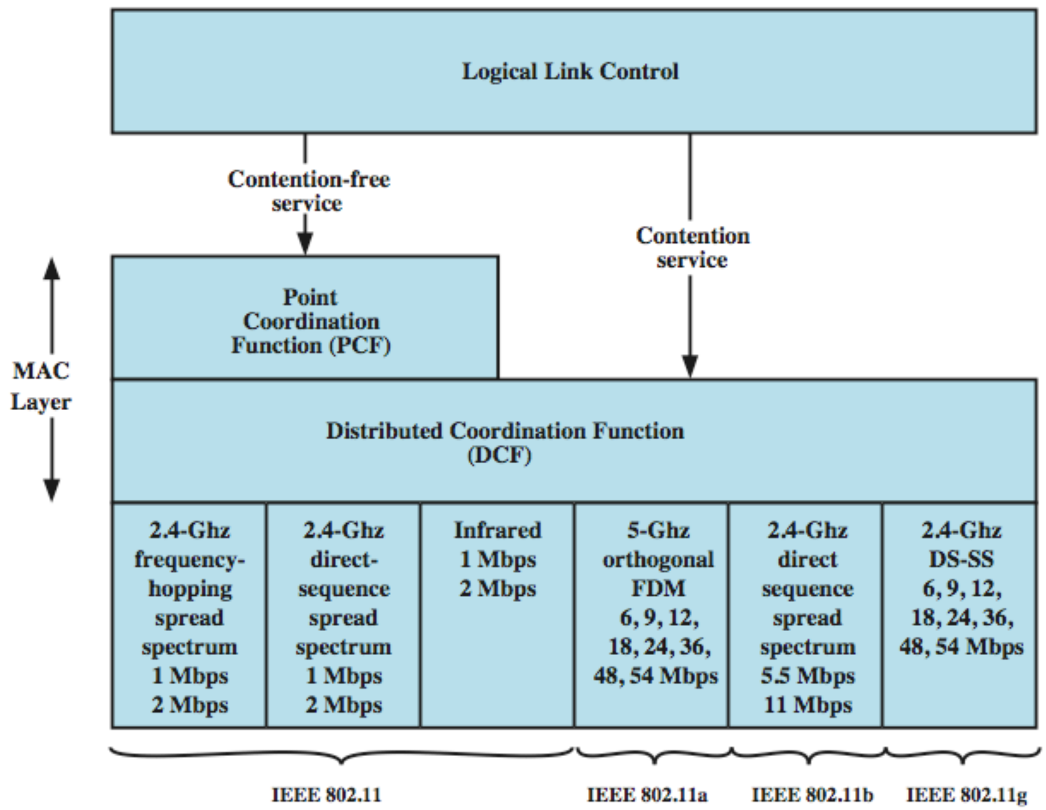
IEEE 802.11

CSMA/CA MAC LAYER

Media Access Control



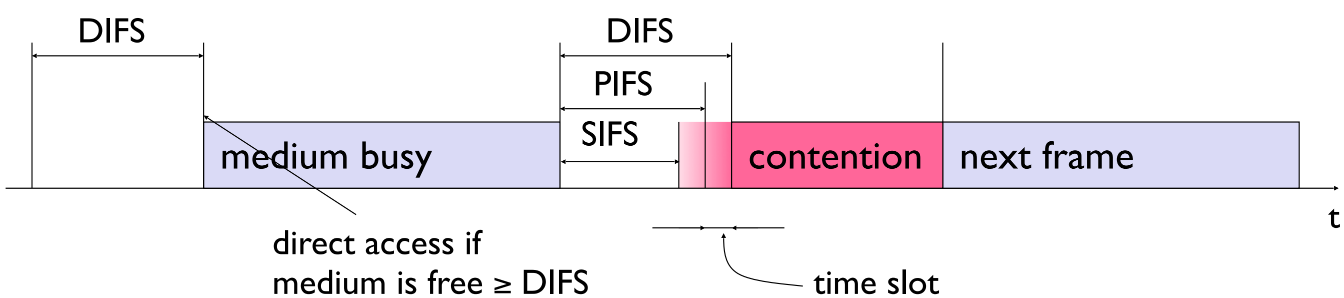
802.11 - MAC Layer Principles

- **Access methods (called DFWMAC: Distributed Foundation Wireless MAC)**
  - **DCF CSMA/CA (mandatory)**
    - collision avoidance via randomized "back-off" mechanism
    - minimum distance between consecutive packets
    - ACK packet for acknowledgements (not for broadcasts)
  - **DCF with RTS/CTS (optional)**
    - avoids hidden terminal problem
  - **PCF (optional and rarely used in practice)**
    - access point polls terminals according to a list

