

# IEEE 802.11

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# IEEE 802.11

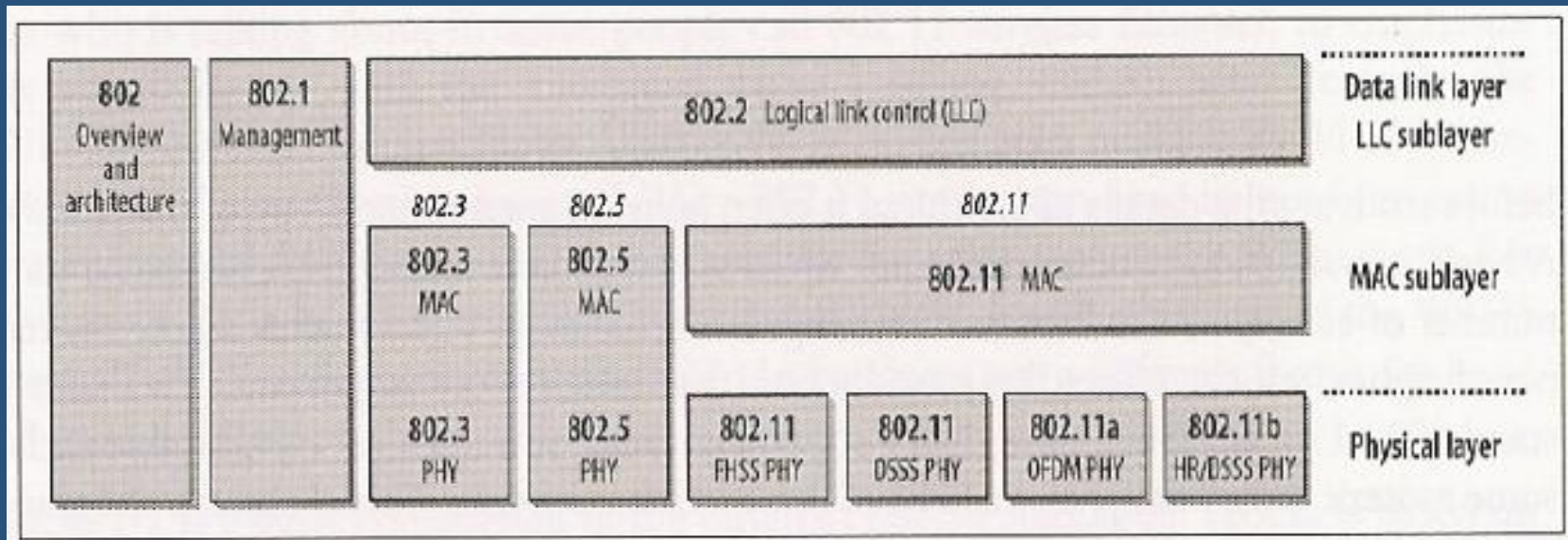
- | a set of standards for wireless local area network (WLAN) computer communication
- | developed by the IEEE LAN/MAN Standards Committee (IEEE 802)
- | Operates in the 5 GHz and 2.4 GHz public spectrum bands.
- | 802.11 Standards include over-the-air modulation techniques that use the same basic protocol.
  - | 802.11a
  - | 802.11b
  - | 802.11g
  - | 802.11n

