On The Impact of User Payload on Deployment Requirements of LTE Networks

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Abstract: - Ever since its inception, Long Term Evolution (LTE) of Universal Mobile Telecommunications System (UMTS) standard has gained great deal of momentum from wireless operators as well as end users. This paper addresses the impact of user or traffic load in LTE cells on total harmful interference emitted towards a victim cell. This is done through deriving coexistence requirements, in terms of land separation, when deploying LTE base stations in band 2.6 GHz. In view of the developed model and results, the interference radiated from the aggressor to the victim is directly proportional with the aggressor's traffic load. In other words, the higher the payload of the aggressor, the higher the interference received by the victim.

Key-Words: - LTE, traffic load, interference, coexistence, inter-cell interference, protection criterion

1 Introduction

Long Term Evolution (LTE) of Universal Mobile Telecommunications System (UMTS) delivers high data rates and low latency connections [1]. In deploying this technology, a wide range of deployment options are possible. However, a vital concern when installing a new system is frequency band. This is ascribed to its scarcity and cost among all radio resources, and yet can impose a serious effect on network planning and performance. Notably, frequency bands of LTE are described in [2].

For many operators, band (2500-2690) MHz is considered one of the key bands due to its flexible radio characteristics [3], [4]. A globally accepted deployment choices are shown in Fig. 1 [3].

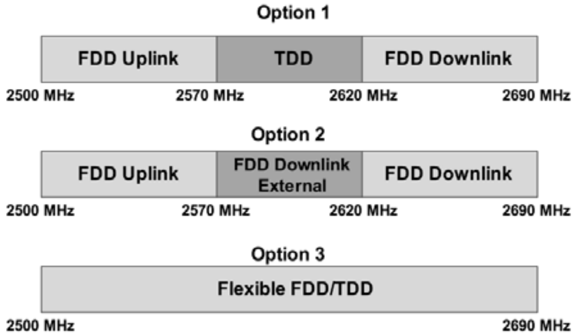

Fig. 1 LTE deployment choices in 2.6 GHz band

In Fig. 1, option (1) denotes Preconfigured allocations of paired (FDD) and unpaired (TDD) spectrum, while Option (2) demonstrates paired spectrum only with the uplink portion of some pairs in another undetermined band. Lastly, Option (3) denotes flexibility, allowing the bidders for spectrum to decide how they want to allocate the spectrum they acquire to paired (FDD) or unpaired (TDD) operation. A major problem faced when deploying LTE cells is coexistence of base stations. Particularly, the inter-cell interference between LTE cells or LTE and other nearby technologies, like UMTS [5]. The latter issue and many others have been tackles by many studies in the relevant literature [5–15]. However, not all radio aspects pertaining to LTE interference have yet been covered [16]. Traffic or user payload is such a key aspect in LTE interference that needs to be considered and modeled [17].

In view of the above, this paper addresses the impact of traffic loading conditions in LTE interfering cells on coexistence requirements. To achieve this, the work is ordered as follows: Section two gives some insight into interference sources and scenarios in general and band 2.6 GHz in particular. Section three discusses the proposed interference model along with its key factors, traffic load among others. System protection criterion in LTE receivers is then considered in Section four. Simulation parameters used throughout this work are tabulated in Section five along with special treatment of user payload in LTE base stations. This afterward tailed by the results and discussions in Section 6. A brief review of the findings is the concluding part in this work.

2 Interference Sources and Scenarios

Radio interference signal refers to the electromagnetic energy that enters the channels or systems of receiving device through direct or indirect coupling [4], [18]. Occasionally, interference may arise between evolved Node B (eNB) of similar radio channels, or in between two eNB(s) of dissimilar bands. This paper essentially tackles the situation where eNB(s) are using dissimilar channels but in the same band, as illustrated in Fig.2. Similar procedure may be used in co-channel scenarios, or even scenarios of dissimilar bands.

It is worth mentioning that this paper considers chiefly line-of-sight interference of base stations. Statistical scenarios which involve user equipment, on the other hand, will not be of great impact on calculations unless eNB to eNB interference type is alleviated first.

