Chapter 5: IEEE 802.11 Wireless LAN

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Wireless LAN

- Wireless LAN is the basic technology we find in all different places to connect mobile devices to the Internet
- The WLAN standard is published by the IEEE as the

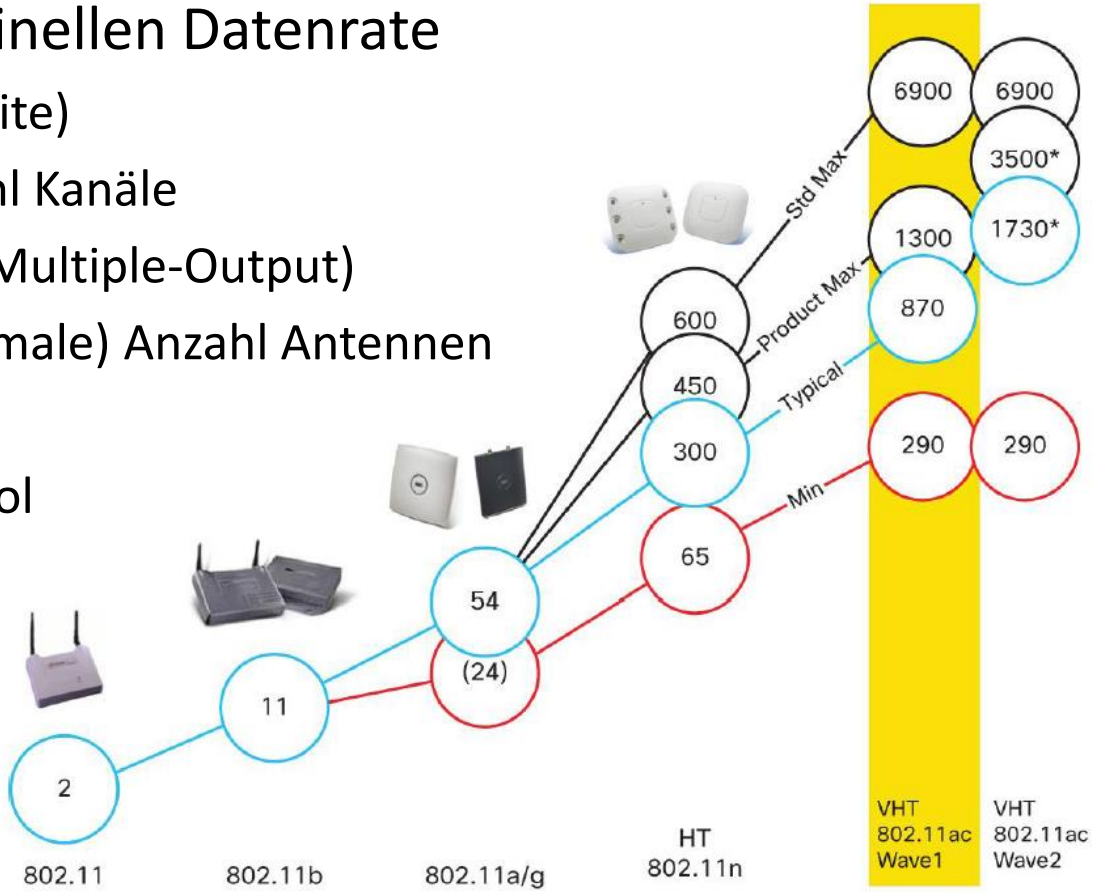
  IEEE Standard for Information technology — Telecommunications and information exchange between systems

  Local and metropolitan area networks — Specific requirements

  Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications
- The Wi-Fi Alliance (Wireless Fidelity) is an industry consortium for certifying products based on the IEEE 802.11 standard

Entwicklung des WLAN Standards IEEE 802.11

- Vergrößerung der nominellen Datenrate
  - Anzahl Kanäle (Bandbreite)
    - Multiplikator: Anzahl Kanäle
  - MIMO (Multiple-Input-Multiple-Output)
    - Multiplikator: (minimale) Anzahl Antennen
  - Modulation/Codierung:
    - mehr Bits pro Symbol
  - Aggregation
    - weniger Overhead
  - Guard Intervall
    - dichtere Symbole



- Funktioniert alles nur bei guten Ausbreitungseigenschaften d.h. kleinen und ungestörten Netzen

Erweiterungen des WLAN-Standards

- a-b-e-g-n-p-s-ac-ax: Das sind „Namen“ der Arbeitsgruppen, die den IEEE 802.11 Standard erweitern.

