel selectivity

Rx Parameter	Units	Channel bandwidth							
		1.4 MHz	1.6 MHz	3 MHz	3.2 MHz	5 MHz	10 MHz	15 MHz	20 MHz
ACS	dB	33.0	33.0	33.0	33.0	33.0	33.0	30	[27]
R_{av}	kbps								

c. Adjacent Channel Leakage power Ratio (ACLR) is defined as the ratio of the transmitter mean power centered on the assigned channel frequency to the mean power centered on an adjacent channel frequency. ACLR provides the amount of interference that a transmitter could cause to a receiver operating in the adjacent channel

d. A received interferer power at a frequency offset from the wanted signal, and for an ACIR (function of the frequency offset), the experienced interference power is reduced by the ACIR as sketched in this Figure 2.1 below.

This reasearch will observe the interference in downlink, so in downlink :

$$ACIR^{-1} = ACLR_{BS}^{-1} + ACS_{UE}^{-1}, \qquad (2.1)$$

and the dominant part of ACIR is due to the UE frequency selectivity (ACS) (i.e. $ACLR_{BS}$ is very large compare to ACS_{UE} and it will become :
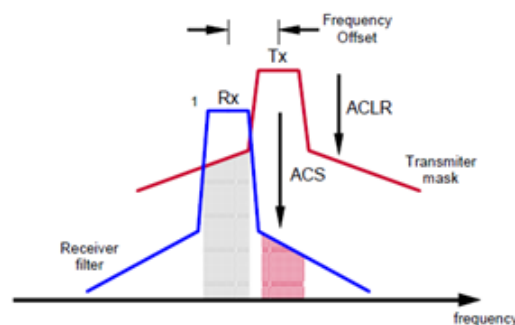
$$ACIR \approx ACS_{UE} \qquad (2.2)$$

Figure 2.1 Interference as a result of limited ACLR and ACS [3]

e. MAPL (Maximum Allowed Path Loss) is calculating to gain the radius which is depend on the frequency and

parameter based on LTE link budget for urban area, with the equations as follow [5]:

$$PL = A + Blog10(d) + C \qquad (2.3)$$

The Extended Hata model pathloss in dB is given by:

$$A = 46.3 + 33.9log10(f) - 13.82log10(hB) - a(hM) \qquad (2.4)$$

The definitions for B, C and $a(hM)$ are as previously defined. This research will be focused in the Extended Hata Model for urban area, so the number of factor C is 3dB, so the result is shown at this table.

Table 2.2 Cell radius based on Cost321 Hatta

Frequency (MHz)	Cell radius d (km)
900	1.22
1800	0.59
2100	0.5

f. Dropped call less than 20% for LTE interferer, which is gives the SINR between -40dB and -45dB.
g. Iterations : 1000 events

In OFDMA DL interferer, only the position of the BSs will be calculated because full transmit power is assumed. The relationship between the contributors of the interference in LTE network is illustrated in Figure 3.1 [3] below.
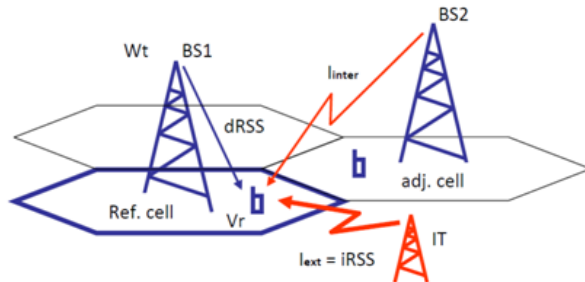

Figure 3.1 Interference mechanism in LTE network

The C/I calculation in DL is calculated as :

$$C/I = \frac{C(j.k)}{I(j.k)} \qquad (3.1)$$

where C(j,k) is the received power at the k-th user from the serving BS, i.e., the j-th BS

$$C(j.k) = P^{UE}_{BS} \ x \ pathloss \ (BS_j.UE_{j.k}) \qquad (3.2)$$

$$C(j.k) = dRSS \ (BS_j, UE_{j.k}) \qquad (3.3)$$

and where P^{UE}_{BS} is the power of resource block and *pathloss $(BS_j.UE_{j.k})$* = max (*pathloss*,MCL). Note that the pathloss includes shadowing. desired Received Signal Strength (dRSS) corresponding to the C, as well as the interfering signal strength (iRSS) corresponding to the I. *I(j,k)* is the sum of the interference power.

