

Chapter 2

Requirements and Regulations in the 5 GHz Unlicensed Spectrum

Licenses and fees are not required for operators to use the 5 GHz unlicensed spectrum. However, in order to avoid interference and to ensure a fair use of this resource, numerous requirements and regulations are imposed by national and international organizations. When operating in this band, the emerging U-LTE technology needs to adhere to these regulations, as any other existing technologies, especially IEEE 802.11/Wi-Fi, would. This chapter provides an overview on the radio spectrum resources in these bands and the related management and allocation concerns. It then summarizes a number of the key requirements and regulations specified by the European Telecommunications Standards Institute (ETSI) and the Federal Communications Commission (FCC) on radio channels, operating channel selection, transmission power, and channel access rules. These technical details are the baselines to be followed when designing medium access control protocols for U-LTE and any other technologies operating in the 5 GHz unlicensed radio band.

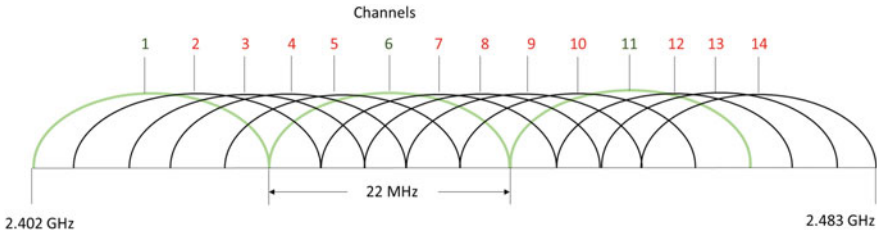
2.1 Radio Spectrum Management: An Overview

The radio frequency (RF) spectrum is the part of the electromagnetic spectrum from 3 Hz to 3000 GHz (3 THz). Radio waves in this frequency range are widely used in modern technologies, especially in telecommunications. The radio spectrum is divided into different chunks or bands, each of which can be used by one or multiple technologies. Radio Frequency Interference (RFI) can disrupt and disturb the normal functioning of devices, and thus, it is always important to avoid or keep the RFI within acceptable levels. For this, the generation and transmission of radio waves is strictly regulated by national laws, coordinated by international organizations, e.g., Federal Communications Commission (FCC), Inter-American Telecommunication Commission (CITEL), International Telecommunication Union (ITU), and the European Telecommunications Standards Institute (ETSI).

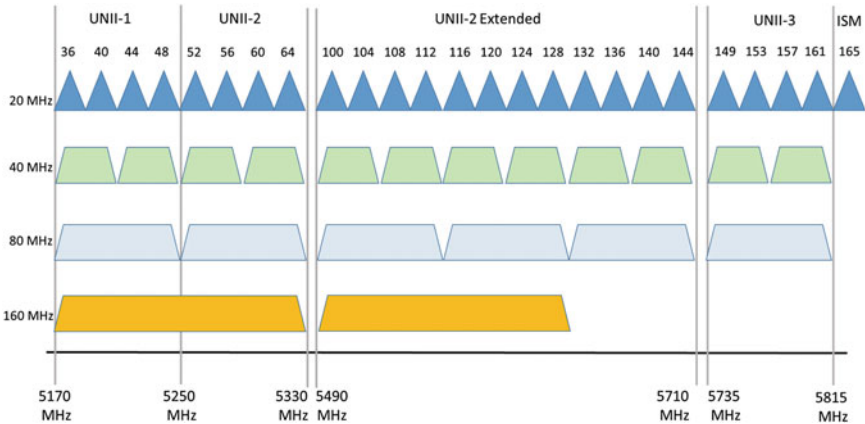
Most countries consider RF spectrum to be a national resource. The process of regulating the use of this resource is spectrum management or allocation. Spectrum allocation varies by country and/or regulatory domain. In the USA, for example, the FCC regulates interstate communications by radio, television, wire, satellite, and cable in all states and territories. From a management perspective, radio bands are categorized into *licensed* and *unlicensed*. Licensing is a way of ensuring that wireless operators do not interfere with each other by giving each of them the exclusive use of one or more bands in given geographical areas, over a set period of time. Licensed bands are mainly sold or assigned to operators through a spectrum auction process. These licensed spectrum allocations are primarily used by the television broadcasting, commercial radio, and cellular voice and data industries. Operating in their own licensed bands, operators can avoid RFI from other users and thus guarantee the quality of services they deliver to their subscribers. However, licensing would be very impractical for certain use cases, such as communications between cordless handsets and base units. Instead, such wireless technologies transmit radio signals in unlicensed frequency bands—usually the Industrial, Scientific and Medical (ISM) band defined by the ITU radio regulations and allocated in most countries for free use by anyone without any licenses and fees. Unlicensed bands enable numerous technologies and products, e.g., Wi-Fi, Bluetooth, and many other low-power short-range communications technologies. These bands are open sandboxes where users can operate without the high barriers to entry, such as cost, that are seen in the licensed spectrum bands. The availability of unlicensed bands provides a platform for innovation, a greenfield space for technology startups and entrepreneurs, as well as established companies. Internet of Things (IoT)—the development and deployment of networking technologies that provide connectivity to everyday objects for many innovative applications—is fundamentally enabled by unlicensed spectrum.