WI-FI Alliance	IEEE Standard	Band	Übertragungs-technologie	Bandbreite	Neuerung	Theoretische Übertragungsrate 2.4 Ghz / 5 GHz
	802.11a	5 GHz	OFDM	20 MHz		54 Mbps
	802.11b	2,4 GHz	DSSS	20 MHz		11 Mbps
WMM	802.11e				QoS	
	802.11g	2,4 GHz	OFDM	20 MHz		54 Mbps
Wi-FI 4	802.11n	2,4 GHz 5 GHz		20 MHz 40 MHz	4x4 MIMO Aggregation	300 Mbps 600 Mbps
	802.11p				Car-2-car	27 Mbps
Wi-Fi 5	802.11ac	5 GHz		160 MHz	8x8 MIMO MU-MIMO	7 Gbps
Wi-Fi 6 WiFi 6E	802.11ax	2,4 GHz 5 GHz 6 GHz	OFDMA		OFDMA MU-MIMO (Uplink) BSS Coloring	600 Mbps 10 Gbps

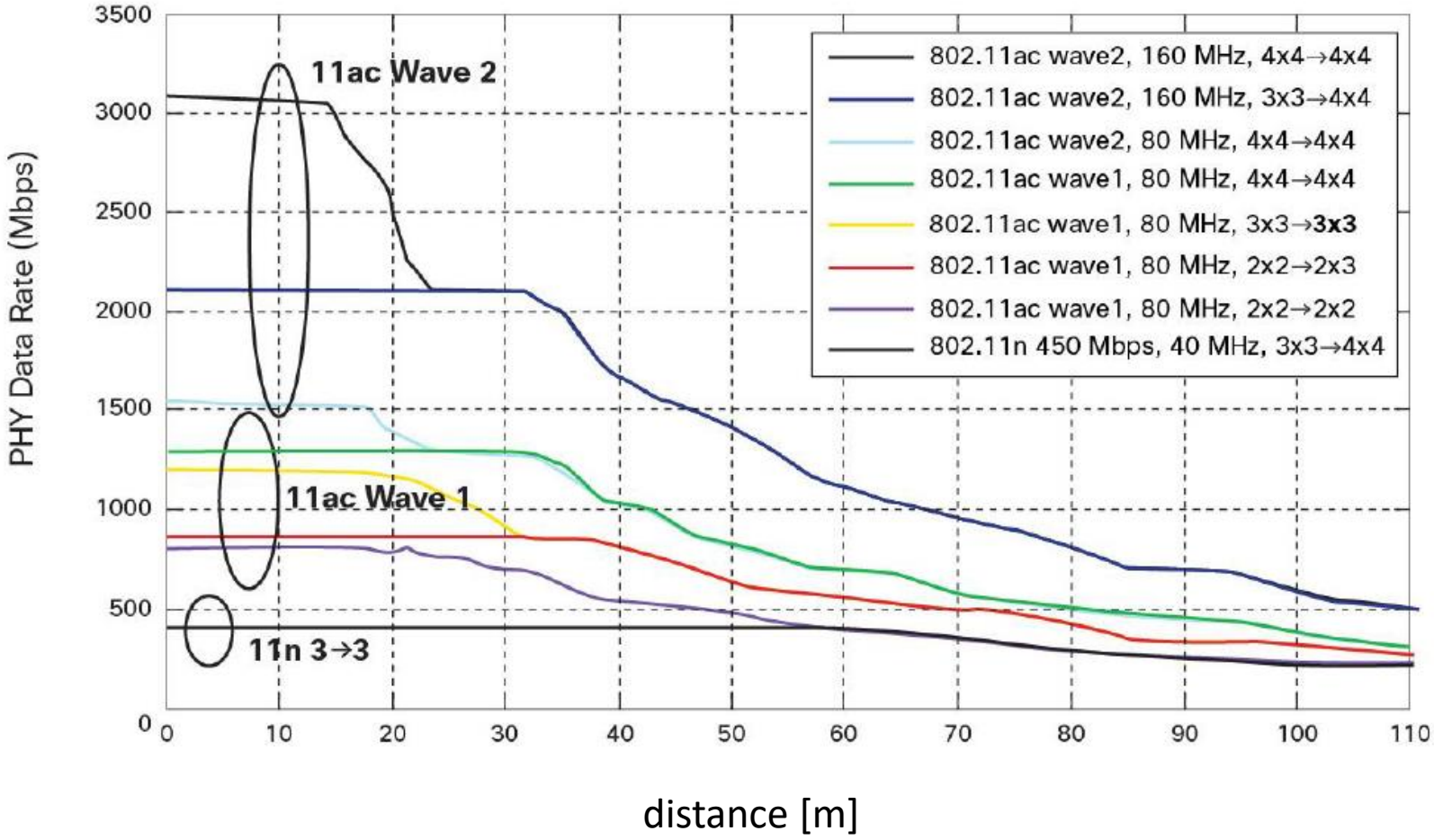
Standards and Amendments

- The standard is evolved by working groups identified by one or two letters and their result is published as an amendment to the standard
  - IEEE 802.11a: OFDM (Orthogonal Frequency Division Multiple) based radio transmission with up to 54 Mbps in the 5 GHz band
  - IEEE 802.11b: DSSS (Direct Sequence Spread Spectrum) based radio transmission with up to 11 Mbps in the 2.4 GHz band
  - IEEE 802.11g: OFDM (Orthogonal Frequency Division Multiple) based radio transmission with up to 54 Mbps in the 5 GHz band
  - IEEE 802.11e: capability for service differentiation, e.g. VoIP may be prioritized
  - IEEE 802.11n: MIMO (Multiple Input Multiple Output), high data rates by using multiple transmit and receives antennas
