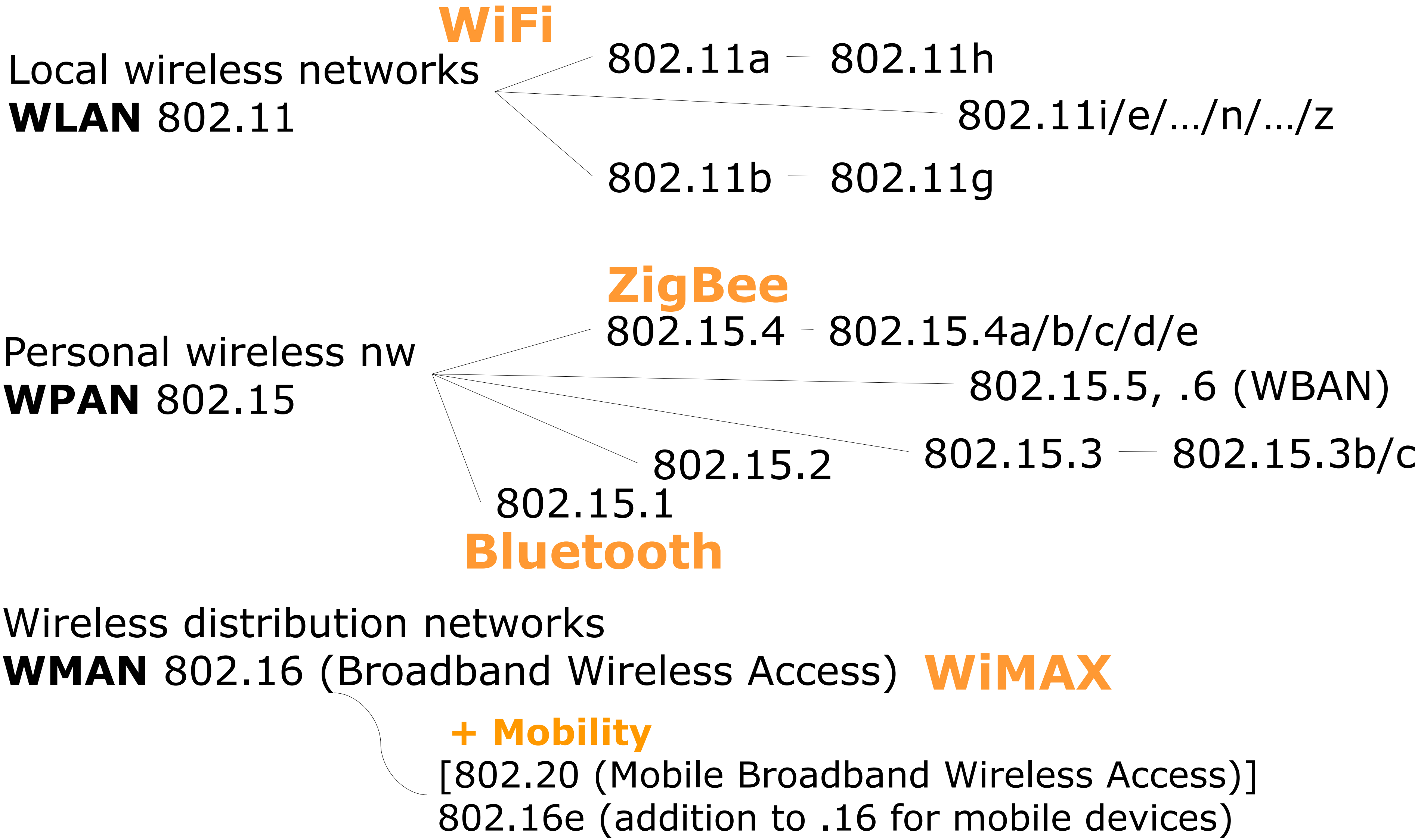
Mobile Communications
Chapter 7: Wireless LANs

- Characteristics
- IEEE 802.11 (PHY, MAC, Roaming, .11a, b, g, h, i, n … z)
- Bluetooth / IEEE 802.15.x
- IEEE 802.16/.20/.21/.22
- RFID
- Comparison

Prof. Jó Ueyama

courtesy from Prof. Dr. Jochen Schiller

Mobile Communication Technology according to IEEE (examples)



WiFi

Local wireless networks
WLAN 802.11

802.11a — 802.11h

802.11i/e/…/n/…/z

802.11b — 802.11g

ZigBee

802.15.4 - 802.15.4a/b/c/d/e

Personal wireless nw
WPAN 802.15

802.15.5, .6 (WBAN)