- DCF: Distributed Coordination Function
- PCF: Point Coordination Function

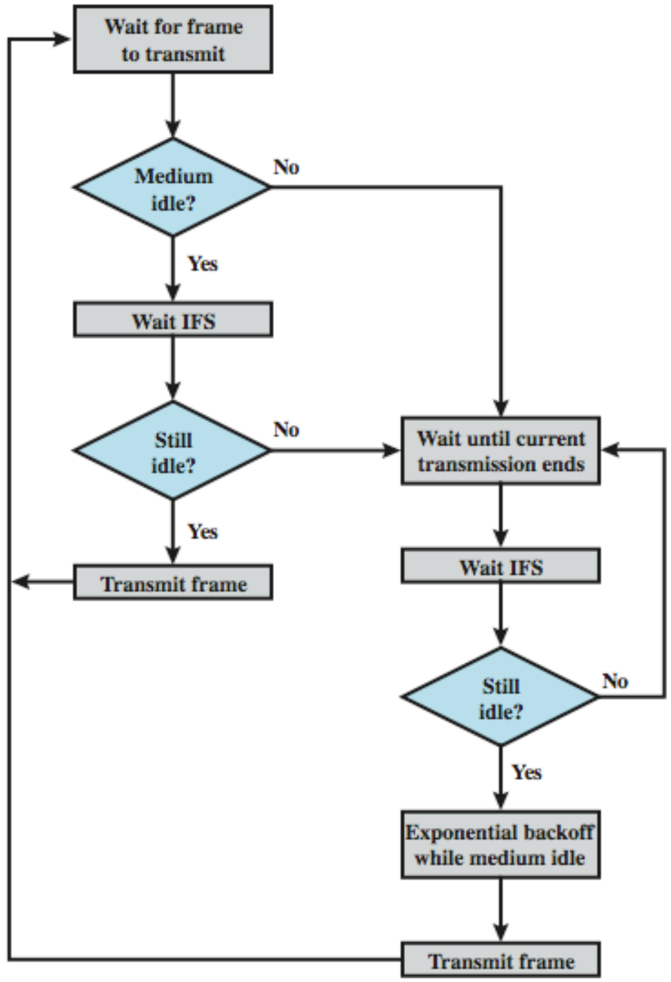
802.11 - MAC Layer Principles

- **Priorities**
  - Defined through different inter frame spaces
  - No guaranteed, hard priorities
  - **SIFS** (Short Inter Frame Spacing)
    - highest priority, for ACK, CTS, polling response
  - **PIFS** (PCF IFS)
    - medium priority, for time-bounded service using PCF
  - **DIFS** (DCF, Distributed Coordination Function IFS)
    - lowest priority, for asynchronous data service

