



This lecture covers the following topics

- 01 | Regulatory Bodies**—This section describes the organizations that regulate radio frequency spectrum and its uses..
- 02 | IEEE Standards Body**—This section discusses the IEEE and the 802.11 standards that define wireless LAN operation.
- 03 | 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.



01- Regulatory Bodies : ITU-R

Regulatory bodies were formed to organize and keep the entire frequency spectrum fair for use.

► The International Telecommunication Union Radiocommunication (ITU-R).

The International Telecommunication Union Radiocommunication Sector (ITU-R) is a specialized agency of the **United Nations** that is responsible for managing the international radio frequency spectrum and satellite orbit resources. It was established in **1927** and has its headquarters in Geneva, Switzerland.

Regulatory Bodies : ITU-R

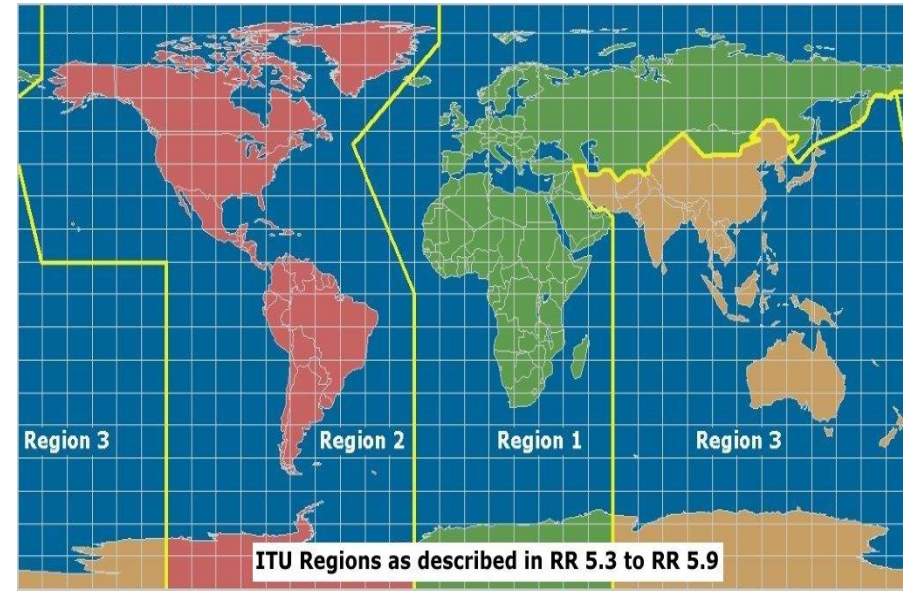
ITU-R Responsibilities

- ❖ Managing the international radio frequency spectrum and satellite orbit resources
- ❖ Coordinating the allocation of frequencies to different radio services
- ❖ Ensuring that the frequency spectrum is used in a manner that does not interfere with other services
- ❖ Developing technical standards for radio communication systems and equipment
- ❖ Ensuring interoperability and compatibility of radio communication systems across different countries and regions
- ❖ Conducting research and providing recommendations on various topics related to radio communication.

Regulatory Bodies : ITU-R

The ITU-R maintains spectrum and frequency assignments for three regions of the world, as follows:

- ❖ **Region 1:** Europe, Africa and the Middle East, and the. The frequency range is from 9 kHz to 275 GHz.
- ❖ **Region 2:** North and South America, Greenland, and some Pacific islands. The frequency range is from 9 kHz to 275 GHz.
- ❖ **Region 3:** Asia, Australia, and the Pacific. The frequency range is from 9 kHz to 400 GHz.



Regulatory Bodies : ITU-R

Band Types

❑ Licensed bands

- ▶ Allocated by regulatory authorities to specific users or services.
- ▶ Requires a license or permit from the regulatory authority.
- ▶ The holder has exclusive access to the frequency band for a specific period of time.
- ▶ Examples include cellular networks, broadcast television and radio, and satellite communication.

Regulatory Bodies : ITU-R

Band Types

❑ Unlicensed bands

- ▶ Unlicensed bands are available for use by anyone without the need for a license or permit.
- ▶ It is used for short-range wireless communication systems, such as Wi-Fi and Bluetooth.
- ▶ Congested and subject to interference from other devices, which can degrade the quality of communication.
- ▶ Regulated by regulatory authorities to ensure that the devices using these bands do not interfere with other services.

