IEEE 802.11

Basic Connectivity

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Acknowledgements

- Based on Jochen Schiller slides

- Supporting text
  - » Jochen Schiller, “Mobile Comunications”, Addison-Wesley
  - » Section 7.3 – Wireless LAN

Characteristics of Wireless LAN

- Advantages over wired LANS
  - » Receiver free to move
  - » Network with less cabling
  - » Possibility of forming, unplanned, ad-hoc networks

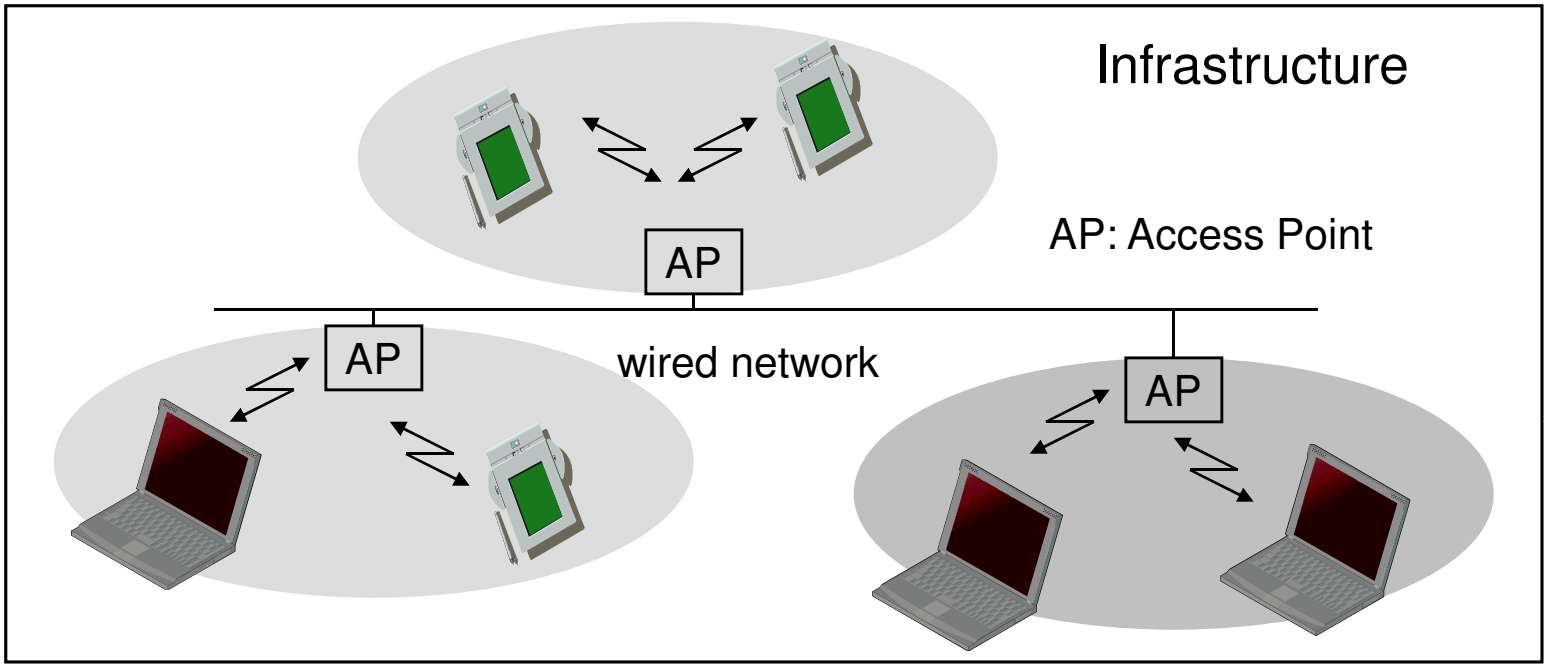
- Disadvantage
  - » Smaller and variable bitrates

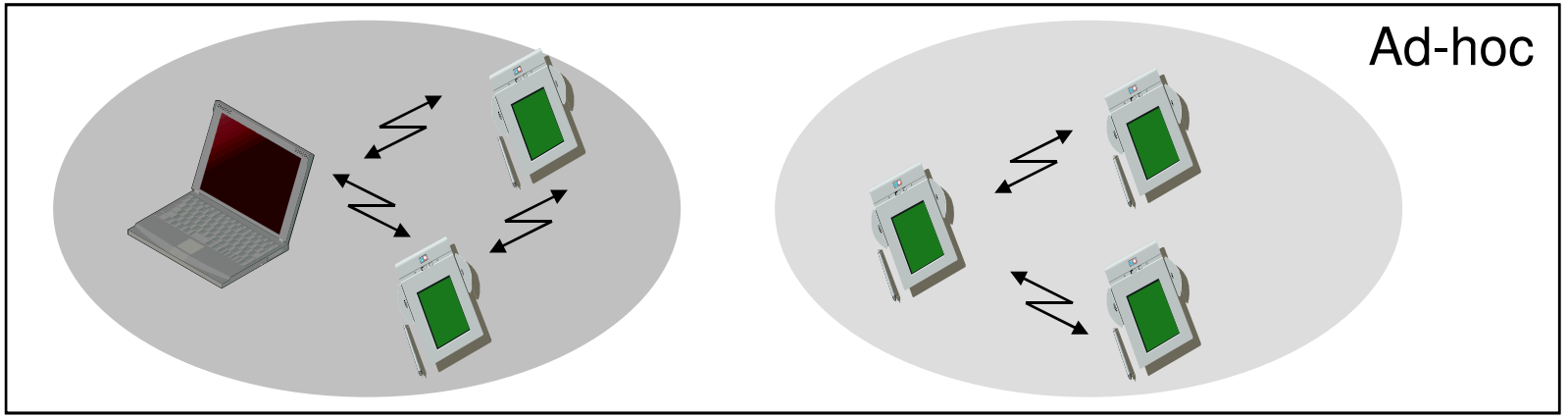
Transmission - Radio vs Infrared

- Radio
  - » Band ISM, 2.4 GHz
- Advantages
  - » Planning similar to cellular networks
  - » Large coverage
- Disadvantages
  - » Limited resources and ISM bands
  - » Less secure

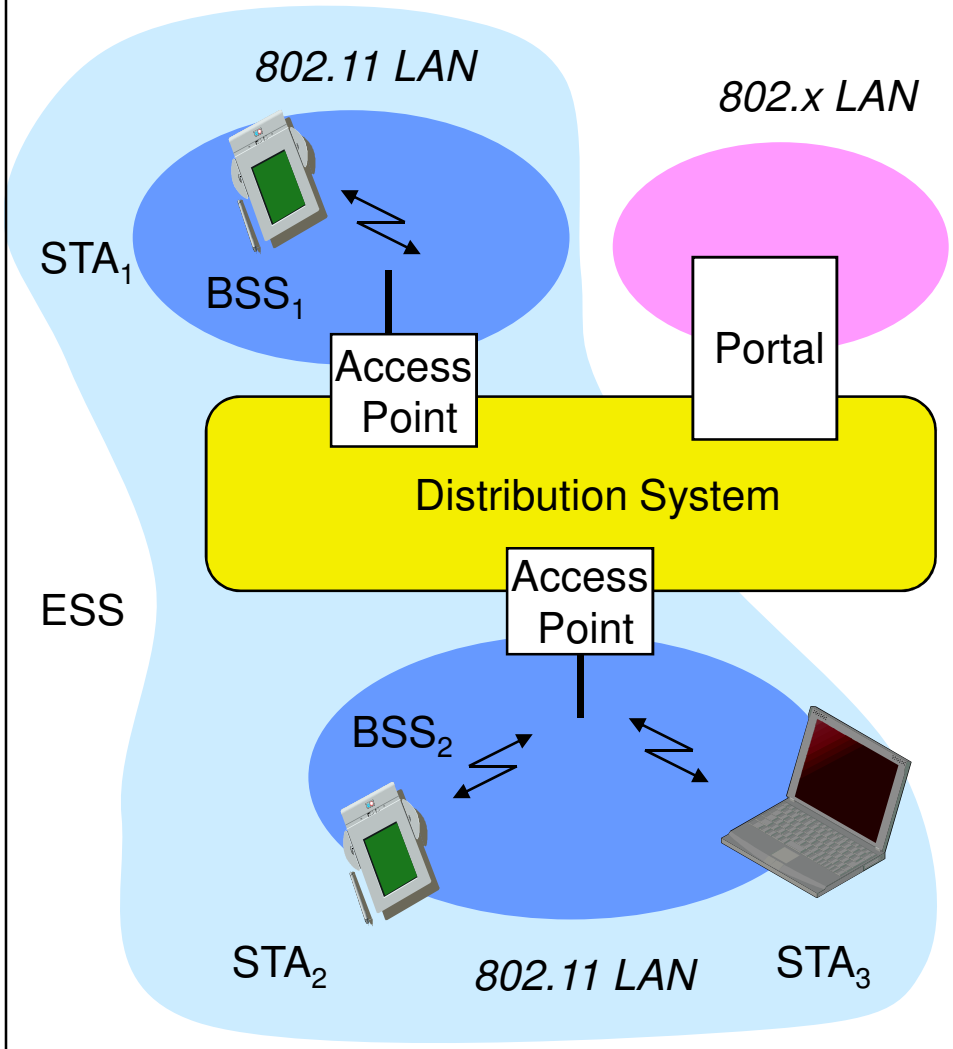
- Infrared
  - » Diods, multiple reflection
- Advantages
  - » Simple
- Disadvantages
  - » Interferences
    - – Solar light, heat sources
  - » Smaller bitrates