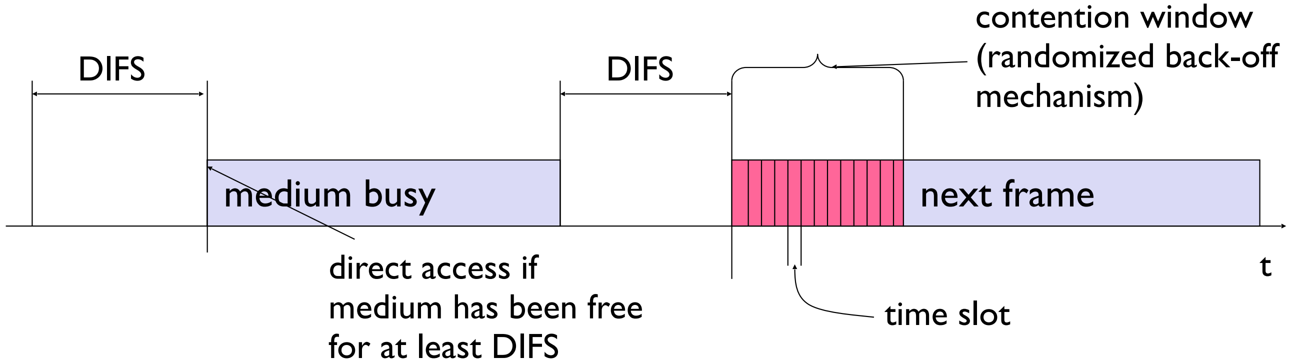


Note : IFS durations are specific to each PHY

CSMA/CA Control Logic



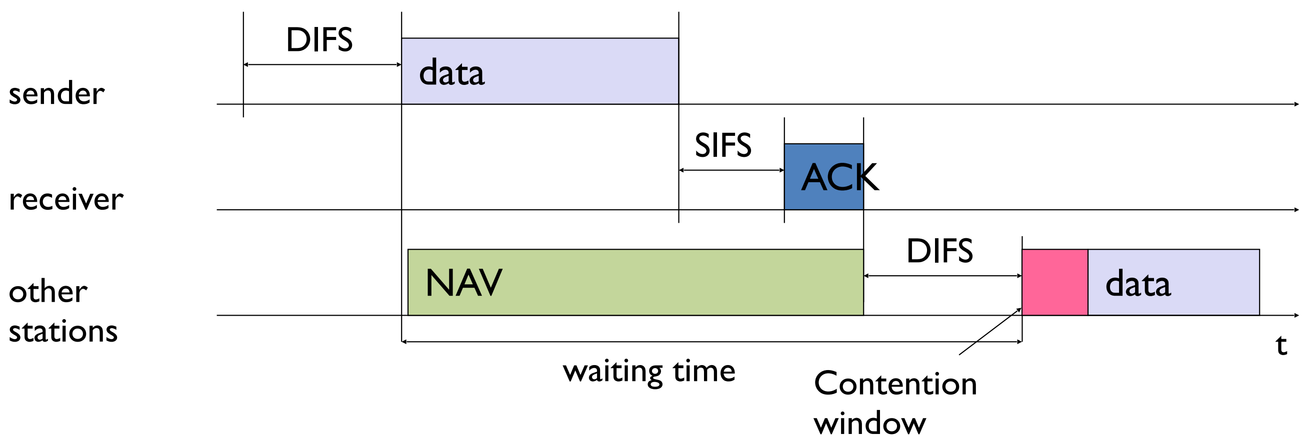
802.11 - CSMA/CA Principles



- Station ready to send starts sensing the medium (Carrier Sense based on CCA, Clear Channel Assessment)
- If the medium is free for the duration of an Inter-Frame Space (IFS), the station can start sending (IFS depends on service type)
- If the medium is busy, the station has to wait for a free IFS, then the station must additionally wait a random back-off time (collision avoidance, multiple of slot-time)
- If another station occupies the medium during the back-off time of the station, the back-off timer stops (to increase fairness)

802.11 - CSMA/CA Unicast

- Sending unicast packets
  - station has to wait for DIFS before sending data
  - receiver acknowledges at once (after waiting for SIFS) if the packet was received correctly (CRC)
  - automatic retransmission of data packets in case of transmission errors

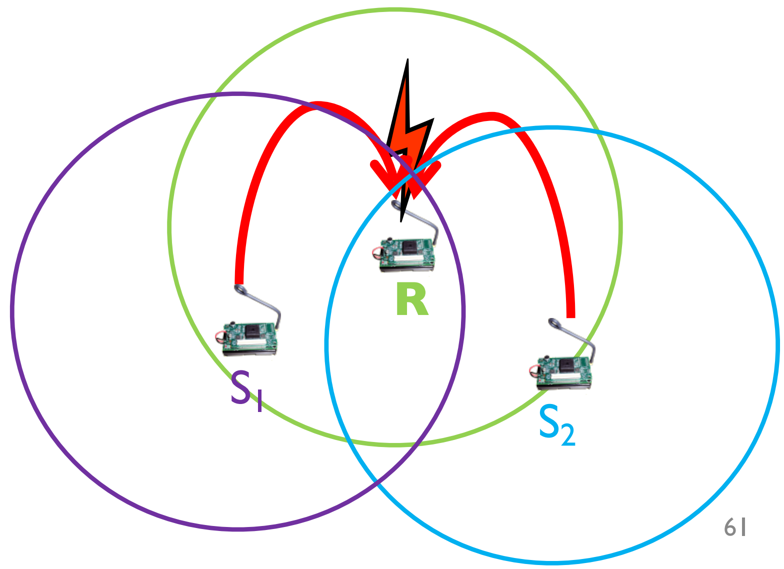


The ACK is sent right at the end of SIFS (no contention)