  - IEEE 802.11s: support for mesh networks, multiple wireless access points build a wireless backbone to connected to the Internet via multiple hops
  - IEEE 802.11ac: higher data rates by enhanced MIMO schemes and usage of multiple 20 MHz channels, MU-MIMO
  - IEEE 802.11ad: usage of 60 GHz band with 1760 MHz channels
  - IEEE 802.11ax: higher data rates, 1024QAM, OFDMA, etc.
  - IEEE 802.11be: TSN support, more spectrum, more MIMO, etc.
- Every couple of years a new complete version of the standard including all intermediate amendments is published
  - IEEE 802.11-2007, IEEE 802.11-2012, IEEE 802.11-2016

Höhere Datenraten

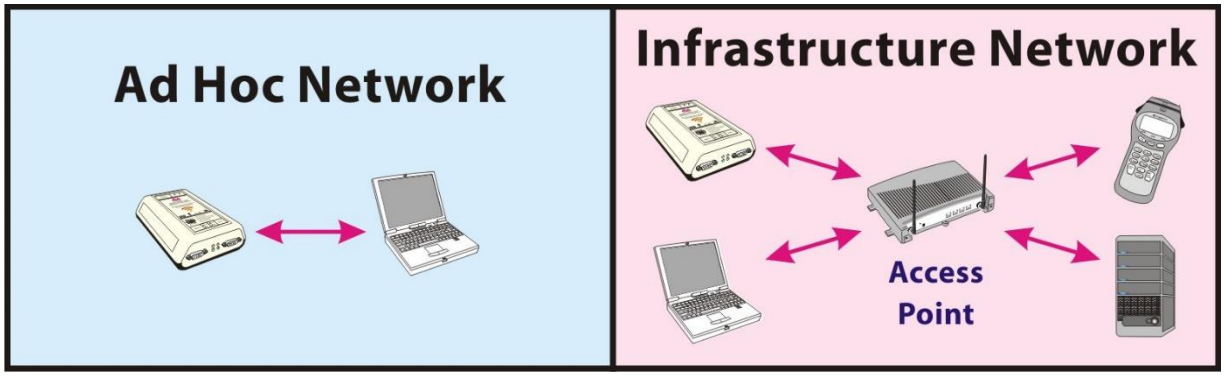
Nominal Configuration	Bandwidth (MHz)	Number of Spatial Streams	Constellation Size and Rate	Guard Interval	PHY Data Rate (Mbps)	Throughput (Mbps)*
802.11a						
All	20	1	64QAMr3/4	Long	54	24
802.11n						
Amendment min	20	1	64QAMr5/6	Long	65	46
Low-end product (2.4 GHz only+)	20	1	64QAMr5/6	Short	72	51
Mid-tier product	40	2	64QAMr5/6	Short	300	210
Max product	40	3	64QAMr5/6	Short	450	320
Amendment max	40	4	64QAMr5/6	Short	600	420
802.11ac 80 MHz						
Amendment min	80	1	64QAMr5/6	Long	293	210
Low-end product	80	1	256QAMr5/6	Short	433	300
Mid-tier product	80	2	256QAMr5/6	Short	867	610