Infrastructure vs Ad-Hoc Networks



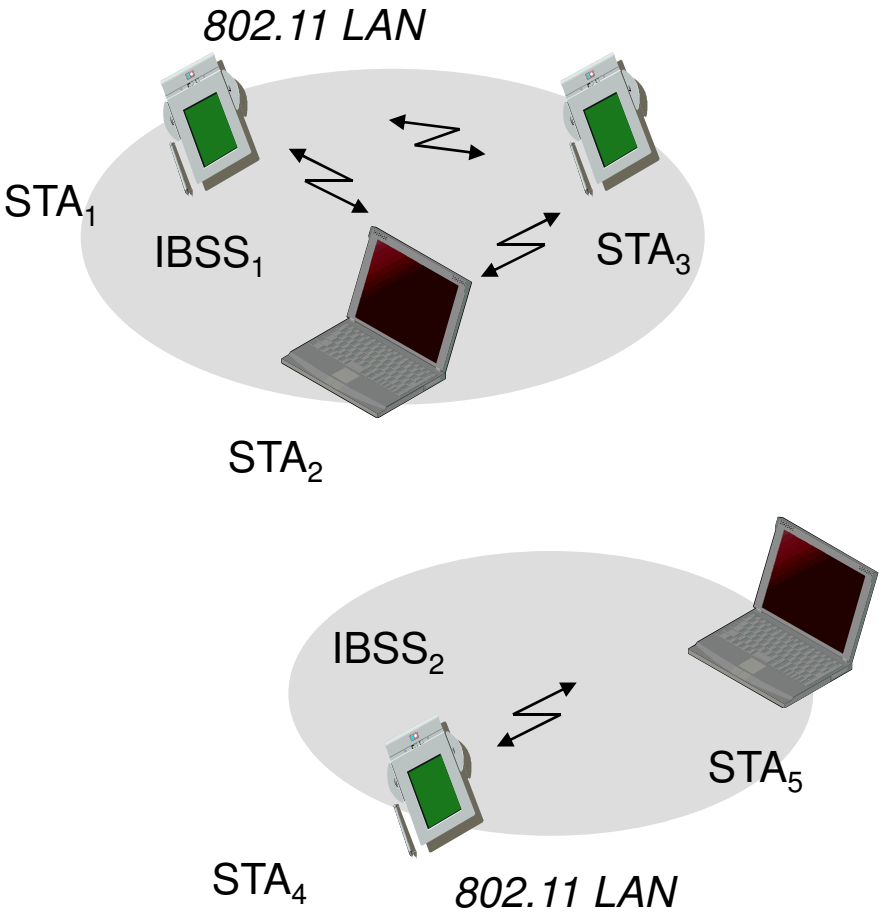


802.11 – Infrastructure Network



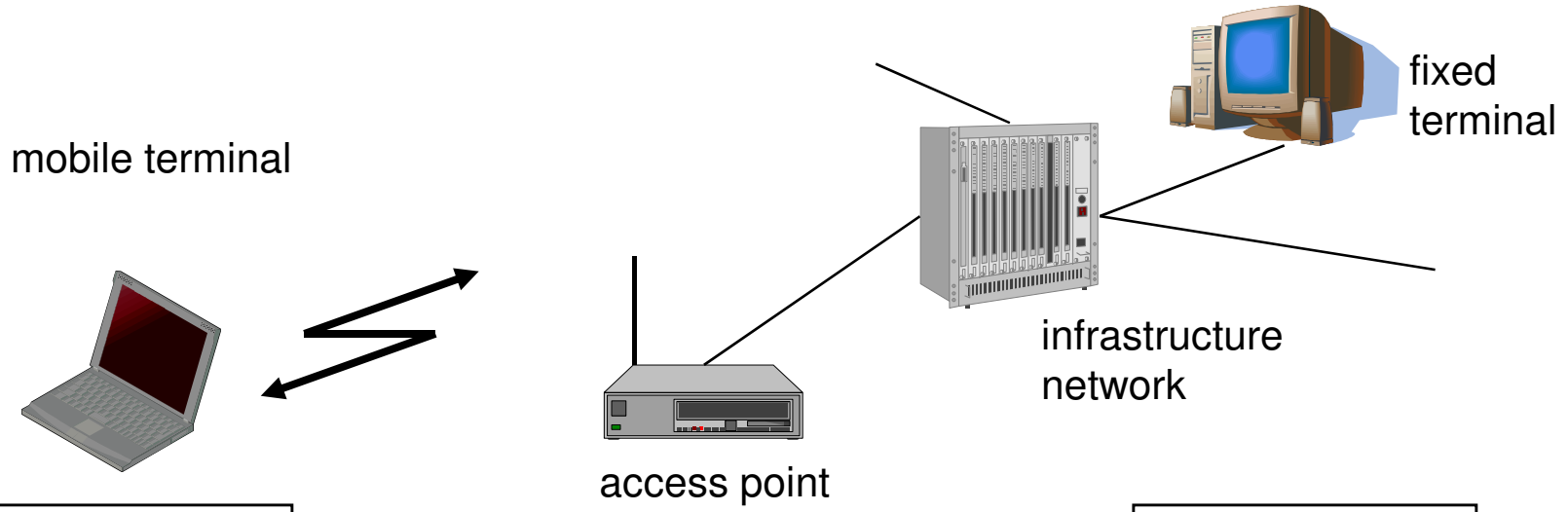
- Station
  - » Terminal with radio access
- Basic Service Set (BSS)
  - » Set of stations in the same band
- Access Point
  - » Interconnects LAN to wired network
- Portal bridge to other networks
- Distribution System
  - » Interconnection network
  - » Logical network
    - – EES, Extended Service Set
    - – Based on BSSs

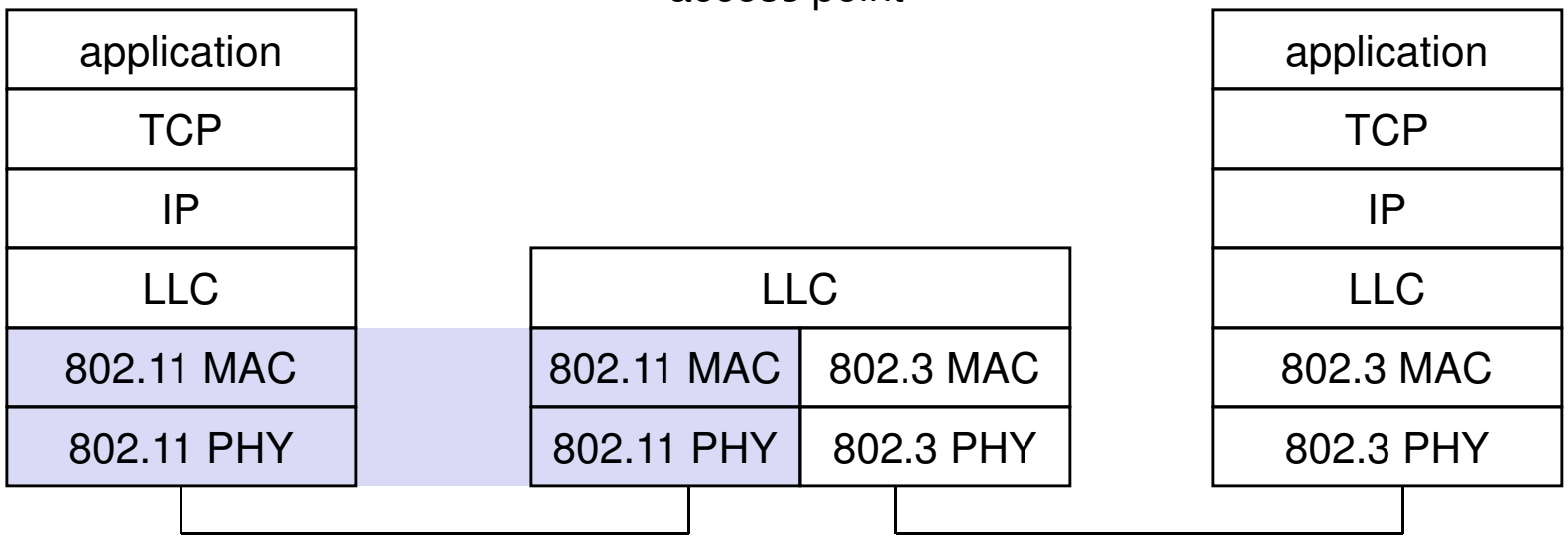
802.11 –Ad-Hoc Network



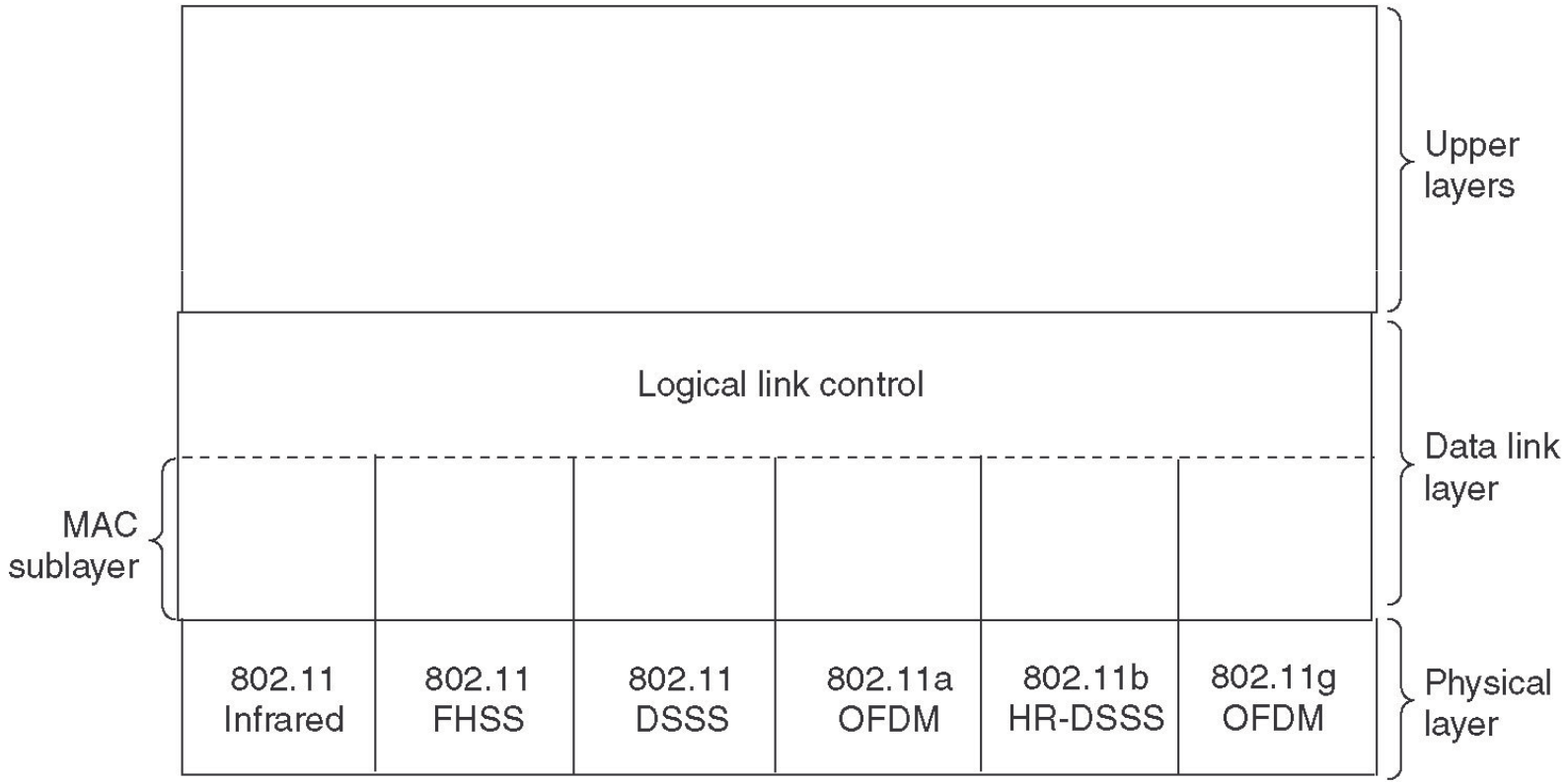
- Direct communication between stations
- Independent Basic Service Set, IBSS
  - » Set of stations working the the same carrier (radio channel)

IEEE 802.11 – Protocol Stack



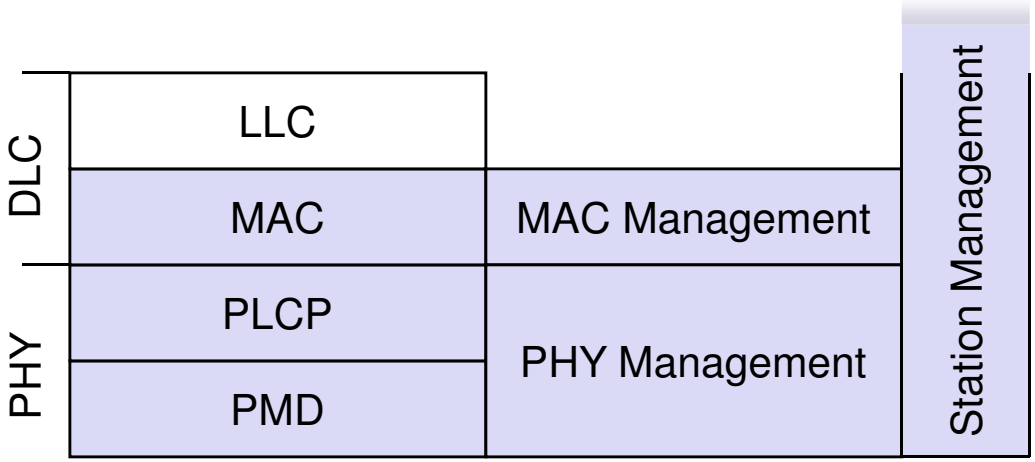


802.11 – Protocol Stack

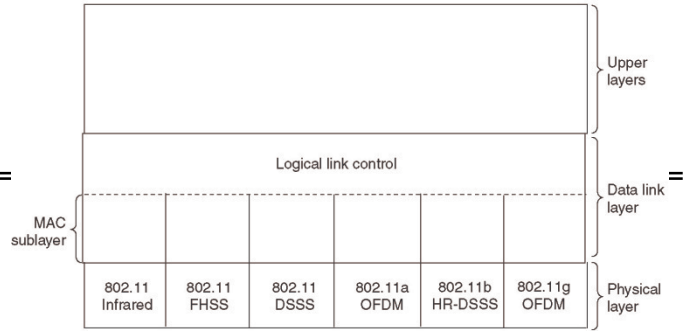


802.11 – Layers and Functionalities

- Data plane
  - » MAC medium access, fragmentation, encryption
  - » PLCP - Physical Layer Convergence Protocol carrier detection
  - » PMD - Physical Medium Dependent modulation, codification
- Management plane
  - » PHY Management channel selection, MIB
  - » MAC Management synchronisation, mobility, power, MIB
  - » Station Management coordenation management functions



