# 802.11 Wireless LAN

# General Info

- Access point connection to wired LANs
- PCs, laptops, cell phones, etc.

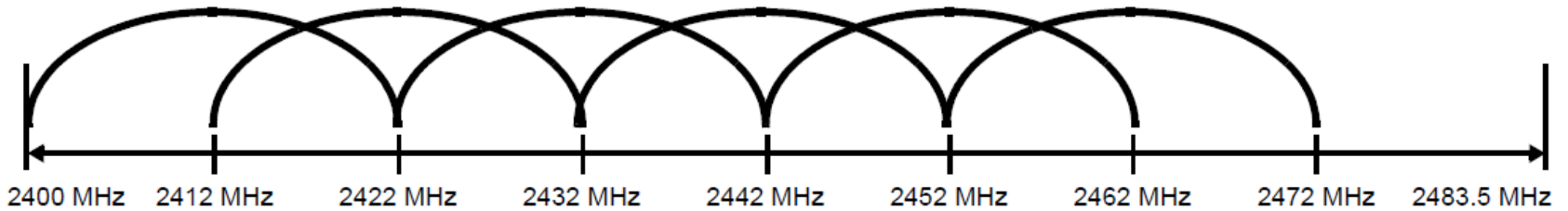# Channels



2400 MHz    2412 MHz    2422 MHz    2432 MHz    2442 MHz    2452 MHz    2462 MHz    2472 MHz    2483.5 MHz

**Figure 4.** 802.11ac Channelization (United States)

Example of a channel-set for a BSS:
- primary 20 MHz on ch60 (beacons, virtual carrier sense and 802.11a devices)
- primary 40 MHz on ch60+64 (802.11n devices)
- primary80 on ch52-64 and 160 MHz on ch36-64 (802.11ac devices)

**40 MHz** = adjacent 20 MHz channels grouped into pairs;
**80 MHz** = adjacent 40 MHz channels grouped into pairs;
**160 MHz** = adjacent 80 MHz channels grouped into pairs
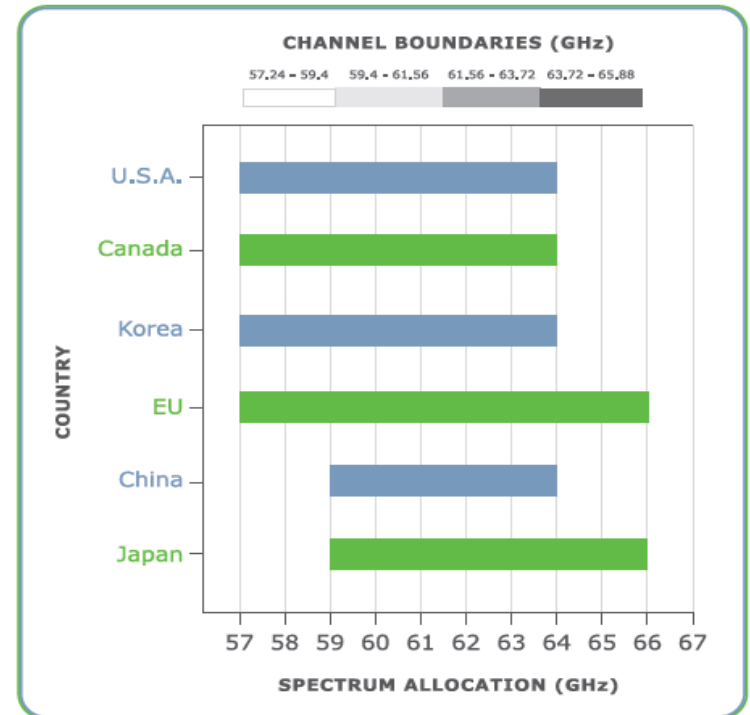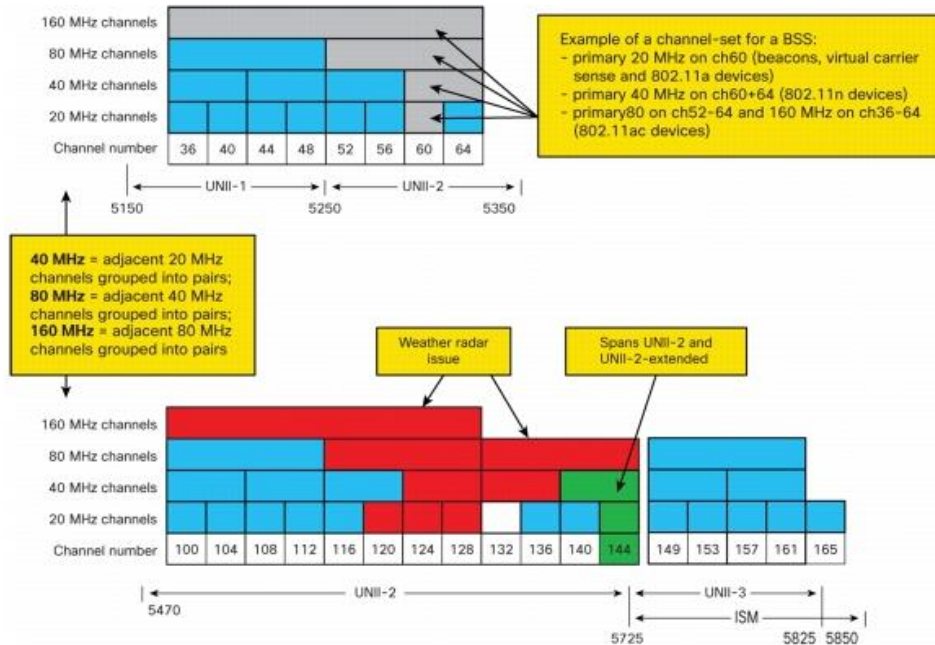
Weather radar issue

