Technical Disclosure Commons

Defensive Publications Series

May 2020

Wi-Fi and Cell Coexistence Mechanism Accounting for Co-Interference

Sriram Sundararajan

Jibing Wang

Nick McDonnell

Nihar Jindal

WI-FI AND CELL COEXISTENCE MECHANISM ACCOUNTING FOR CO-INTERFERENCE

Abstract

Co-interference between Wi-Fi and cellular radios, *e.g.*, in a wireless communication device that is concurrently operating using Wi-Fi and cellular radio technologies, is managed using victim tables that indicate channels that can potentially co-interfere. The victim tables are implemented as lookup tables (LUTs) that include entries for combinations of cell band and Wi-Fi and/or channel. The entries indicate whether the Wi-Fi channel is safe or should be avoided because there is a high likelihood of co-interference. The entries also include a power back off that indicates that the Wi-Fi subsystem is to back off its transmission power setting by a specified amount to become a safe channel.

Background

Wireless communication systems include a network of cells (also referred to as base stations or access points) that provide wireless connectivity to user equipment within the network. The cells operate according to different radio access technologies (RATs) including cellular RATs that are served by base stations that operate according to protocols such as Fourth Generation (4G) protocols including Long Term Evolution (LTE) protocols and Fifth Generation (5G) protocols. In some cases, the cells are used to implement a wireless wide area network (WWAN) that transfers data using mobile communication cellular network technologies including 4G/LTE and 5G. A subset of the cells operates according to other RATs such as Wi-Fi. In some cases, a single device such as a smart phone is concurrently supporting communication via radios that operate according to multiple RATs. For example, the smart phone can be configured as a Wi-Fi hotspot that provides Wi-Fi coverage to nearby smart phones and connects the nearby smart phones to the network via a cellular communication channel. The

devices that operate according to the different RATs typically operate in different frequency bands that support one or more channels for communication. For example, Wi-Fi access points (or a smart phone operating as a Wi-Fi hotspot) can provide connectivity via channels in the 2.4 GHz and/or 5 GHz bands. Base stations and smart phones that operate according to the 4G/LTE standards support connectivity on channels in numerous bands including 2.1 GHz and 2.3 GHz, as well as other bands at higher and lower frequencies.

Devices that operate concurrently in the same geographic area (or overlapping geographic areas) using different RATs can interfere with each other. For example, signals conveyed by different radios in a smart phone via bands or channels at neighboring frequencies can cause leakage between the bands/channels that are being used by radios that operate according to different RATs. Harmonics or inter-modulation effects can generate interference at frequencies outside the band or channel being used by the radios. For example, harmonics of the frequency of an LTE or Wi-Fi channel can fall into the band of another LTE or Wi-Fi channel. For another example, inter-modulation between the signals transmitted at frequencies used in different bands that are aggregated (*e.g.*, during carrier aggregation of multiple bands or channels) can produce interference that falls into other bands. Use cases for concurrent operation include a phone that concurrently operates as a Wi-Fi hotspot and voice over LTE being used concurrently with Internet browsing over Wi-Fi.

Reducing power is sometimes used to mitigate interference between a wireless local area network (WLAN) and an LTE receiver, *e.g.*, as disclosed in U.S. Patent Application Publication No. 2015/0215811, entitled "Joint WLAN power and rate control to mitigate co-located LTE TDD interference." Multi-radio coexistence is supported by defining time/frequency masks to schedule radios based upon historical frequency usage information and historical time usage

information for the radios, *e.g.*, as disclosed in U.S. Patent No. 9,596,693, entitled "Method and apparatus for multi-radio coexistence."