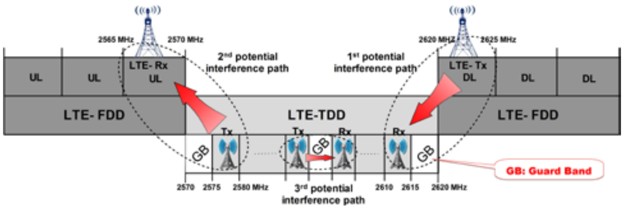

Fig. 2 Potential interferences in 2.6 GHz band

Theoretically, there are a couple of interference mechanisms that give rise to degradation in LTE eNB receivers. Both may arise together or discretely, namely Out-of-Band Emissions (OOBE) and system overload such as blocking. On one hand, OOBE is ascribed to any signaling that goes beyond the channel of interest of the disturbed receiver. This usually affects the closely adjacent channels, normally known as adjacent channel interference (ACI). Chances are there in which certain OOBE(s) may cover greater channel separations [19].

On the other hand, system (or receiver) overload implies receiver-based symptoms, blocking and intermodulations among others. This is mainly attributed to the reception of large radio signals at the receiver's pass-band [20].

3 Interference Model

For the sake of assessing the inter-cell interference power transmitted in between LTE eNB(s), the following analytical model is proposed:

$$I = P_t + G_t + G_r + TL - ACIR - 32.4 - 20Log(f) - 20Log(d) - A_h \quad (1)$$

where I is the interference (dBm) emitted from aggressor eNB, P_t is power (dBm) of aggressor, G_t and G_r are gains (dBi) of transmitter and receiver antennas, respectively, TL is the traffic load (dB) of interfering transmitter, $ACIR$ is Adjacent channel interference power ratio (dB), f is frequency (MHz) of disturbing transmitter, d is separation (km) between aggressor and victim eNB(s), and Ah is surrounding clutter loss (dB). Notably, 32.4 is the free-space pathloss constant when the separation d in km and the frequency f in megahertz.

The value of ACIR defines the overall power leakage in between two signals located on contiguous channels. This power ratio is subdivided into two components, namely Adjacent Channel Leakage Ratio (ACLR) and Adjacent Channel Selectivity (ACS), and found as follows [21]:

$$ACIR = \left(\frac{1}{ACLR} + \frac{1}{ACS} \right)^{-1} \quad (2)$$

Whereas A_h is given by [22]:

$$A_h = 10.25e^{-d_k} \left[1 - \tanh \left[6 \left(\frac{h}{h_a} - 0.625 \right) \right] \right] - 0.33 \quad (3)$$

where d_k is distance (km) in between clutters and aggressor's antenna, h and h_a are heights of aggressor's antenna and clutter, respectively. Table 1 [22] shows used values.

Table 1. Clutter categories and heights

Clutter Category	Clutter Height h_a (m)	Nominal Distance d_k (km)
Rural	4	0.1
Suburban	9	0.025
Urban	20	0.02
Dense urban	25	0.02

For a better understanding of A_h and its parameters, Fig. 3 shows clutter loss values as functions of antenna heights through different environments.

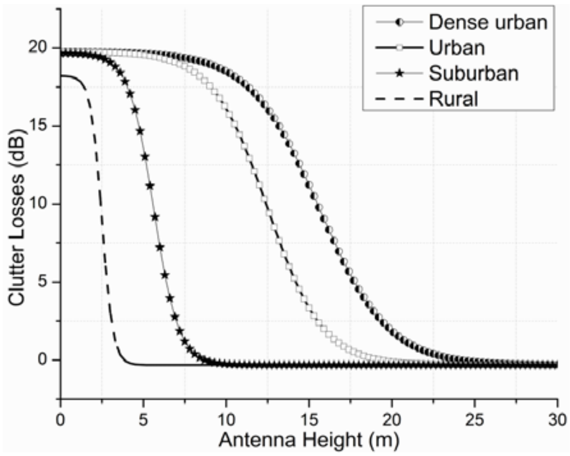

Fig. 3 Clutter loss values as functions of antenna height for different environments

4 Sensitivity Degradation

Receiver sensitivity degradation (S) is defined as any noise rise caused by any received interference. This can be expressed as [21]:

$$S = 10Log\left(\frac{10^{\frac{N}{10}} + 10^{\frac{I}{10}}}{10^{\frac{N}{10}}}\right) \quad (4)$$

where S is receiver sensitivity degradation (dB), I is the incoming interference (dBm) as previously calculated in Eq. 1 and N is noise floor (dBm) of victim's receiver. N is calculated as follows:

$$N = N_t + N_f + 10Log(BW) \quad (5)$$

where N_f is noise figure (dB), N_t *is* receiver thermal noise density, that is -174 dBm/Hz, and BW is noise bandwidth of the receiver (Hz).
In view of 3GPP [21], 1 dB of sensitivity degradation can be tolerated by LTE eNB's receiver. Therefore, in Eq. 4 setting S=1 and solving for I, yields I= N−6. This is formally known as Interference Protection Criterion (IPC). Namely, it is the amount of interference an eNB's receiver can tolerate without significant degradation in performance.