Today, most people are within a few meters of consumer products (e.g., microwave ovens, Wi-Fi, and Bluetooth) that use the unlicensed bands. In other words, there is a great chance for RFI in these bands. As a result, even though no permission is required for the use of unlicensed bands, manufacturers and users must comply with numerous rules and regulations (related to transmission power, transmission time, etc.) in order to minimize RFI to others as well as to ensure a fair sharing of the radio resource in these bands. IEEE 802.11/Wi-Fi is the most successful and popular technology operating in unlicensed spectrum. Wi-Fi manufacturers need to obtain compliance certifications from Wi-Fi Alliance whose certification program is designed following rules imposed by radio spectrum management organizations/authorities such as ETSI and FCC.

The two most widely used unlicensed bands are 2.4 and 5 GHz. These two bands have their own advantages and disadvantages in various perspectives. 5 GHz band provides faster data rates at a shorter distance, whereas 2.4 GHz band offers coverage for greater distances but supports lower rates. New technologies, particularly unlicensed LTE variants including LTE-U, LAA-LTE, and MulteFire, as mentioned in Chap. 1, have been targeted to operate in the 5 GHz band alongside Wi-Fi. The selection of the 5 GHz band for U-LTE technologies (rather than the 2.4 GHz band) is mainly due to the following reasons:



(a) 2.4 GHz band



(b) 5GHz band

Fig. 2.1 2.4 and 5 GHz unlicensed spectrums

- *More available channels:* In the 2.4GHz band, only 14 channels, each of which provides 20 MHz of bandwidth, are defined. In USA (or Europe), only 11 (or 13) of those channels are legally available. However, those channels overlap excessively with one another. Due to this overlapping, the maximum possible number of parallel independent connections is limited to 3 channels (channels 1, 6, and 11). In the 5 GHz band, there are 21 nonoverlapping 20 MHz channels (or 9 nonoverlapping 40 MHz channels). Figure 2.1 depicts spectrum analyzer views of radio channels defined in 2.4 and 5 GHz bands, respectively.
- *Lower level of interference:* Since the 2.4 ISM band was released for Wi-Fi technology use more than fifteen years ago, this band is overcrowded with billions of existing Wi-Fi devices. There are also many consumer products which use this band, including microwave ovens, cordless phones, baby monitors, and garage door openers. In contrast, the relatively recent release of the 5 GHz band for private use makes this band much less crowded and thus having a much lower level of RFI.
- *Higher performance:* The 5 GHz band operates on a larger spectrum and does not suffer the overcrowding. Therefore, compared to the 2.4 GHz band, each channel

in the 2.4 GHz band allows for much better spectrum efficiency and higher data rates.