## IEEE 802.11 (cont)



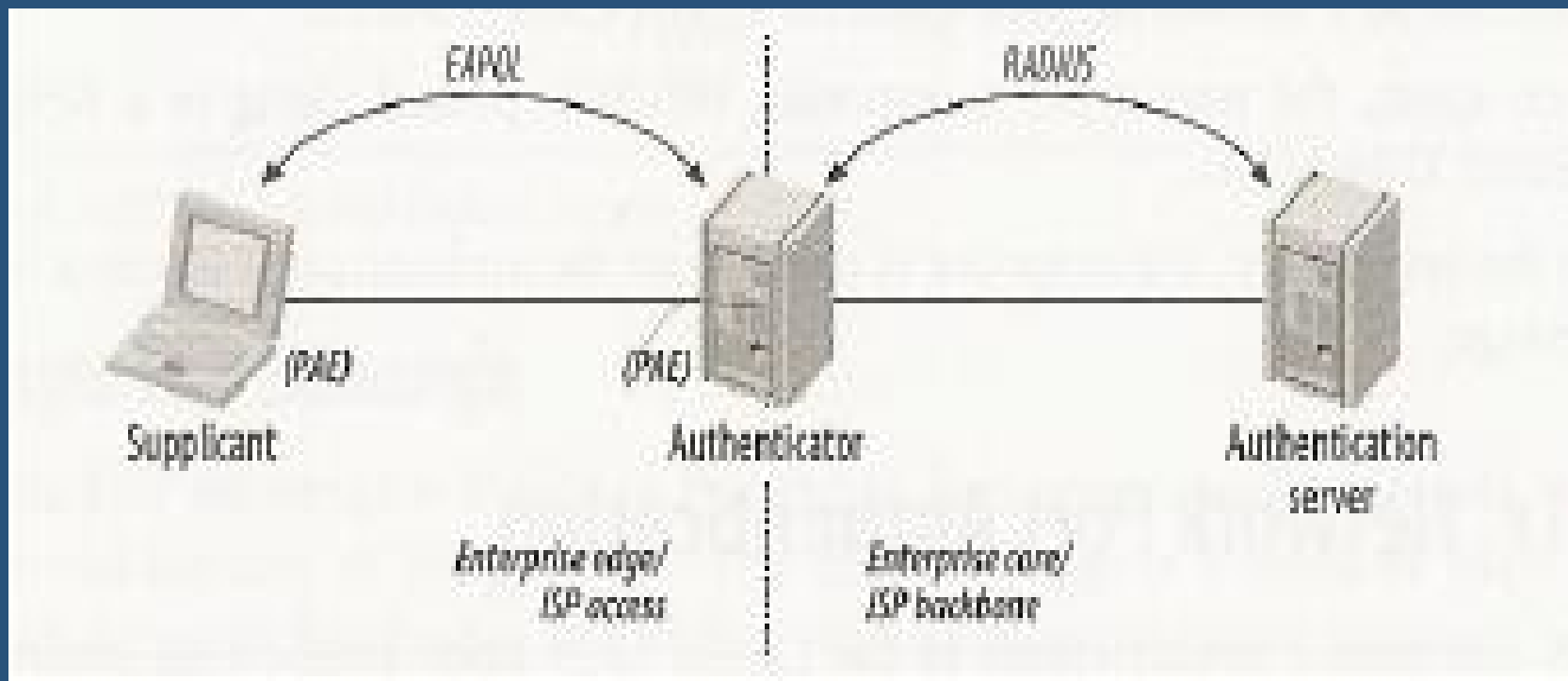
- | Security was originally purposefully weak due to export requirements of some governments, and was later enhanced via the 802.11i amendment after governmental and legislative changes.
- | Other standards in the family (c–f, h, j) are service amendments and extensions or corrections to previous specifications.

# IEEE 802 Standards & OSI Model



- | Observe 802.11 MAC is common to all 802.11 Physical Layer (PHY) standards
- | 802.11 PHY is split into Physical Layer Convergence Procedure (PLCP) and Physical Medium Dependent (PMD) sublayers

# 802.1x Architecture



# Standards and Amendments



- | Within the IEEE 802.11 Working Group, the following IEEE Standards Association Standard and Amendments exist:
  - | IEEE 802.11 - THE WLAN STANDARD was original 1 Mbit/s and 2 Mbit/s, 2.4 GHz RF and IR standard (1997), all the others listed below are Amendments to this standard, except for Recommended Practices 802.11F and 802.11T.
  - | IEEE 802.11a - 54 Mbit/s, 5 GHz standard (1999, shipping products in 2001)
  - | IEEE 802.11b - Enhancements to 802.11 to support 5.5 and 11 Mbit/s (1999)
  - | IEEE 802.11c - Bridge operation procedures; included in the IEEE 802.1D standard (2001)
  - | IEEE 802.11d - International (country-to-country) roaming extensions (2001)