MAC Layer - Characteristics

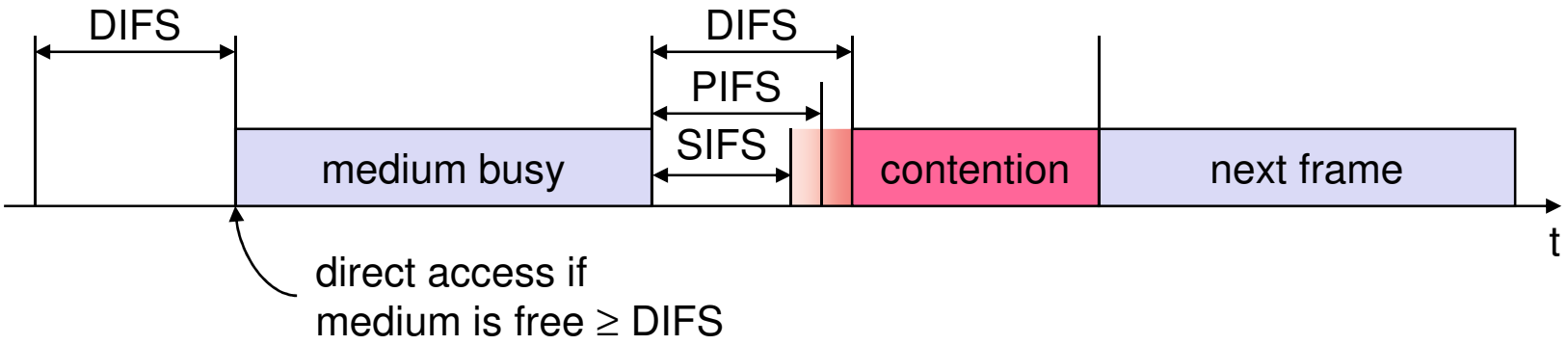


DCF – Distributed Coordination Function
PCF - Point Coordination Function

- Traffic Services
  - » Asynchronous Data Service (obrigatório)
    - u Packet exchanged in “best-effort”
    - u Broadcast and multicast support
  - » Time-Bounded Service (opcional)
    - u Implemented as PCF (Point Coordination Function)
- Medium access methods
  - » MAC-DCF CSMA/CA (obrigatório)
    - u Carrier sense, collision avoidance using back-off mechanism
    - u ACK packet required for confirmations (except broadcasts)
  - » MAC-DCF c/ RTS/CTS (optional)
    - u Used to avoid hidden terminal problem
  - » MAC- PCF (opcional)
    - u Access Point interrogates stations according to a rule

Nível MAC – Tempos de Guarda

- Access Priorities
  - Defined by inter-frame-space (intervals); fix
- SIFS (Short Inter Frame Spacing)
  - Maximum priority used for ACK, CTS, answers to polling
- PIFS (PCF IFS)
  - Medium priority, real time service using PCF
- DIFS (DCF IFS)
  - Lowest priority, used for asynchronous data



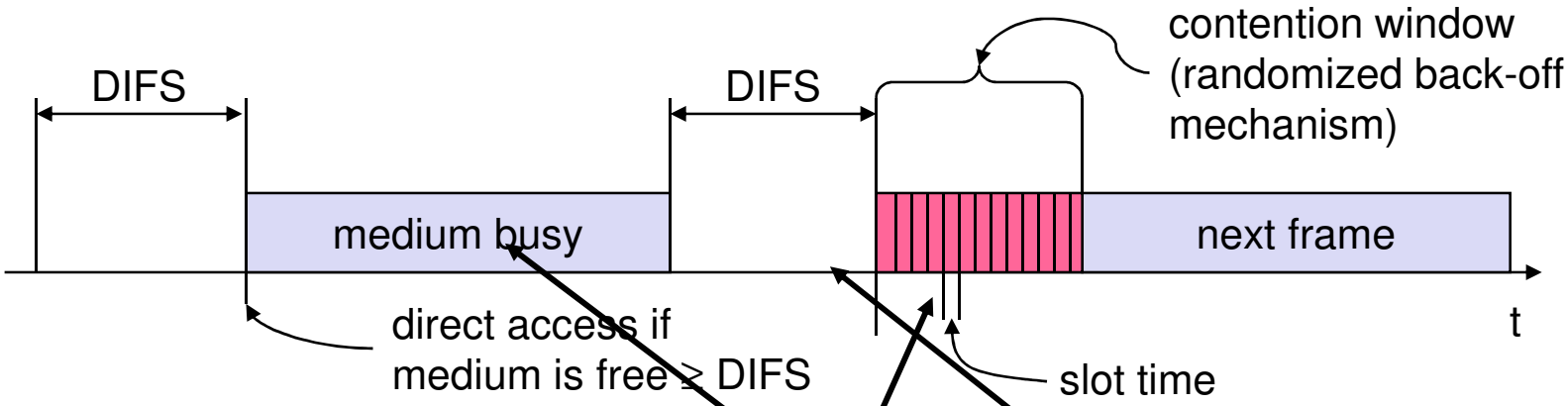
Virtual Carrier Sensing – Network Allocation Vector

- How does a station detect is the medium is free?
  - » Usually , by listening the carrier

- IEEE 802.11 also uses Network Allocation Vector (NAV)
  - » 802.11 frames contain a duration field; used to reserve the medium
  - » Stations have a timer ***NAV***
    - – Update with the values seen in the frames
    - – Decremented in real-time
    - – If != zero ⇾ medium not free

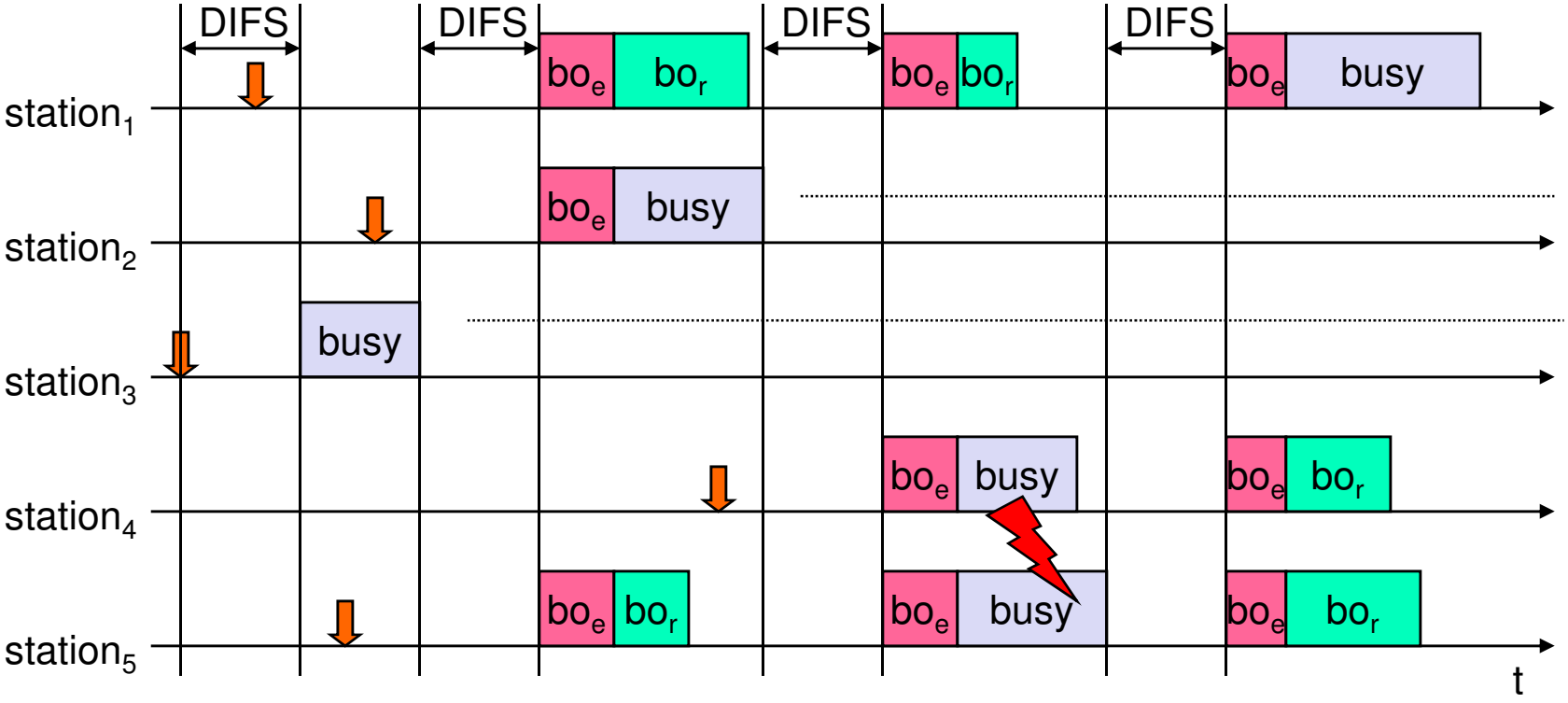
MAC-DCF CSMA/CA – Access Method

- Station having a packet to transmit sense the medium
  - » Carrier Sense based on CCA (Clear Channel Assessment)
- If the medium is free during one Inter-Frame Space (IFS)
  - » Station starts sending the frame (IFS depends on the service type)



- If medium is busy
  - » Station waits for the medium to become free (using NAV), + one IFS + random contention period (collision avoidance, múltiplo de slot n* 20 us)
- If other station access the medium during the contention time
  - » Timer is suspended

MAC-DCF CSMA/CA – Concurring Stations



busy — medium not idle (frame, ack etc.)