As mentioned, any technology operating in unlicensed bands needs to comply with existing rules and regulations in order to limit RFI and to ensure that it does not unfairly grab a larger portion of the shared spectrum. Coexistence is one of the most notable concerns when U-LTE technology is introduced into the 5 GHz unlicensed band considering the sheer number of Wi-Fi devices and networks that have been deployed in the same band for everyday applications in homes, offices, and campuses. Since the number of wireless devices using the 5 GHz band has grown rapidly over the last few years, ETSI has updated its related regulations. For background knowledge necessary for developments of radio channel access protocols for U-LTE and Wi-Fi technologies in this band, the following sections summarize a number of key requirements and mechanisms presented in ETSI EN 301 893. Specifically, the available frequency channels, transmission power, and channel access mechanisms are explained in detail.

2.2 Frequency Channels

The ETSI EN 301 893 V1.7.2 regulations [1] released in July 2014 define three unlicensed frequency bands:

- RLAN band 1: 5150–5350 MHz, divided into 2 sub-bands
 - Sub-band I: 5150–5250 MHz. This sub-band is comparable to FCC U-NII-1.
 - Sub-band II: 5250–5350 MHz. This sub-band is comparable to FCC U-NII-2.
- RLAN band 2: 5470–5725 MHz. This band comparable to FCC U-NII-2 extended (U-NII-2e).
- RLAN band 3, also known as Broadband Radio Access Networks (BRAN): 5725–5875 MHz. This sub-band is comparable to FCC U-NII-3 (5725–5825 MHz) band with a higher upper frequency range.

The radio channels defined in the 5 GHz band by ETSI 301 893 standard (with a reference to FCC regulations) are summarized in Fig. 2.1b. Technical details and the availability of each channel in four main regions (USA, Europe, Japan, and China) are presented in Fig. 2.2.

2.3 Transmission Power

Each of the bands defined by ETSI EN 301 893 V1.7.2 regulations [1] has different maximum allowable transmission power levels. Note that the RF output power is defined as the mean Equivalent Isotropically Radiated Power (EIRP) of the equipment during a transmission burst. In general, the limits are valid for the device with antenna gain and cable loss and not only the output power of WLAN module.

Channel Number	Center Frequency	U.S	Europe	Japan
36	5180	Yes	Indoors	Yes
38	5190	No	No	Client Only
40	5200	Yes	Indoors	Yes
42	5210	No	No	Client Only
44	5220	Yes	Indoors	Yes
46	5230	No	No	Client Only
48	5240	Yes	Indoors	Yes
52	5260	DFS	Indoors/DFS/TPC	DFS/TPC
56	5280	DFS	Indoors/DFS/TPC	DFS/TPC
60	5300	DFS	Indoors/DFS/TPC	DFS/TPC
64	5320	DFS	DFS/TPC	DFS/TPC
100	5500	DFS	DFS/TPC	DFS/TPC
104	5520	DFS	DFS/TPC	DFS/TPC
108	5540	DFS	DFS/TPC	DFS/TPC
112	5560	DFS	DFS/TPC	DFS/TPC
116	5580	DFS	DFS/TPC	DFS/TPC
120	5600	No	DFS/TPC	DFS/TPC
124	5620	No	DFS/TPC	DFS/TPC
128	5640	No	DFS/TPC	DFS/TPC
132	5660	DFS	DFS/TPC	DFS/TPC
136	5680	DFS	DFS/TPC	DFS/TPC
140	5700	DFS	DFS/TPC	DFS/TPC
149	5745	Yes	SRD	No
153	5765	Yes	SRD	No
157	5785	Yes	SRD	No
161	5805	Yes	SRD	No
165	5825	Yes	SRD	No

Fig. 2.2 Details of 5 GHz unlicensed channels in different regions

2.3.1 RLAN Band 1 (5150–5350 MHz)

2.3.1.1 Indoor-Only Sub-band I (5150–5250 MHz)

The first RLAN sub-band includes the channels 36–48 and has an EIRP power limit to 23 dBm (200 mW). These channels are considered for indoor-only usage and do not require any Dynamic Frequency Selection (DFS) or Transmit Power Control (TPC) features.