Regulatory Bodies : ITU-R

The ITU-R allocated the following two frequency ranges specifically for industrial, scientific, and medical (ISM) applications.

- ❖ **2.4 GHz band:** Wi-Fi, Bluetooth, ZigBee, and other wireless communication systems. Its range from 2.4 GHz to 2.4835 GHz.
- ❖ **5 GHz band:** Wi-Fi, WiMAX, and other wireless communication systems. Its range from 5.15 GHz to 5.35 GHz, and from 5.47 GHz to 5.725 GHz.
- ❖ **900 MHz band:** cordless phones, baby monitors, and other low-power wireless communication systems. Its range from 902 MHz to 928 MHz.
- ❖ **5.8 GHz band:** The band from 5.725 to 5.825 GHz.

Regulatory Bodies : FCC

In USA, Federal Communications Commission (FCC)

FCC is responsible for regulating interstate and international communications by radio, television, wire, satellite, and cable. The FCC has the following responsibilities:

- ▶ Allocating and managing the use of the radio frequency spectrum
- ▶ Enforcing regulations to ensure that the use of the radio frequency spectrum is safe and does not cause harmful interference
- ▶ Regulating the rates and quality of communication services
- ▶ Enforcing rules and regulations related to emergency communications.

Regulatory Bodies : FCC

In USA, Federal Communications Commission (FCC)

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:

- ▶ **U-NII-1:** This band covers frequencies from 5.15 to 5.25 GHz and is used for low-power applications.
- ▶ **U-NII-2:** This band covers frequencies from 5.25 to 5.35 GHz and is used for medium-power applications.
- ▶ **U-NII-3:** This band covers frequencies from 5.725 to 5.825 GHz and is used for high-power applications. (also allocated as ISM)

Regulatory Bodies : FCC

Some notes on FCC bands

- ▶ 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.

Regulatory Bodies : FCC

FCC Requirements

Table 2-2 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 (avoid) 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**).

Regulatory Bodies : ETSI

❖ The European Telecommunication Standards Institute (ETSI).

- ❖ ETSI used in In Europe and several other countries,
- ❖ ETSI allows wireless LANs to be used in the 2.4-GHz ISM and most of the same 5-GHz U-NII bands
- ❖ the U-NII-3 band is a licensed band and cannot be used.
- ❖ The ETSI include DFS, which requires wireless LAN transmitters to move to a random frequency after a radar signal is detected.

Table 2-3 ETSI Requirements in the 2.4- and 5-GHz 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 |

❖ The Institute of Electric and Electronic Engineers (IEEE) Standards Body

The IEEE is responsible for developing and publishing globally-applicable standards for various areas of electrical and electronics engineering. Some of its key responsibilities include:

- IEEE: specifies how RF is modulated to transfer data over a wireless link.
- IEEE maintains the industry standards that are used for wireless LANs.
- Developing standards for communications protocols, such as Ethernet, Wi-Fi, and Bluetooth.
- Developing standards for electronic devices and components, such as sensors, amplifiers, and microcontrollers.
- Developing standards for software engineering, such as programming languages, software architecture, and software quality.

❖ The Institute of Electric and Electronic Engineers (IEEE) Standards Body

- ▶ 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.
- ▶ The eleventh working group, 802.11, is responsible for the wireless LAN standards