# Standards and Amendments



- | IEEE 802.11e - Enhancements: QoS, including packet bursting (2005)
- | IEEE 802.11F - Inter-Access Point Protocol (2003)  
*Withdrawn February 2006*
- | IEEE 802.11g - 54 Mbit/s, 2.4 GHz standard (backwards compatible with b) (2003)
- | IEEE 802.11h - Spectrum Managed 802.11a (5 GHz) for European compatibility (2004)
- | IEEE 802.11i - Enhanced security (2004)
- | IEEE 802.11j - Extensions for Japan (2004)
- | IEEE 802.11-2007 - A new release of the standard that includes amendments a, b, d, e, g, h, i & j. (July 2007)
- | IEEE 802.11k - Radio resource measurement enhancements (proposed - 2007?)

# Standards and Amendments



- | IEEE 802.11l - (reserved and will not be used)
- | IEEE 802.11m - Maintenance of the standard. Recent edits became 802.11-2007. (ongoing)
- | IEEE 802.11n - Higher throughput improvements using MIMO (multiple input, multiple output antennas) (September 2008)
- | IEEE 802.11o - (reserved and will not be used)
- | IEEE 802.11p - WAVE - Wireless Access for the Vehicular Environment (such as ambulances and passenger cars) (working - 2009?)
- | IEEE 802.11q - (reserved and will not be used, can be confused with 802.1Q VLAN trunking)
- | IEEE 802.11r - Fast roaming Working "Task Group r" - 2007?
- | IEEE 802.11s - ESS Extended Service Set Mesh Networking (working - 2008?)

# Standards and Ammendments



- | IEEE 802.11T - Wireless Performance Prediction (WPP) - test methods and metrics Recommendation (working - 2008?)
- | IEEE 802.11u - Interworking with non-802 networks (for example, cellular) (proposal evaluation - ?)
- | IEEE 802.11v - Wireless network management (early proposal stages - ?)
- | IEEE 802.11w - Protected Management Frames (early proposal stages - 2008?)
- | IEEE 802.11x - (reserved and will not be used, can be confused with 802.1x Network Access Control)
- | IEEE 802.11y - 3650-3700 MHz Operation in the U.S. (March 2008?)
- | IEEE 802.11z - Extensions to Direct Link Setup (DLS) (Aug. 2007 - Dec. 2011)



# Operation

- | Use the 2.4 GHz or 5 GHz ISM band.
- | Due to frequency band choice, 802.11b and g equipments may suffer interference from microwave ovens, cordless telephones and other devices operating at same frequency.
- | The segment of the radio frequency spectrum used varies between countries.
  - | *802.11 is the standard adopted world-wide*

# Vital Amendments



- | 802.11-1997 (802.11 legacy)
- | 802.11a
- | 802.11b
- | 802.11g
- | 802.11n
- | 802.11-2007 (802.11-REVma)

# 802.11-1997 (802.11 legacy)



RELEASE DATE	OPERATING FREQUENCY	DATA RATE (typical ~ maximum)	RANGE
1997	2.4 GHz	0.9 Mbits ~ 2 Mbits	~ 20 m

- | The original version of the standard IEEE 802.11,
- | Released in 1997 and clarified in 1999
- | Transmitted in Industrial Scientific Medical frequency band at 2.4 GHz.
- | Legacy 802.11 was rapidly supplemented (and popularized) by 802.11b.

# 802.11a



RELEASE DATE	OPERATING FREQUENCY	DATA RATE (typical ~ maximum)	RANGE
October 1999	5 GHz	23 Mbits ~ 54 Mbits	~ 35 m

- | Same core protocol as the original standard
  - | yields realistic net achievable throughput in the mid-20 Mbit/s.
- | **Modulation Technique:** OFDM
- | **Advantage:**
  - | uses un-used 5 GHz band instead of the crowded 2.4 GHz band.
- | **Disadvantage** [High carrier frequency]:
  - | 802.11a signals cannot penetrate as far as those for 802.11b because they are absorbed more readily by walls and other solid objects in their path.