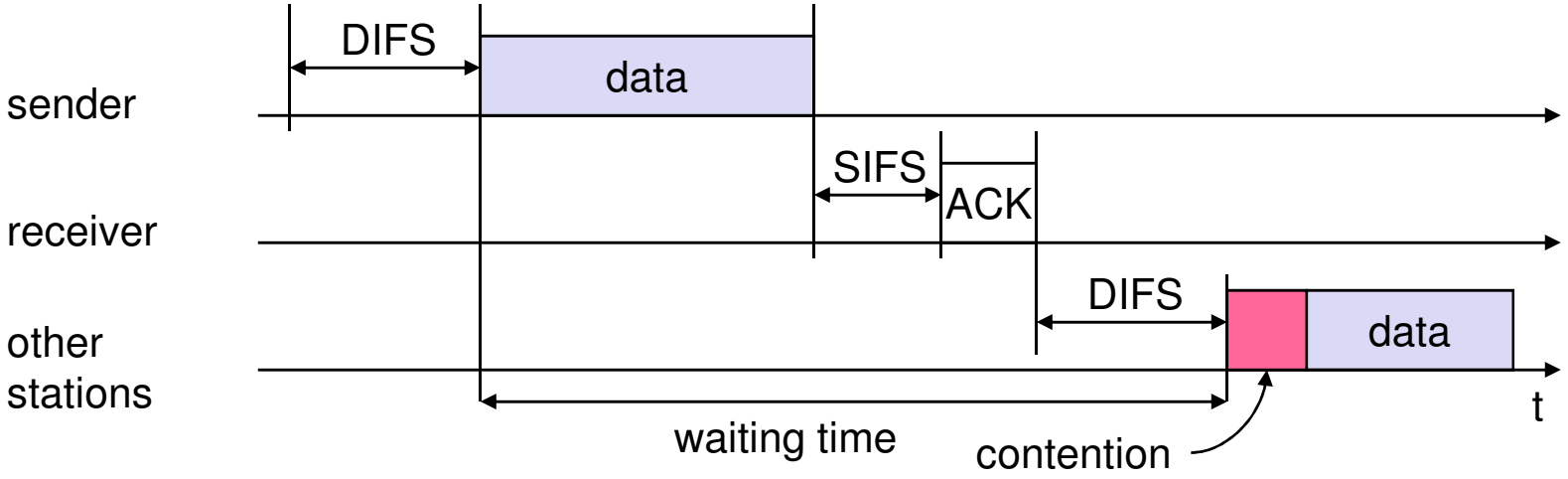
packet arrival at MAC

bo_e — elapsed backoff time

bo_r — residual backoff time

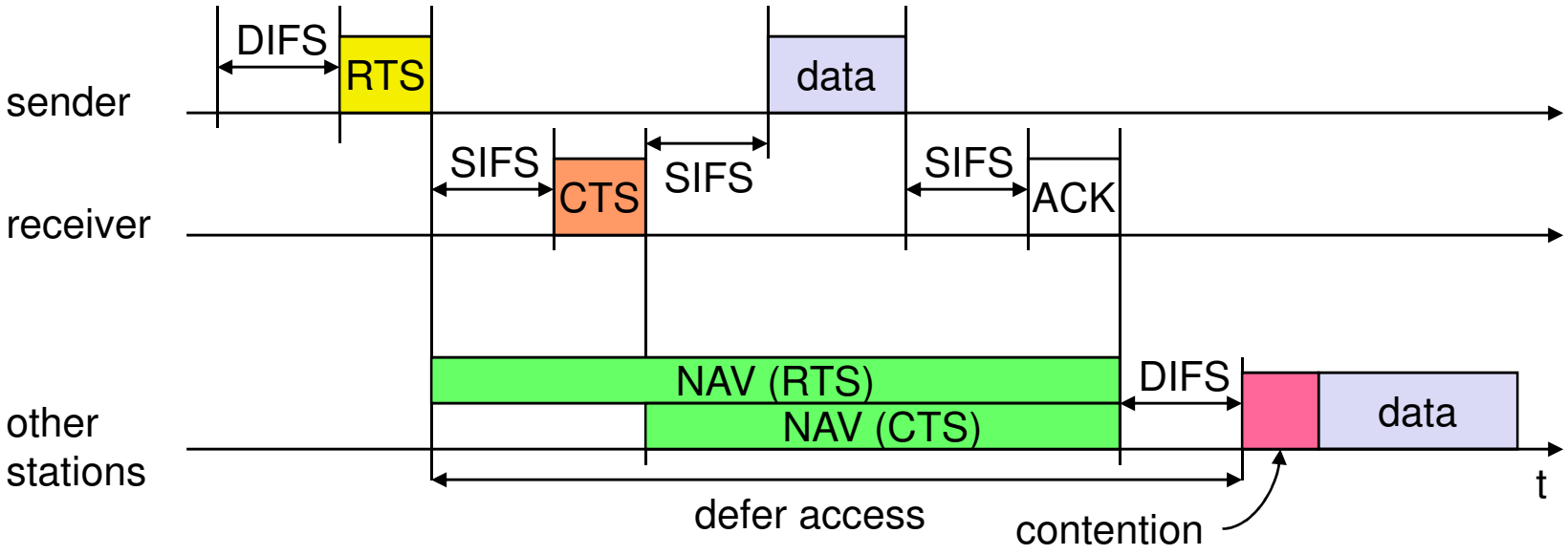
MAC-DCF CSMA/CA – Access Method

- Sending a frame in unicast
  - » Station waits DIFS before sending the packet
  - » If packet is correctly received (no errors in CRC)
    - u Receiver confirms reception immediatly, using ACK, after waiting SIFS
  - » In case of errors, frame is re-transmitted
  - » In case of retransmission
    - u Maximum value for the contention window duplicates
    - u Contetion window has minimum and maximum values (eg.: 7 and 255)

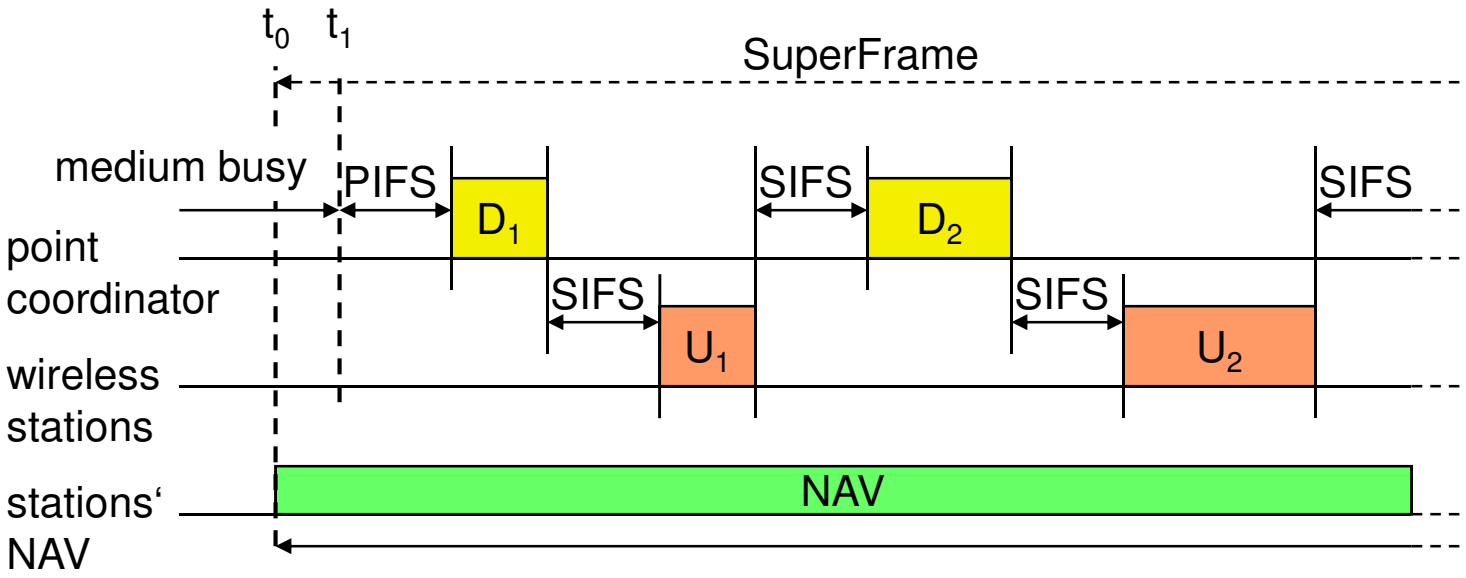


MAC DCF c/ RTS/CTS

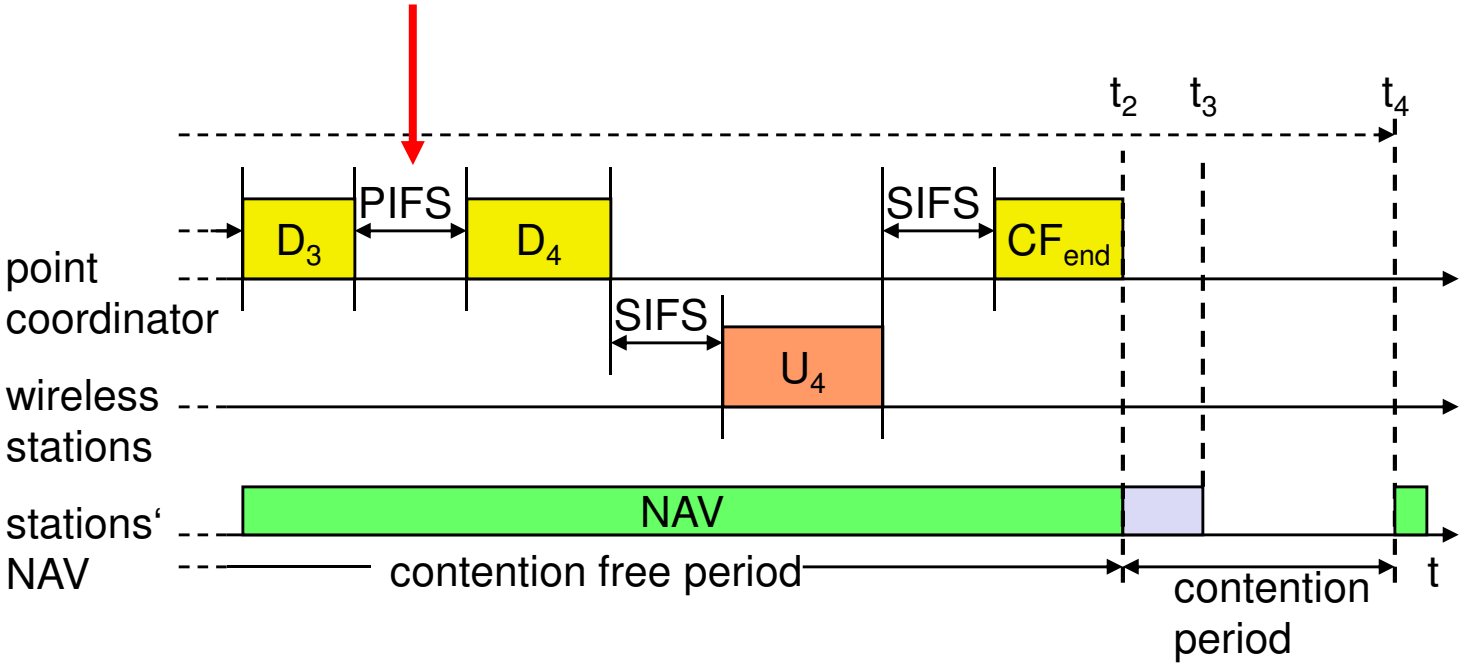
- Sending a frame in unicast
  - » Station sends RTS with a reserve parameter, after waiting DIFS
    - – Reserve time includes RTS+SIFS+CTS+SIFS+DATA+SIFS+ACK
  - » Receiver confirms with CTS, after waiting SIFS
  - » Transmitter sends frame, after waiting SIFS. Confirmation with ACK
  - » Other stations become aware of reserved time by listening RTS and CTS



MAC- PCF I

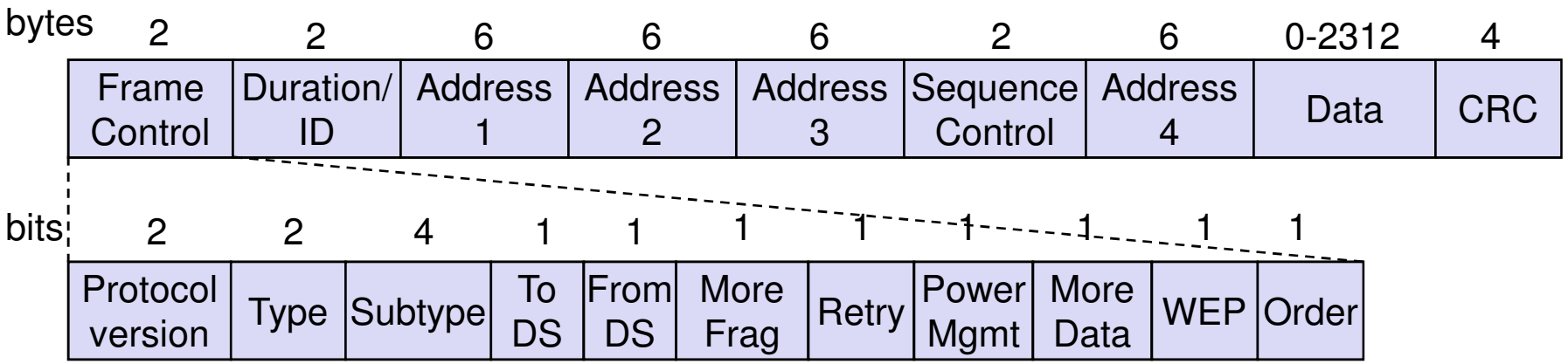

t0
t1
SuperFrame
medium busy
PIFS
D1
SIFS
D2
SIFS
point coordinator
SIFS
U1
SIFS
U2
wireless stations
stations‘ NAV
NAV