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❖ IEEE Working Groups

Table 2-4 Example IEEE 802 Working Groups

| 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) |

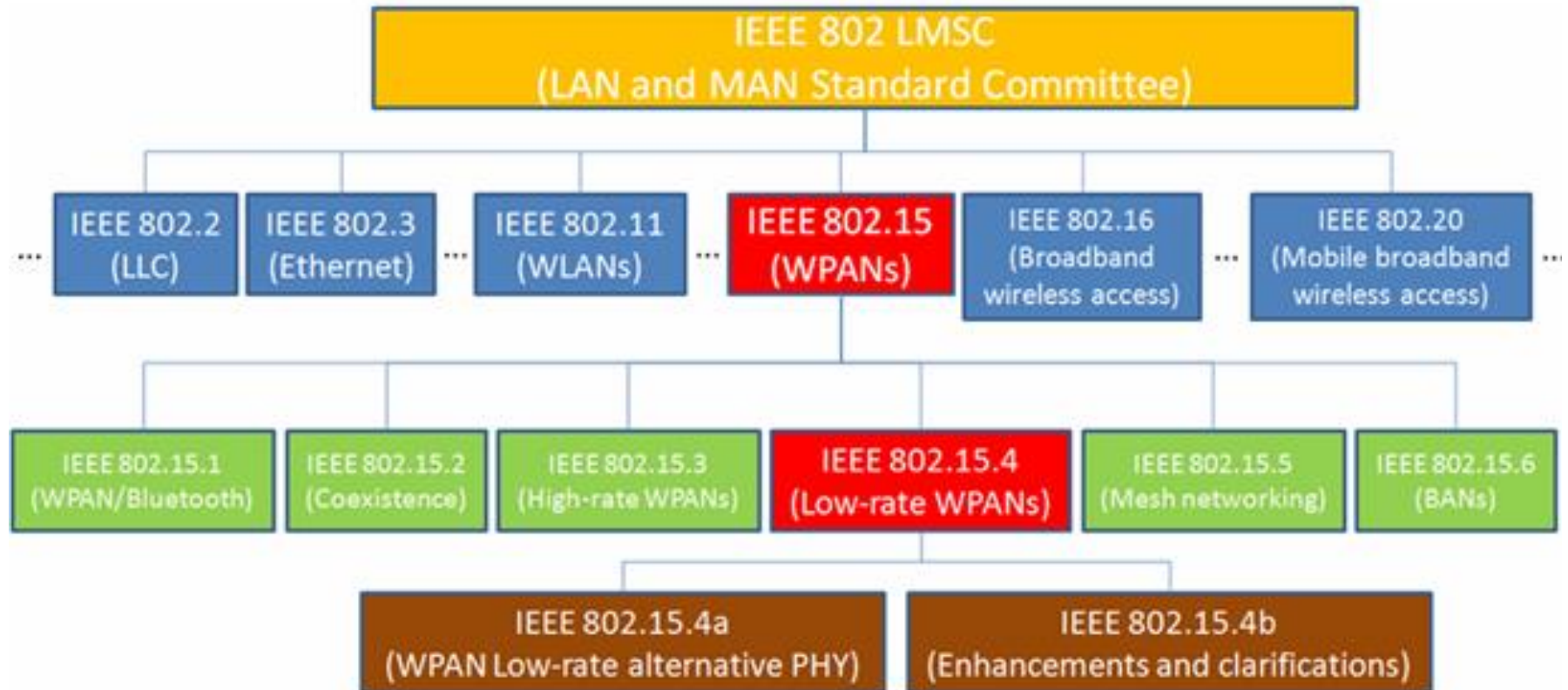
IEEE Working Groups

The eleventh working group, 802.11, is responsible for the wireless LAN standards

- ❖ As a new improvement is needed, 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.
- ❖ TGs are assigned a suffix letter like 802.11a, 802.11b, 802.11c, 802.11aa through 802.11ay and so on.