A look up table is used to map throughput in terms of spectral efficiency (bps per Hz) with respect to calculated SINR (= C/I) (dB) level.
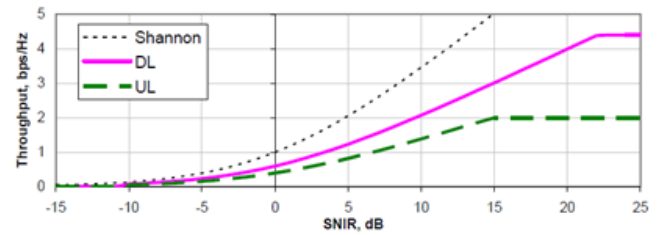

Figure 3.2 Throughput vs SINR for Baseline E- UTRA Coexistence Studies [3]

The achieved bit rate or throughput is calculated as follows:

$$BiteRate_{[kbps]} = \frac{N_{Subcarriers\_per\_UE}}{N_{total\_subcarriers}} \times \left(x_{bps/Hz}\right)_{SINR} \times BW_{[MHz]} \times bps\_to\_kbps\_conversion$$

$$(3.4)$$

Lower boundary of SINR to take into account in the simulation. In DL, any UE with a C/I lower than the SINR minimum will be disconnected right away.[3]

SINR is one of the most important factors that determine the downlink throughput for the UE. Per UE SINR is highly impacted by power control mechanism. [6]

This study will analyze on the througput and SINR performances, while LTE is interfered by GSM (850, 900, 1800MHz) and UMTS 2100 MHz.

IV. PERFORMANCE ANALYSIS AND DISCUSSION

A. THROUGHPUT ANALYSIS

Refers to equation 3.4 the achieved throughput from the simualtion bring out the similar pattern while LTE is interfered by GSM and UMTS, that is the greater the bandwidth that is allocated the greater the throughput obtained.

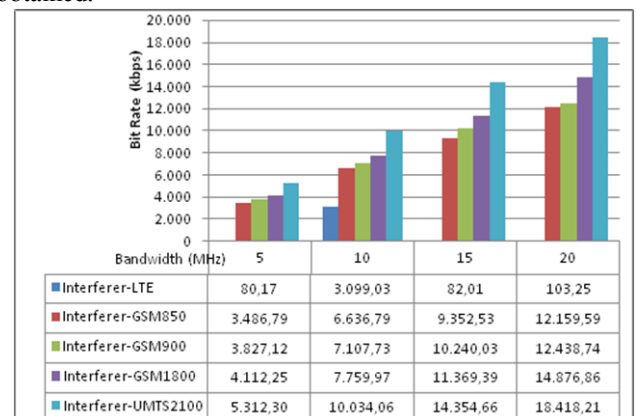| Bandwidth (MHz)	5	10	15	20
Interferer-LTE	80,17	3.099,03	82,01	103,25
Interferer-GSM850	3.486,79	6.636,79	9.352,53	12.159,59
Interferer-GSM900	3.827,12	7.107,73	10.240,03	12.438,74
Interferer-GSM1800	4.112,25	7.759,97	11.369,39	14.876,86
Interferer-UMTS2100	5.312,30	10.034,06	14.354,66	18.418,21

Figure 4.1   Throughput for frequency 900MHz

In Figure 4.1 can be examined that the best throughput value obtained when LTE interfered by LTE at 900 MHz in the 10MHz bandwidth reaches up to 3 Mbps. This may occur

due to the bandwidth of 10 MHz at 900 MHz, LTE runs optimally when interfered by LTE itself. Also, it may come about due to a fairly limited bandwidth in the frequency.