802.15.3 — 802.15.3b/c

802.15.2

802.15.1

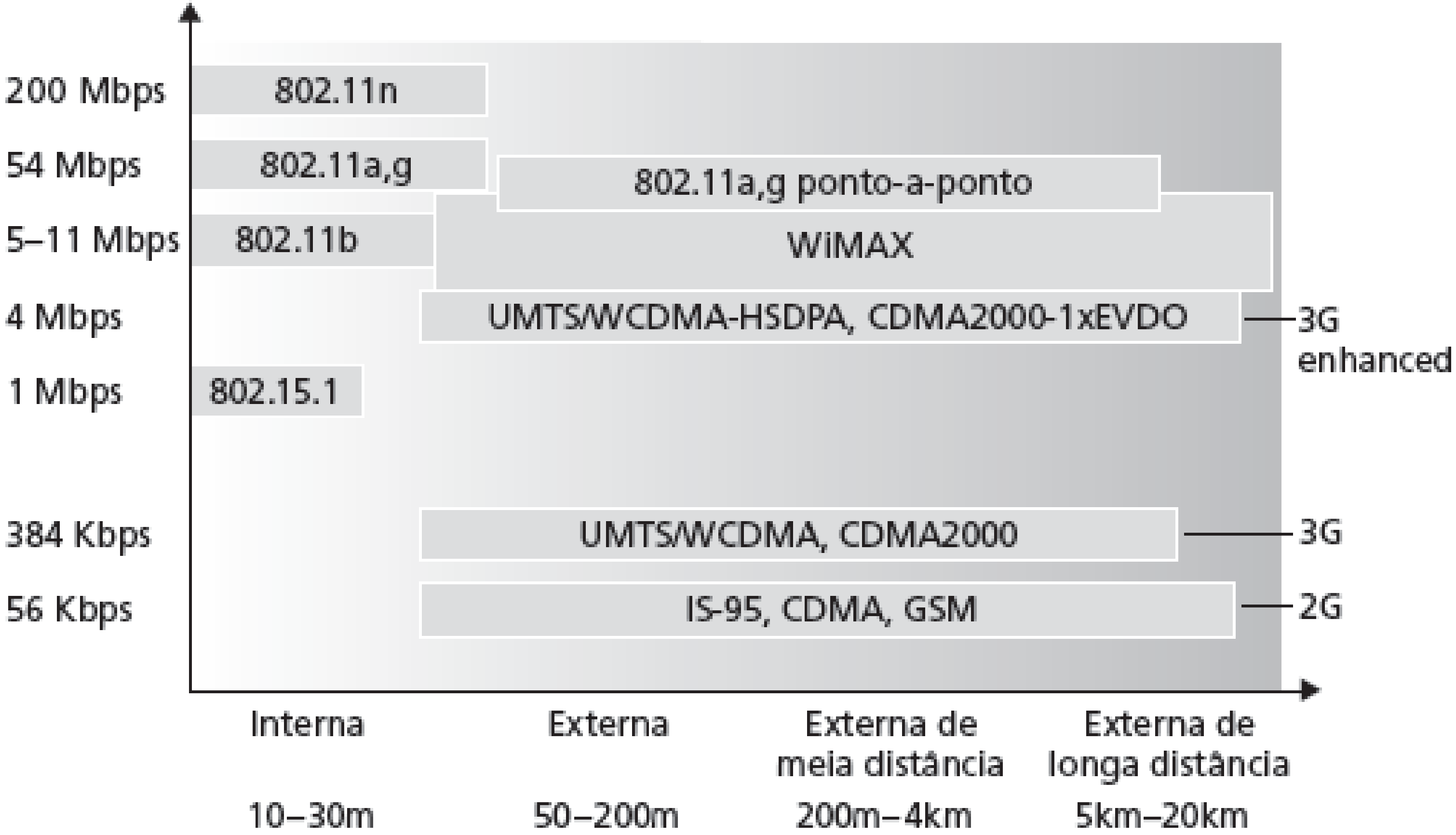
Bluetooth

Wireless distribution networks
WMAN 802.16 (Broadband Wireless Access) **WiMAX**

+ Mobility

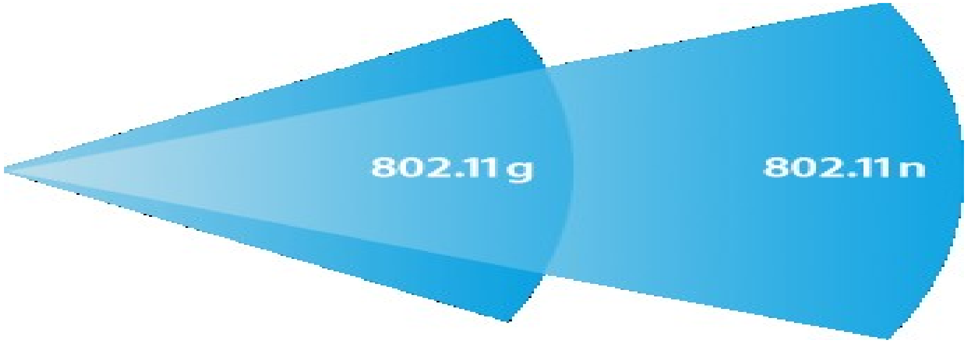
[802.20 (Mobile Broadband Wireless Access)]
802.16e (addition to .16 for mobile devices)

Main features of the existing wireless technologies



Why is 802.11n faster?

- MIMO technology
  - Multiple Output Multiple Input
  - Signal processing smart antenna
  - Transmits multiple data streams through multiple antennas
  - The result?
  - Up to five times the performance
  - Achieves twice the range to that of 802.11g
- Simultaneous dual band: 2.4/5 GHz frequencies
- Range 175 feet
- Typically up to 450 Mbps



Why is 802.11n faster?

- MIMO is also employed in WiMax
- 802.11g typically achieves up to 54Mbps
- MIMO can simultaneously transmit three streams of data and receive two
- Three non overlapping channels at 2.4 GHz (1, 6 and 11)
- Payload optimization: more data being transmitted in each packet
- 802.11n is ideal for video streaming
- If your 802.11n working with 802.11g laptop will result in slower 802.11g speeds

Characteristics of wireless LANs

- Advantages
  - very flexible within the reception area
  - Ad-hoc networks without previous planning possible
  - (almost) no wiring difficulties (e.g. historic buildings, firewalls)
  - more robust against disasters like, e.g., earthquakes, fire - or users pulling a plug...
- Disadvantages
  - typically very low bandwidth compared to wired networks (1-450 Mbit/s) due to shared medium
  - many patented proprietary solutions, especially for higher bit-rates, standards take their time (e.g. IEEE 802.11n)
  - products have to follow many national restrictions such as frequencies that are permitted within a country (e.g. police, aircraft control, etc.)

Design goals for wireless LANs

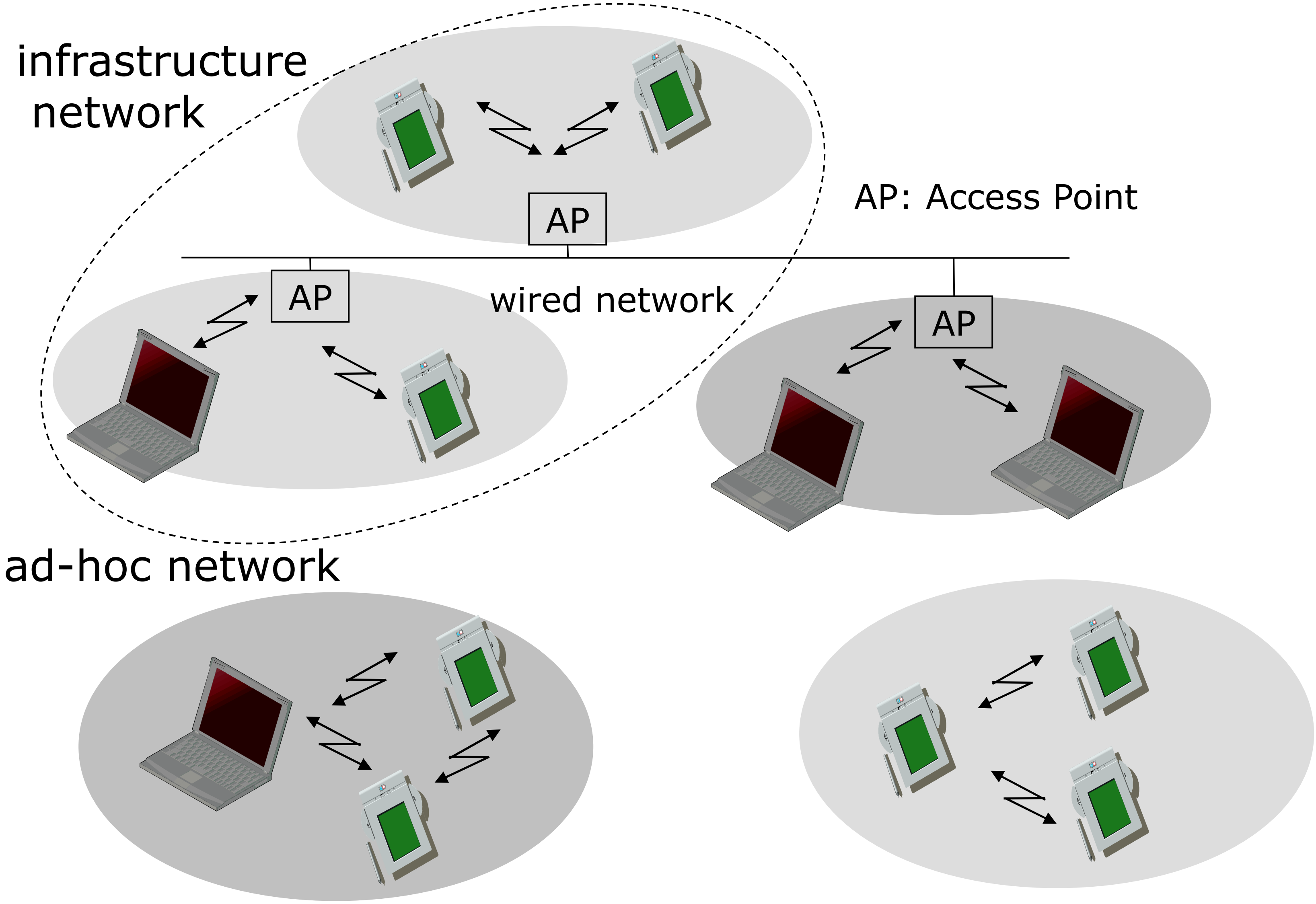
- global, seamless operation
- low power for battery use (e.g. WSNs and cell phones)
- no special permissions or licenses needed to use the LAN
- robust transmission technology
- simplified spontaneous cooperation at meetings
- easy to use for everyone, simple management
- protection of investment in wired networks (i.e. interoperable with wired LANs)
- security (no one should be able to read my data), privacy (no one should be able to collect user profiles), safety (low radiation)
- transparency concerning applications and higher layer protocols, but also location awareness if necessary