5 Simulation Parameters

Table 2 shows key parameters used through the simulations of coexistence scenarios of LTE eNB(s).

Table 2. LTE simulation parameters

System parameters		**value**
Frequency (GHz)		2.6 GHz
Traffic Loads (%)		30, 80 & 100
eNB transmission power (dBm)		43
eNB antenna gain (dBi)		17
eNB antenna height (m)		15
Receiver noise figure		5
ACLR(dB)	@ Co-channel	27.9
	@ offset 3.2 MHz	43
	@ offset 5 MHz	45
	@ offset 7.5 MHz	46.8
	@ offset 12.5 MHz	49
ACS(dB)	@ Co-channel	16
	@ offset 3.2 MHz	31.1
	@ offset 5 MHz	33
	@ offset 7.5 MHz	34.8
	@ offset 12.5 MHz	37

Among all, the traffic or system load (TL) is a measure of how heavily loaded the LTE eNB is. It is a function of total cell physical resources. It follows that LTE cell capacity (or physical resources) is measured by total cell resource elements (RE) available at the cell to serve network need after total overheads are subtracted. The overhead, on the other hand, normally is due to physical channels and signals resource elements consumption for the sake of channel estimation and other guiding tasks. Available cell resources are then distributed through the system scheduling unit (or the scheduler) to different UE(s) according to their traffic needs.
Analytically, the total LTE base station physical resources can be determined as follows [23]:

$$N_{re}^{cell} = N_{RB} \times N_{re}^{SF} \times N_{SF}^{frame} \quad (6)$$

where N_{re}^{cell} is the total number of cell's physical resource elements, N_{RB} is the total number of base station resource blocks, that is, 6, 15, 25, 50, 75 and 100 RB(s) for 1.4, 3, 5, 10, 15 and 20 MHz cell bandwidths, respectively, N_{re}^{SF} is the number of resource elements in one subframe and N_{SF}^{frame} is the number of subframes per one LTE frame which equals 10.

Eq. 6 gives the total number of LTE physical cell resources including control channels and signals overheads, where overhead is the percentage of the number of channel-specific resource elements to the total resource elements of LTE cell.

At this point, it is possible to calculate cell total physical resources as a function of total resource elements, based on system bandwidth and number of RBs used, as expressed in Eq. 6. However, actual total cell physical resources remain user and time-dependent variable, as decided by the scheduler (as depicted in Fig. 4. In this paper, to show the effect of loading conditions of interfering cell on victim cell, cell loads are considered in percentage, and simulated over several values due to the non-static operation of LTE physical resources allocations.

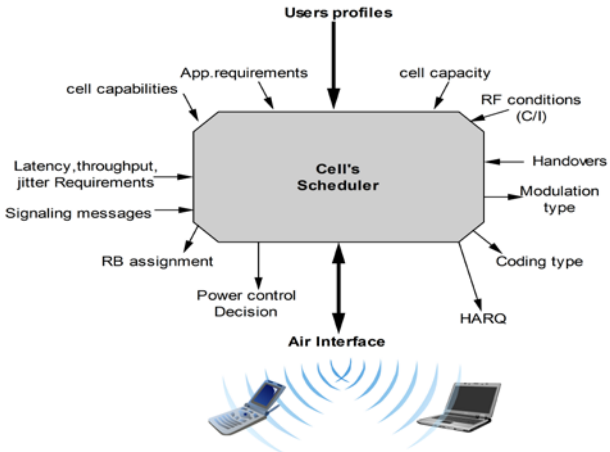

Fig. 4 Inputs and outputs of an LTE scheduler

In view of that, given an LTE base station with various traffic demands, the interference from its disturbing transmitter to another disturbed receiver is a function of traffic loadings of that interfering base station. Since the higher the traffic load in the neighbour cell, the more subcarriers are used there and, consequently, the higher the interfering signal power. And vice versa, that is, the lower the number of subcarriers assigned to the cell' traffic, the less power is received at the victim receiver, as shown in Fig. 5, where cell physical resources are not fully used owing to unused resource elements within transmission resource blocks to meet various traffic profiles.