# 802.11a (cont)



Regulatory domain	Band (GHz)	Operating channel numbers	Channel center frequencies (MHz)
United States	U-NII lower band (5.15–5.25)	36 40 44 48	5180 5200 5220 5240
United States	U-NII middle band (5.25–5.35)	52 56 60 64	5260 5280 5300 5320
United States	U-NII upper band (5.725–5.825)	149 153 157 161	5745 5765 5785 5805

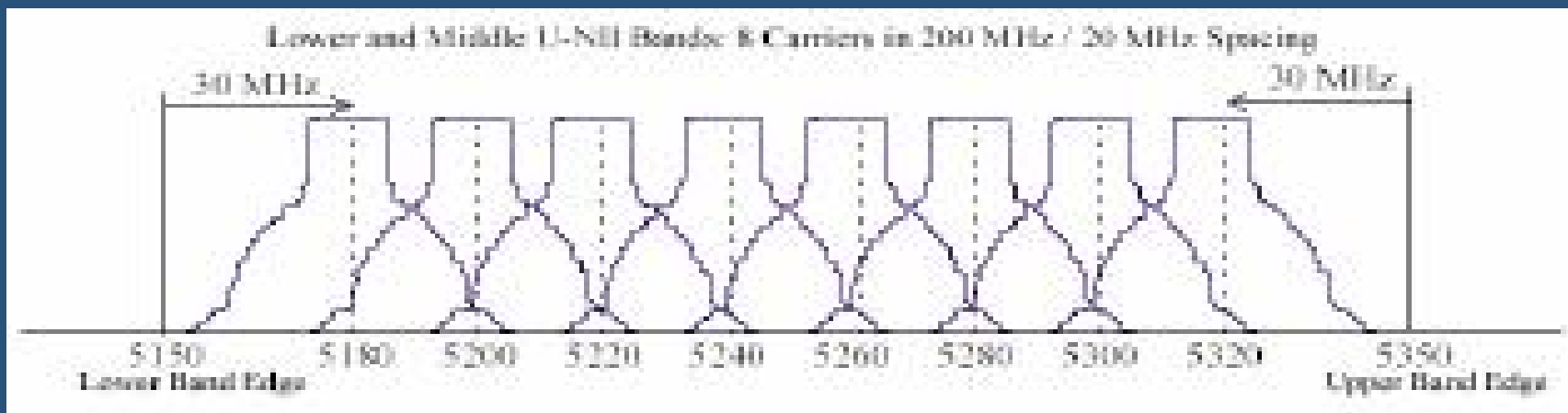
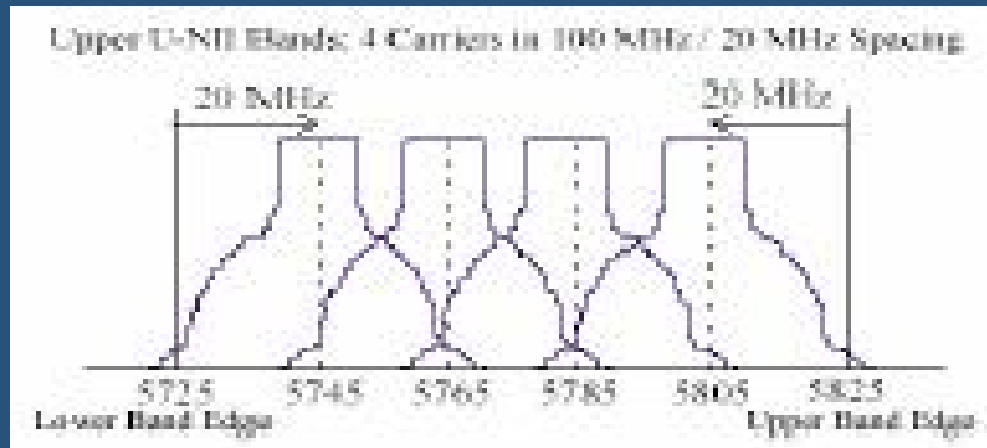
- | In U.S., there are 12 channels, each 20 MHz wide
- | Each channel is divided into 52 subchannels: 48 are used for data