Comparison: infrared vs. radio transmission

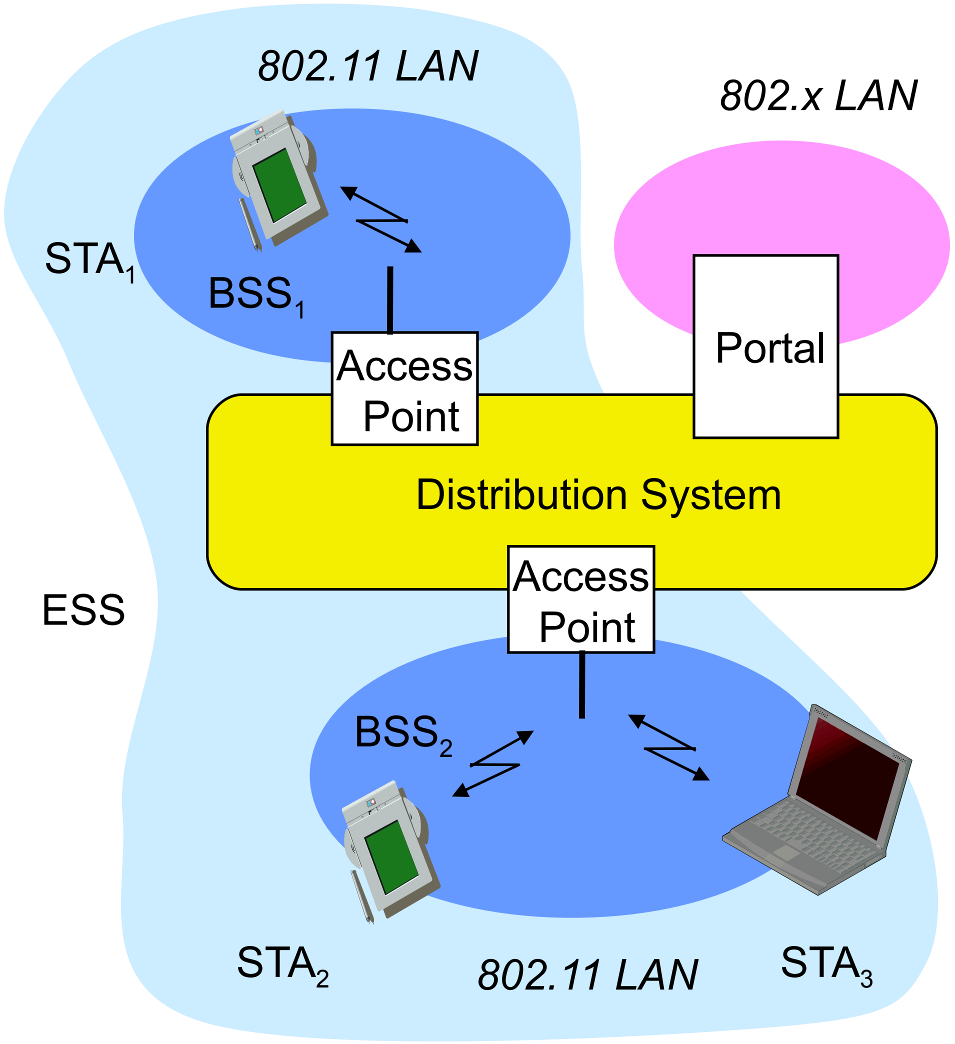
- Infrared
  - uses IR diodes, multiple reflections (walls, furniture etc.)
- Advantages
  - simple, cheap, available in many mobile devices
  - no licenses needed
  - simple shielding possible
- Disadvantages
  - interference by sunlight, heat sources etc.
  - many things shield or absorb IR light
  - low bandwidth
- Example
  - IrDA (Infrared Data Association) interface available everywhere

- Radio
  - typically using the license free ISM band at 2.4 GHz
- Advantages
  - experience from wireless WAN and mobile phones can be used
  - coverage of larger areas possible (radio can penetrate walls, furniture etc.)
- Disadvantages
  - very limited license free frequency bands
  - shielding more difficult, interference with other electrical devices
- Example
  - Many different products

