

Unit-3

RF Standards

This chapter covers the following topics

- *Regulatory Bodies—This section describes the organizations that regulate radio frequency spectrum and its uses.*
- *IEEE Standards Body—This section discusses the IEEE and the 802.11 standards that define wireless LAN operation.*
- *IEEE 802.11 Channel Use—This section covers each of the frequency bands used for 802.11 wireless LANs and the encoding and modulation methods that are used in wireless LANs.*

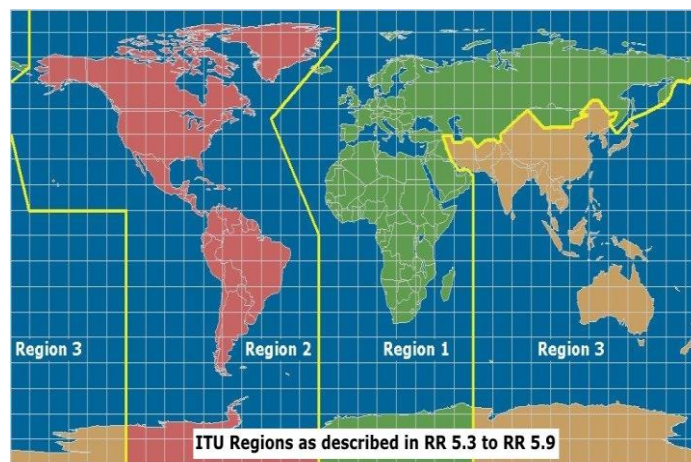
1. Regulatory Bodies

The entire **frequency spectrum** is composed of all possible frequencies. To keep the RF spectrum organized and open for fair use, **regulatory bodies** were formed.

1.1 International Telecommunication Union Radiocommunication ITU-R

ITU sector (ITU-R) maintains spectrum and frequency assignments in three distinct regions:

- Region 1: Europe, Africa, and Northern Asia
- Region 2: North and South America
- Region 3: Southern Asia and Australasia



The responsibility of ITU-R includes:

- 1) Makes sure that the RF signals from one country do not **interfere** with the signals of another country.
- 2) Determines the expected usages of each segment of the spectrum.
- 3) Keeps track of geostationary satellite orbits and frequencies.

There are two types of bands:

- 1) **Licensed bands:** To use it, you have to submit an application to a regulatory body in a given country, wait for approval, and then abide by any restrictions that are imposed.
- 2) **Unlicensed bands:** While unlicensed bands are more accessible and convenient to use, they are much more **vulnerable** (subjected) to interference and **misuse**.

The ITU-R allocated the following two frequency ranges specifically for industrial, scientific, and medical (ISM) applications. Although there are other ISM bands, too,

there are mainly two that apply to wireless LANs:

- 1) **2.4 GHz band:** This band is used by Wi-Fi, Bluetooth, ZigBee, and other wireless communication systems. The frequency range covered by this band is from 2.4 GHz to 2.4835 GHz.
- 2) **5 GHz band:** This band is used by Wi-Fi, WiMAX, and other wireless communication systems. The frequency range covered by this band is from 5.15 GHz to 5.35 GHz, and from 5.47 GHz to 5.725 GHz.
- 3) **900 MHz band:** This band is used by cordless phones, baby monitors, and other low-power wireless communication systems. The frequency range covered by this band is from 902 MHz to 928 MHz.
- 4) **5.8 GHz band:** The band from 5.725 to 5.825 GHz.

Fortunately, all the frequency bands used for wireless LANs are unlicensed. You can purchase a wireless LAN device and begin to use it immediately—provided you abide (follow) by the rules set up by the regulatory agency that governs RF use in your country

1.2 Federal Communications Commission

In the United States, the **Federal Communications Commission (FCC)** regulates:

- 1) RF frequencies,
- 2) Channels,
- 3) and transmission power.
- 4) Allocating and managing the use of the radio frequency spectrum
- 5) Enforcing regulations to ensure that the use of the radio frequency spectrum is safe and does not cause harmful interference
- 6) Regulating the rates and quality of communication services
- 7) Enforcing rules and regulations related to emergency communications

Some other countries choose to follow the FCC rules, too. In addition to the 2.4–2.5-GHz ISM band allocated by the ITU-R, the FCC has allocated the **Unlicensed National Information Infrastructure (U-NII)** frequency space in the 5-GHz band for wireless LAN use. U-NII is actually four separate sub-bands, as follows:

- 1) U-NII-1 (band 1): 5.15 to 5.25 GHz
- 2) U-NII-2 (band 2): 5.25 to 5.35 GHz
- 3) U-NII-2 Extended (band 3): 5.47 to 5.725 GHz
- 4) U-NII-3 (band 4): 5.725 to 5.825 GHz (also allocated as ISM)

All transmitting equipment must be **approved** by the FCC before it can be sold to users. WLAN equipment **does not exceed the EIRP** net power limits.