Spans UNII-2 and UNII-2-extended

Figure 3. Worldwide spectrum availability in the 60 GHz band used by WiGig

# Market

- Exceeded 1 billion devices in 2011 (http://www.isuppli.com/Mobile-and-Wireless-Communications/News/Pages/More-Than-1-Billion-Devices-to-Have-Embedded-Wireless-Networking-Capability.aspx )

- Estimated to exceed 2 billion in 2015

- 802.11b transceiver under $6 from Digikey (http://www.digikey.ca/product-detail/en/MAX2830ETM%2B/MAX2830ETM%2B-ND/1937403 )

# Data Rates and Modulation

| 802.11 protocol | Release[6] | Freq. (GHz) | Bandwidth (MHz) | Data rate per stream (Mbit/s)[7] | Allowable MIMO streams | Modulation | Approximate indoor range[citation needed] | | Approximate outdoor range[citation needed] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | (m) | (ft) | (m) | (ft) |
| — | Jun 1997 | 2.4 | 20 | 1, 2 | 1 | DSSS, FHSS | 20 | 66 | 100 | 330 |
| a | Sep 1999 | 5 | 20 | 6, 9, 12, 18, 24, 36, 48, 54 | 1 | OFDM | 35 | 115 | 120 | 390 |
| a | Sep 1999 | 3.7[A] | 20 | 6, 9, 12, 18, 24, 36, 48, 54 | 1 | OFDM | — | — | 5,000 | 16,000[A] |
| b | Sep 1999 | 2.4 | 20 | 1, 2, 5.5, 11 | 1 | DSSS | 35 | 115 | 140 | 460 |
| g | Jun 2003 | 2.4 | 20 | 6, 9, 12, 18, 24, 36, 48, 54 | 1 | OFDM, DSSS | 38 | 125 | 140 | 460 |
| n | Oct 2009 | 2.4/5 | 20 | 7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2[B] | 4 | OFDM | 70 | 230 | 250 | 820[8] |
| n | Oct 2009 | 2.4/5 | 40 | 15, 30, 45, 60, 90, 120, 135, 150[B] | 4 | OFDM | 70 | 230 | 250 | 820[8] |
| ac (DRAFT) | Dec 2012 | 5 | 20 | up to 87.6[9] | 8 | OFDM | | | | |
| ac (DRAFT) | Dec 2012 | 5 | 40 | up to 200[9] | 8 | OFDM | | | | |
| ac (DRAFT) | Dec 2012 | 5 | 80 | up to 433.3[9] | 8 | OFDM | | | | |
| ac (DRAFT) | Dec 2012 | 5 | 160 | up to 866.7[9] | 8 | OFDM | | | | |
| ad | ~Feb 2014 | 2.4/5/60 | | up to 7000 | | | | | | |

# Security

- WEP – broken, don't use
- Uses a 40 bit key up to 104 bits
- Must avoid repetition, but not always possible
- WPA, WPA2 – work well, but common SSIDs are easier to break
- In 802.11 clause 11, ammendment 802.11i

# Standards

- 802.11# most letters are not for entire new standards but for housekeeping
- a, b, g, n, ac, ad are the major standards
- b is specified in 802.11-2012 in clause 16
- g in clause 18
- n in clause 20
- ac is still draft, extends n
- ad was accepted in January

Table 1. Radio link power budgets.

| | | 802.11b | | | | WCDMA | EDGE |
|---|---|---|---|---|---|---|---|
| a | Thermal noise (dBm/Hz) | -174 | | | | -174 | -174 |
| b | Channel BW* (dBm) | 73 | | | | 66 | 53 |
| c | Noise factor (dBm) | 5 | | | | 5 | 5 |
| d | **Noise power (dBm)** | -96 | | | | -103 | -116 |
| e | Interference margin (dB) | 3 | | | | 3 | 3 |
| f | Minimum SINR (dB) | 0 | | | | -5 | 10 |
| g | **Min. RX sig. power (dBm)** | -93 | | | | -105 | -103 |
| h | Terminal EIRP** (dBm) | 24 | 24 | 30 | 30 | 30 | 30 |
| I | Sector gain (dBi) | 10 | 10 | 10 | 10 | 10 | 10 |
| j | Shadowing margin (dB) | -8 | -8 | -8 | -8 | -8 | -8 |
| k | Building penetration (dB) | -15 | 0 | -15 | 0 | -15 | -15 |
| l | **Allowable path gain (dB)** | -104 | -119 | -110 | -125 | -122 | -120 |
| m | Med. path gn. @100m (dB) | -73 | -73 | -73 | -73 | -73 | -73 |
| n | Adnl. gain at cell edge (dB) | -31 | -46 | -37 | -52 | -49 | -47 |
| o | Propagation exponent | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| p | **Cell radius (km)** | **0.7** | **2** | **1.1** | **3** | **2.5** | **2.2** |

* Bandwidths 22 MHz, 3.84 MHz, 200 kHz, respectively.
** 0.25 W and 1 W.

- Clark, Martin V., et al. "Outdoor IEEE 802.11 cellular networks: Radio link performance." *Communications, 2002. ICC 2002. IEEE International Conference on*. Vol. 1. IEEE, 2002.