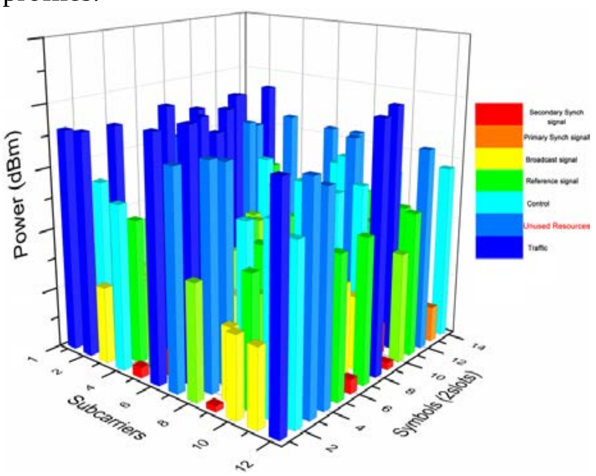

Fig. 5 LTE cell resource elements utilization

6 Results and Discussion

To demonstrate the impact of LTE cell's payload on coexistence guidelines, this part brings forward simulation results (Matlab™ software is used for simulation) of several traffic loads and their corresponding land separations. The effect of variable system load is captured in terms of terrestrial separations versus I/N ratios. Accordingly, Fig. 6 shows isolation measures for the protection of 1.4 MHz victim receiver bandwidth from being desensitized by 5 MHz interfering bandwidth. Accordingly, increased cell load gives rise to higher inter-cell interference and therefore requires larger land separations. This is due to the fact that loaded cell (base station) needs to serve its load (users) through increased transmission (payload), as depicted in Fig. 6.

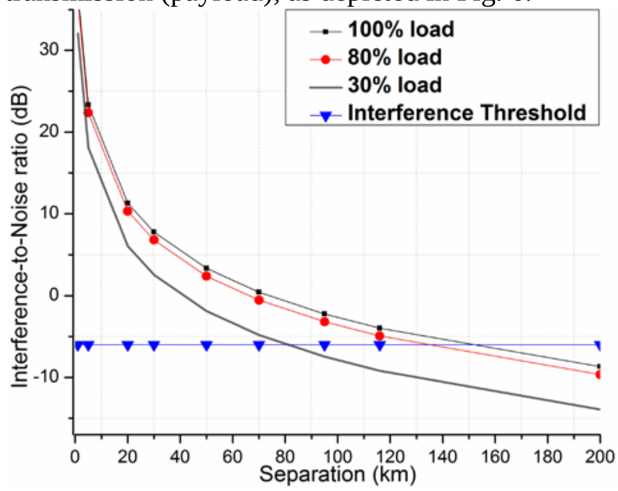

Fig. 6 Impact of traffic load of 5 MHz aggressor when interfering with 1.4 MHz victim

It is shown (Fig. 6) that 80 km of separation is required to keep the 1.4 MHz receiver running properly when being affected by 30% loaded aggressor. As the user payload goes higher in value, distances of 138 and 152 are needed to maintain interference-free situations for the 1.4 MHz receiver along with 5 MHz transmitter (whose loads are 8 and 100%, respectively).

The coexistence of 5 MHz aggressor with 5 MHz victim receiver is depicted in Fig. 7. In this figure, one can see that separations of 61, 98 and 111 km are required to alleviate the harmful interference levels from the 5 MHz transmitted whose loads 30, 80 and 100%, respectively. This is considerably lesser than Fig. 6 scenario due to larger overlapping bandwidths.

Fig. 8 through 9 illustrate coexistence scenarios of larger overlapping bandwidths, namely 10 and 20 MHz receivers bandwidths, respectively. For 10 MHz victim, isolations of 33, 58 and 65 km are compulsory to maintain safe operating conditions against the 5 MHz transmitter of 30, 80 and 100% loading states, respectively. These protecting limits are less stringent when 20 MHz victim is overlapping, where 21, 32, and 36 km are kept in between the 20 MHz receiver and 5 MHz, respectively.