Tx and antenna must be purchased from the same manufacturer. Transmitters in the 2.4-GHz band can be used indoors or outdoors. The power emitted at the transmitter must be limited to 30 dBm and the EIRP limited to 36 dBm.

FCC Requirements in the 5-GHz U-NII Bands

Band	Allowed Use	Transmitter Max	EIRP Max
U-NII-1	Indoor only	17 dBm (50 mW)	23 dBm
U-NII-2	Indoor or outdoor	24 dBm (250 mW)	30 dBm
U-NII-2 Extended	Indoor or outdoor	24 dBm (250 mW)	30 dBm
U-NII-3	Indoor or outdoor	30 dBm (1 W)	36 dBm

Normally, transmitters operating in any of the 2.4- and 5-GHz unlicensed bands must **endure** (capable of) any interference caused by other transmitters.

The FCC requires one **exception in the U-NII-2 and U-NII-2 Extended bands**: When a signal from an approved device, such as a military or weather radar, is detected on a frequency, all other transmitters must move out of the way to a different frequency. This is known as dynamic frequency selection (**DFS**).

1.3 European Telecommunication Standards Institute

In Europe and several other countries, the European Telecommunication Standards Institute (ETSI) regulates radio transmitter use. Like the FCC, the ETSI allows wireless LANs to be used in the 2.4-GHz ISM and most of the same 5-GHz U-NII bands;

however, the U-NII-3 band is a licensed band and cannot be used. The following table lists the transmitter requirements for each of the bands.

Band	Allowed Use	EIRP Max
2.4 GHz ISM	Indoor or outdoor	20 dBm
U-NII-1	Indoor only	23 dBm
U-NII-2	Indoor only	23 dBm
U-NII-2 Extended	Indoor or outdoor	30 dBm
U-NII-3	Licensed	N/A

2. IEEE Standards Body

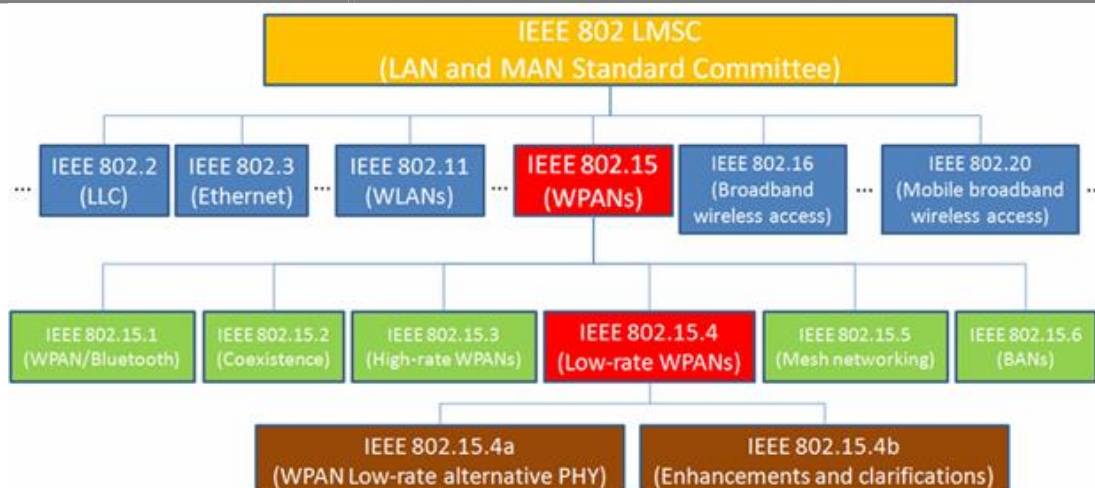
2.1 Institute of Electric and Electronic Engineers Standards

- IEEE: specifies how RF is **modulated** to transfer data over a wireless link.
- IEEE **maintains the industry standards** that are used for wireless LANs.
- IEEE is a **professional organization** made up of engineers from around the world.
- IEEE is a collection of “societies” that are focused on particular engineering areas

To develop networking standards, the IEEE is organized into **working groups**, which have an open membership. Each working group is assigned an **index number** that is appended to the **802** standards family number.