Comparison: infrastructure vs. ad-hoc networks

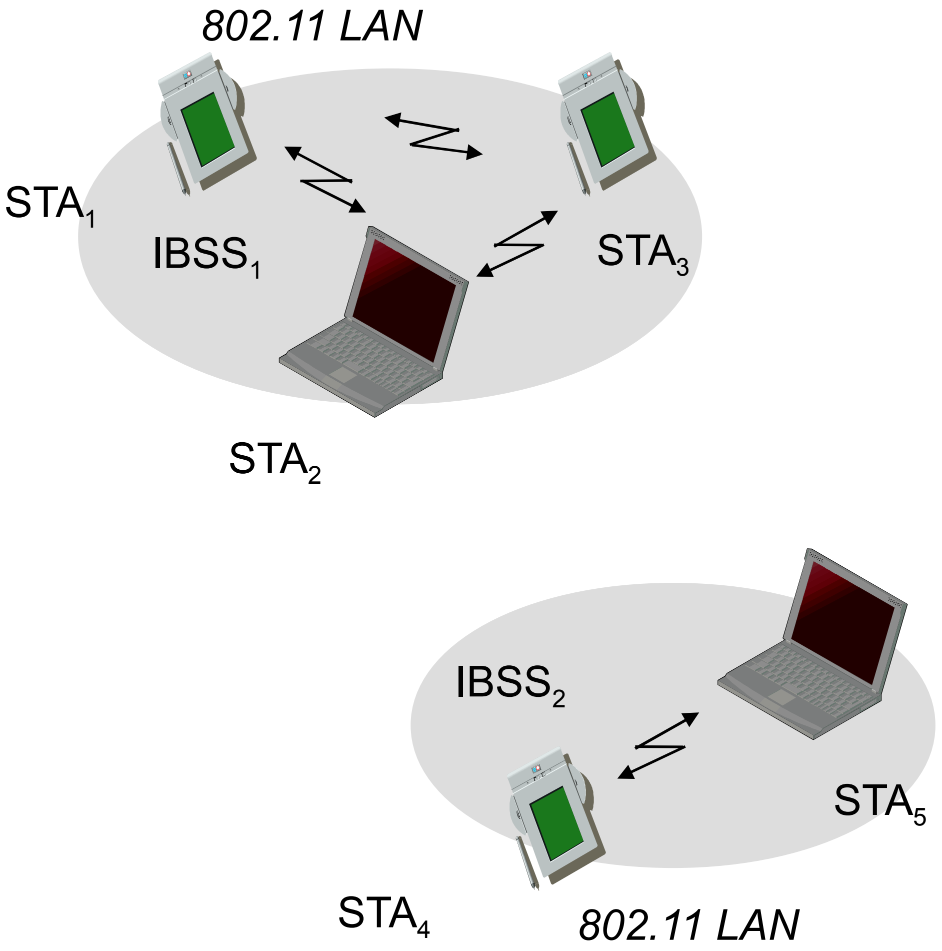


802.11 - Architecture of an infrastructure network



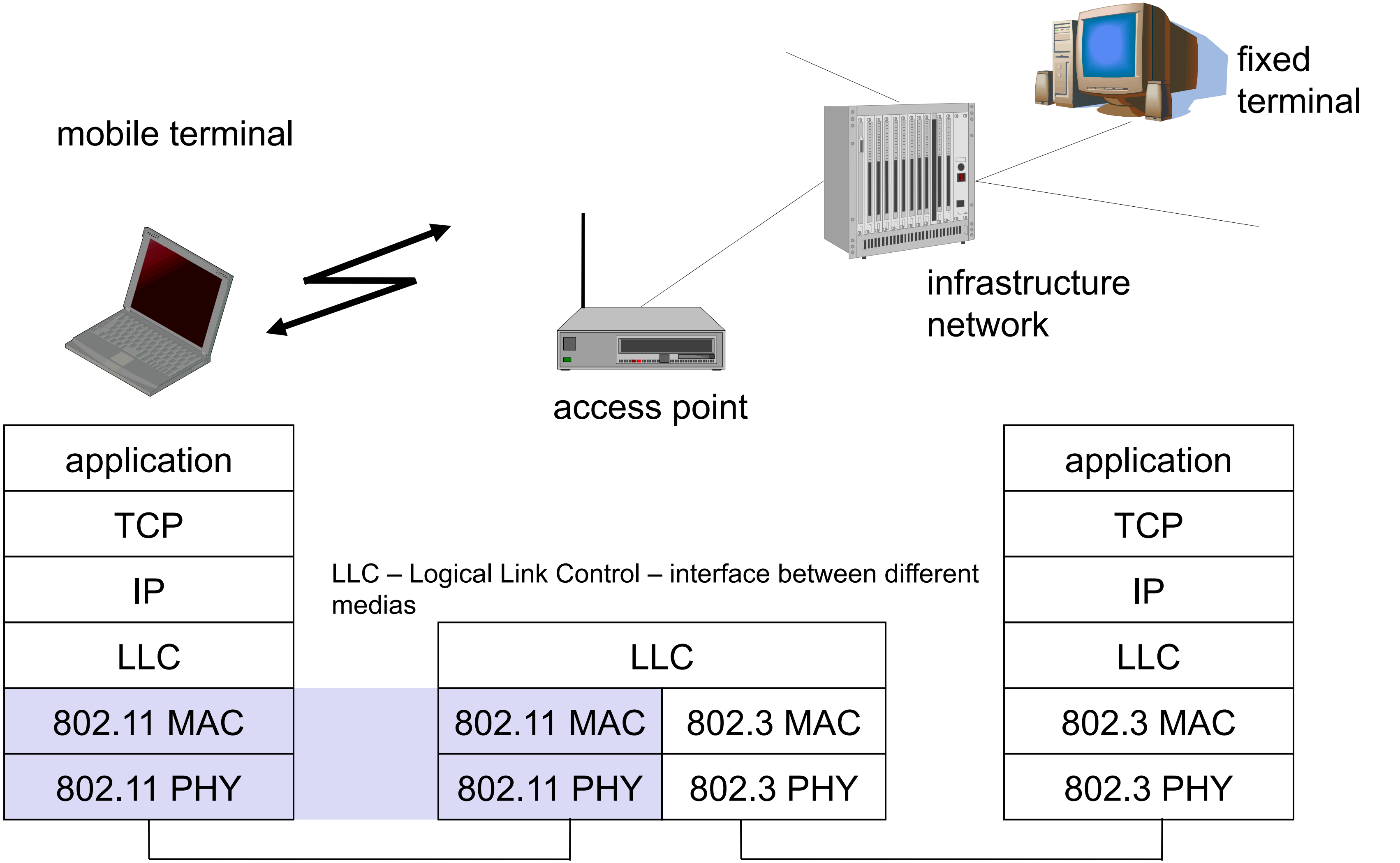
- Station (STA)
  - terminal with access mechanisms to the wireless medium and radio contact to the access point
- Basic Service Set (BSS)
  - group of stations using the same radio frequency
- Access Point
  - station integrated into the wireless LAN and the distribution system
- Portal
  - bridge to other (wired) networks
- Distribution System
  - interconnection network to form one logical network (EES: Extended Service Set) based on several BSS

802.11 - Architecture of an ad-hoc network



- Direct communication within a limited range
  - Station (STA):
    terminal with access mechanisms to the wireless medium
  - Independent Basic Service Set (IBSS):
    group of stations using the same radio frequency

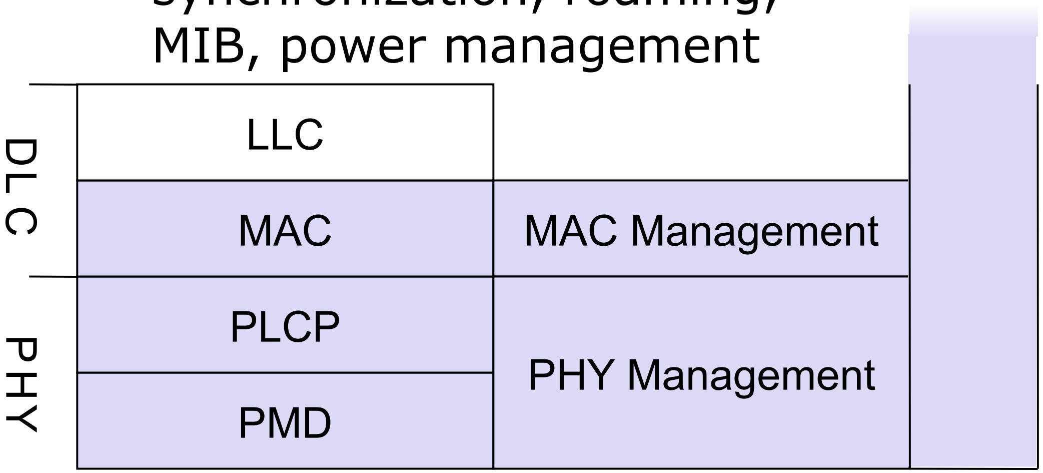
IEEE standard 802.11



LLC – Logical Link Control – interface between different medias

802.11 - Layers and functions

- MAC
  - access mechanisms, fragmentation, encryption
- MAC Management
  - synchronization, roaming, MIB, power management

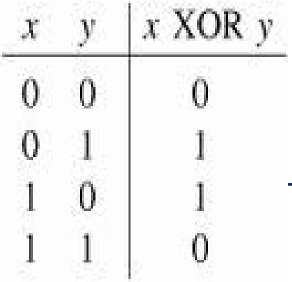

DLC
PHY
LLC
MAC
MAC Management
PLCP
PMD
PHY Management
Station Manag

- PHY Management includes
  - PLCP Physical Layer Convergence Protocol
    - clear channel assessment signal (carrier sense)
    - Medium currently idle?
  - PMD Physical Medium Dependent
    - modulation, coding, transforms bits into signals
- Station Management
  - coordination of all management functions

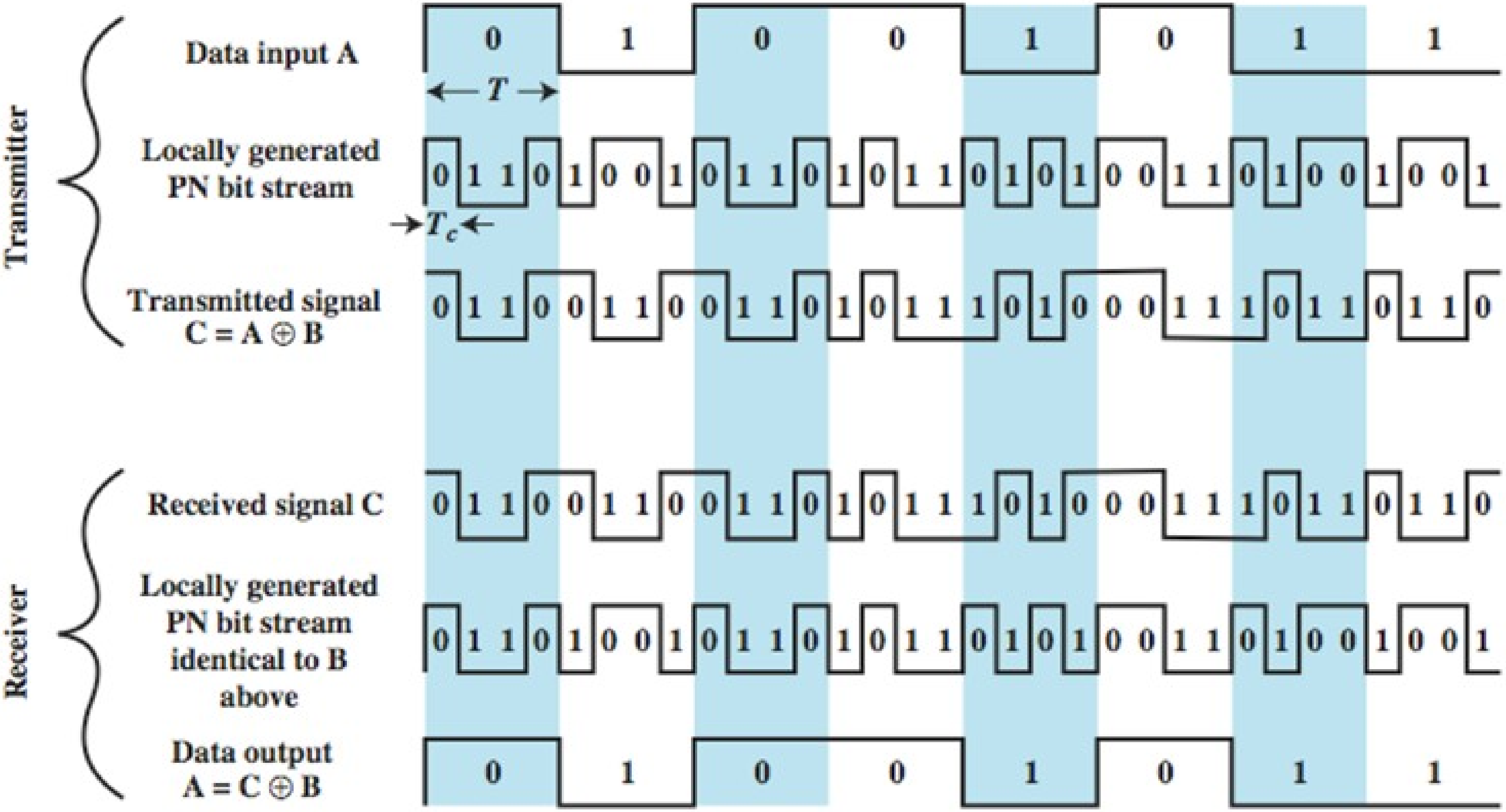
802.11 - Physical layer (legacy)