MAC-PCF II


t2
t3
t4
D3
PIFS
D4
SIFS
CFend
point coordinator
SIFS
U4
wireless stations
NAV
stations' NAV
contention free period
contention period
t

MAC – Frame Format

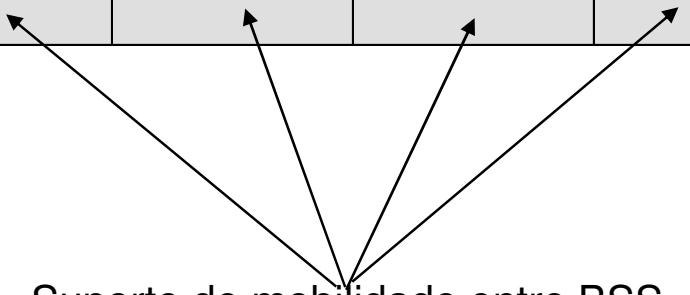
- Frame types
  - » Data, control, management
- Sequence number
- Addresses
  - » destination, source, BSS identifier, ...
- Others
  - » Error control, frame control, data



Addresses in MAC

scenario	to DS	from DS	address 1	address 2	address 3	address 4
ad-hoc network	0	0	DA	SA	BSSID	-
infrastructure network, from AP	0	1	DA	BSSID	SA	-
infrastructure network, to AP	1	0	BSSID	SA	DA	-
infrastructure network, within DS	1	1	RA	TA	DA	SA

DS: Distribution System
AP: Access Point
DA: Destination Address
SA: Source Address
BSSID: Basic Service Set Identifier
RA: Receiver Address
TA: Transmitter Address

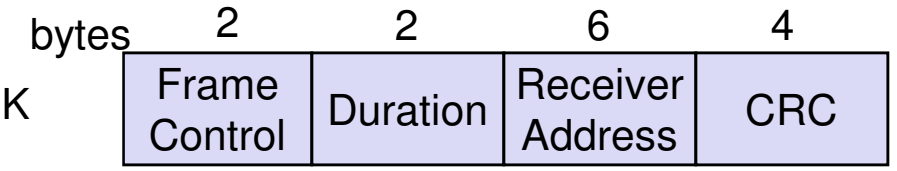


Suporte de mobilidade entre BSS
Usado para evitar túneis

Special Frames- ACK, RTS, CTS

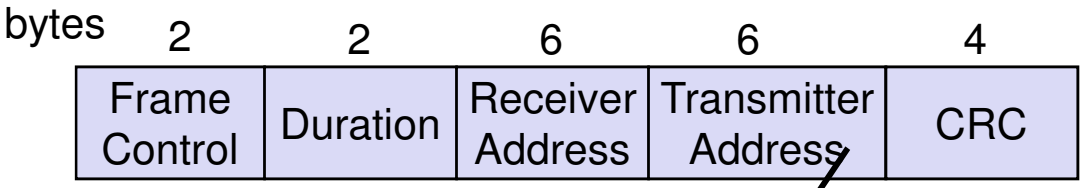
- Acknowledgement

ACK



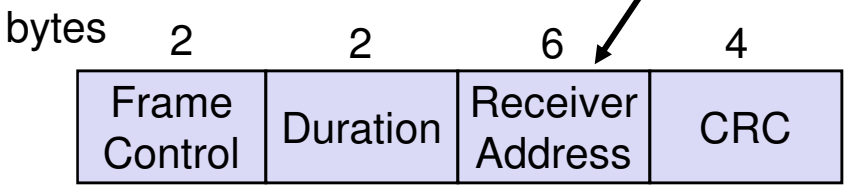
- Request To Send

RTS



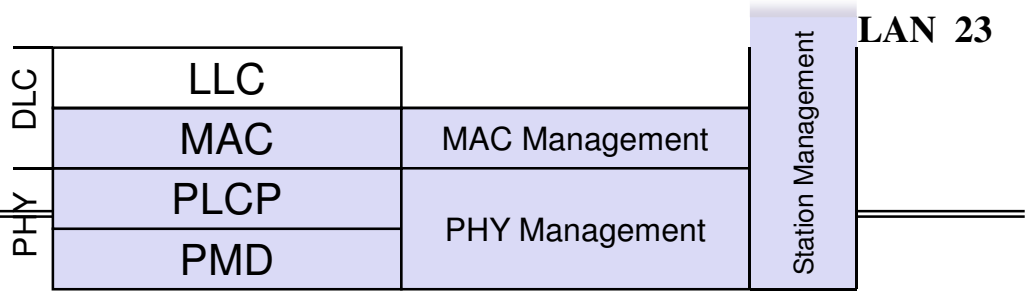
- Clear To Send

CTS



(Fig. 7.17 do livro está errada)

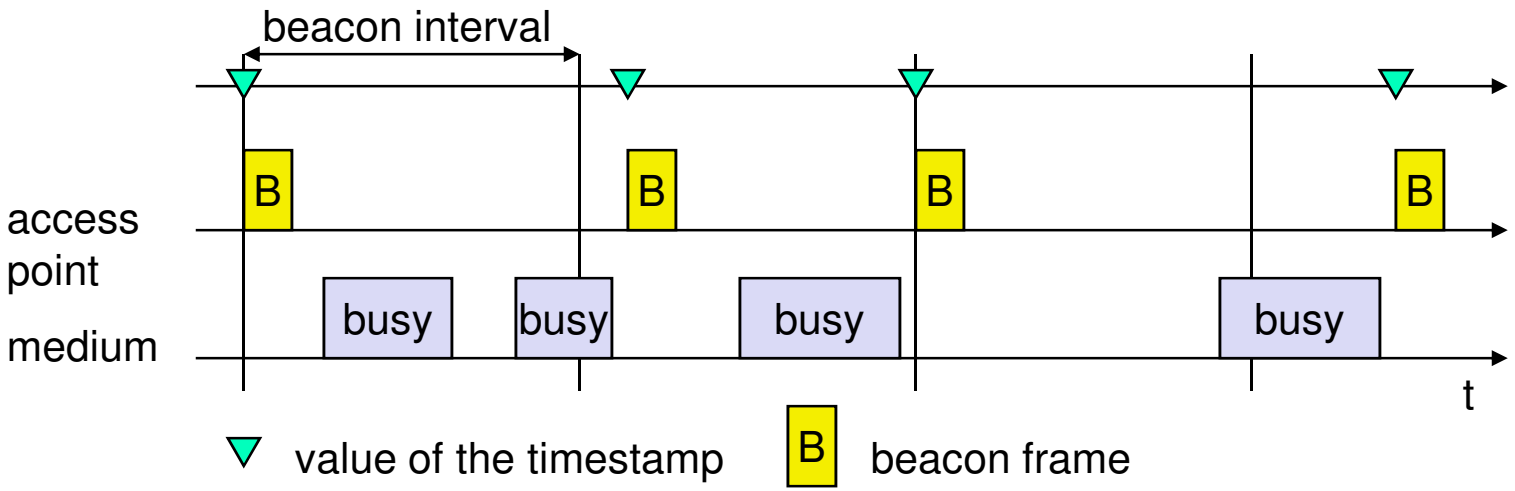
MAC Management



- Sinchronization
  - Station discovers a LAN; station associates to an AP
  - stations synchronize clocks; *Beacon is generated*
- Power management
  - Save terminal's power terminal enters *sleep* mode
    - Periodically
    - No frame loss; frames are stored
- Roaming
  - Station looks for new access points
  - Station decides about better access point
  - Station (re-)associates to new AP
- MIB - Management Information Base

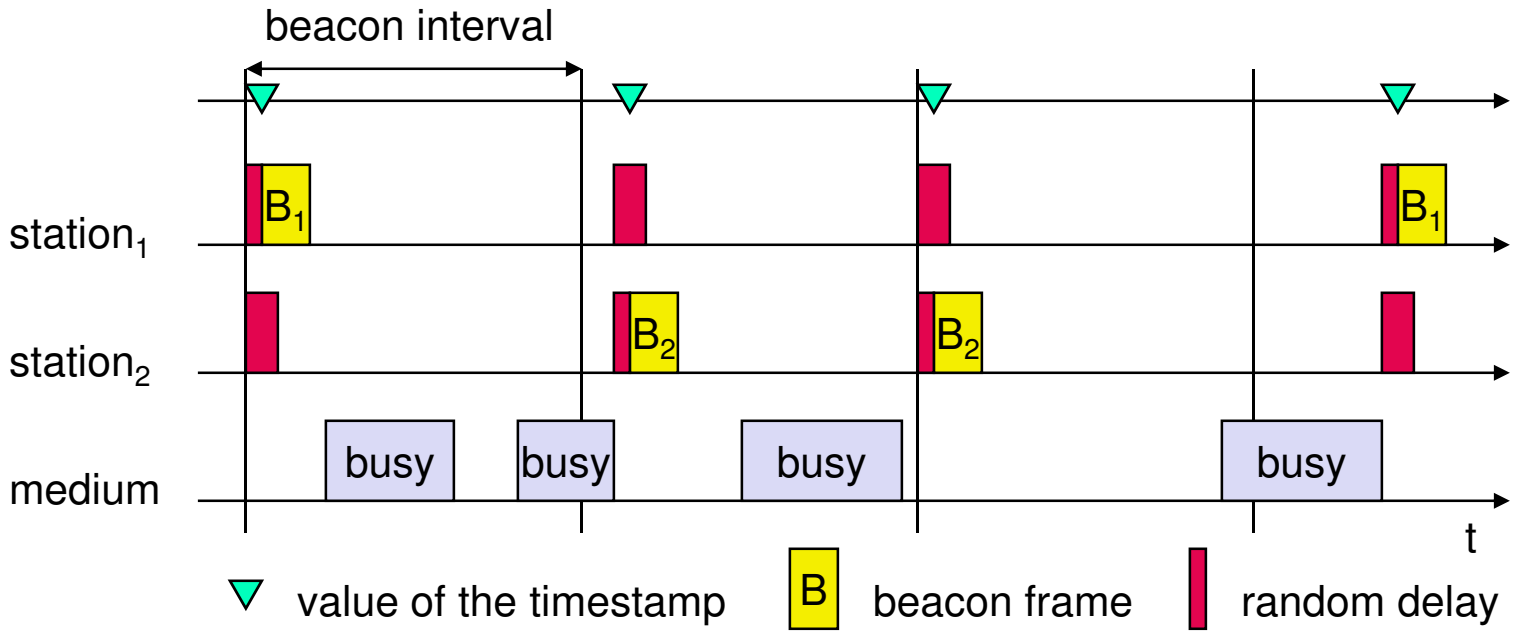
Synchronization by Beacon – Infrastructure Network

- Stations must be synchornised. E.g.
  - To preview PCF cycles
  - To change state: sleep wake
- Infrastructure networks
  - Access Point sends (almost) periodically *beacon* with *timestamp* e *BSSid*
    sometimes medium is busy
  - Timestamp sent is the correct
  - Other stations adjust their clocks