IEEE Standards Body

The Institute of Electric and Electronic Engineers (IEEE) Standards Body



802.11 Channel Use

❖ Channels in the 2.4-GHz ISM Band

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

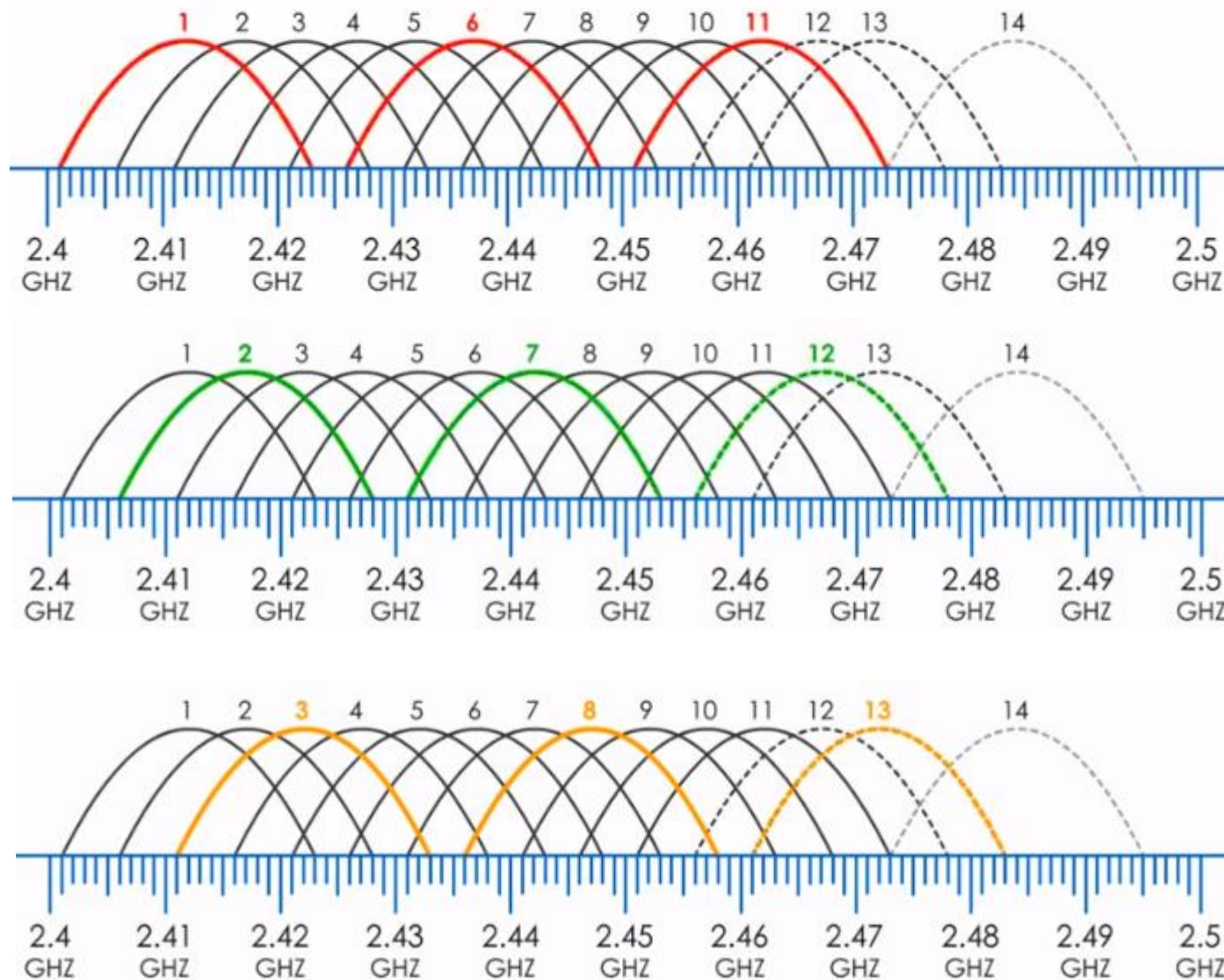
- There are 13 usable channels
- Channel 1 starts at 2.412 GHz
- Channels are spaced in 5 MHz increments
- Channels are 20 MHz wide so there is considerable overlap between them
- 40 MHz wide channels exist in some 802.11n deployments
- Due to this overlap, only three channels can be active at any one 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



Channels are designated by their center frequency. Channel width is decided by type of technology used by the transmitter. It is 22 MHz in legacy 802.11 & 802.11b standards and 20 MHz in 802.11g/n/ac