- 3 versions: 2 radio (typ. 2.4 GHz), 1 IR
    - data rates 1 or 2 Mbit/s
- FHSS (Frequency Hopping Spread Spectrum) only up to 2Mbs
    - spreading, despreading
    - Frequency multiplexing
- DSSS (Direct Sequence Spread Spectrum) → 802.11b/g/n
    - Multiplexes by code (i.e. using a chipping code)
    - Implementation is more complex than FHHS
    - chipping sequence: +1, -1, +1, +1, -1, +1, +1, +1, -1, -1, -1 (Barker code)
    - DATA XOR chipping code
- Infrared
    - Wavelength around 850-950 nm, diffuse light, typ. 10 m range
    - uses near visible light
    - carrier detection, up to 4Mbits/s data rate

802.11 – DSSS, how does it work?

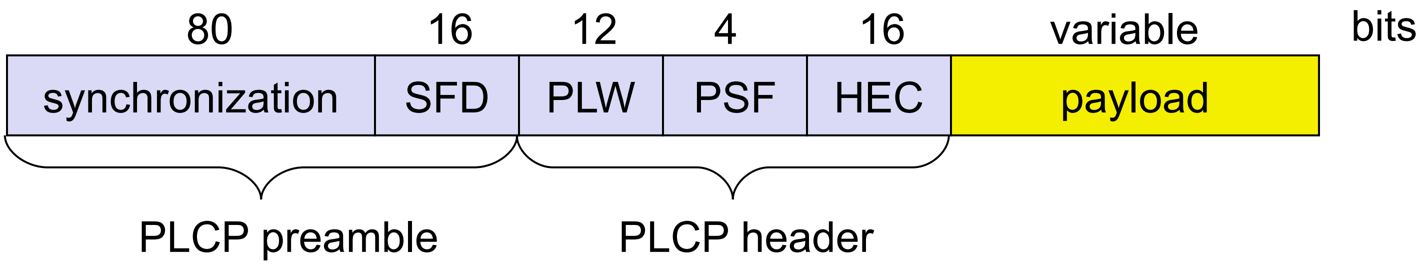


x	y	x XOR y
0	0	0
0	1	1
1	0	1
1	1	0



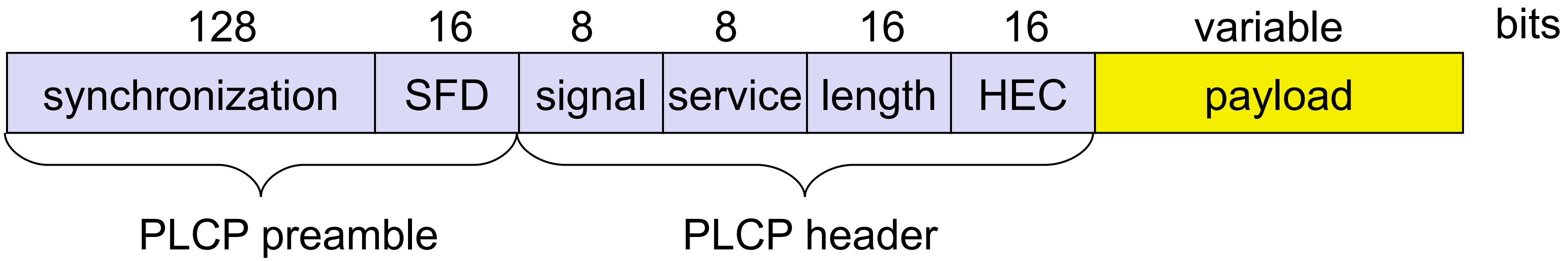
FHSS PHY packet format (legacy)

- Synchronization
  - synch with 010101... pattern
- SFD (Start Frame Delimiter)
  - 0000110010111101 start pattern
- PLW (PLCP_PDU Length Word)
  - length of payload incl. 32 bit CRC of payload, PLW < 4096
- PSF (PLCP Signaling Field)
  - data rate of the payload (0000 -> the lowest data rate 1Mbs)
- HEC (Header Error Check)
  - checksum with the standard ITU-T polynomial generator



DSSS PHY packet format (legacy)

- Synchronization
  - synch., gain setting, energy detection, frequency offset compensation
- SFD (Start Frame Delimiter)
  - 1111001110100000
- Signal
  - data rate of the payload (0A: 1 Mbit/s)
- Service
  - future use, 00: 802.11 compliant
- Length
  - length of the payload
- HEC (Header Error Check)
  - protected by checksum using ITU-T standard polynomial error check



802.11 - MAC layer I - DFWMAC

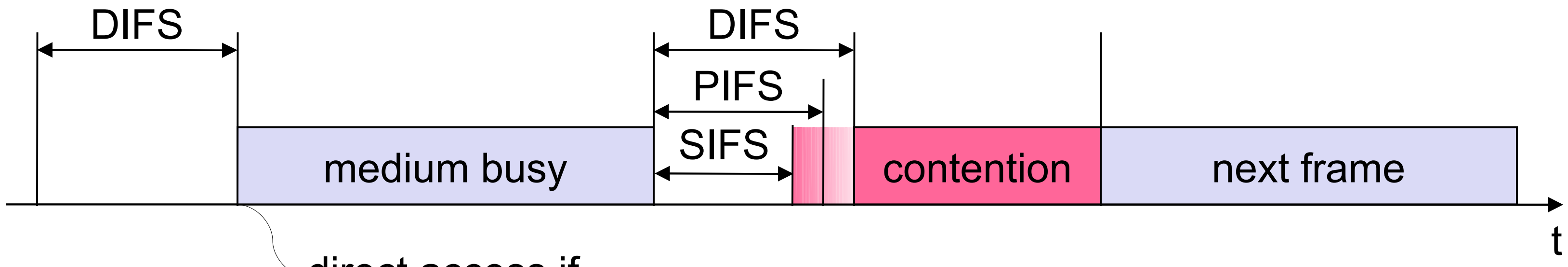
- MAC layer has to fulfill several tasks including:
  - control medium access
  - support for roaming
  - authentication
  - power conservation
- In summary, it has two key tasks:
  - traffic services
  - access control

802.11 - MAC layer I - DFWMAC

- Traffic services (two implementations)
  - Asynchronous Data Service (mandatory)
    - exchange of data packets based on "best-effort"
    - support of broadcast and multicast
  - Time-Bounded Service (optional)
    - implemented using PCF (Point Coordination Function)
- Access methods
  - DFWMAC-DCF CSMA/CA (mandatory)
    - collision avoidance via randomized „back-off" mechanism
    - minimum distance between consecutive packets
    - ACK packet for acknowledgements (not for broadcasts)
  - DFWMAC-DCF w/ RTS/CTS (optional)
    - Distributed Foundation Wireless MAC
    - avoids hidden terminal problem
  - DFWMAC- PCF (optional)
    - access point polls terminals according to a list

