Template:802.11 network standards

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| hide   * v * [t](https://en.wikipedia.org/wiki/Template_talk:802.11_network_standards) * [e](https://en.wikipedia.org/w/index.php?title=Template:802.11_network_standards&action=edit)   [**IEEE 802.11**](https://en.wikipedia.org/wiki/IEEE_802.11)**network PHY standards** | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Frequency range, or type** | **PHY** | **Protocol** | **Release date**[[1]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-80211timeline-template-1) | **Frequency** | **Bandwidth** | **Stream**[**data rate**](https://en.wikipedia.org/wiki/Data_signaling_rate)[[2]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-2) | **Allowable** [**MIMO**](https://en.wikipedia.org/wiki/MIMO)**streams** | **Modulation** | **Approximate range[**[***citation needed***](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)**]** | |
| **Indoor** | **Outdoor** |
| **(GHz)** | **(MHz)** | **(Mbit/s)** |
| 1–6 GHz | DSSS/FHSS[[3]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-IJMNCT-3) | [802.11-1997](https://en.wikipedia.org/wiki/IEEE_802.11_(legacy_mode)) | Jun 1997 | 2.4 | 22 | 1, 2 | N/A | [DSSS](https://en.wikipedia.org/wiki/Direct-sequence_spread_spectrum), [FHSS](https://en.wikipedia.org/wiki/Frequency-hopping_spread_spectrum) | 20 m (66 ft) | 100 m (330 ft) |
| HR-DSSS[[3]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-IJMNCT-3) | [802.11b](https://en.wikipedia.org/wiki/IEEE_802.11b-1999) | Sep 1999 | 2.4 | 22 | 1, 2, 5.5, 11 | N/A | [DSSS](https://en.wikipedia.org/wiki/Direct-sequence_spread_spectrum) | 35 m (115 ft) | 140 m (460 ft) |
| OFDM | [802.11a](https://en.wikipedia.org/wiki/IEEE_802.11a-1999) | Sep 1999 | 5 | 5/10/20 | 6, 9, 12, 18, 24, 36, 48, 54 (for 20 MHz bandwidth, divide by 2 and 4 for 10 and 5 MHz) | N/A | [OFDM](https://en.wikipedia.org/wiki/Orthogonal_frequency-division_multiplexing) | 35 m (115 ft) | 120 m (390 ft) |
| [802.11j](https://en.wikipedia.org/wiki/IEEE_802.11j-2004) | Nov 2004 | 4.9/5.0[[D]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211jD1)[[4]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-4)[[*failed verification*](https://en.wikipedia.org/wiki/Wikipedia:Verifiability)] | ? | ? |
| [802.11p](https://en.wikipedia.org/wiki/IEEE_802.11p) | Jul 2010 | 5.9 | ? | 1,000 m (3,300 ft)[[5]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-5) |
| [802.11y](https://en.wikipedia.org/wiki/IEEE_802.11y-2008) | Nov 2008 | 3.7[[A]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_37ghzA1) | ? | 5,000 m (16,000 ft)[[A]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_37ghzA2) |
| ERP-OFDM(, etc.) | [802.11g](https://en.wikipedia.org/wiki/IEEE_802.11g-2003) | Jun 2003 | 2.4 | 38 m (125 ft) | 140 m (460 ft) |
| HT-OFDM[[6]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-ekahau-6) | [802.11n](https://en.wikipedia.org/wiki/IEEE_802.11n-2009) | Oct 2009 | 2.4/5 | 20 | Up to 288.8[[B]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiB1) | 4 | [MIMO-OFDM](https://en.wikipedia.org/wiki/MIMO-OFDM) | 70 m (230 ft) | 250 m (820 ft)[[7]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-wifiplanet-7)[[*failed verification*](https://en.wikipedia.org/wiki/Wikipedia:Verifiability)] |
| 40 | Up to 600[[B]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiB2) |
| VHT-OFDM[[6]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-ekahau-6) | [802.11ac](https://en.wikipedia.org/wiki/IEEE_802.11ac) | Dec 2013 | 5 | 20 | Up to 346.8[[B]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiB3) | 8 | [MIMO-OFDM](https://en.wikipedia.org/wiki/MIMO-OFDM) | 35 m (115 ft)[[8]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-litepoint-8) | ? |
| 40 | Up to 800[[B]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiB4) |
| 80 | Up to 1733.2[[B]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiB5) |
| 160 | Up to 3466.8[[B]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiB6) |
| HE-OFDM | [802.11ax](https://en.wikipedia.org/wiki/IEEE_802.11ax) | September 2019 [[9]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-9) | 2.4/5/6 | 20 | Up to 1147[[F]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiF1) | 8 | [MIMO-OFDM](https://en.wikipedia.org/wiki/MIMO-OFDM) | 30 m (98 ft) | 120 m (390 ft) [[G]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiG1) |
| 40 | Up to 2294[[F]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiF2) |
| 80 | Up to 4804[[F]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiF3) |
| 80+80 | Up to 9608[[F]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiF4) |
| mmWave | DMG[[10]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-10) | [802.11ad](https://en.wikipedia.org/wiki/IEEE_802.11ad) | Dec 2012 | 60 | 2,160 | Up to 6,757[[11]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-11) (6.7 Gbit/s) | N/A | [OFDM](https://en.wikipedia.org/wiki/Orthogonal_frequency-division_multiplexing), single carrier, low-power single carrier | 3.3 m (11 ft)[[12]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-12) | ? |
| [802.11aj](https://en.wikipedia.org/wiki/IEEE_802.11aj) | Apr 2018 | 45/60[[C]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211aj_45ghzC1) | 540/1,080[[13]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-13) | Up to 15,000[[14]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-14) (15 Gbit/s) | 4[[15]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-E101.B-15) | [OFDM](https://en.wikipedia.org/wiki/Orthogonal_frequency-division_multiplexing), single carrier[[15]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-E101.B-15) | ? | ? |