# 802.11a (cont)



- | uses a 52-subcarrier orthogonal frequency-division multiplexing (OFDM) with a maximum raw data rate of 54 Mbit/s, which yields realistic net achievable throughput in the mid-20 Mbit/s.
- | The data rate is reduced to 48, 36, 24, 18, 12, 9 then 6 Mbit/s if required.
- | 802.11a originally had 12/13 non-overlapping channels, 12 that can be used indoor and 4/5 of the 12 that can be used in outdoor point to point configurations.
- | The advantages of using OFDM include reduced multi-path effects in reception and increased spectral efficiency.
- | On the other hand, OFDM has fundamental propagation advantages when in a high multi-path environment, such as an indoor office, and the higher frequencies enable the building of smaller antennas with higher RF system gain which counteract the disadvantage of a higher band of operation.
- | The increased number of usable channels (4 to 8 times as many in FCC countries) and the near absence of other interfering systems (microwave ovens, cordless phones, baby monitors) give 802.11a significant aggregate bandwidth and reliability advantages over 802.11b/g.

# 802.11a Spectrum Layout



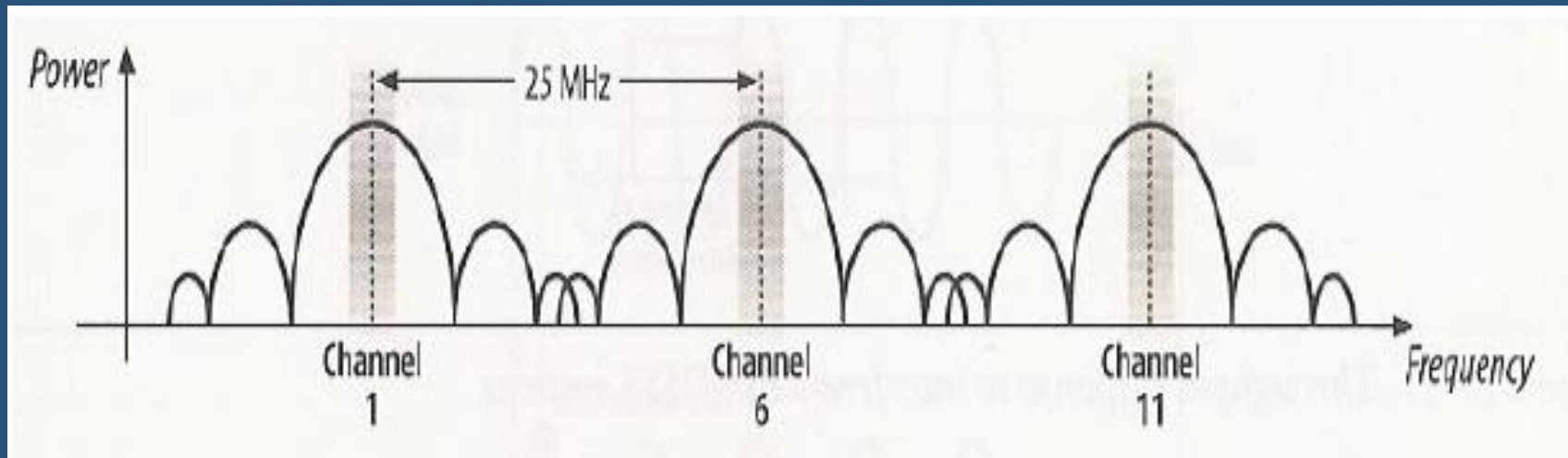
# 802.11b



RELEASE DATE	OPERATING FREQUENCY	DATA RATE (typical ~ maximum)	RANGE
October 1999	2.4 GHz	4.5 Mbits ~ 11 Mbits	~ 38 m

- | Accepted as the definitive wireless LAN technology standard.
- | **Modulation Technique:** DSSS
- | **Advantage:**
  - | The dramatic increase in throughput
  - | Simultaneous substantial price reductions of devices with this technology
- | **Disadvantage:**
  - | Devices suffer interference from other products operating in the 2.4 GHz band.