802.11 - MAC layer II

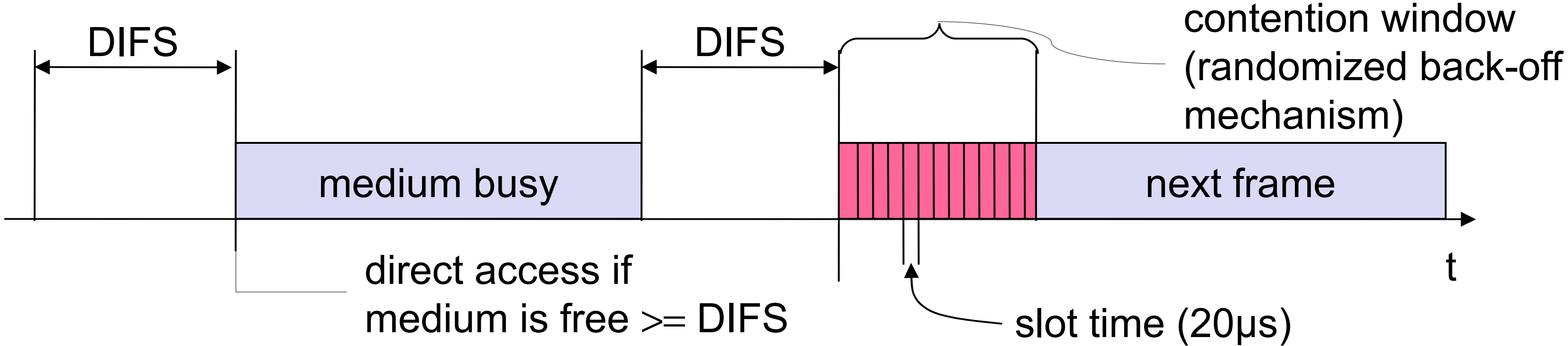
- Priorities
  - defined through different inter frame spaces
  - no guarantee, hard priorities
  - SIFS (Short Inter Frame Spacing)
    - highest priority, for ACK, CTS, polling response
    - DSSS SIFS 10 micro seconds
  - PIFS (PCF IFS)
    - medium priority, for time-bounded service using PCF
  - DIFS (DCF Inter frame spacing)
    - lowest priority, for asynchronous data service



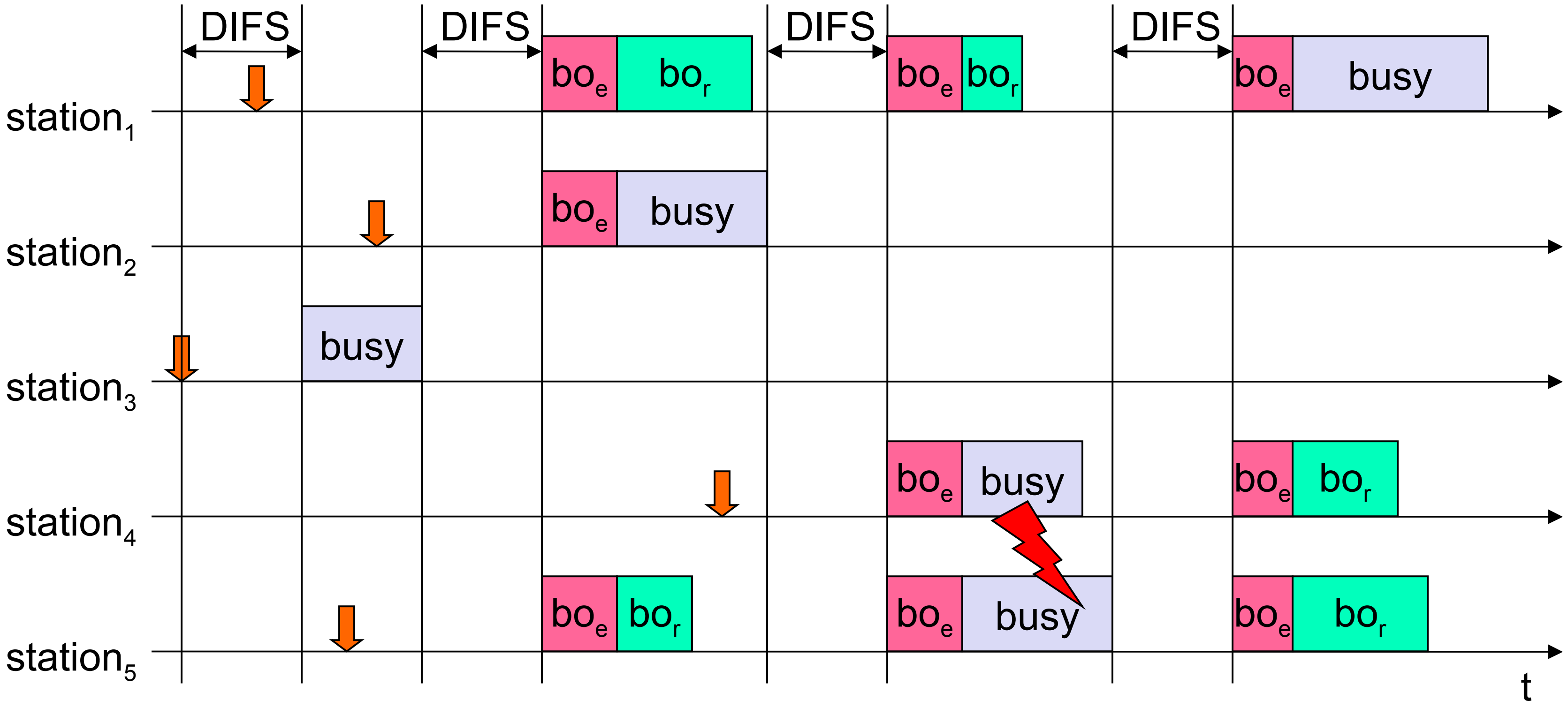
direct access if
medium is free >= DIFS

802.11 - CSMA/CA access method I

- 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 (fairness)



802.11 - competing stations - simple version



busy medium not idle (frame, ack etc.)

