Generic Channel Overlap Calculations Algorithm

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Abstract

The ever-increasing shortage of the spectrum leaves fourth generation wireless technologies no choice but to re-use their existing spectra repeatedly by the so-called re-farming strategy. This alternative, nevertheless, increases overlap levels between cells and rapidly escalates into interference situations. In this paper, channel overlap in wireless systems is defined and quantified. The proposed models account for cross and adjacent types of overlap in almost any radio network.

Keywords: *Channel overlaps, Cross channel overlap, adjacent channel overlap, Absolute radio frequency channel number*

1. Introduction

The ever increasing penetration of cellular mobile devices along with innovative and emerging data applications has drained spectral resources and thus resulted in a constant search for new spectrum bands for mobile communications by regulatory bodies and/or mobile operators [1, 2]. A natural extension of this deprived situation is that mobile network operators are now forced to re-use their allocated frequency blocks to accommodate their new networks by the so-called re-farming strategy [3, 4]. Consequently, the inevitable pressure on spectrum resources promotes radio channels overlap between cells and thus elevates deteriorating interference levels.

Typically, the intersection of channels of the same or contiguous carrier frequency is referred to as an overlap [5–7].

Typically, the intersection of channels of the same or contiguous carrier frequency is referred to as an overlap [5–7]. Based on the contiguity of overlapped carriers, overlap can be broadly divided into two types: cross, i.e. co-channel, and adjacent, i.e. contiguous [8–10]. In this paper, we propose a verification algorithm; by which overlap type, i.e. cross or adjacent is identified, we then quantify that overlap based on victim and intruder bandwidths and Absolute Radio Frequency Channel Numbers (ARFCN).

To serve its purpose, this paper is broken down into the following sections: Section 2 discusses the proposed algorithm along with a set of conditions to be followed when using it, Section 3 addresses some of the applications and implications of the offered algorithm and finally, Section 4 concludes the findings of this work.

2. Algorithm Formulation

The algorithm first verifies whether or not overlap exists for each type of overlap based on a type-specific criterion, as thoroughly explained below:

a) Cross Channel

For this type of overlap to take place, the start and end frequencies of overlapped channels must comply with the following criteria:

$$f_{start-ch}^{int} < f_{end-ch}^{vic} \quad \& \quad f_{end-ch}^{int} > f_{start-ch}^{vic}$$

Where $f_{start-ch}^{int}$ and $f_{start-ch}^{vic}$ are the start frequencies (MHz) of intruder and victim, respectively, while f_{end-ch}^{int} and f_{end-ch}^{vic} are the end frequencies (MHz) of intruder and victim channels, respectively, and are found as follows:

$$f_{start-ch}^{int} = f_{start-block}^{int} + BW_{ch}^{int} \times \left(ARF_{ch}^{int} - ARF_{1st}^{int} \right) \tag{1}$$

$$f_{end-ch}^{vic} = f_{start-block}^{vic} + BW_{ch}^{vic} \times \left(ARF_{ch}^{vic} - ARF_{1st}^{vic} + 1 \right) \tag{2}$$

$$f_{end-ch}^{int} = f_{start-block}^{int} + BW_{ch}^{int} \times \left(ARF_{ch}^{int} - ARF_{1st}^{int} + 1 \right) \tag{3}$$

$$f_{start-ch}^{vic} = f_{start-block}^{vic} + BW_{ch}^{vic} \times \left(ARF_{ch}^{vic} - ARF_{1st}^{vic} \right) \tag{4}$$

Where $f_{start-block}^{int}$ and $f_{start-block}^{vic}$ are start frequencies (MHz) of intruder and victim blocks, BW_{ch}^{int} and BW_{ch}^{vic} are intruder and victim channels bandwidths (MHz), respectively, ARF_{ch}^{int} and ARF_{ch}^{vic} are Absolute Radio Frequency Channel Numbers ARFCN(s) of intruder and victim channels, respectively, and, finally, ARF_{1st}^{int} and ARF_{1st}^{vic} are ARFCN(s) of intruder and victim 1st channels in their corresponding blocks, respectively. As shown in Fig.1.