It is worth noting that the larger the victim bandwidth the lower the interference levels received from interfering base stations as interference inversely proportional with victim bandwidth.

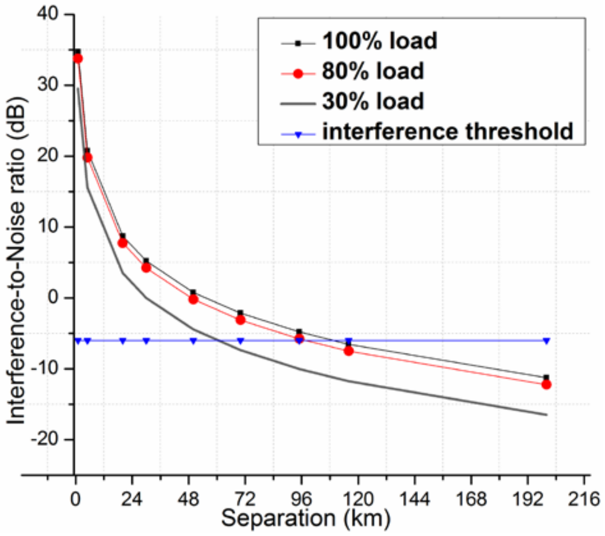

Fig. 7 Impact of traffic load of 5 MHz aggressor when interfering with 5 MHz victim

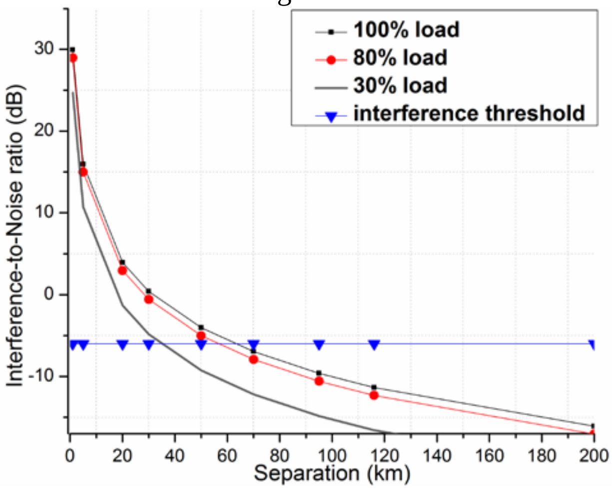

Fig. 8 Impact of traffic load of 5 MHz aggressor when interfering with 10 MHz victim

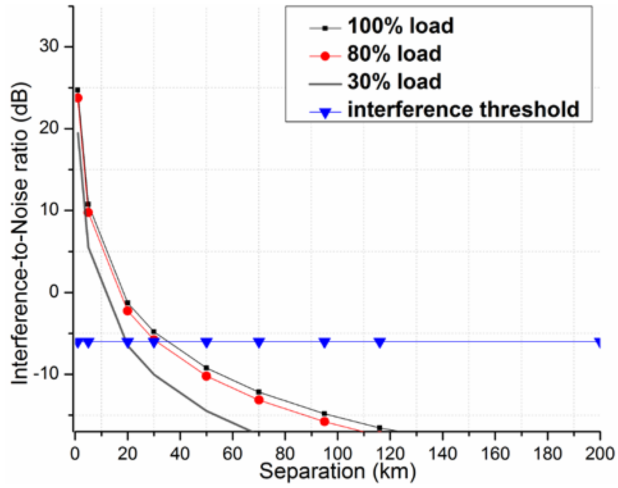

Fig. 9 Impact of traffic load of 5 MHz aggressor when interfering with 20 MHz victim

7 Conclusions

Long term evolution networks keep expanding and replacing the legacy ones owing to their compelling speed, spectral resource management and reduced cost per bit features, among others. This technology blend, however, brings forward several interference situations that are unique to LTE networks. In this paper, the effect of changing user payload of interfering LTE cell on the amount of interference affecting nearby victim cells has been investigated and characterized. This effect has manifested itself clearly when measuring required land separations for their corresponding traffic loads. Worst-case scenario of maximum emitted interference has also been discussed; in which the disturbing cell are fully loaded.

Acknowledgement

This research work has not been possible without the financial support from Universiti Malaysia Pahang (UMP) Vot. RDU 130387. Therefore, the authors would like to thank UMP for the continuous support.

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