2.3.1.2 Indoor-only Sub-band II (5250–5350 MHz)

In the second sub-band of the RLAN band 1 with channels 52 to 64, ETSI has set the EIRP power limit to 23 dBm (200 mW) for devices with TPC and 20 dBm (100 mW) for devices without TPC. For a device with TPC, the mean EIRP at the lowest power

level of the TPC range must not exceed 17 dBm (50 mW). This band requires DFS support (and requires TPC support in Europe and Japan).

2.3.2 RLAN Band 2 (5470–5725 MHz)

Channels from 100 to 140 are part of the second RLAN band and have an EIRP power limit of 30 dBm (1000 mW) for devices with DFS and TPC support, 27 dBm (500 mW) for non-TPC devices, and 20 dBm (100 mW) for devices with neither TPC or DFS support. The mean EIRP power level for a slave device with TPC must not exceed 24 dBm at the lowest TPC power level if the device is also capable of radar detection or 17 dBm otherwise.

2.3.3 BRAN (5725–5875 MHz)

ETSI has restricted the channels 155–171 for Broadband Wireless Access (BWA) use only. The idea is to provide Internet access to locations without any wired access network available. The maximum EIRP output power has been set to 36 dBm (4000 mW) with the limitation of RF power into antenna of 30 dBm (1000 mW).

2.4 Transmission Power Control

Dynamic adjustment of the transmission power is intended to reduce RFI. Dynamically adjusting the transmission power facilitates the shared use of the 5250–5350 MHz and 5470–5725 MHz frequency bands with satellite services. TPC determines the minimum transmission power necessary to maintain the connection with the partner (such as an access point).

If TPC is not used within these frequency bands, the highest permissible average EIRP and the corresponding maximum EIRP density are reduced by 3 dB. This restriction does not apply to the frequency range of 5150–5350 MHz. Without DFS and TPC, a maximum of only 30 mW EIRP is permitted. When DFS and TPC are used, a maximum 1000 mW EIRP is permitted as the transmission power (compared with 100 mW with 802.11 b/g, 2.4 GHz, DFS and TPC are not possible here). The higher maximum transmission power not only compensates for the higher attenuation of 5 GHz radio waves in air, but also makes noticeably longer ranges possible than in the 2.4 GHz range.

2.5 Dynamic Frequency Selection

DFS was stipulated to (i) detect interference from radar systems (radar detection) and to avoid co-channel operation with these systems and (ii) to provide, on aggregate, a near-uniform loading of the spectrum (Uniform Spreading). DFS is stipulated for the frequency ranges of 5250–5350 MHz and 5470–5725 MHz. It is optional for the frequency range of 5150–5250 MHz.

DFS initially assumes that no channel is available in the corresponding frequency band. The WLAN device selects an arbitrary channel at the start and performs what is known as a Channel Availability Check (CAC). Before transmitting on a channel, a Channel Observation Time (COT) of 60 s is observed to allow a check to see whether a different device is already working on this channel and the channel is therefore occupied. If the channel is occupied, then a different channel is checked by the CAC. If not, then the WLAN device can perform its transmission operation. Even during operation, a check is run to see whether a primary application such as a radar device is using this channel. This exploits the fact that radars frequently work according to the rotation method, whereby a tightly bundled directional transmission signal is transmitted by a rotating antenna. A remote receiver perceives the radar signal as a short pulse (radar peak). If a device receives such a radar peak, then it pauses the transmission operation and monitors the channel for further pulses. If additional radar peaks occur during the COT, then a new channel is selected automatically. A check of this type is required to be carried out every 24 h. This is why interrupting the data transmission for 60 s is unavoidable.

2.6 Channel Access Mechanisms

In order to avoid channel collisions when two or more than two devices transmit the signal in the same channel at the same time, Listen-Before-Talk (BLT) strategy is employed. ETSI EN 301 893 V1.7.2 [1] describes two mechanisms that require equipment or a device to apply CCA before using the channel. The first mechanism is frame based equipment (FBE) which defines a fixed (not directly demand-driven) timing frame for channel access. The second mechanism is load based equipment (LBE) which defines demand-driven timing frame.