Accordingly, the cross-channel overlap bandwidth (MHz) can be found as follows:

$$BW_{cco} = Min\left| f_{end-ch}^{vic}, f_{end-ch}^{int} \right| - Max\left| f_{start-ch}^{vic}, f_{start-ch}^{int} \right| \tag{5}$$

From Eq. (5), the cross-channel overlap factor is expressed as below:

$$F_{cco} = {BW_{cco}} \big/ {BW_{ch}^{vic}} \tag{6}$$

Where F_{cco} is the cross channel factor, BW_{cco} is the cross channel overlap bandwidth (MHz) as found in Eq.(5) and BW_{ch}^{vic} is the victim channel bandwidth (MHz).

b) Adjacent Channel

Cells can operate in frequency blocks that are higher or lower than other block-contiguous cells. Consequently, three types of adjacent channel overlap scenarios are possible: adjacently overlapped on higher frequency (victim channel left side) , lower frequency channel (victim channel right side) or on both sides; such as the case when a TDD block of an operator is confined by the downlink and uplink FDD-blocks of another operator. Therefore, the following conditions apply:

On higher frequency side

$$f_{start-ch}^{\text{int}} < \left(BW_{ch}^{vic} + f_{end-ch}^{vic} \right) \ \& \ f_{end-ch}^{\text{int}} > f_{end-ch}^{vic}$$

On lower frequency side

$$f_{start-ch}^{\text{int}} < f_{start-ch}^{vic} \ \& \ f_{end-ch}^{\text{int}} > \left(f_{start-ch}^{vic} - BW_{ch}^{vic} \right)$$

When both logical statements return true values, corresponding overlap bandwidths are:

$$BW_{aco}^{H} = Min\left| \left(f_{end-ch}^{vic} + BW_{ch}^{vic} \right), f_{end-ch}^{\text{int}} \right| - Max\left| f_{end-ch}^{vic}, f_{start-ch}^{\text{int}} \right| \tag{7}$$

$$BW_{aco}^{L} = Min\left| f_{start-ch}^{vic}, f_{end-ch}^{\text{int}} \right| - Max\left| \left(f_{start-ch}^{vic} - BW_{ch}^{vic} \right), f_{start-ch}^{\text{int}} \right| \tag{8}$$

Where BW_{aco}^{H} and BW_{aco}^{L} are adjacent overlap bandwidths on higher and lower frequency (MHz) sides, respectively.
From Equations (7) and (8), total adjacent overlap factor can be expressed as below:

$$F_{aco} = \frac{BW_{aco}^{H} + BW_{aco}^{L}}{BW_{ch}^{vic}} \times \mathrm{F} \tag{9}$$

Where F_{aco} is the total adjacent overlap factor and F is the adjacent channel attenuation factor, i.e. victim receiver’s capability to attenuate adjacent interfering signals.