NAV: Net Allocation Vector

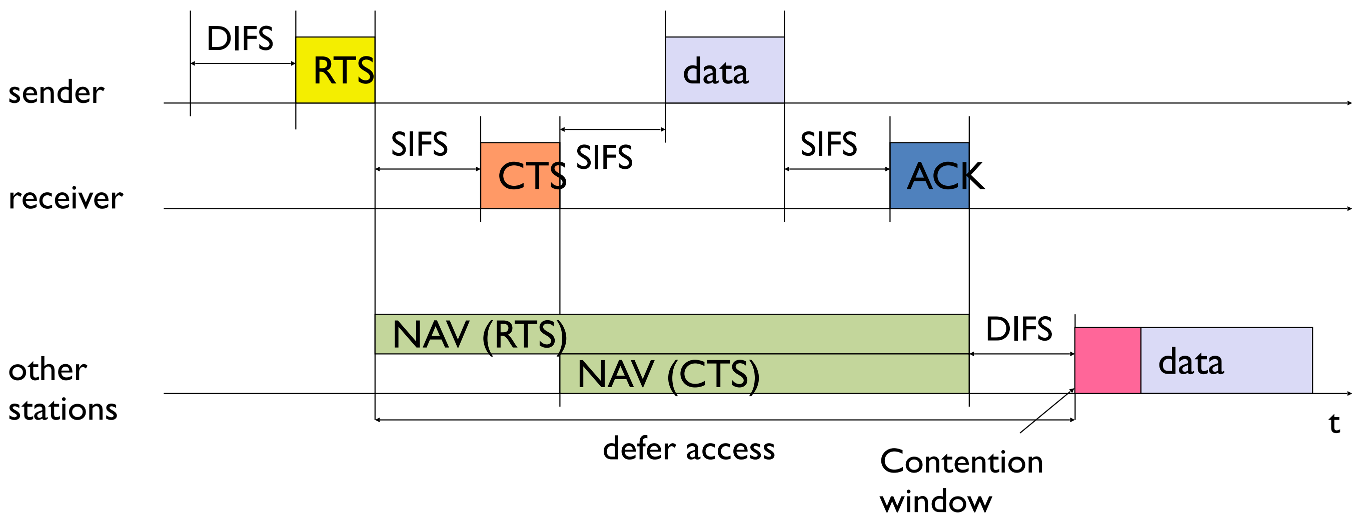
Hidden Terminals

- **Hidden terminals**
  - S_1 sends to R, S_2 cannot receive S_1
  - S_2 wants to send to R, S_2 senses a "free" medium (CS fails)
  - Collision at R, S_1 cannot receive the collision (CD fails)
  - S_1 is "hidden" for S_2



802.11 – DCF with RTS/CTS

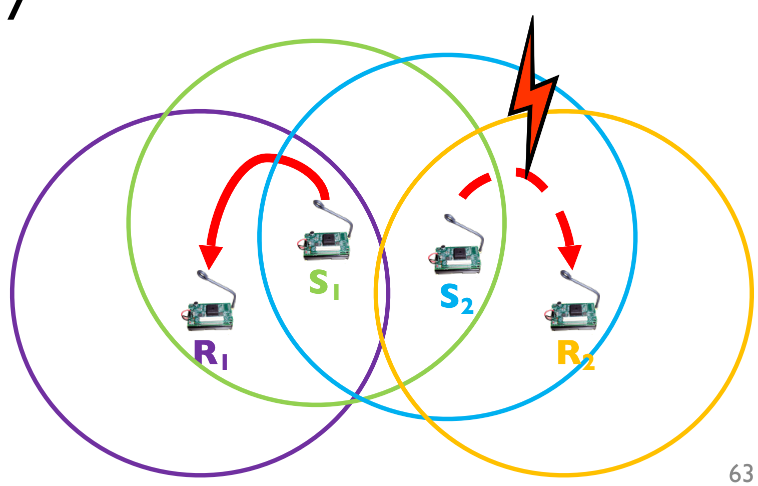
- Sending unicast packets
  - station can send RTS with reservation parameter after waiting for DIFS (reservation determines amount of time the data packet needs the medium)
  - acknowledgement via CTS after SIFS by receiver (if ready to receive)
  - sender can now send data at once, acknowledgement via ACK
  - other stations store medium reservations distributed via RTS and CTS