2.6.1 FBE-Based Mechanism

A simplified flowchart and an illustrative example of the channel access procedure used for FBE are given in Figs. 2.3 and 2.4, respectively.

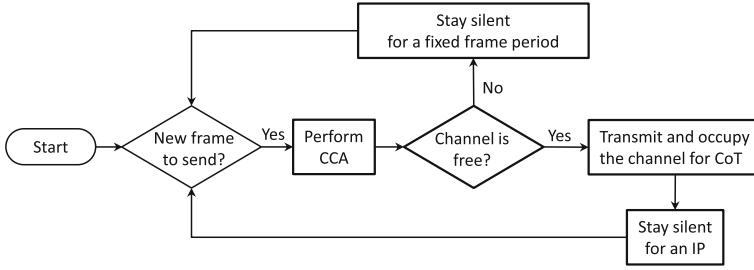


Fig. 2.3 Simplified flowchart of FBE

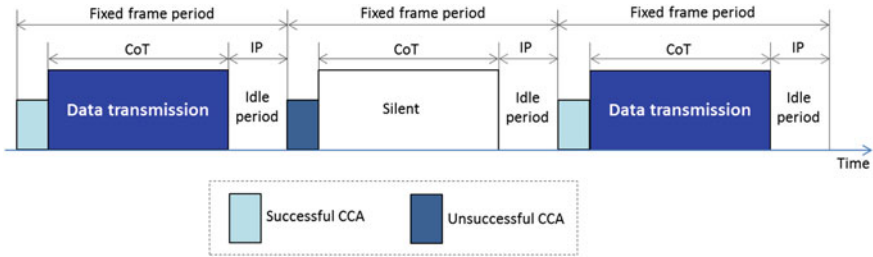


Fig. 2.4 An illustrative example of FBE

FBE shall comply with the following requirements:

- *R1*: Before starting transmissions on an operating channel, the equipment shall perform a CCA check using energy detect (ED). The equipment shall observe the channel for the duration of the CCA observation time. The operating channel shall be considered occupied if the energy level in the channel exceeds the threshold corresponding to the power level.
- *R2*: If the CCA procedure finds that the channel is clear, the equipment may transmit immediately and occupy the channel for a fixed time period.
- *R3*: If the CCA procedure finds that the channel is occupied, the equipment shall not transmit on that channel during the next fixed frame period.
- *R4*: The total time during which the equipment has transmissions on a given channel without re-evaluating the availability of that channel is defined as the *Channel Occupancy Time* (CoT).
- *R5*: After occupying the channel for CoT, the equipment keeps silent and waits for a short time, namely *Idle Period* (IP).
- *R6*: Toward the end of the idle period, the equipment shall perform a new CCA procedure as described in *R1* above.
- *R7*: The equipment, upon correct reception of a packet which was intended for this equipment, can skip CCA and immediately proceed with the transmission of management and control frames, e.g., acknowledgment (ACK) and block ACK frames.

