Coexistence between Radar and LTE-U Systems: Survey on the 5 GHz Band

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Abstract— **LTE (Long Term Evolution) technology is unarguably becoming the primary standard for 4G cellular networks. But due to the tremendous growth in data traffic, LTE for Unlicensed Spectrum (LTE-U) has been proposed to allow cellular network operators to meet such high demands in data traffic. The initial studies for the choice of the unlicensed frequency bands for LTE-U suggested using the 5 GHz frequency band. The 5 GHz band is mainly occupied by different radar systems and by the 802.11 technology (Wi-Fi). There are different regulations imposed by the Federal Communication Commission (FCC) for each sub-band of the 5 GHz band to allow fair spectrum sharing. In this paper, we present a survey about the RF regulations and the different radar types within the different sub-bands of the 5 GHz band and we introduce the major approaches for spectrum sharing techniques.**

I. Introduction

Billions of people rely on wireless infrastructures for communication and connectivity. As of June 2015, there are an estimated 7.226 billion users subscribing to cellular service [1]. Cellular networks provide a myriad of useful and desirable services such as high-speed data links, teleconferencing, cyber collaboration, and video streaming. Accordingly, data traffic demand in cellular networks has been tremendously growing and has led to creating congested RF environment. The Long Term Evolution (LTE) and LTE-Advanced (LTE-A) have been standardized by the 3rd Generation Partnership Project (3GPP) to become highly flexible 4G radio system that enables cellular network operators to meet such high demands in data traffic.

On the other hand, given how congested the RF spectrum has become, innovative approaches for spectrum sharing have been proposed and implemented to accommodate several systems within the same frequency band. Currently, there are different access technologies are utilizing the unlicensed bands, namely the 2.4 GHZ ISM (Industrial, Scientific and Medical) and 5 GHz U-NII (Unlicensed National Information Infrastructure) bands. These bands were traditionally unsuitable for LTE. However due to the Career Aggregation (CA) feature, and to further expand the LTE capacity to meet this high traffic demand, LTE for Unlicensed Spectrum (LTE-U) has been proposed [2]. The initial studies for the choice of the unlicensed frequency bands for LTE-U suggested using the 5 GHz frequency. For the LTE to be used in the 5 GHz band, certain changes need to be done to the LTE standard and it is expected that these changes will be incorporated in LTE Release 13, which could be released by early 2016. The LTE-U will be designed to be integrated with the licensed carriers and to coexist with the different systems within the 5 GHz band [3].

In this paper, we present a survey about the general RF regulations within the different sub-bands of the 5 GHz spectrum that are imposed by the Federal Communication Commission (FCC) in the United States, we present the different radar types within the 5 GHz band, and we investigate the spectrum sharing approaches that can be used to allow the LTE-U to coexist with the radar systems at the 5 GHz band.

II. 5 GHz Allocation in the United States

The 5 GHz band is subdivided into 3 sub-bands as shown in Fig. 1 [4]:

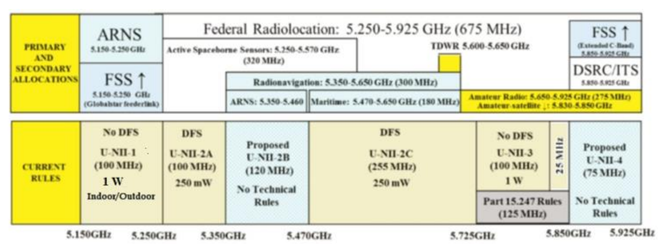

Fig. 1. 5 GHz allocations in the United States [4].

A. *U-NII-1 (5150-5250 MHz)*

U-NII-1 is reserved in the United States for Fixed Satellite Service (FSS) (earth-to-space) for non-Federal Mobile Satellite Service (MSS) feeder link operations. In April 2014, the FCC has changed the requirements for U-NII devices in this band and allowed the U-NII devices to work both indoor and outdoor, and has increased the maximum allowable transmit power to be 1 W [4].

B. *U-NII-2 (5250-5725 MHz)*

The sub-band U-NII-2 band is further subdivided into three sub-bands as follows:

- U-NII-2A (5250-5350 MHz)
- U-NII-2B (5350-5470 MHz)
- U-NII-2C (5470-5725 MHz)

For sub-bands U-NII-2A and U-NII-2C, spectrum sharing is allowed, given that the U-NII devices enable Dynamic Frequency Selection (DFS) technology for radar detection. Also the FCC mandates the maximum allowable transmit power to be 250 mW. For sub-band U-NII-2B, spectrum sharing is not allowed [4].