For example, 802.1 refers to the first working group, which developed standards for network bridging.

Name	Description
802.1	Network bridging (includes Spanning Tree Protocol)
802.2	Link-layer control
802.3	Ethernet
802.4	Token Bus
802.5	Token Ring MAC layer
...	
802.11	Wireless LANs
...	
802.15	Wireless PANs (personal-area networks such as Bluetooth, ZigBee, and so on)



The eleventh working group, **802.11**, is responsible for the wireless LAN standards that are used by Cisco, many other wireless vendors, and users like yourself.

- As a new improvement is needed or the technology advances, **a study group (SG)** researches the topic to see whether an **amendment** to the 802.11 standard is needed.
- Each time a new amendment is necessary, **a new task group (TG)** is formed to collaborate and develop it.
- Task groups are assigned a **suffix letter** in alphabetic order. For example, as amendments are introduced, their names become 802.11a, 802.11b, 802.11c, and so on.
- If there are enough amendments to reach letter z, any subsequent amendments are given a **two-letter suffix**, beginning with the letter a followed by letters a through z. At the time of this writing, the 802.11 working group had assigned amendments 802.11aa through 802.11ay.

3. 802.11 Channel Use

3.1 Channels in the 2.4-GHz ISM

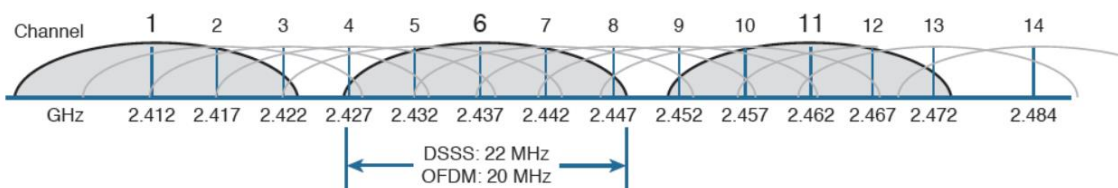
In the 2.4-GHz ISM band

The 2.4 GHz radio band is split into a number of fixed-frequency channels:

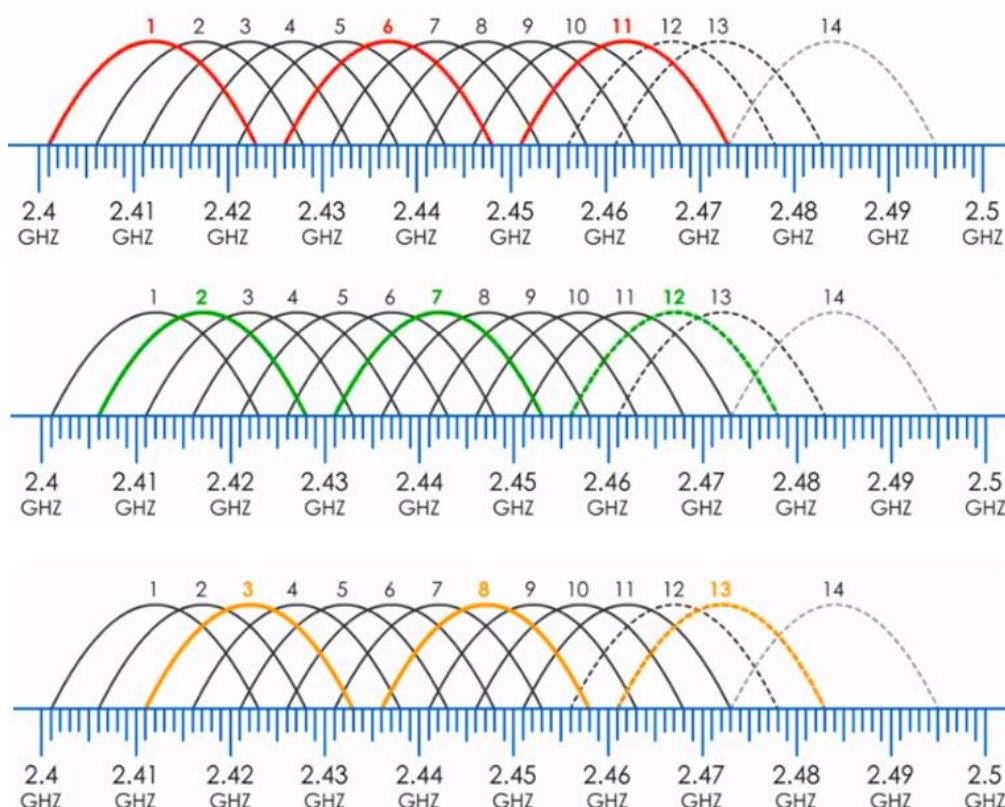
- There are 13 usable channels
- Channel 1 starts at 2.412 GHz
- Channels are spaced in 5 MHz increments
- Channels are 20 MHz wide so there is considerable overlap between them
- 40 MHz wide channels exist in some 802.11n deployments
- Due to this overlap, only three channels can be active at any one time
- In practice users and manufacturers tend to choose channels 1, 6 and 11 (USA)
- Channel 13 is at 2.472 GHz
- Channel 14, sits at 12 MHz above channel 13 (only legal for use in Japan)
- Channels 12 and 13 are illegal in the USA