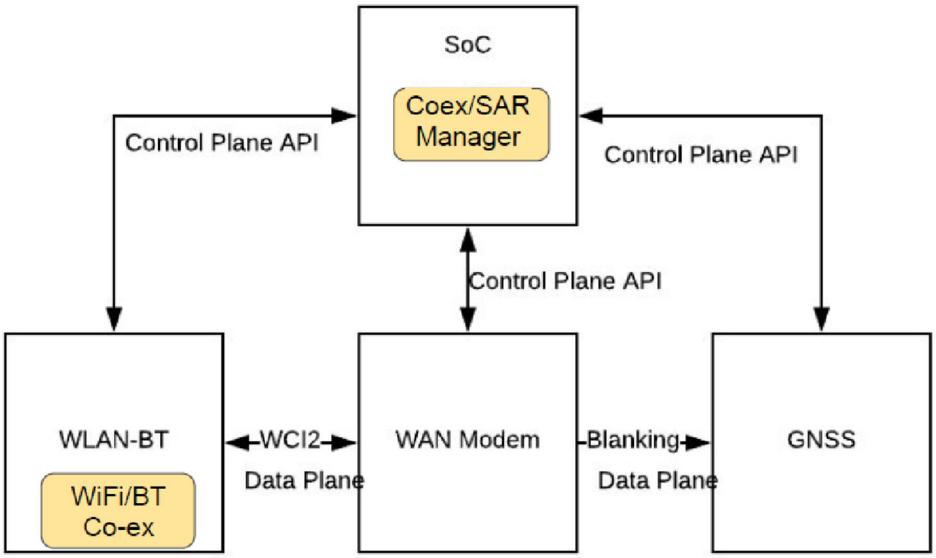
Description

Co-interference is managed using a set of "victim tables" that indicate channels that can potentially co-interfere when multiple radios are operating concurrently within the same device such as a smart phone in interfering bands or channels. In some cases, the victim tables are implemented as lookup tables (LUTs) that include entries for combinations of cell bands and Wi-Fi channels. The entries indicate whether the Wi-Fi channel is safe, *e.g.*, unlikely to be victimized by co-interference from another channel, or whether the Wi-Fi channel should be avoided because there is a high likelihood of co-interference. The entries also include a power back off that indicates that the Wi-Fi subsystem is to back off its transmission power setting by a specified amount to become a safe channel. Table 1 illustrates a portion of an LUT that includes entries for a 2.1 GHz WWAN band and three Wi-Fi channels.

Table 1

WWAN Band (GHz)	Wi-Fi Band	Wi-Fi BW (Hz)	Wi-Fi Channel	Avoidance (0=No, 1-Yes)	Power Backoff (dB)
2.1	20	20	1	0	0
2.1	20	20	2	0	0
2.1	20	20	3	0	0

Tables such as the LUT shown in Table 1 are used by coexistence managers implemented within the wireless communication system. An example architecture including coexistence (Co-Ex) managers is shown in the figure below:

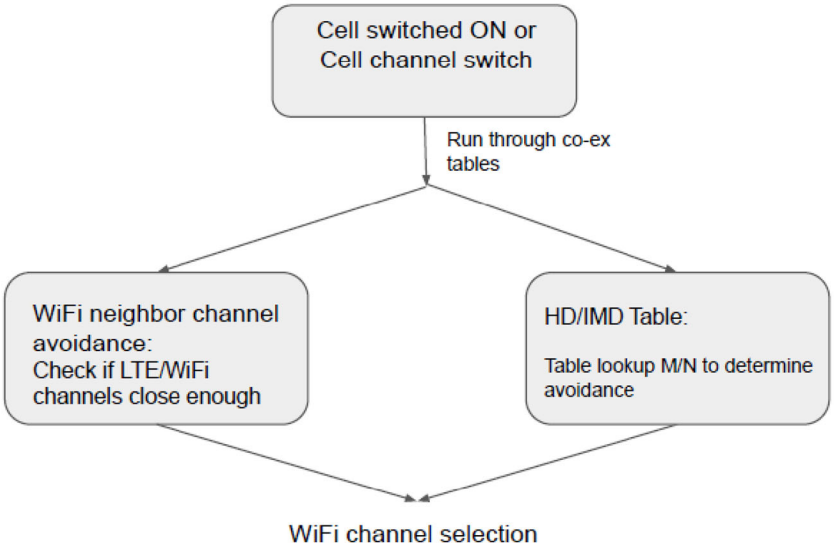


The victim table is determined statically before the product ships (as described in the next paragraph). The WiFi-channel blacklist is computed based upon the entries in the victim table. For example, a Wi-Fi channel is blacklisted (so that the channel is unavailable for use) if the frequency separation between the Wi-Fi channel and an LTE channel in the WWAN is less than a threshold value. In some cases, the blacklisted channels can be allowed if the channels are operated with a specified power backoff as indicated in the victim table. In the case of carrier aggregation, the same co-existence logic may be used for each of the primary and secondary carriers.

A victim table is populated according to the following flow. First, the de-sense team determines the harmonics and inter-modulation frequencies that impact radios that operate according to different RATs such as LTE/4G and Wi-Fi. A system team then determines priorities of the radios or RATs. The system team also determines how to fill in the victim table.

The victim table can potentially be different on a per device/SKU basis. The victim table is read in by software to implement channel avoidance logic.

The following flow chart illustrates how a Wi-Fi channel is selected based on the victim tables.



The Wi-Fi channel selection is performed based on the results of checking the two victim tables on the branches of the flowchart. The system attempts to choose channels that are not blacklisted by either of the victim tables. However, if all the Wi-Fi channels are blacklisted, then a default Wi-Fi channel is used. Other Wi-Fi channels and/or other frequency bands can also be used. For example, if all the 2.4 GHz channels are blacklisted, a 5 GHz channel is selected. If choosing a 5 GHz band is not an option, the default Wi-Fi channel is used. Bands or channels can also be selected based on priorities indicated in the victim tables, *e.g.*, bands/channels that have relatively high priorities are preferentially selected instead of bands/channels that have relatively low priorities.

An analytical (formula-based) approach can also be used to determine whether to avoid a channel. The formula for determining whether to avoid or not avoidance channel is determined

as a function of the bandwidth of the LTE cell channel and the bandwidth of the Wi-Fi channel. In some cases, the function considers a predetermined number of harmonics (such as second and third order harmonics) and a predetermined number of intermodulation frequencies, such as a third order intermodulation. Parameter-based approaches can also be used to check whether harmonics of a cell frequency fall within the bandwidth of a Wi-Fi victim and whether intermodulation frequencies from the Wi-Fi bands fall within a band of an LTE victim cell. The parameters for the function used to compute the harmonics are also part of the victim table.