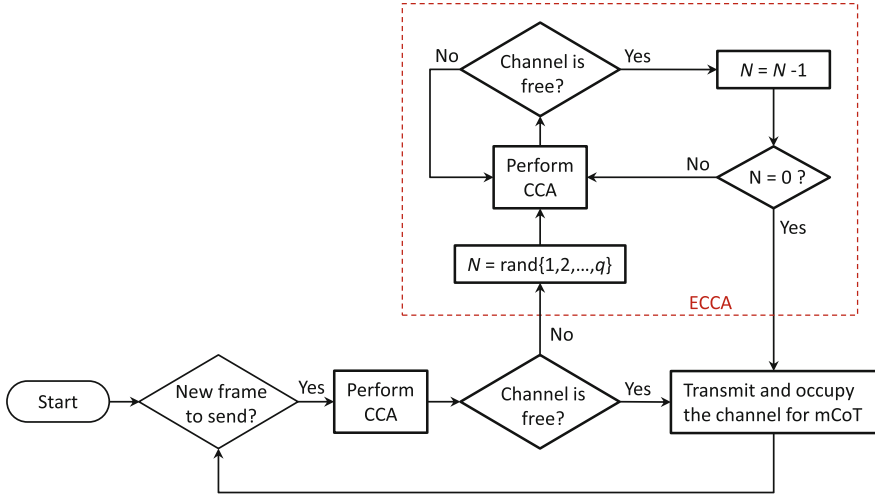


Fig. 2.5 Simplified flowchart of LBE

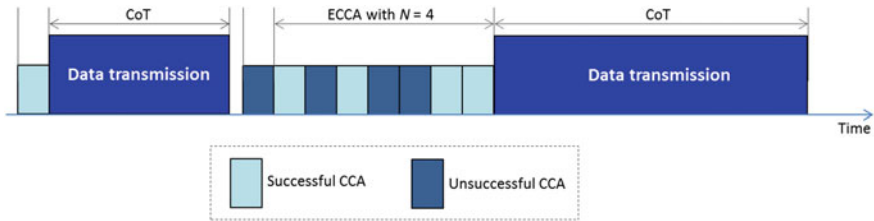


Fig. 2.6 An illustrative example of LBE

- *R8*: A consecutive sequence of such transmissions by the equipment, without it performing a new CCA, shall not exceed the maximum CoT.
- *R9*: CCA observation time shall be not less than 20 μ s.
- *R10*: CoT shall be in the range from 1 to 10 ms.
- *R11*: The minimum IP shall be at least 5% of CoT used by the equipment for the current fixed frame period.

2.6.2 LBE-Based Mechanism

A simplified flowchart and an illustrative example of the channel access procedure used for LBE are shown in Figs. 2.5 and 2.6, respectively.

LBE shall comply with the following requirements:

- *R1*: Before starting transmissions on an operating channel, the equipment shall perform a CCA check using ED. The equipment shall observe the channel for the

duration of the CCA observation time. The operating channel shall be considered occupied if the energy level in the channel exceeds the threshold corresponding to the power level.

- *R2*: If the CCA procedure finds that the channel is clear, the equipment may transmit immediately on that channel.
- *R3*: If the CCA procedure finds that the channel is occupied, it shall not transmit in that channel. The equipment shall perform an Extended CCA (ECCA) procedure in which the channel is observed for a random duration.
- *R4*: If the ECCA procedure has determined the channel to be clear, the equipment may initiate transmissions on this channel.
- *R5*: The total time that an equipment makes use of the channel (without performing CCA) is the maximum channel occupancy time (mCoT), after which the device shall perform a new CCA procedure as described in R1 above.
- *R6*: The equipment, upon correct reception of a packet which was intended for this equipment, can skip CCA and immediately proceed with the transmission of management and control frames, e.g., ACK and block ACK frames.
- *R7*: A consecutive sequence of transmissions by the equipment, without it performing a new CCA, shall not exceed mCoT.
- *R8*: CCA observation time shall be not less than 20 μ s.
- *R9*: The random duration in an ECCA procedure is $N \times$ (CCA observation time), where N is randomly selected in the range $\{1, 2, \dots, q\}$, $q \in \{4, 5, \dots, 32\}$ (declared by the manufacturer).
- *R10*: mCoT should be less than $(13/32) \times q$ ms (mCoT is in the range from 1.625 to 13 ms).

Reference

1. *ETSI EN 301 893 V1.7.2 (2014-07): Broadband radio access networks (BRAN); 5 GHz high performance RLAN; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive*, European Telecommunications Standards Institute Std., 2014.

Long Term Evolution in Unlicensed Bands

Ho, Q.-D.; Tweed, D.; Le-Ngoc, T.

2017, XII, 65 p. 31 illus., Softcover

ISBN: 978-3-319-47345-1