RTS/CTS can be present for some packets and not for other

Exposed terminals

- Exposed terminals
  - S_1 sends to R_1, S_2 wants to send to another terminal (not S_1 or R_1)
  - S_2 has to wait, CS signals a medium in use
  - But R_1 is outside the radio range of R_2, therefore waiting is not necessary
  - S_2 is "exposed" to S_1



Backoff Time and CW

- A backoff time (measured in slot times) is chosen randomly in the interval [0,CW), where CW stands for the contention window
- CW is an integer whose range is determined by the PHY layer characteristics: CW_{min} and CW_{max}
- CW is doubled after each unsuccessful transmission, up to the maximum value equal to $CW_{max} + 1$

Inter Frame Space and CW Times

Parameters	*802.11a*	*802.11b (FH)*	*802.11b (DS)*	*802.11b (IR)*	*802.11b (High Rate)*
Slot Time (μs)	9	50	20	8	20
SIFS (μs)	16	28	10	10	10
DIFS (μs)	34	128	50	26	50
EIFS (μs)	92.6	396	364	205 or 193	268 or 364
$CW_{min}(SlotTime)$	15	15	31	63	31
$CW_{max}(SlotTime)$	1023	1023	1023	1023	1023
Physical Data Rate (*Mbps*)	6 to 54	1 and 2	1 and 2	1 and 2	1, 2, 5.5, and 11

More on Frame Formats

RTS

2 Bytes	2 Bytes	6 Bytes	6 Bytes	4 Bytes
Frame Control	Duration	Destination Address	Source Address	FCS

MAC Header

CTS

2 Bytes	2 Bytes	6 Bytes	4 Bytes
Frame Control	Duration	Destination Address	FCS

MAC Header

ACK

2 Bytes	2 Bytes	6 Bytes	4 Bytes
Frame Control	Duration	Destination Address	FCS

MAC Header

802.11b Packet Layout

Preamble	PLCP Header	Payload Header	LLC Protocol Data Unit	Payload Trailer

Preamble:

Sync Bytes	Start of Frame
7 or 16 bytes	2 bytes

PLCP Header:

Signal Rate	Service	Length	Header Error Check
1 byte	1 byte	2 bytes	2 bytes

Payload Header:

Frame Control	Duration ID	Destination Address	Source Address	Address 3	Sequence Control	Address 4
2 bytes	2 bytes	6 bytes	6 bytes	6 bytes	2 bytes	6 bytes

LLC PDU:

DSAP	SSAP	Control	Data
1 byte	1 byte	1–2 bytes	43–1497 bytes

Payload Trailer:

Frame Check Sequence
4 bytes

Preamble of 802.11b Packets

- ➢Used to mark the start of the packet
- ➢Always transmitted at 1 Mbps
- ➢Sub fields of Preamble
  - – Long preamble version
    - 16 sync bytes of alternating 1's and 0's
    - 1 byte of start of frame delimiter (1010101)
  - – Short preamble version
    - 7 sync bytes
    - 1 byte of start of frame