IEEE 802.11ac Datenraten in Abhängigkeit der Entfernung



Wireless LAN

- Wireless LAN can be operated in infrastructure mode or ad-hoc mode
- In infrastructure mode there is a access point and multiple clients connect to the access point
  - the access point identifies itself by regularly broadcasting beacon frames containing the SSID
  - client scan channels for beacons and can connects to the access point when they detect a beacon signal
- In Ad-Hoc mode there is no access point involved and two clients (peers) directly communicate with each other

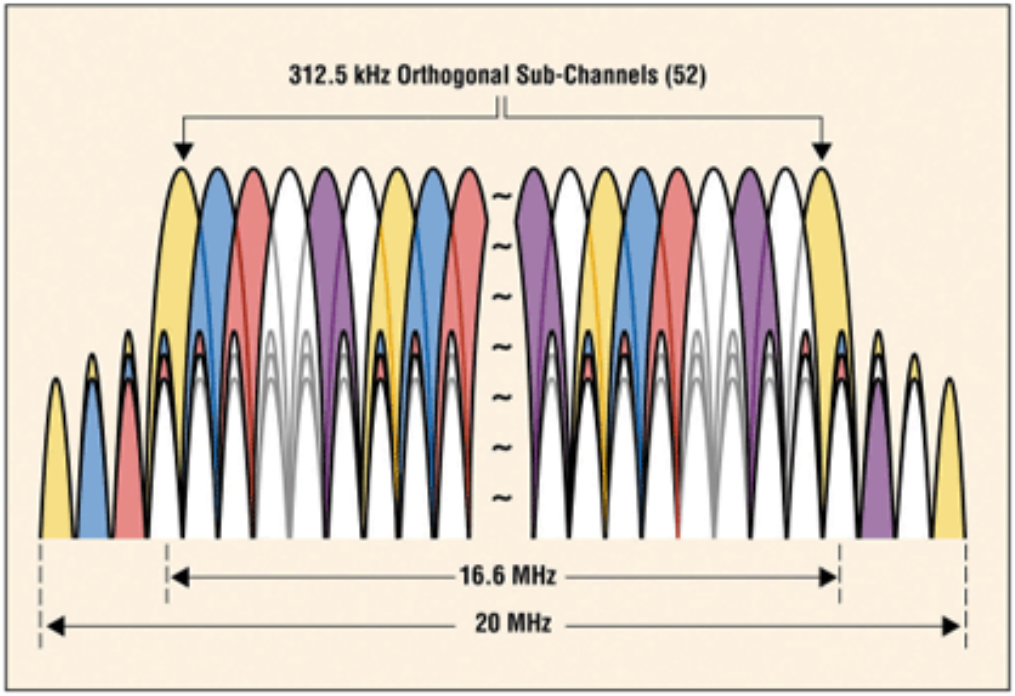


WLAN Technology - General

- WLAN is specified for transmission in the
  - 2.4 GHz band, 5 GHz band and 60GHz band
- WLAN uses basic 20 MHz channels that can be combined for higher data rates
- The multiple access scheme of WLAN is CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance):
  - Access to the medium is not coordinated but follows certain rules.
  - Stations listen on the channel before they transmit.
  - Stations resolve collisions by randomly delaying the retransmissions.
- Convolutional codes or LDPC codes are used for channel coding. Decoding process is typically soft-decision decoding. Coding rates ranges from 1/2 to 5/6
- Modulation schemes are BPSK, QPSK, 16 QAM, 64 QAM, and 256 QAM

WLAN Technology - OFDM

- OFDM (orthogonal frequency division multiplex) is used for data transmission
  - the 20 MHz channel is split into 64 smaller channels with 312,5 kHz
  - OFDM generates a baseband signal that consists of all modulated signals on the smaller channels
  - the signals on the smaller channels are BPSK, QPSK, QAM modulated



WLAN Technology - MIMO

- MIMO (multiple input multiple output) is a technology for transmitting data over multiple transmit or receive antennas to
  - increase the SNR of a single data stream between a source and a destination ➔ increase the data rate
  - transmit multiple data streams between a source and a destination in parallel ➔ increase the data rate
  - transmit multiple data streams between a source and a multiple destinations in parallel ➔ increase the data rate (multi-user MIMO)