Beside that, while LTE interfered by UMTS2100 the best value is at 900 MHz in 20 MHz which is achieved 18,4 Mbps. this is in accordance with relation to the equation 3.4 which shows that the value of throughput increased with the amount of bandwidth.

In addition, a higher throughput occurs when the frequencies 900 and 1800 interfered by UMTS 2100MHz. This is most likely to occur because of different frequency interfered by different technologies.
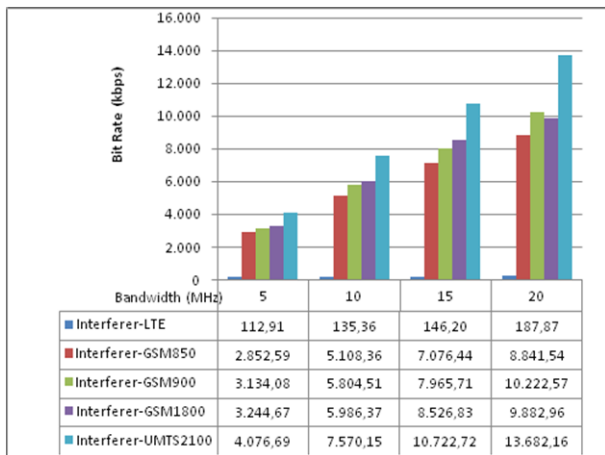

Bandwidth (MHz)	5	10	15	20
■ Interferer-LTE	112,91	135,36	146,20	187,87
■ Interferer-GSM850	2.852,59	5.108,36	7.076,44	8.841,54
■ Interferer-GSM900	3.134,08	5.804,51	7.965,71	10.222,57
■ Interferer-GSM1800	3.244,67	5.986,37	8.526,83	9.882,96
■ Interferer-UMTS2100	4.076,69	7.570,15	10.722,72	13.682,16

Figure 4.2   Throughput for frequency 1800MHz

The best throughput performace value achieved at 2100 MHz while LTE interfered by GSM850 in 20 MHz is17,5 Mbps, also while interfered by GSM900 in 20 MHz is18,1 Mbps and interfered by GSM1800 in 20 MHz is18,1 Mbps.

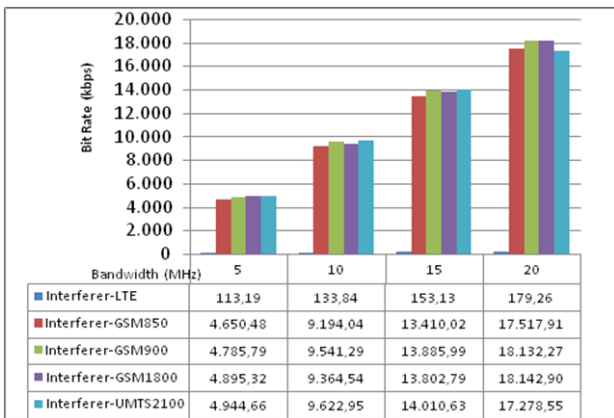| Bandwidth (MHz)	5	10	15	20
■ Interferer-LTE	113,19	133,84	153,13	179,26
■ Interferer-GSM850	4.650,48	9.194,04	13.410,02	17.517,91
■ Interferer-GSM900	4.785,79	9.541,29	13.885,99	18.132,27
■ Interferer-GSM1800	4.895,32	9.364,54	13.802,79	18.142,90
■ Interferer-UMTS2100	4.944,66	9.622,95	14.010,63	17.278,55

Figure 4.3   Throughput for frequency 2100MHz

Figure 4.1 until Figure 4.3 shows that the smallest throughput occurs when LTE interfered by LTE as well. Despite, if LTE interfered by other technologies such as GSM and UMTS has the same pattern that the higher the bandwidth so the higher the throughput.

B. SINR ANALYSIS

In these simulations, the SINR parameter value is -40dB for bandwidth 5MHz and 10 MHz, otherwise -45dB for bandwidth 15MHz and 20 MHz.