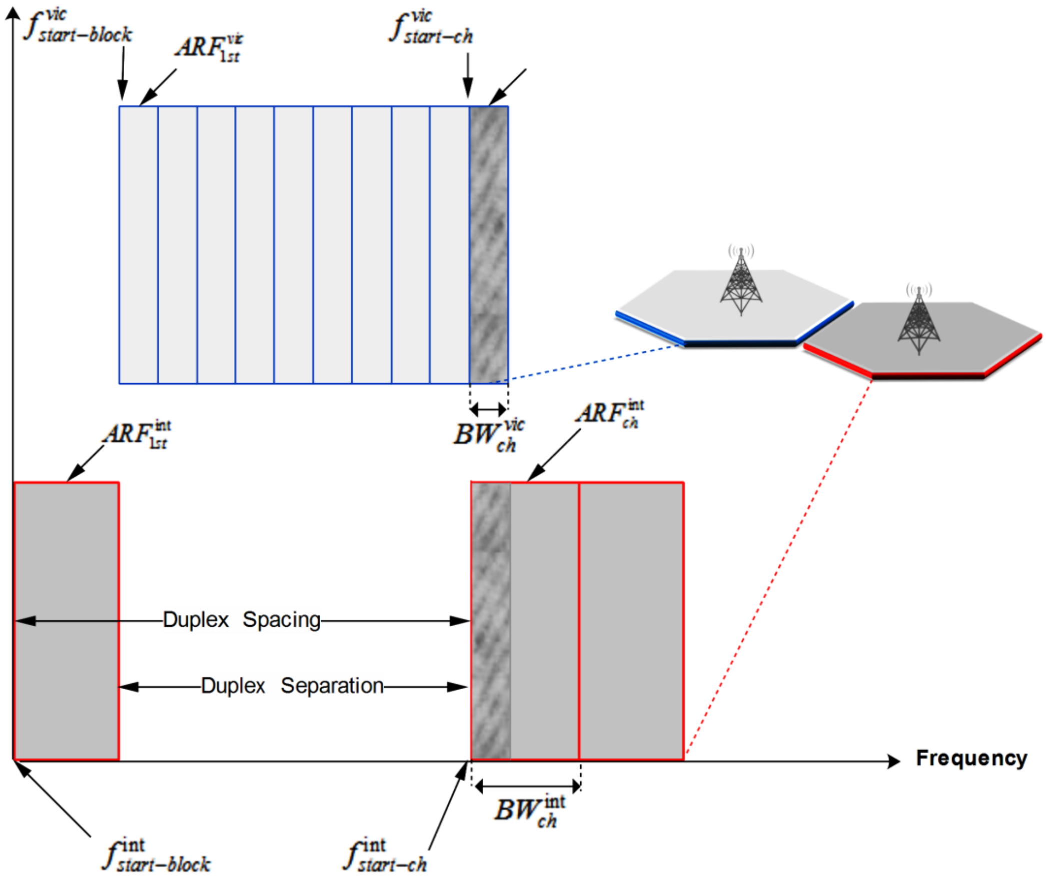

Figure 1. Algorithm's Basic Parameters

3. Areas of Applications

Broadly, the parameters tackled in this work are virtually available in any wireless system. Therefore, it is applicable to almost any network type. One example of this is channel overlap scenarios in Long term evolution (LTE) networks. Figure 2 shows two overlapped TDD and FDD LTE cells and Table 1 gives corresponding Evolved-Absolute Radio Frequency Channel Numbers (E-ARFCN) [3]. Outstandingly, around the 2.3 GHz band (Band 40), there is a significant frequency overlap (100MHz) between LTE TDD with Worldwide Interoperability for Microwave Access (WiMAX).

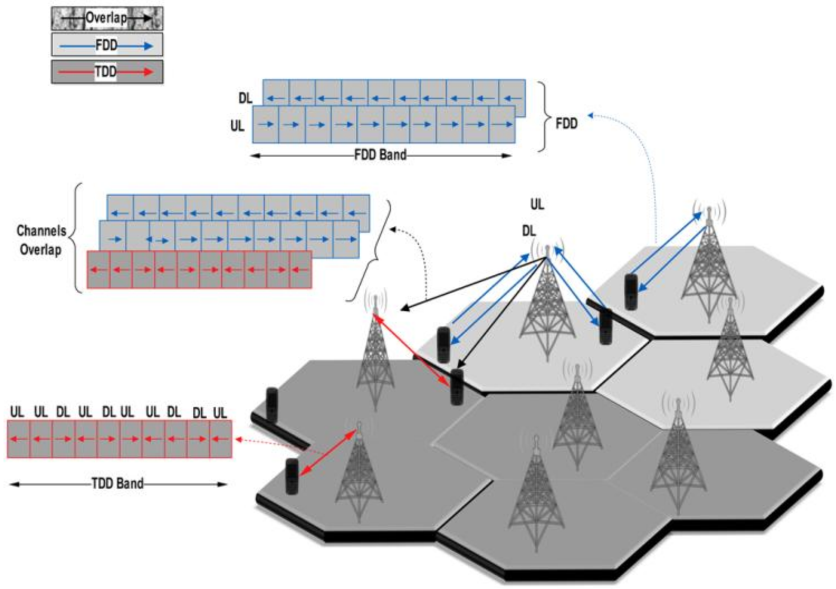

Figure 2. Two Overlapped LTE Cells (LTE-TDD with LTE-FDD)