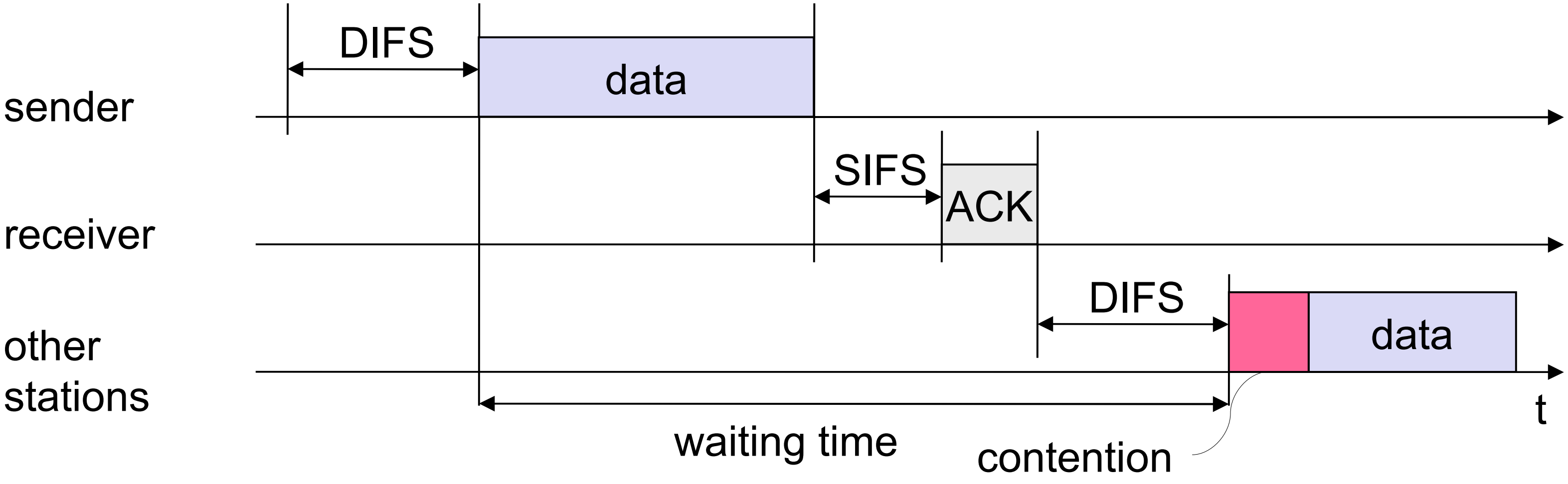
bo_e elapsed backoff time

⇩ packet arrival at MAC

bo_r residual backoff time

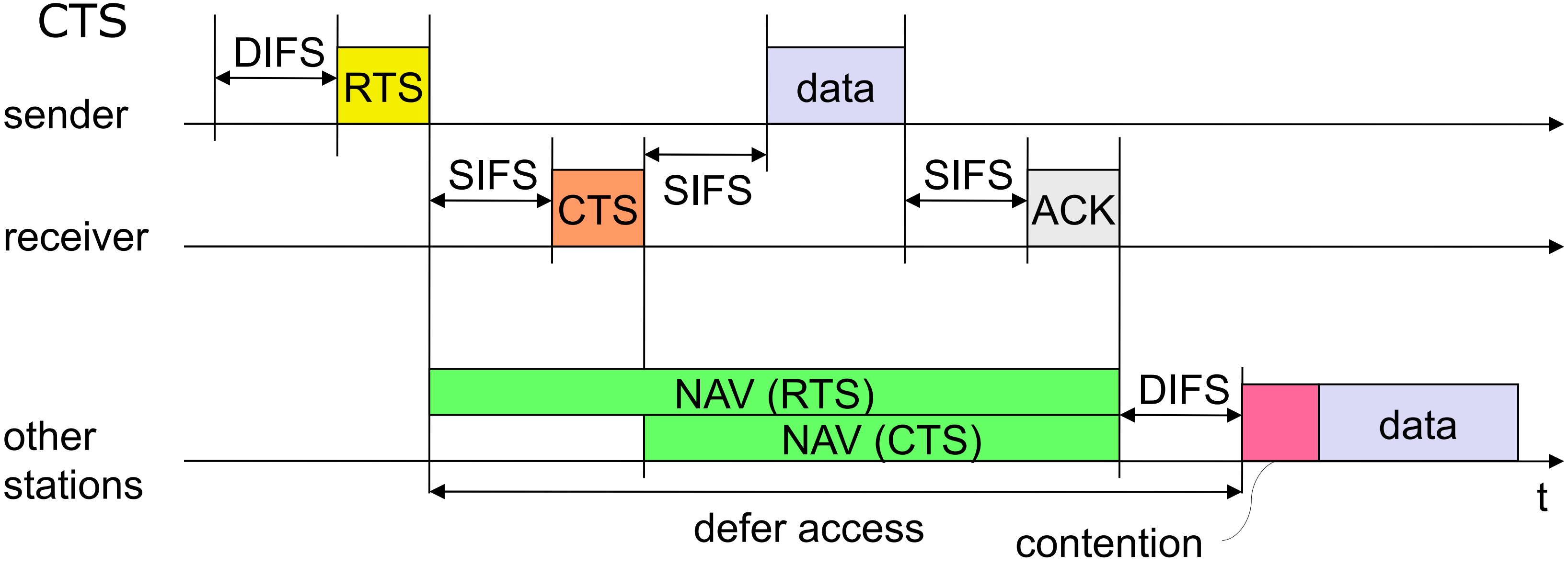
802.11 - CSMA/CA access method II

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

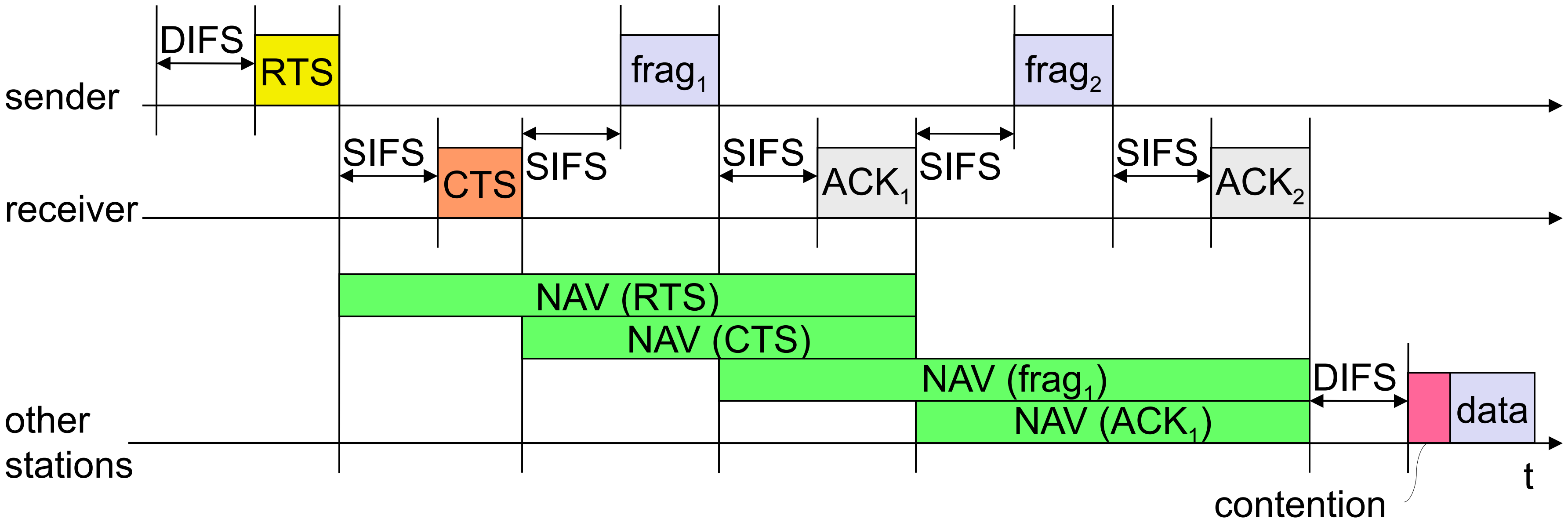


802.11 – Access scheme details (NAV-net allocat. vect.)