# 802.11b (cont)



- | In US, channels 1-11 (with center frequencies at 2.412 – 2.462 GHz and 5 MHz distance) are available
- | For 11 Mbps, Channels 1, 6, and 11 give maximum number of channels with minimum interference



## 802.11b (cont)

- | 802.11b is used in a point-to-multipoint configuration, wherein an access point communicates via an omni-directional antenna with one or more nomadic or mobile clients that are located in a coverage area around the access point.
- | The overall bandwidth is dynamically demand shared across all the users on a channel.
- | 802.11b cards can operate at 11 Mbit/s, but will scale back to 5.5, then 2, then 1 Mbit/s (also known as Adaptive Rate Selection), if signal quality becomes an issue.

# 802.11a vs. 802.11b Channel Maps



Channel ID	FCC	Start Freq.	End Freq.
*1	2412	2400	2424
2	2417	2405	2429
3	2422	2410	2434
4	2427	2415	2439
5	2432	2420	2444
*6	2437	2425	2449
7	2442	2430	2454
8	2447	2435	2459
9	2452	2440	2464
10	2457	2445	2469
*11	2462	2450	2474
12	2467	Not supported in IEEE Stand:	
13	2472	Not supported in IFFF Stand:	
14	2484	Japan Only	

Band	Operating Channel	Center Freq.
Lower Band	36	5180
	40	5200
	44	5220
	48	5240
U-NII Middle Band	52	5260
	56	5280
	60	5300
	64	5320
U-NII Upper Band	149	5745
	153	5764
	157	5785
	161	5805

- | **802.11a provides more channels and greater bandwidth**
- | **But 5GHz is not legal in Euro countries, thus not widely acceptable as 802.11b**

# 802.11g



RELEASE DATE	OPERATING FREQUENCY	DATA RATE (typical ~ maximum)	RANGE
June 2003	2.4 GHz	19 Mbits ~ 54 Mbits	~ 38 m

- | Works at 2.4 GHz band but operates at a maximum raw data rate of 54 Mbit/s, or about 19 Mbit/s net throughput.
- | **Modulation Technique:** OFDM
- | **Advantage:**
  - | 802.11g hardware is fully backwards compatible with 802.11b hardware.
- | **Disadvantage:**
  - | Like 802.11b, 802.11g devices suffer interference from other products operating in the 2.4 GHz band.

# 802.11g (cont)



- | uses a 52-subcarrier orthogonal frequency-division multiplexing (OFDM) with a maximum raw data rate of 54 Mbit/s, which yields realistic net achievable throughput in the mid-20 Mbit/s.
- | The data rate is reduced to 48, 36, 24, 18, 12, 9 then 6 Mbit/s if required.
- | 802.11a originally had 12/13 non-overlapping channels, 12 that can be used indoor and 4/5 of the 12 that can be used in outdoor point to point configurations.
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- | On the other hand, OFDM has fundamental propagation advantages when in a high multi-path environment, such as an indoor office, and the higher frequencies enable the building of smaller antennas with higher RF system gain which counteract the disadvantage of a higher band of operation.
- | The increased number of usable channels (4 to 8 times as many in FCC countries) and the near absence of other interfering systems (microwave ovens, cordless phones, baby monitors) give 802.11a significant aggregate bandwidth and reliability advantages over 802.11b/g.

# 802.11n



RELEASE DATE	OPERATING FREQUENCY	DATA RATE (typical ~ maximum)	RANGE
December 2008	2.4 GHz or 5 GHz	74 Mbits ~ 248 Mbits (2 streams)	~ 70 m

- | A proposed amendment which improves upon the previous 802.11 standards by adding multiple-input multiple-output (MIMO) and many other newer features.

# 802.11-2007



- | Also known as 802.11-REVma
- | Done in 2003 by task group TGma
  - | Make amendments to the 1999 version of the 802.11 standard.
- | They created a single document that merged 8 amendments (802.11a,b,d,e,g,h,i,j) with the base standard.
- | Upon approval on March 08, 2007, 802.11REVma was renamed to the current standard **IEEE 802.11-2007**.
  - | This is the single most modern 802.11 document available that contains cumulative changes from multiple sub-letter task groups.