802.11 Channel Use

❖ Channels in the 2.4-GHz ISM Band



802.11 Channel Use

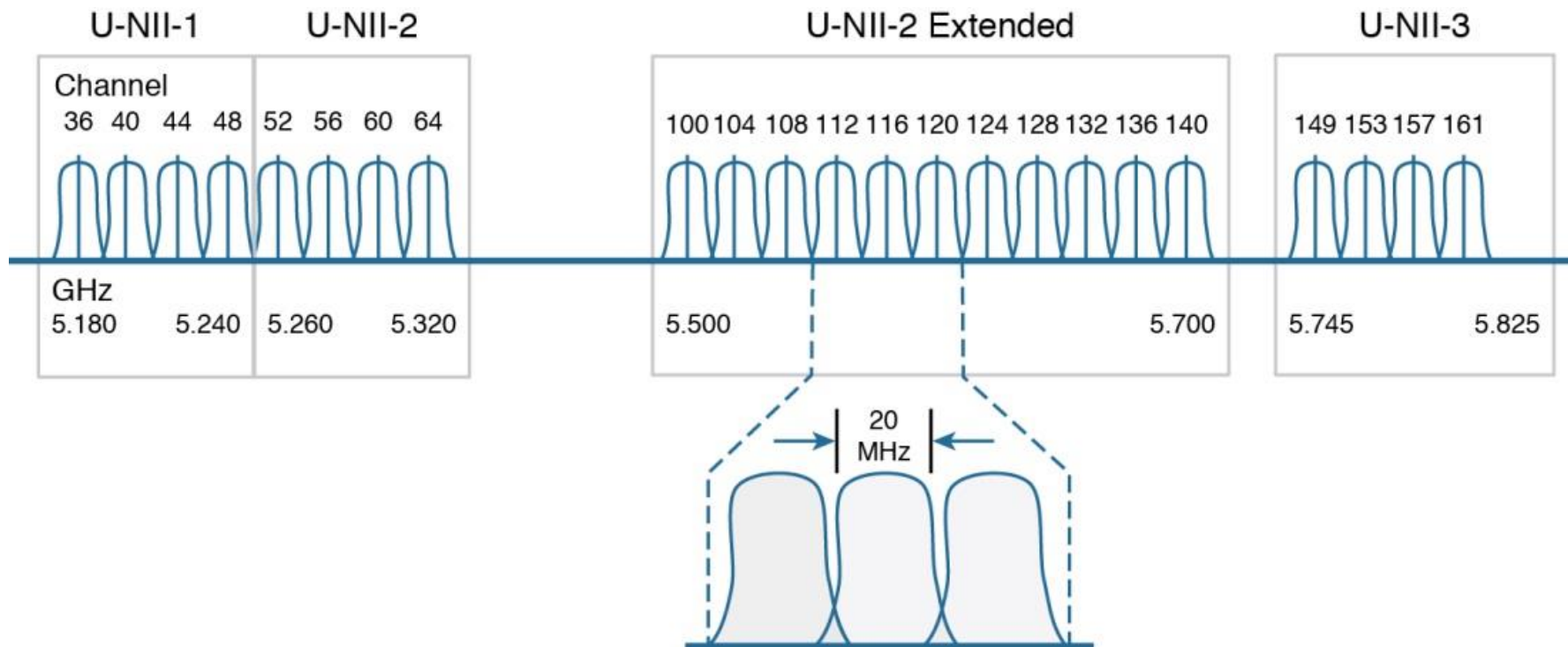
❖ Channels in the 5-GHz ISM Band

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 |

802.11 Channel Use

❖ Channels in the 2.5-GHz ISM Band



- 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.
- Therefore, the first U-NII-1 channel is located at 5.180 GHz, which corresponds to channel number 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.

IEEE 802.11 Standards

❖ IEEE 802.11 Physical Layer Standards

TABLE I
EVOLUTION OF THE IEEE 802.11 STANDARDS [1]

| 802.11 Protocol | Year Released | Frequency Band | Channel Widths | Highest Single Stream Data Rate | Modulation Type | MIMO Streams | Highest Aggregate Data Rate |
|------------------------|----------------------|-----------------------|-----------------------|--|-------------------------------------|---------------------|------------------------------------|
| 802.11 legacy | 1997 | 2.4 GHz | 20 MHz | 2 Mb/s | DBPSK, DQPSK | 1 | 2 Mb/s |
| 802.11a | 1999 | 5 GHz | 20 MHz | 54 Mb/s | BPSK, QPSK, 16-QAM, 64-QAM | 1 | 54 Mb/s |
| 802.11b | 1999 | 2.4 GHz | 20 MHz | 11 Mb/s | CCK | 1 | 11 Mb/s |
| 802.11g | 2003 | 2.4 GHz | 20 MHz | 54 Mb/s | BPSK, QPSK, 16-QAM, 64-QAM | 1 | 54 Mb/s |
| 802.11n | 2009 | 2.4 and 5 GHz | 20, 40 MHz | 150 Mb/s | BPSK, QPSK, 16-QAM, 64-QAM | 4 | 600 Mb/s |
| 802.11ac | 2012 | 5 GHz only | 20, 40, 80, 160 MHz | 866.7 Mb/s | BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM | 8 | 6.77 Gb/s |