- 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

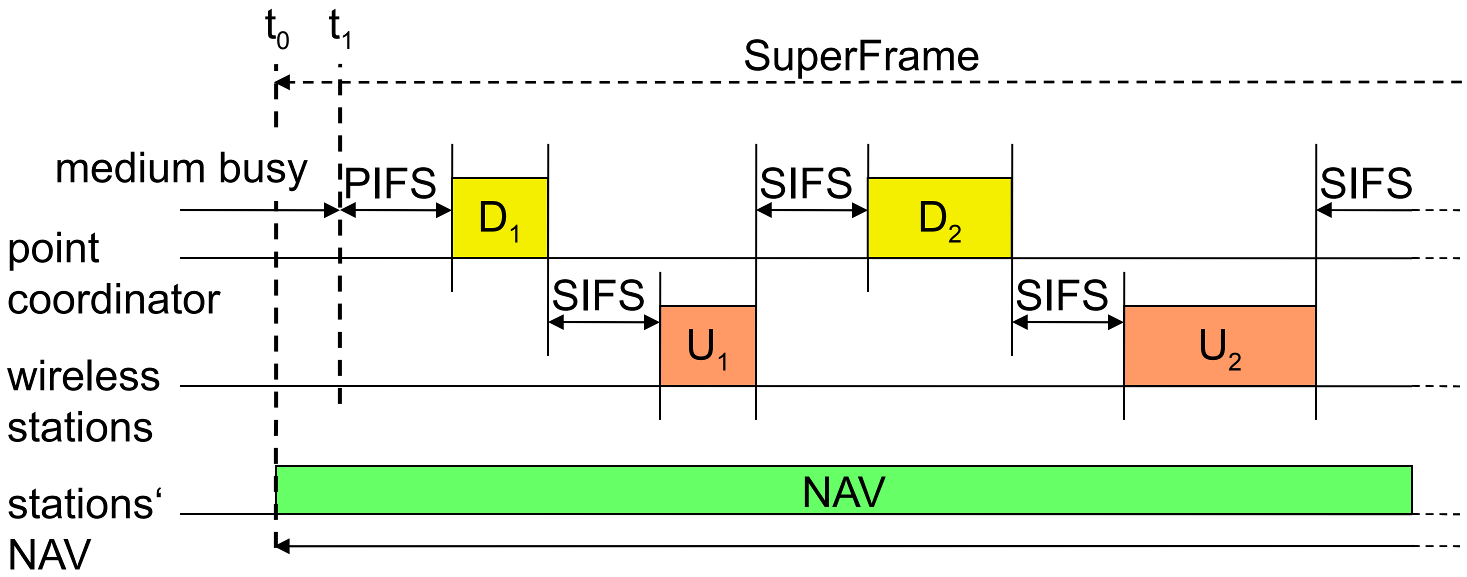


Fragmentation (advantages?)



DFWMAC-PCF I (almost never used)

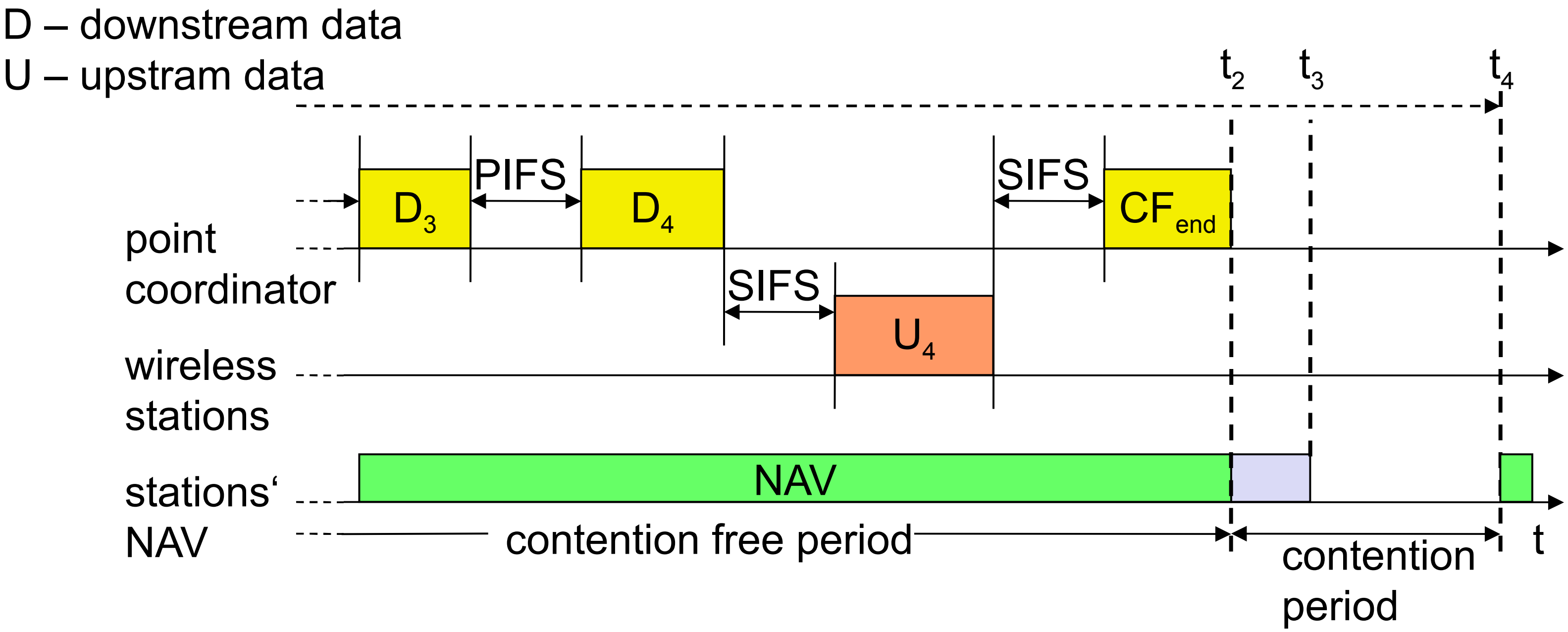
- The two previous mechanisms cannot guarantee QoS
- PCF on top of the standard DCF (random backoff)
- Using PCF → AP controls medium access and polls single nodes
- Super frame → comprises contention-free + contention period
- Contention period can be used for the two mechanisms



D – downstream data
U – upstram data

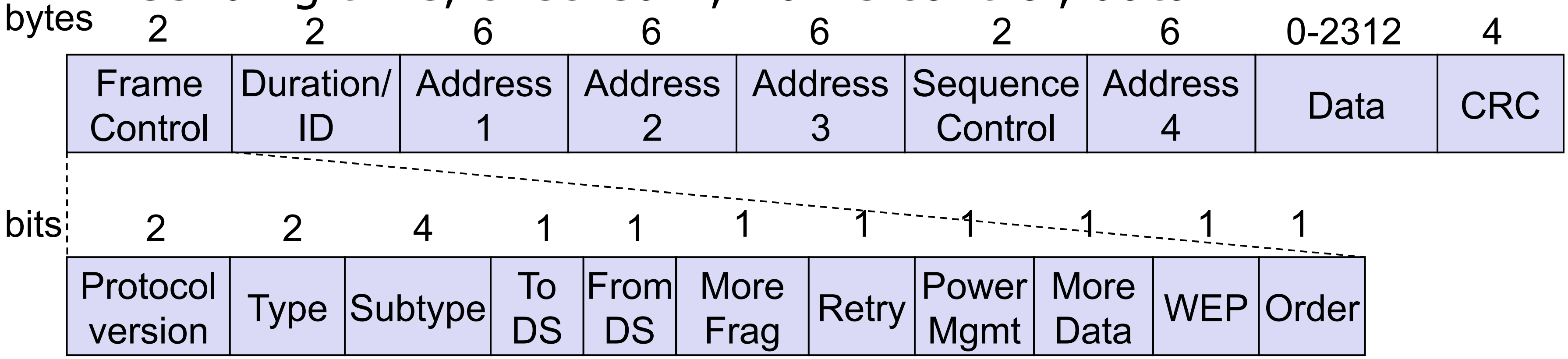
DFWMAC-PCF II

- As PIFS is smaller than DIFS no station can start sending earlier
- Node 3 has nothing to answer and AP will not receive a packet after SIFS



802.11 - Frame format

- Types
  - control, management (e.g. beacon) and data frames
- Sequence numbers
  - important against duplicated frames due to lost ACKs
- Addresses
  - receiver, transmitter (physical), BSS identifier, sender (logical)
- Miscellaneous
  - sending time, checksum, frame control, data



bytes	2	2	6	6	6	2	6	0-2312	4
	Frame Control	Duration/ ID	Address 1	Address 2	Address 3	Sequence Control	Address 4	Data	CRC

bits	2	2	4	1	1	1	1	1	1	1	1
	Protocol version	Type	Subtype	To DS	From DS	More Frag	Retry	Power Mgmt	More Data	WEP	Order

MAC address format

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
Address1 – destination
Address2 – source (ACK will be sent to)
Address3 – filter (often it will carry BSSID addr)
Address4 – Address of the source Access Point

Special Frames: ACK, RTS, CTS

- Acknowledgement

	bytes	2	2	6	4
ACK		Frame Control	Duration	Receiver Address	CRC

- Request To Send

	bytes	2	2	6	6	4
RTS		Frame Control	Duration	Receiver Address	Transmitter Address	CRC

- Clear To Send

	bytes	2	2	6	4
CTS		Frame Control	Duration	Receiver Address	CRC