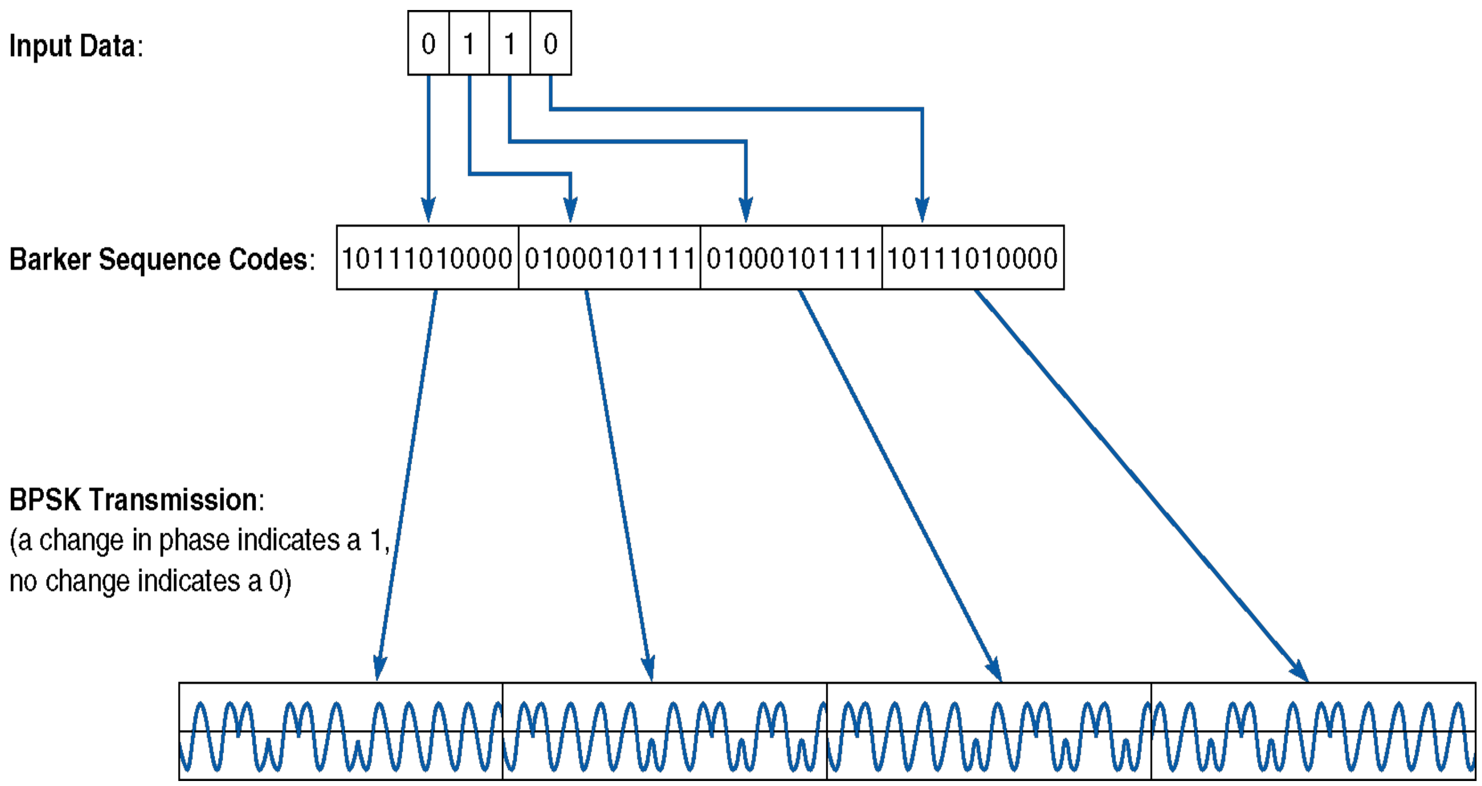
Data Transmission in PL

- ➢Via radio waves
  - – Analog medium
  - – Digital computer data transmitted using analog transmission (Translations done by NIC and AP)
- ➢Frequency and bandwidth (range of frequencies)
  - – 2.4000 – 2.4835 GHz => 83.5 MHz bandwidth in USA

Bit Transmission in DSSS

- **Each bit converted into a special code**
  - 8-bit or 11-bit code (designed to reduce interference)
  - Called spreading a bit into many bits across spectrum
- **1-Mbps DSS**
  - Uses an 11-bit Barker sequence code
    - Transmitted using binary phase shift keying (BPSK) (1 bit per symbol)
    - 11 Mbps signaling rate ==> 1 Mbps data rate
- **2-Mbps DSS**
  - Uses the same 11-bit code
    - Transmits using Quadrature phase shift keying (QPSK) (2 bits per symbol)