Similar to throughput and dropped user, the performance of LTE when interfered by LTE is in the lowest value than interfered by GSM and UTMS. While LTE is interfered by GMS and UMTS, its has the same patterns. It can be shown that while LTE is interfered by LTE, SINR reaches the highest value at 900MHz is bandwidth 10 MHz is -10,89 dB

The worst cases happenned at bandwidth 15MHz while LTE is interfered by LTE. Same case The best SINR value is achieved while LTE 1800MHz is interfered by UMTS2100 due value is -0,92 dB at 5MHz of bandwidth. It might happened because different frequencies is interfered by different systems at different frequencies too.
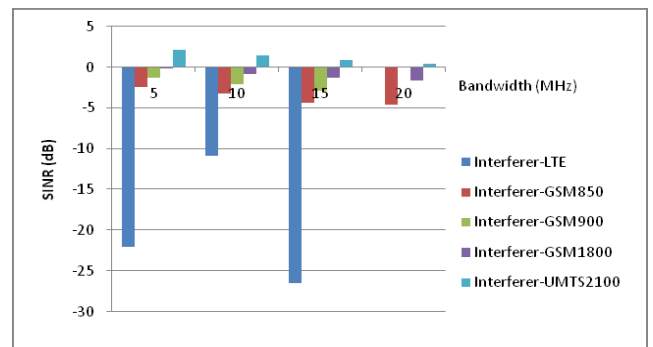

Figure 5.1   SINR for frequency 900MHz

The same cases happened in the value of throughput performance. At bandwodth 20 MHz, when LTE 900 MHz interfered by GSM 900 the SINR value that appears is NaN (undefinite), this may happen because the same frequency interfered by different systems on the same frequency.
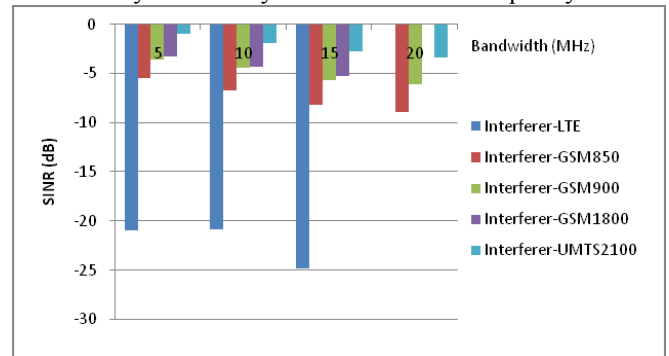

Figure 5.2   SINR for frequency 1800MHz

Getting simulated the SINR for frequency 900 MHz, the value achieved the best performance at 5MHz of bandwitdh while LTE is interfered by UMTS2100 which is 2,16 dB. It might happenned because different frequencies is interfered by different systems at different frequencies also.

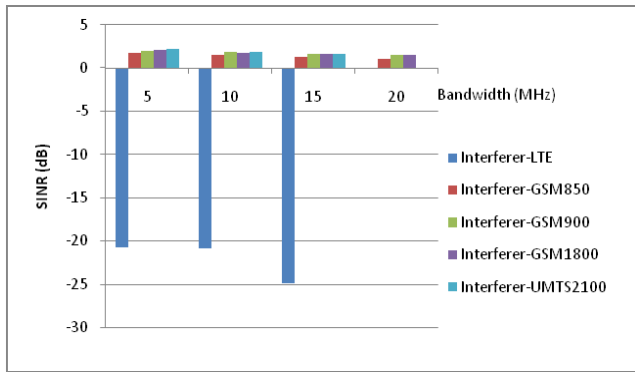The same case happened like at 900 MHz, when LTE 1800 MHz in 20 MHz interfered by GSM 1800 the SINR

Figure 5.3 SINR for frequency 2100MHz

value that appears is NaN (undefinite), this may happen because the same frequency interfered by different systems on the same frequency.