Syncronization by Beacon – Ad-hoc Network

- Every station tries to send a ***beacon***
- Stations use normal method to access the networks CSMA/CA
- Only one station gains the medium the other difer attempt to next period

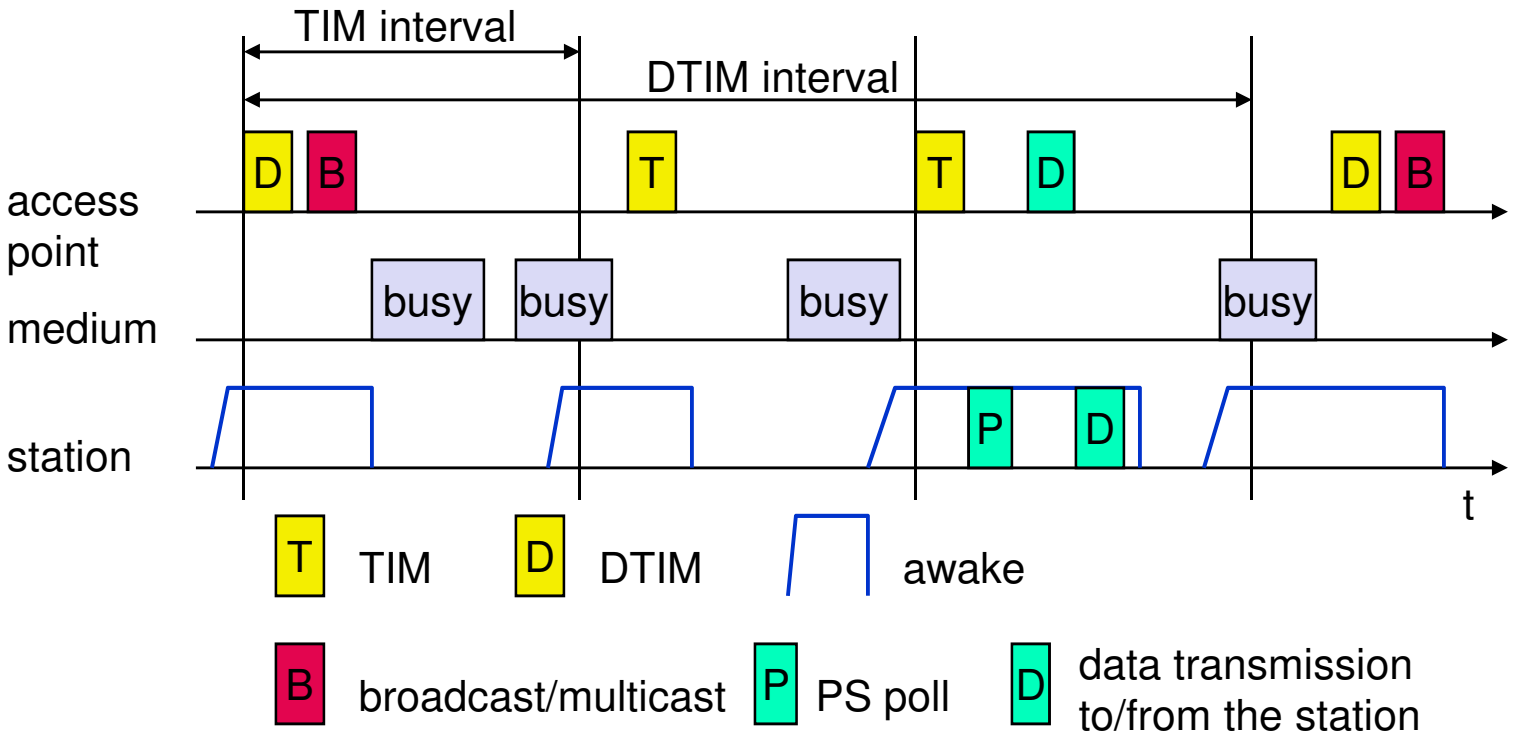


Power Management

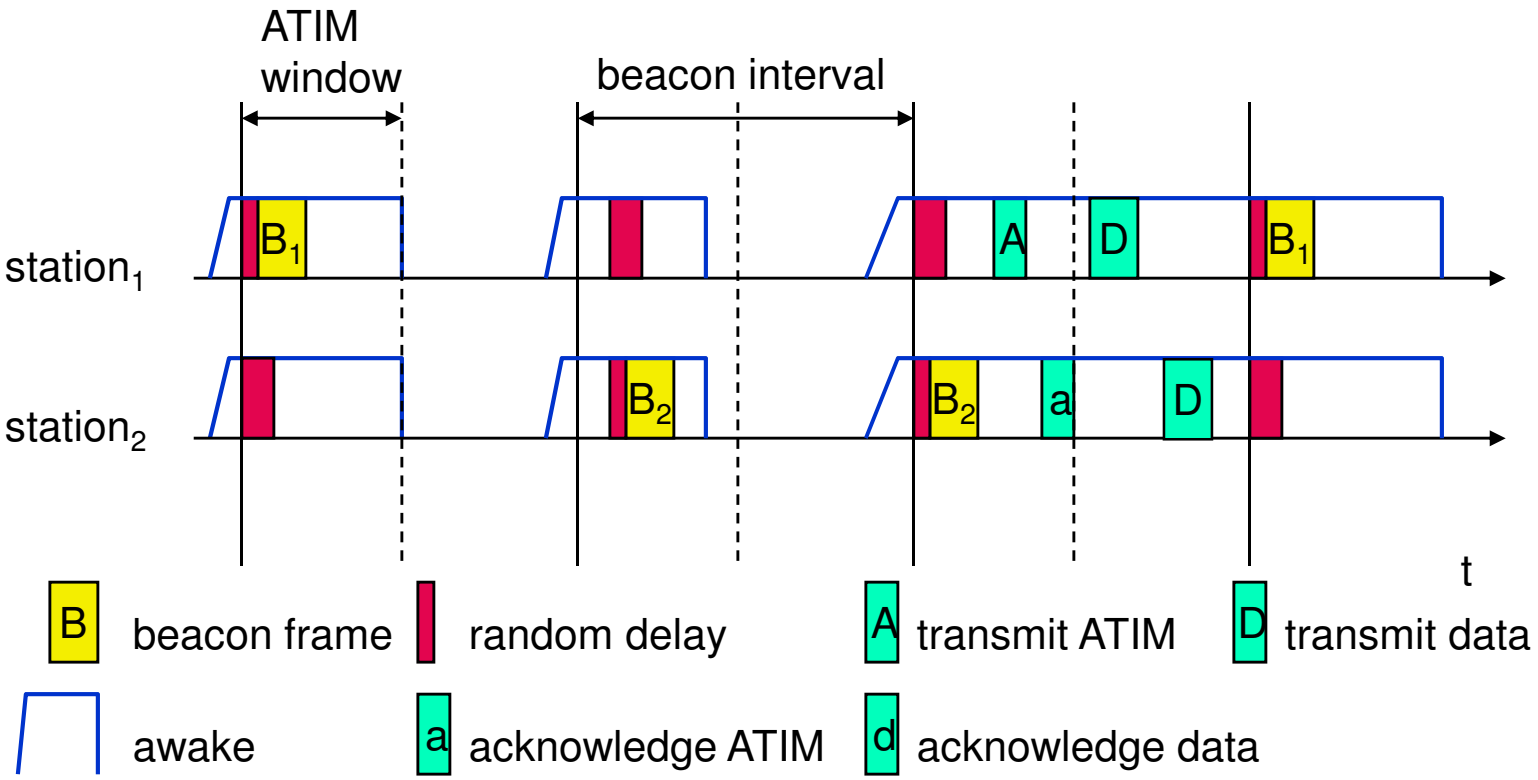
- Objective
  - » If transceiver not in use sleep mode
- Station in 2 states: ***sleep***, ***wake***
- Infrastructure network
  - » Stations wake periodically and simultaneously
  - » They listen beacon to know if there are packets to receive
  - » If a station has packets to receive remains awake until it receives them
    - – If not, go sleep; after sending its packets!
- Ad-hoc network, a station
  - » Listens/sends the beacon
  - » Informs other stations it has packets for them
  - » Receive and send packets
  - » Sleeps again

Power Management – Infrastructure Network

- Infrastructure network traffic information sent in the *beacon*
  - » *Traffic Indication Map – TIM:* list of unicast receivers
  - » *Delivery Traffic Indication Map - DTIM:* list broadcast/multicast receivers



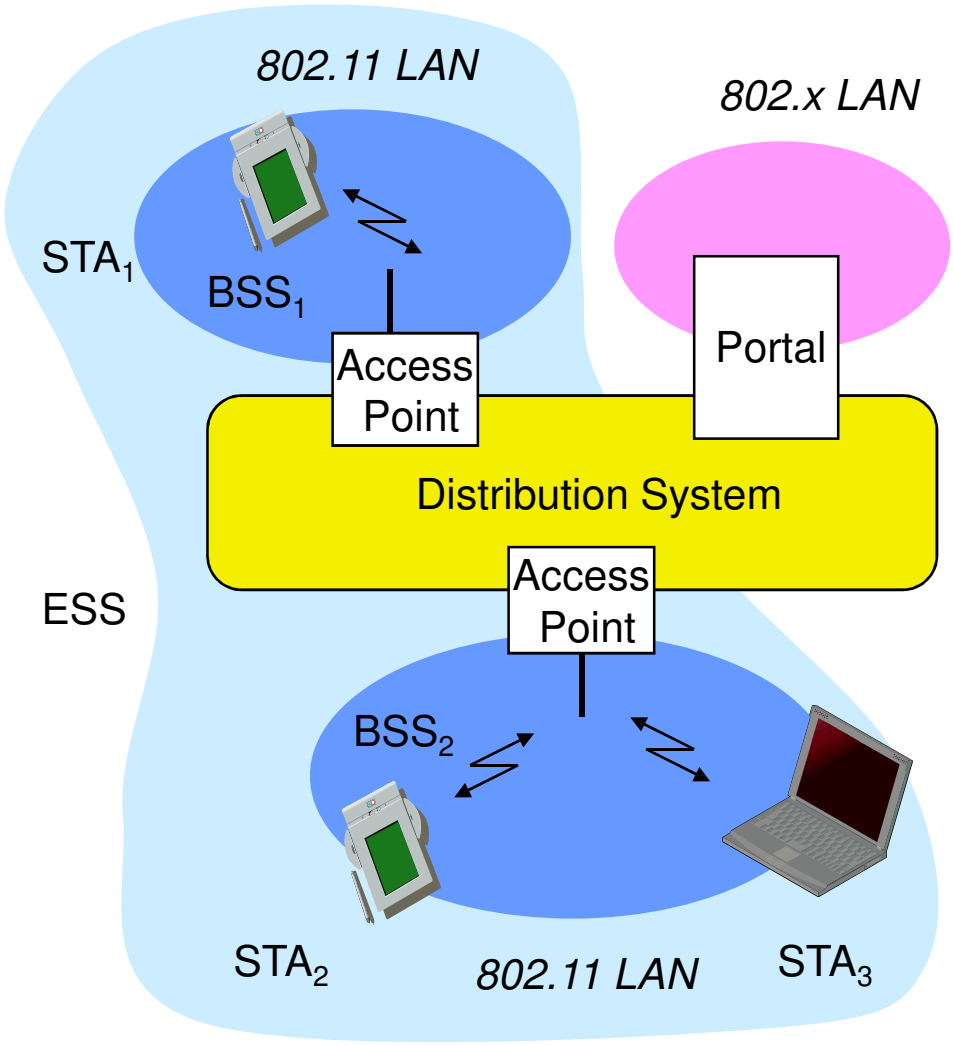
Power Management – Ad-hoc Network



(Micro) Mobility

- Station without link or with bad link? Then:
  - » Monitor the medium
    - u Passively listen to *Beacons*
    - u Actively sending *Probe* message in every channel; waits an answer
  - » Re-association request. Station
    - – Selects best access point (eg., AP with best power received)
    - – Sends Re-association Request to AP
  - » Answer to request
    - – Sucess AP answered; station can use new AP.
    - – Fail station continues monitoring
  - » New AP accepts Re-association Request
    - – AP informs distribution system about the new station arrival
    - – Distribution system may inform old AP about the new location of station
    - – 4 addresses used to route traffic