- The frequency space is divided up into 14 channels, numbered 1 through 14.
- Channel 1 starts at 2.412 GHz.
- With the exception of channel 14, the channels are spaced 5 MHz apart.
- The 802.11 standard allows either **DSSS** or **OFDM** modulation in the 2.4-GHz band. DSSS radios require each channel to be 22 MHz wide.
- **OFDM** requires 20 MHz.
- Since only 5 MHz between channels, transmissions on neighboring channels are bound to overlap and interfere with each other.



- Not all of the 14 channels are used in all countries.
- The FCC limits the band to channels 1 through 11 only.
- The ETSI permits channels 1 through 13.
- Japan permits all 14 channels to be used, but channel 14 has some restrictions.
- The only way to **prevent** transmitters on nearby channels from **interfering** with each other is to **keep them** on channels that are **spaced** farther apart.
- The most common arrangement is to use only channels **1, 6, and 11**, which do not overlap with each other at all.



Tip One scheme uses channels 1, 5, 9, and 13 to gain an extra channel, but it is not commonly used. With DSSS, the channels end up overlapping, which violates the 802.11 definition for adjacent channels and also raises the noise floor. Only the OFDM 20-MHz-wide channels can avoid overlapping each other. Channel 13 presents an interesting case because it is not supported on all wireless clients in all areas of the world.

Problems can arise when you need to set up several wireless LAN transmitters in the same general area. You could set the first **three** transmitters to each use a different channel, but the fourth or fifth ones would have to reuse one of the three non-overlapping channels. Reusing channels becomes a puzzle that you have to solve when you administer a growing wireless LAN