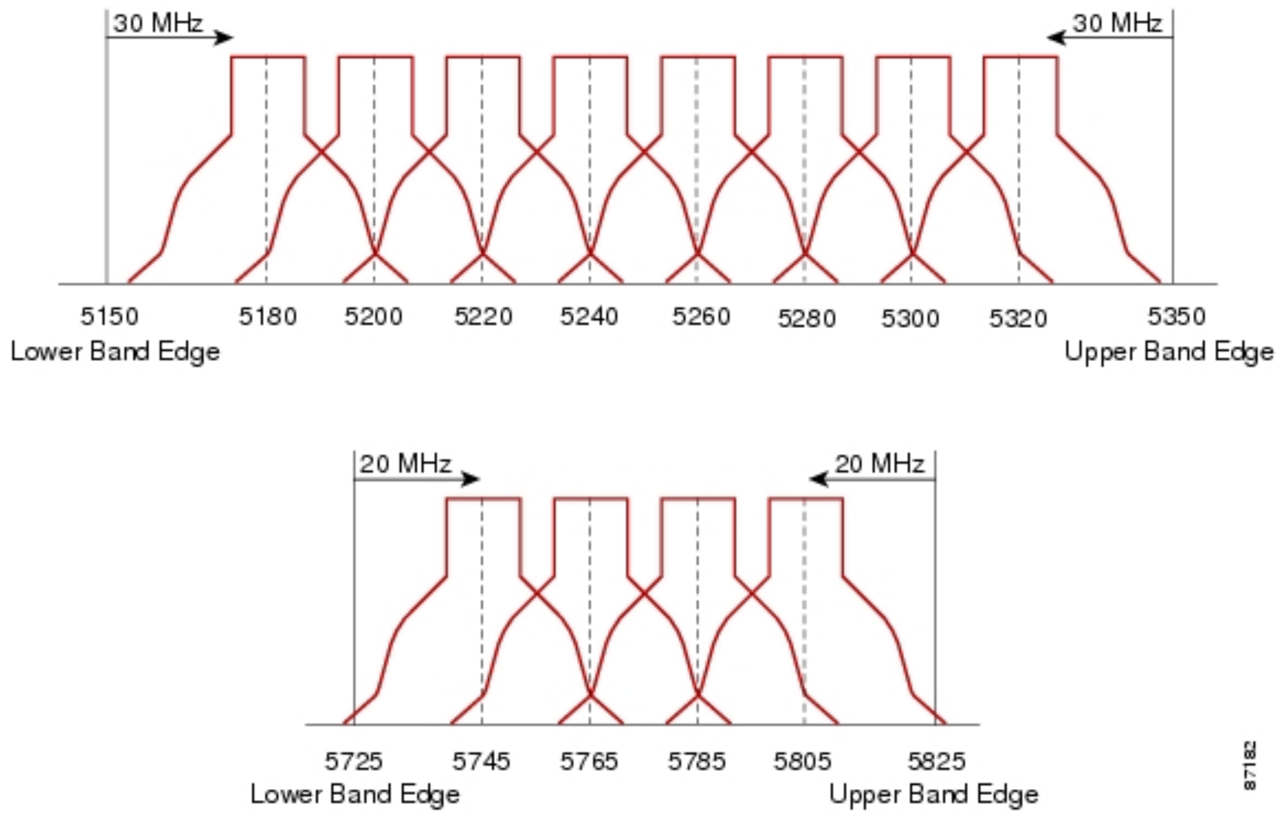
1Mbps DSSS with Barker code



IEEE 802.11a

- ➢Operates in a 5 GHz frequency range
- ➢Total bandwidth is 300 MHz
  - – Faster data rates possible: Up to 54 Mbps
    - • 6, 9, 12, 18, 24, 36, 48, and 54 Mbps
- ➢Uses the same topology as .11b
- ➢Reduced range because of higher speed
  - – 50 meters (150 feet)
  - – Highest speed achievable within 15 meter