(Micro) Mobility

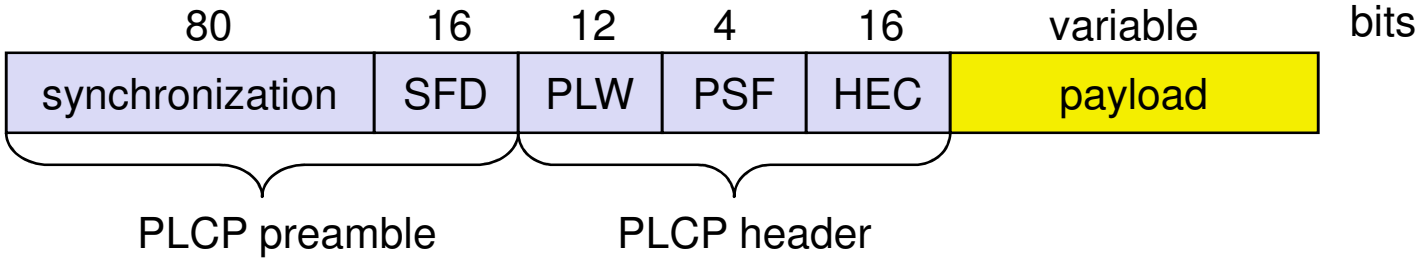


802.11 – Nível Físico

- 3 versões: 2 rádio, 1 IR
  - Bitrates: 1, 2 Mbit/s
- FHSS (Frequency Hopping Spread Spectrum)
  - Spreading, despreading
  - 79 sequências de salto pseudo aleatórias. Para 1 Mbit/s, modulação de 2 níveis GFSK
- DSSS (Direct Sequence Spread Spectrum)
  - 1 Mbit/s Modulation DBPSK (Differential Binary Phase Shift Keying)
  - 2 Mbit/s Modulation DQPSK (Differential Quadrature PSK)
  - Preamble and header of frame transmitted at 1 Mbit/s (DBPSK)
    - Remainning transmitted at 1 (DBPSK) ou 2 Mbit/s (DQPSK)
  - Maximum radiated power 1 W (EUA), 100 mW (UE), min. 1mW
- Infravermelho
  - 850-950 nm, distância de 10 m
  - Detecção de portadora, detecção de energia, sincronização
- All versions provide ***Clear Channel Assessment (CCA)***
  - Used by MAC to detect if medium is free

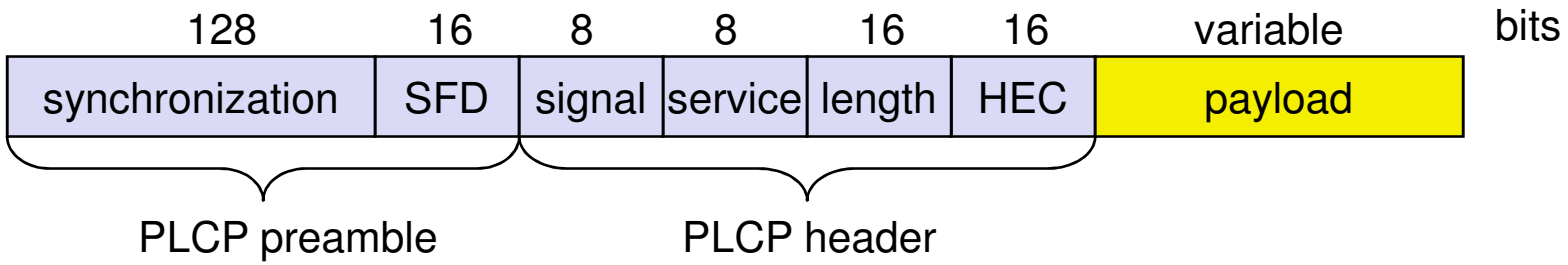
Frame FHSS PHY

- Sincronization 010101...
- SFD (Start Frame Delimiter 0000110010111101
- PLW (PLCP_PDU Length Word)
  - Payload length in bytes, including 2 CRC bytes. PLW < 4096
- PSF (PLCP Signaling Field)
  - Transmission bitrate of payload (1, 2 Mbit/s)
    - PLCP (preâmbulo and header) sent at 1 Mbit/s
    - Payload sent at 1 ou 2 Mbit/s
- HEC (Header Error Check)
  - CRC with $x^{16}+x^{12}+x^5+1$
- Data MAC scrambled with z^7+z^4+1



Frame DSSS PHY

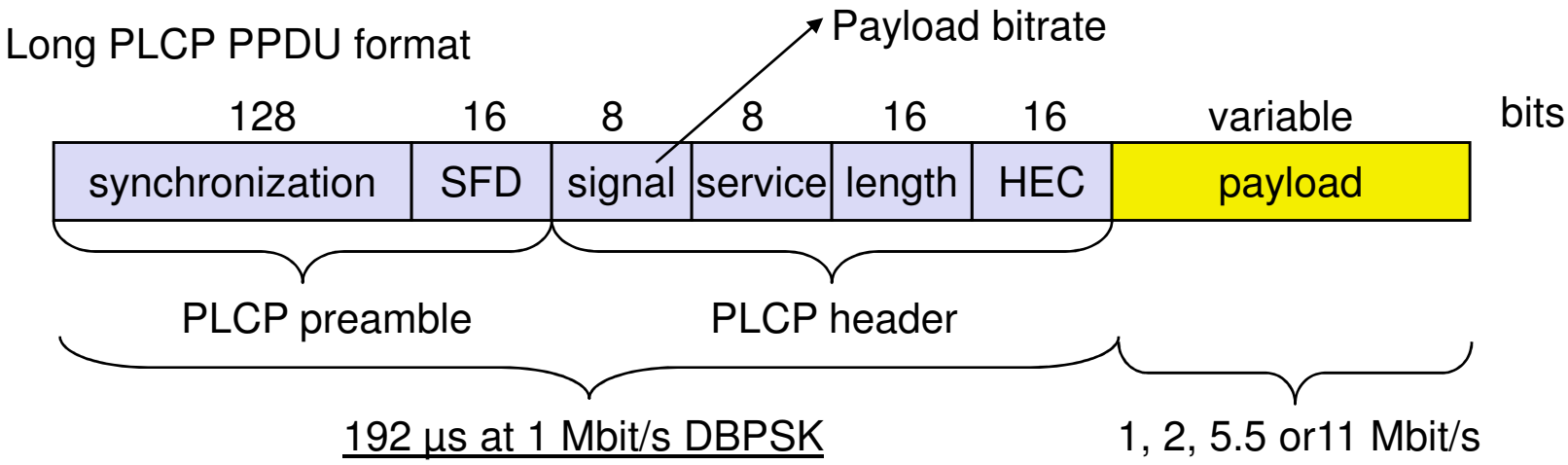
- Barker sequence of 11 chips +1,-1,+1,+1,-1,+1,+1,+1,-1,-1,-1
- Sincronization
  - Sincronization
  - Gain control, Clear Channel Assessement, compensate frequency deviation
- SFD (Start Frame Delimiter 1111001110100000
- Signal
  - Payload bitrate (0A: 1 Mbit/s DBPSK; 14: 2 Mbit/s DQPSK)
- Service utilização futura, 00 = conforme 802.11
- Length Payload length **in us**
- HEC (Header Error Check)
  - Protection of sinal, service and length, using $x^{16}+x^{12}+x^5+1$
- Data (payload) MAC scrambled with z^7+z^4+1

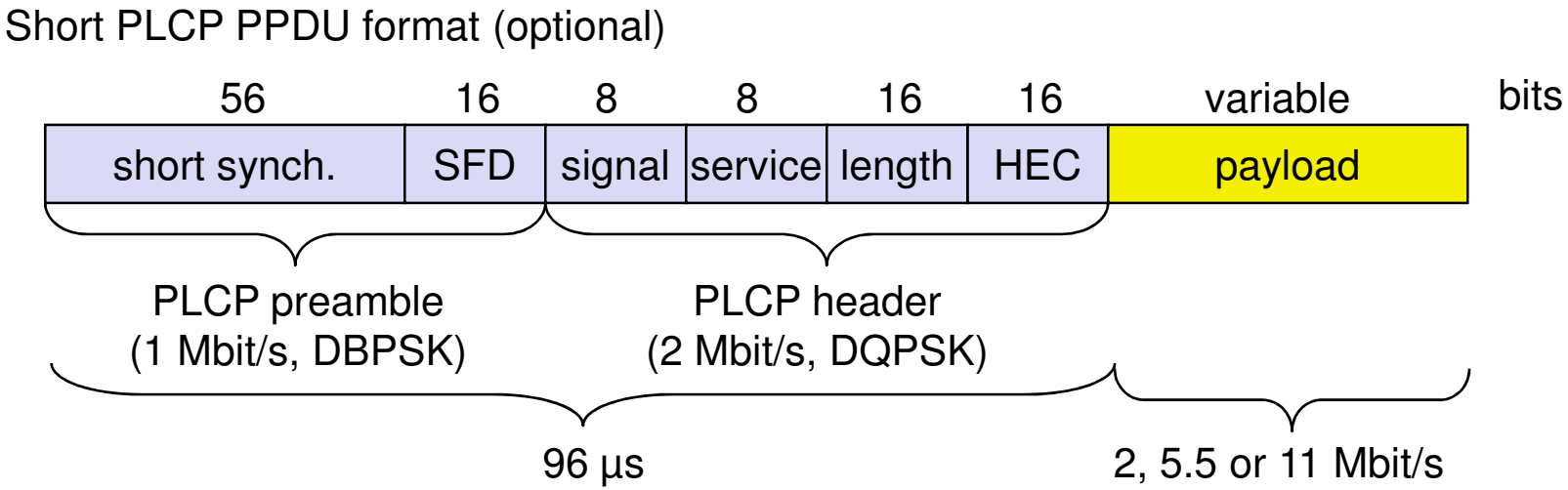


IEEE 802.11b

- Bitrate (Mbit/s)
  - 1, 2, 5.5, 11 (depends on SNR)
  - Useful bitrate 6
- Transmission range
  - 300m outdoor, 30m indoor
- Frequencies open, ISM 2.4 GHz band
- Only physical layer is redefined
  - » MAC and MAC management are the same