The best value of SINR achieved at 2100 MHz in 5 MHz while LTE is interfered by GSM and UMTS, which is for GSM850 is 1,71 dB, while interfered by GSM900 is 1,98 dB , for GSM1800 is 2,14 dB and while interfered by UMTS2100 is 2,18 dB. The best performance is while LTE interfered by UMTS 2100 which is might happened because in the bandwidth 5 MHz LTE 2100 MHz can operate optimally although inetrefered by other systems at the same frequencies. At bandwidth 20 MHz, the same case happened like at 900 MHz and 1800 MHz that is, when LTE 2100 MHz interfered by UMTS 2100 the SINR value that appears is NaN (undefinite), this may happen because the same frequency interfered by different systems on the same frequency.

C. THROUGHPUT VS SINR ANALYSIS

Basically, an increase in SINR in line with the increase in throughput that interfered. This chart pattern in accordance with the pattern of the graph in Figure 3.2 and the equation 3.4 which shows the relationship between throughput with SINR.
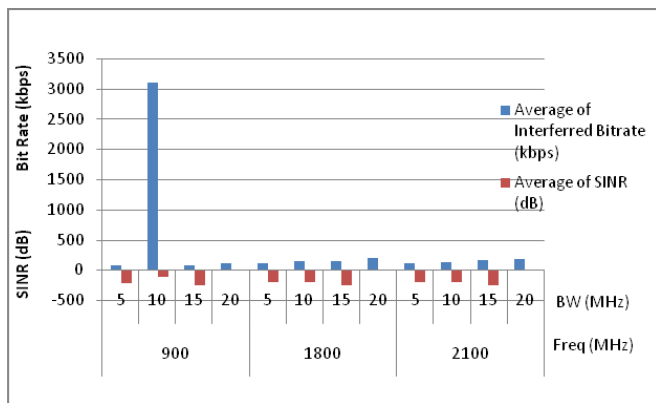

Figure 6.1 LTE interfered by LTE; Throughput vs SINR

Despite, it can be seen at Figure 6.1 that the best value in received throughput and SINR cases in frequency 900 MHz

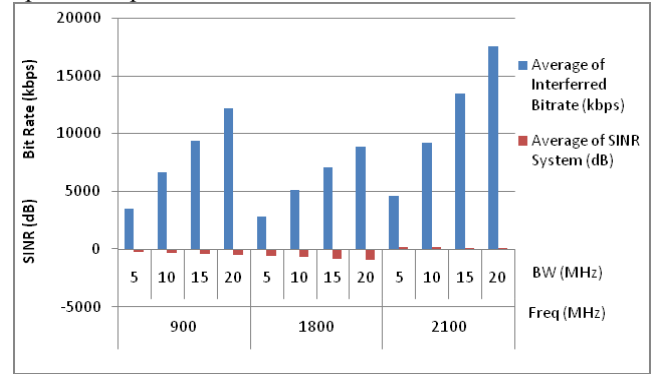on 10 MHz while LTE interfered by LTE is -10,89 dB and up to 3 Mbps.

Figure 6.2 LTE interfered GSM850

The best performance occurs while LTE is interferrred by GSM850 at 2100 MHz in 20MHz of bandwidth which the value is 18,145 Mbps and SINR at 1,12 dB.
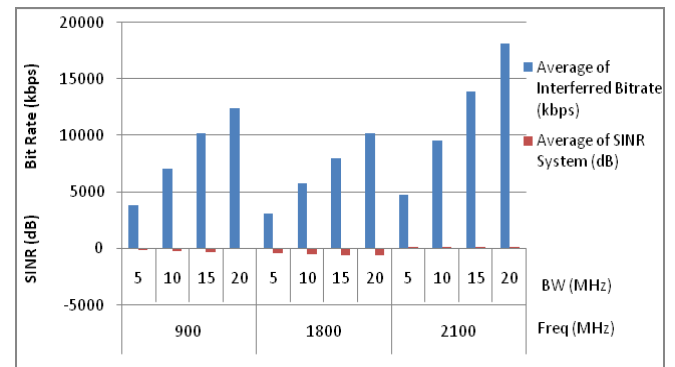