802.11a



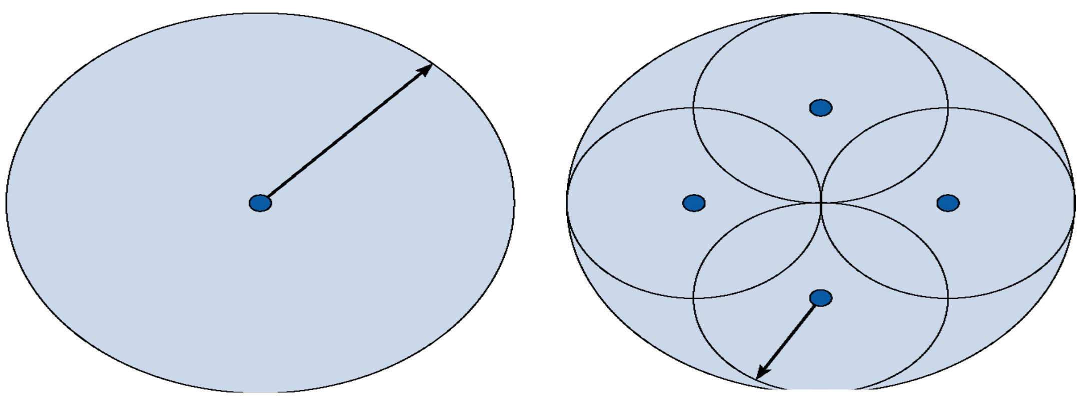
30 MHz
30 MHz
5150
Lower Band Edge
5180
5200
5220
5240
5260
5280
5300
5320
5350
Upper Band Edge
20 MHz
20 MHz
5725
Lower Band Edge
5745
5765
5785
5805
5825
Upper Band Edge
87182

IEEE 802.11a Coverage

➢ Provides 4-12 channels (depending on configuration)

– Important for coverage; takes more .11a AP to cover the same area (small range)

– Make it possible to locate many APs in the same area to increase capacity



Range from 802.11b AP
100 meters = 5.5 - 11 Mbps

Range from 802.11a AP
50 meters = 6 - 12 Mbps

802.11a Packet Layout

Preamble	PLCP Header	Payload Header	LLC Protocol Data Unit	Payload Trailer

Preamble:

Sync Bytes	Start of Frame
8 bytes	2 bytes

PLCP Header:

Rate	Reserved	Length	Parity	Tail
4 bits	1 bit	12 bits	1 bit	6 bits

Payload Header:

Service	Frame Control	Duration ID	Destination Address	Source Address	Address 3	Sequence Control	Address 4
2 bytes	2 bytes	2 bytes	6 bytes	6 bytes	6 bytes	2 bytes	6 bytes

LLC PDU:

DSAP	SSAP	Control	Data
1 byte	1 byte	1-2 bytes	43-1497 bytes

Payload Trailer:

Frame Check Sequence	Tail
4 bytes	6 bits

802.11a Data Transmission

- Similar to 802.11b; spreads its transmission over a wider spectrum
- Each of 12 channel's bandwidth = 20 MHz
  - Broken into 52 separate channels: 312.5 KHz each, plus guard bands
    - 48 channels for data (sent across all channels in parallel using Orthogonal Frequency Division Multiplexing (OFDM)
    - 4 channels for control

OFDM Versions

- ➢ **6-Mbps version of .11a**
  - – Groups data into sets of 24 data bits
  - – Converts each group into an OFDM symbol of 48 bits
    - • Pattern chosen enables some error correction
  - – Transmit each symbol in one of 48 sub channels using BPSK sent at 250 KHz
    - • 24 data bits x 250 KHz => 6 Mbps
- ➢ **9-Mbps version**
  - – Groups data into sets of 36 bits
  - – Transmits each symbol using BPSK
    - • 36 data bits x 250 KHz => 9 Mbps

OFDM Versions (Cont.)

- **12-Mbps version**
  - Groups data into sets of 48 bits
  - Transmit OFDM symbol using QPSK (2 bits per symbol)
- **18-Mbps version**
  - Groups data into sets of 72 bits; uses QPSK
- **24-Mbps version**
  - Groups data into sets of 96 bits
  - Transmit OFDM symbol using 16-QAM (4 bits per symbol)

OFDM Versions (Cont.)

- **36-Mbps version**
  - Groups data into sets of 128 bits; uses 16-QAM
  - Transmit OFDM symbol using QPSK (4 bits per symbol)
- **48-Mbps version**
  - Groups data into sets of 192 bits
  - Transmit OFDM symbol using 64-QAM (6 bits per symbol)
- **54-Mbps version**
  - Groups data into sets of 216 bits; uses 64-QAM

802.11a: Use of OFDM and BPSK