IEEE 802.11b – Trama PHY

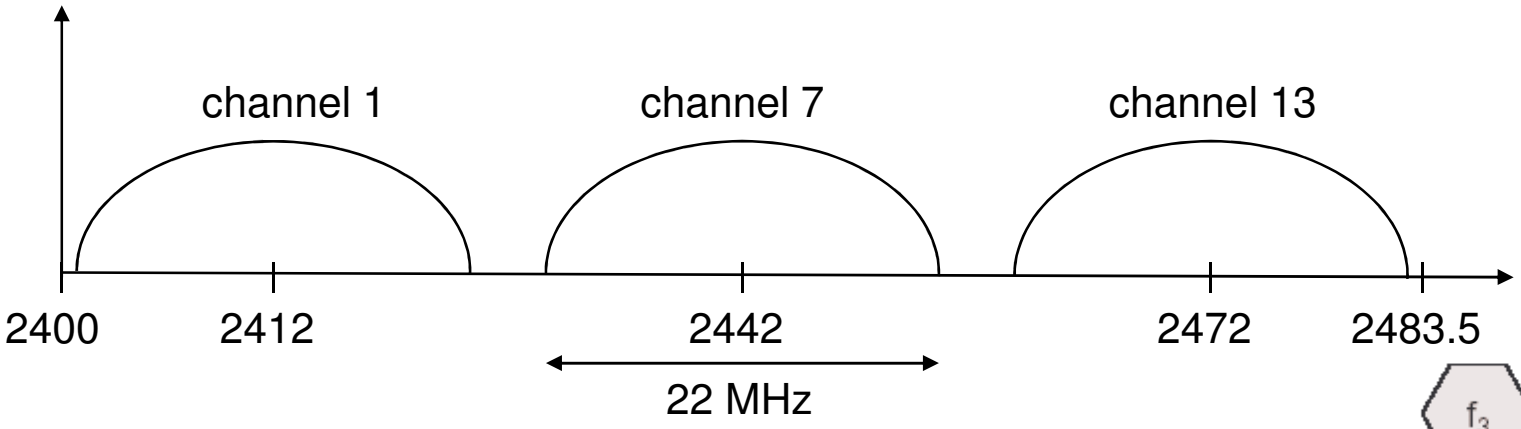




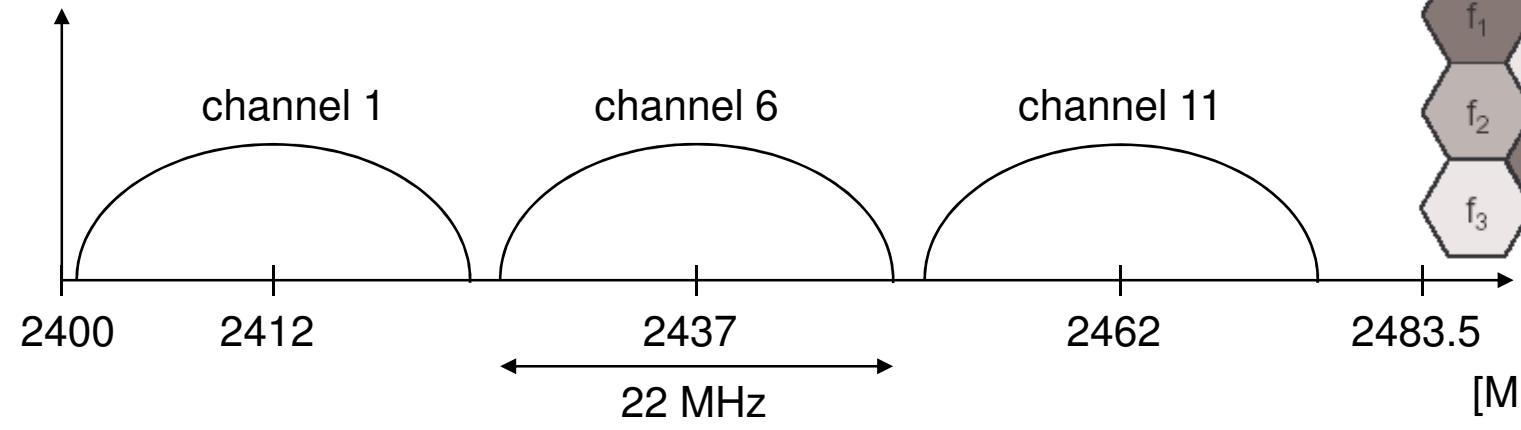
Channel Selection

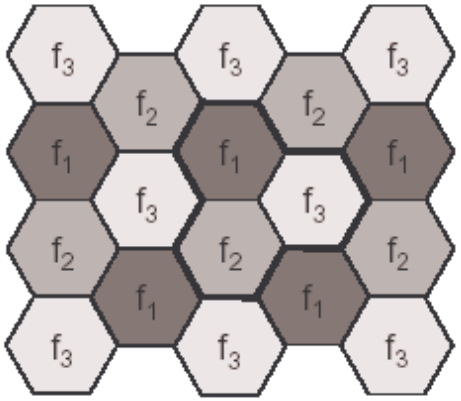
channel i = 2412MHz + (i-1)*5MHz
There are 14 channels of 5MHz
In 801.11b only 3 non-overlap channels can be used

Europe (ETSI)



US (FCC)/Canada (IC)

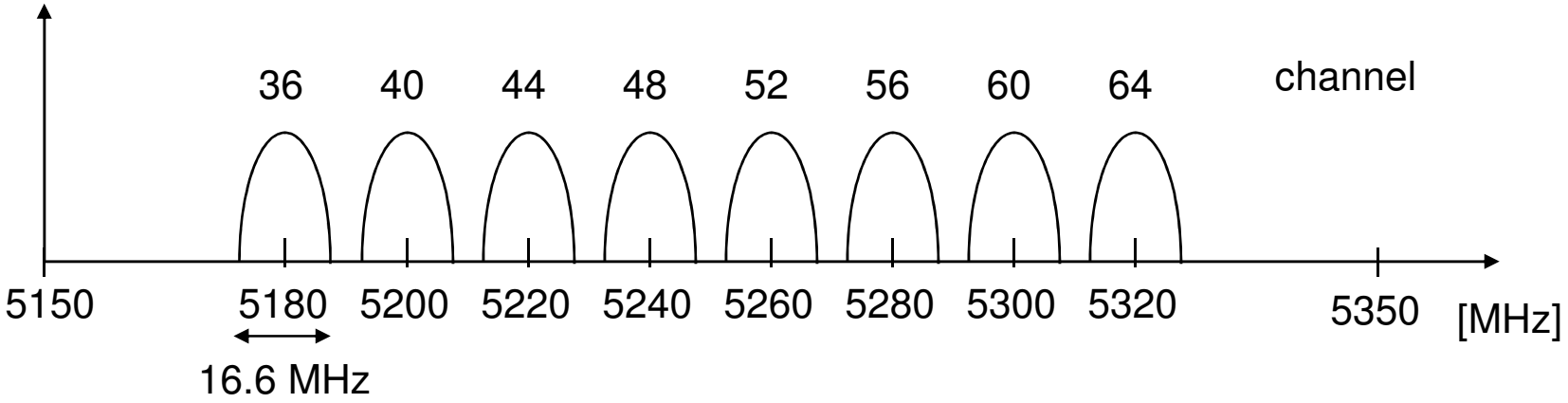


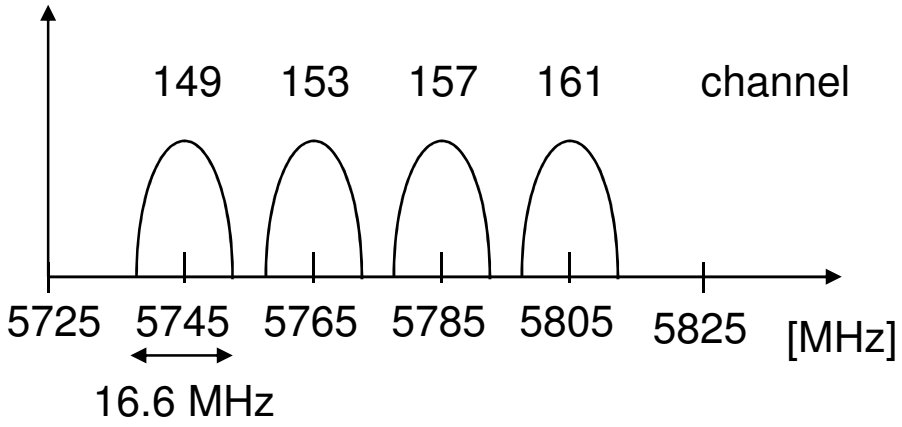


IEEE 802.11a

- Bitrate (Mbit/s)
  - » 6, 9, 12, 18, 24, 36, 48, 54 (depends on SNR)
  - » Mandatory 6, 12, 24
- Useful bit rate (frames 1500 bytes, Mbit/s)
  - » 5.3 (6), 18 (24), 24 (36), 32 (54)
- Transmission range
  - » 100m outdoor, 10 m indoor
    - – 54 Mbit/s até 5 m, 48 até 12 m, 36 até 25 m, 24 até 30m, 18 até 40 m, 12 até 60 m
- Frequencies
  - » Free, band ISM
  - » 5.15-5.35, 5.47-5.725 GHz (Europa)
- Only the physical layer changes

Operating channels for 802.11a / US U-NII

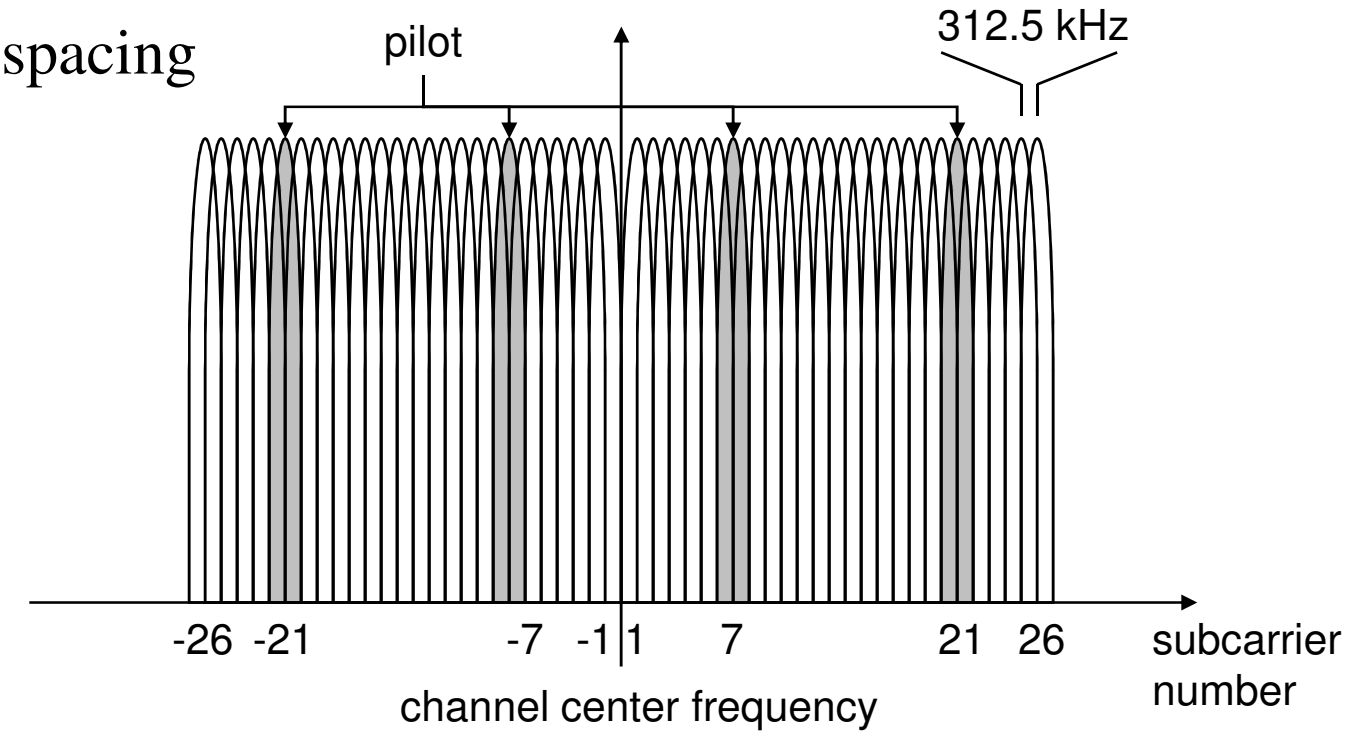




center frequency =
5000 + 5*channel number [MHz]

OFDM in IEEE 802.11a

- OFDM with 52 used subcarriers (64 in total)
- 48 data + 4 pilot
- (plus 12 virtual subcarriers)
- 312.5 kHz spacing



Percebem a tabela!

802.11a – Rate Dependent Parameters

Data rate (Mbits/s)	Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSC})	Coded bits per OFDM symbol (N_{CBPS})	Data bits per OFDM symbol (N_{DBPS})
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

% of useful information

250 kSymbol/s