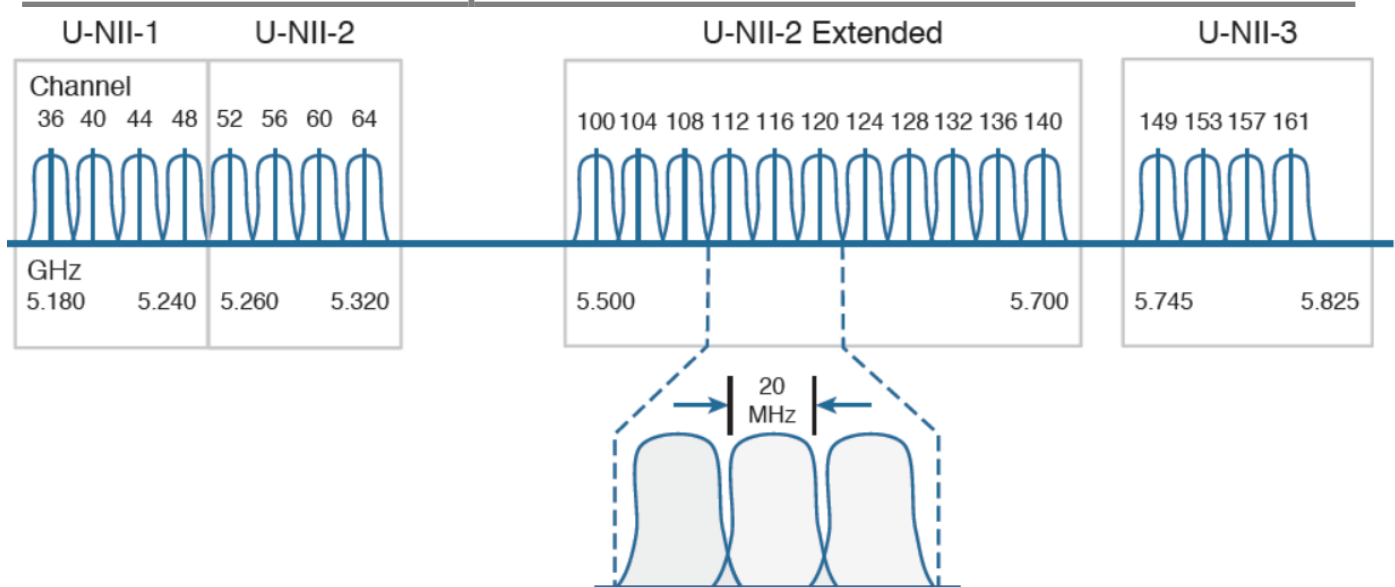
3.2 Channels in the 5-GHz U-NII Bands

The 5-GHz band is organized as four separate, smaller bands: U-NII-1, U-NII-2, U-NII-2 Extended, and U-NII-3. The bands are all divided into channels that are 20 MHz apart, as listed in below Table

Table 2-6 IEEE 802.11 Channel Layout in the 5-GHz Bands

Band	Channel	Frequency (GHz)
U-NII-1	36	5.180
	40	5.200
	44	5.220
	48	5.240
U-NII-2	52	5.260
	56	5.280
	60	5.300
	64	5.320
U-NII-2 Extended	100	5.500
	104	5.520
	108	5.540
	112	5.560
	116	5.580
	120	5.600
	124	5.620
	128	5.640
	132	5.660
	136	5.680
	140	5.700
U-NII-3	149	5.745
	153	5.765
	157	5.785
	161	5.805

- The entire 5-GHz frequency space is defined as a sequence of channels spaced 5 MHz apart, beginning with channel 0 at 5.000 GHz.
- Each channel spans four channels. That is $4 \times 5\text{MHz} = 20\text{MHz}$
- Therefore, the first U-NII-1 channel is located at 5.180 GHz, which corresponds to channel number 36 (i.e. $180/5=36$).
- Each U-NII channel is 20 MHz wide, so an adjacent channel is located four 5-MHz channel widths, or four channel numbers, away.
- The FCC originally allocated three separate bands as U-NII-1, U-NII-2, and U-NII-3, each having four 20-MHz channels.
- In 2004, the FCC added the U-NII-2 Extended band, which offered **11 additional 20-MHz channels**.



Channel Layout in the 5-GHz U-NII Bands

The 802.11 standard allows only **OFDM** modulation and coding schemes to be used in the U-NII bands. OFDM requires a 20-MHz channel width, which fits perfectly with the 20-MHz spacing in the U-NII bands. In other words, **neighboring channels can be used in the same area without overlap or interference.**

4. Questions

Which regulatory body allocated the 2.4–2.5-GHz band for industrial, scientific, and medical use?

- IEEE
- ETSI
- ITU-R
- FCC

2. The U-NII-1 band is used for which one of the following purposes?

- 2.4-GHz wireless LANs
- 5-GHz wireless LANs
- Medical applications
- Point-to-point links

3. In the 2.4-GHz band, the FCC limits the EIRP of a point-to-multipoint link to which one of the following maximum values?

-
- a. 100 mW
 - b. 20 dBm
 - c. 50 mW
 - d. 36 dBm
4. Wireless LAN operation is defined in which one of the following standards?
- a. 802.1
 - b. 802.2
 - c. 802.3
 - d. 802.11
 - e. 802.15
5. Which one of the following specifies the correct list of non-overlapping channels for DSSS use in the 2.4-GHz band?
- a. 1, 2, 3
 - b. 1, 5, 10
 - c. 1, 6, 11
 - d. 1, 8, 13
 - e. All of channels 1–14
6. The U-NII-1 band begins at which one of the following channel numbers?
- a. 0
 - b. 1
 - c. 24
 - d. 36