| EDMG[[16]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-16) | [802.11ay](https://en.wikipedia.org/wiki/IEEE_802.11ay) | Est. May 2020 | 60 | 8000 | Up to 20,000 (20 Gbit/s)[[17]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-17) | 4 | [OFDM](https://en.wikipedia.org/wiki/Orthogonal_frequency-division_multiplexing), single carrier | 10 m (33 ft) | 100 m (328 ft) |
| Sub-1 GHz IoT | TVHT[[18]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-APL-18) | [802.11af](https://en.wikipedia.org/wiki/IEEE_802.11af) | Feb 2014 | [0.054–0.79](https://en.wikipedia.org/wiki/White_spaces_(radio)) | 6–8 | Up to 568.9[[19]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-80211afDraft-19) | 4 | [MIMO-OFDM](https://en.wikipedia.org/wiki/MIMO-OFDM) | ? | ? |
| S1G[[18]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-APL-18) | [802.11ah](https://en.wikipedia.org/wiki/IEEE_802.11ah) | Dec 2016 | 0.7/0.8/0.9 | 1–16 | Up to 8.67 (@2 MHz)[[20]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#cite_note-20) | 4 | ? | ? |
| 2.4 GHz, 5 GHz | WUR | 802.11ba[[E]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_WURE1) | Est. Sep 2020 | 2.4/5 | 4.06 | 0.0625, 0.25 (62.5 kbit/s, 250 kbit/s) | N/A | [OOK](https://en.wikipedia.org/wiki/On-off_keying) (Multi-carrier OOK) | ? | ? |
| Light ([Li-Fi](https://en.wikipedia.org/wiki/Li-Fi)) | [IR](https://en.wikipedia.org/wiki/Infrared) | [802.11-1997](https://en.wikipedia.org/wiki/IEEE_802.11_(legacy_mode)) | Jun 1997 | ? | ? | 1, 2 | N/A | [PPM](https://en.wikipedia.org/wiki/Pulse-position_modulation) | ? | ? |
| ? | 802.11bb | Est. Jul 2021 | 60000-790000 | ? | ? | N/A | ? | ? | ? |
| **802.11 Standard rollups** | | | | | | | | | | | | |
|  | | 802.11-2007 | Mar 2007 | 2.4, 5 |  | Up to 54 |  | [DSSS](https://en.wikipedia.org/wiki/Direct-sequence_spread_spectrum), [OFDM](https://en.wikipedia.org/wiki/Orthogonal_frequency-division_multiplexing) |  |  |  |  |
| 802.11-2012 | Mar 2012 | 2.4, 5 |  | Up to 150[[B]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiB6) |  | [DSSS](https://en.wikipedia.org/wiki/Direct-sequence_spread_spectrum), [OFDM](https://en.wikipedia.org/wiki/Orthogonal_frequency-division_multiplexing) |  |  |  |  |
| 802.11-2016 | Dec 2016 | 2.4, 5, 60 |  | Up to 866.7 or 6,757[[B]](https://en.wikipedia.org/wiki/Template:802.11_network_standards#endnote_80211ns_sgiB6) |  | [DSSS](https://en.wikipedia.org/wiki/Direct-sequence_spread_spectrum), [OFDM](https://en.wikipedia.org/wiki/Orthogonal_frequency-division_multiplexing) |  |  |  |  |
| * [**A1**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_37ghzA1) [**A2**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_37ghzA2) [IEEE 802.11y-2008](https://en.wikipedia.org/wiki/IEEE_802.11y-2008) extended operation of 802.11a to the licensed 3.7 GHz band. Increased power limits allow a range up to 5,000 m. As of 2009, it is only being licensed in the United States by the [FCC](https://en.wikipedia.org/wiki/Federal_Communications_Commission). * [**B1**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_sgiB1) [**B2**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_sgiB2) [**B3**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_sgiB3) [**B4**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_sgiB4) [**B5**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_sgiB5) [**B6**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_sgiB6) Based on short [guard interval](https://en.wikipedia.org/wiki/Guard_interval); standard guard interval is ~10% slower. Rates vary widely based on distance, obstructions, and interference. * [**C1**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211aj_45ghzC1) For Chinese regulation. * [**D1**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211jD1) For Japanese regulation. * [**E1**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_WURE1) Wake-up Radio (WUR) Operation. * [**F1**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_sgiF1) [**F2**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_sgiF2) [**F3**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_sgiF3) [**F4**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_sgiF4) For single-user cases only, based on default [guard interval](https://en.wikipedia.org/wiki/Guard_interval) which is 0.8 micro seconds. Since multi-user via [OFDMA](https://en.wikipedia.org/wiki/OFDMA) has become available for 802.11ax, these may decrease. Also, these theoretical values depend on the link distance, whether the link is line-of-sight or not, interferences and the [multi-path](https://en.wikipedia.org/wiki/Multipath_routing) components in the environment. * [**G1**](https://en.wikipedia.org/wiki/Template:802.11_network_standards#ref_80211ns_sgiG1) The default [guard interval](https://en.wikipedia.org/wiki/Guard_interval) is 0.8 micro seconds. However, 802.11ax extended the maximum available [guard interval](https://en.wikipedia.org/wiki/Guard_interval) to 3.2 micro seconds, in order to support Outdoor communications, where the maximum possible propagation delay is larger compared to Indoor environments. | | | | | | | | | | |  |  |