Table 1. Some LTE Frequency Bands and their Channel

E-UTRA Band	Bandwidth UL (MHz)	E-ARFCN UL	Bandwidth DL (MHz)	E-ARFCN DL	Duplex Mode
1	1920-1980	13000 – 13599	2110-2170	0 – 599	FDD
2	1850-1910	13600 – 14199	1930-1990	600 - 1199	FDD
8	880-915	16450 – 16799	925-960	3450 – 3799	FDD
9	1749.9-1784.9	16800 – 17149	1844.9-1879.9	3800 – 4149	FDD
...	...	...	...	...	...
33	1900-1920	26000 – 26199	1900-1920	26000 – 26199	TDD
34	2010-2025	26200 – 26349	2010-2025	26200 – 26349	TDD
37	1910-1930	27550 – 27749	1910-1930	27550 – 27749	TDD

4. Conclusions

Frequency or channel overlapping scenarios are often incurred in wireless systems. However, the very congested spectrum along with re-farming strategies and coexistence deployments of communications networks escalate into more severe overlap values. In this paper, the two main types of overlap, cross and adjacent, have been tackled. The paper provided a means of diagnosing and measuring overlap occurrences in terms of affected bandwidth, victim's adjacent overlap attenuation factor and relevant channel numbers.

References

[1] Z. Shamsan and T. Rahman, "Point-Point Fixed Wireless and Broadcasting Services Coexistence with IMT-Advanced System", Progress In Electromagnetics, vol. 122, no. 2011, **(2012)**, pp. 537-555.

[2] Z. Shamsan and A. Al-Hetar, "Spectrum sharing studies of IMT-advanced and FWA services under different clutter loss and channel bandwidths effects", Progress In Electromagnetics, vol. 2007, **(2008)**, pp. 331-344.

[3] 3GPP TS 36.104, “Evolved Universal Terrestrial Radio Access (E-UTRA);Base Station (BS) radio transmission and reception(Release 8)”, (**2008)**.
[4] R. Ghaffar and R. Knopp, “Fractional frequency reuse and interference suppression for OFDMA networks”, in Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt), 2010 Proceedings of the 8th International Symposium on, **(2010)**, pp. 273–277.
[5] C. B. Rodriguez-Estrello and F. A. Cruz-Perez, “System level analytical model for SDMA mobile cellular networks considering cochannel interference”, 2009 IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications, **(2009)** September, pp. 1472-1476.
[6] Z. Yushu, H. Guo, X. Wang and X. Zhang, “Co-existence Analysis of LTE and WiMAX in Uplink”, in Wireless Communications Networking and Mobile Computing (WiCOM), 2010 6th International Conference on, **(2010)**, pp. 1–4.
[7] R. Chávez-Santiago, E. Gigi and V. Lyandres, “Channel assignment for cellular mobile networks with nonuniform cells-an improved heuristic algorithm”, in Communications, IEE Proceedings-, vol. 153, no. 1, **(2006)**, pp. 61–68.
[8] M. A. Nguyen and A. I. Zaghloul, “On the Characterization of Cochannel Interference in an Aeronautical Mobile Environment”, IEEE Transactions on Vehicular Technology, vol. 56, no. 2, **(2007)** March, pp. 837-848.
[9] M. Raghavendra, M. Juntti and M. Myllyla, “Co-channel interference mitigation for 3G LTE MIMO-OFDM systems”, in Communications, 2009. ICC’09, IEEE International Conference on, **(2009)**, pp. 1–5.
[10] H. R. Karimi and G. Lapierre, “On the impact of adjacent-channel interference from TDD terminal stations to FDD terminal stations in the 2500–2690 MHz band”, 2009 Global Mobile Congress, **(2009)** October, pp. 1-6.

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