Figure 6.3 LTE interfered GSM900

The same case happened while LTE interfered by GSM900, the best performance achieved at 2100 MHz in 20 MHz of bandwidth which value is 18,312 Mbps and SINR 1,52 dB. It is also happened in Figure 6.4 while LTE interfered by GSM1800, with the value is 18,353 Mbps and SINR 1,5 dB. That case might happen because at 2100 MHz the bandwidth is greater that other bands of frequencies.
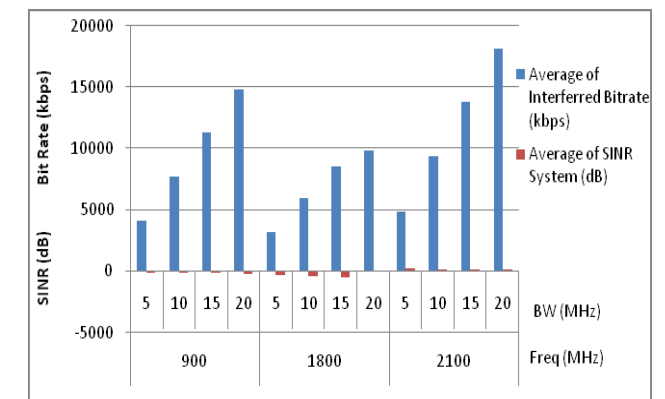

Figure 6.4 LTE interfered GSM1800

While LTE 900MHz interfered by GSM 900MHz then SINR's value in 20MHz occurred NaN (undefinite), it

maybe occurs because different technology using same frequency bands. It happenned in the same case while LTE 1800 MHz interfered by GSM 1800MHz.

From Figure 6.1 until Figure 6.5, can be shown that the greater the allocated bandwidth, the greater the throughput obtained. In line with this, that the greater throughput obtained then the better the SINR. This is in line with equation 3.1.

Similar to other frequencies, which is currently LTE 2100 MHz interfered by UMTS 2100MHz, so SINR's value in 20MHz are NaN (undefinite). This likely occurred because the same frequency band using two different technologies, so the results of SINR's value are NaN (undefinite).
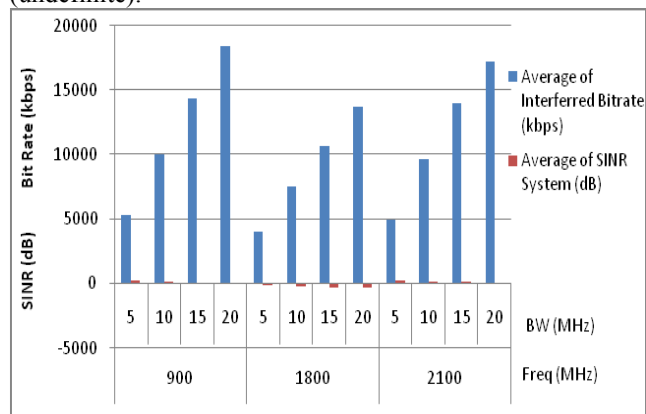

Figure 6.5 LTE interfered UMTS2100

V. CONCLUSION AND FUTURE WORK

The importance of refarming and interconnection scheme is fair for the state to encourage operators to build networks as a form of fulfilling commitments and to build a network license is not limited only in big cities.

Spectrum refarming for LTE in 900MHz, 1800 MHz or 2100 MHz frequencies band is considered to be triggered the potential degradation of existing services such as GSM and UMTS. The simulation's results decribe that in those frequencies band options, LTE can well coexist with other technologies in the ecosystem such as GSM and UMTS that can be seen from throughput and SINR performance.

Overall simulation shows the performance of 2100 MHz is the best value while LTE is interfered by other systems such as GMS and UMTS in terms of SINR and throughput as well.

For further research, it would be needed to explore and compare the performance analysis while using another simulations such as Matlab and NS3. Also it can be analyzed with different parameter.

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