For any device to be certified to work in bands U-NII-2A or U-NII-2C, the device must have DFS feature. DFS is a mechanism that enables the device to avoid introducing interference to non-IMT systems (International Mobile Telecommunications), such as radar systems. DFS mandates that the U-NII device much check the channel for 60 seconds before using it and must continuously monitor the channel during operation. Once the radar has been detected, the operating channel must be vacated within 10 seconds and the device must not utilize that channel for 30 minutes.

C. *U-NII-3 (5725-5850 MHz)*

Spectrum sharing is allowed in the U-NII-3 sub-band without the requirement of using DFS. The FCC mandates limiting the maximum transmit power to 1 W and the maximum power spectral density to be 30 dBm/500 KHz. Also FCC mandates the antenna gain to be a maximum of 6 dBi, and 1 dB in power reduction is required for every 1 dB increase in antenna gain above 6 dBi.

D. *U-NII-4 (5850-5925 MHz)*

U-NII-4 sub-band is restricted from usage by U-NII devices. In 2003, the 5.850-5.925 GHz band has been licensed for Dedicated Short Range Communications (DSRC) Service in the Intelligent Transportation Systems (ITS). The DSRC Service involves vehicle-to-vehicle and vehicle-to-infrastructure communications, helping to protect the safety of the traveling public.

III. Radar Types Within The 5 GHz Band

There are different radar types within the different sub-bands of the 5 GHz band. The radiolocation radars are the main ones spanning the frequency range 5250-5950 MHz. The aeronautical radio-navigation radars are operating within U-NII-2B. The maritime radio-navigation radars are operating within the frequency band 5470-5650 MHz. The Terminal Doppler Weather (TDWR) radars are operating within the frequency range 5600-5650 MHz [5].

On the other hand, the Department of Defense (DoD) uses the 5 GHz frequency band for different radar systems and other communications links. The radar systems are mainly Range and Tracking Radars, Tactical Anti-Air Warfare Radar Systems, Navigation Radars, or Weather Radars [6]. Consequently, there is a need to develop innovative sharing techniques to mitigate the effect of potential and imminent interference issues between the radar systems and the LTE-U systems.

IV. Spectrum Sharing Techniques

A. *General Regulations*

The general regulations to allow fair usage of the shared spectrum can be summarized as follows [7]:

- Limit the maximum allowable transmit power to a certain threshold.
- Limit the U-NII device to be used indoor only or allow the usage to be either indoor or outdoor.
- Dynamic Frequency Selection (DFS).
- Listen Before Talk (LBT): In many markets in the world (Europe, Japan, Korea), there is a requirement for fair usage of the unlicensed spectrum among IMT systems, where the equipment will periodically check the spectrum (few microseconds) then start transmitting for few milliseconds (<13 ms).
- Transmission Power Control (TPC): where the U-NII device must use power control to restrict the power leakage to neighbour bands.

B. *Spectrum Sensing*

In order for devices to use DFS, an algorithm for spectrum sensing needs to be used. Spectrum sensing algorithms are usually based on transmitter detection and can be categorized as follows [6]:

- Energy Detection: compares the energy received in a given bandwidth with pre-defined threshold. This algorithm does not require knowing the nature of the signal transmitted but does not perform well under low SNR conditions.
- Matched Filter: correlates the received signal with known signal. This algorithm requires knowing the characteristics of signal transmitted and performs well in low SNR conditions.
- Cyclostationary Feature Detection: couples the received modulated signals with sine wave carriers, pulse trains or repeating spreading based on knowing a certain feature of the received signal. The signal detection is performed by analyzing a spectral correlation function.

References

[1] GSA (The Global mobile Suppliers Association), Fast Facts, [Online]. Available: http://www.gsacom.com/news/gsa_fastfacts.php4

[2] Qualcomm, "LTE in unlicensed spectrum: Harmonious coexistence with Wi-Fi," White Paper, June 2014.

[3] Signals Research Group, "The Prosect of LTE and Wi-Fi Sharing Unlicensed Spectrum," White Paper, Feb 2015. [Online] available: http://www.signalsresearch.com/Docs/LTE%20U%20SRG_whitepaper_120214.pdf

[4] Federal Communications Commission (FCC), "Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band", April 1, 2014.

[5] International Telecommunication Union, "Characteristics of and protection criteria for sharing studies for radiolocation (except ground based meteorological radars) and aeronautical radionavigation radars operating in the frequency bands between 5 250 and 5 850 MHz", Recommendation ITU-R M.1638-1, M-Series, January 2015.

[6] Rebecca Blank and Lawrence E. Strickling, "Evalution of the 5350-5470 MHz and 5850-5925 MHz Bands Pursuant to Section 6406(b) of The Middle Class Tax Relief And Job Creation Act of 2012" Department of Commerce, January 2013.

[7] Huawei, "U-LTE: Unlicensed spectrum utilization of LTE," White Paper, Feburary 2014. [Online]. available: www.huawei.com/ilink/en/download/hw_327803