Introduction to Wireless Networks

Chapter 2: Introduction to IEEE 802.11

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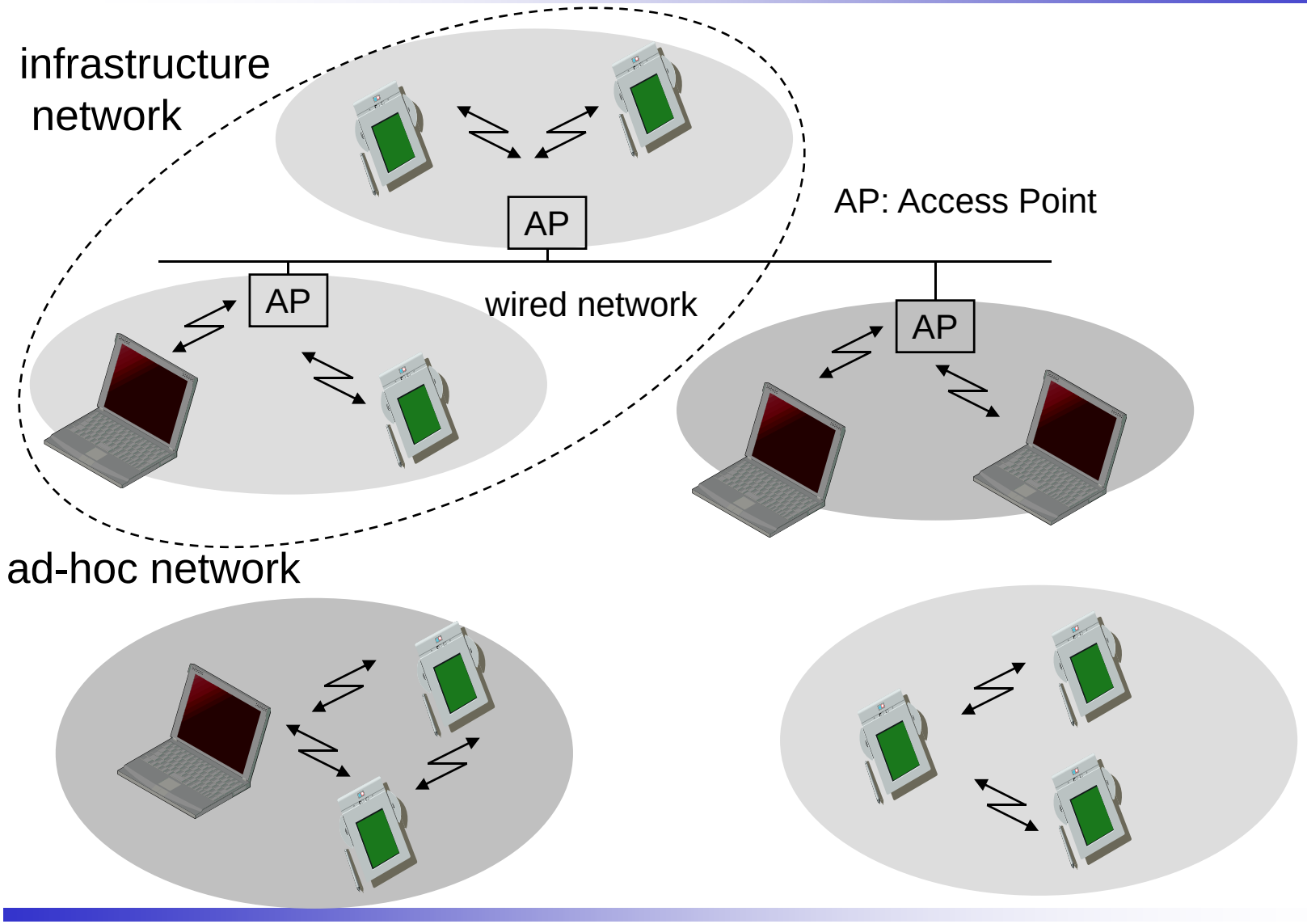
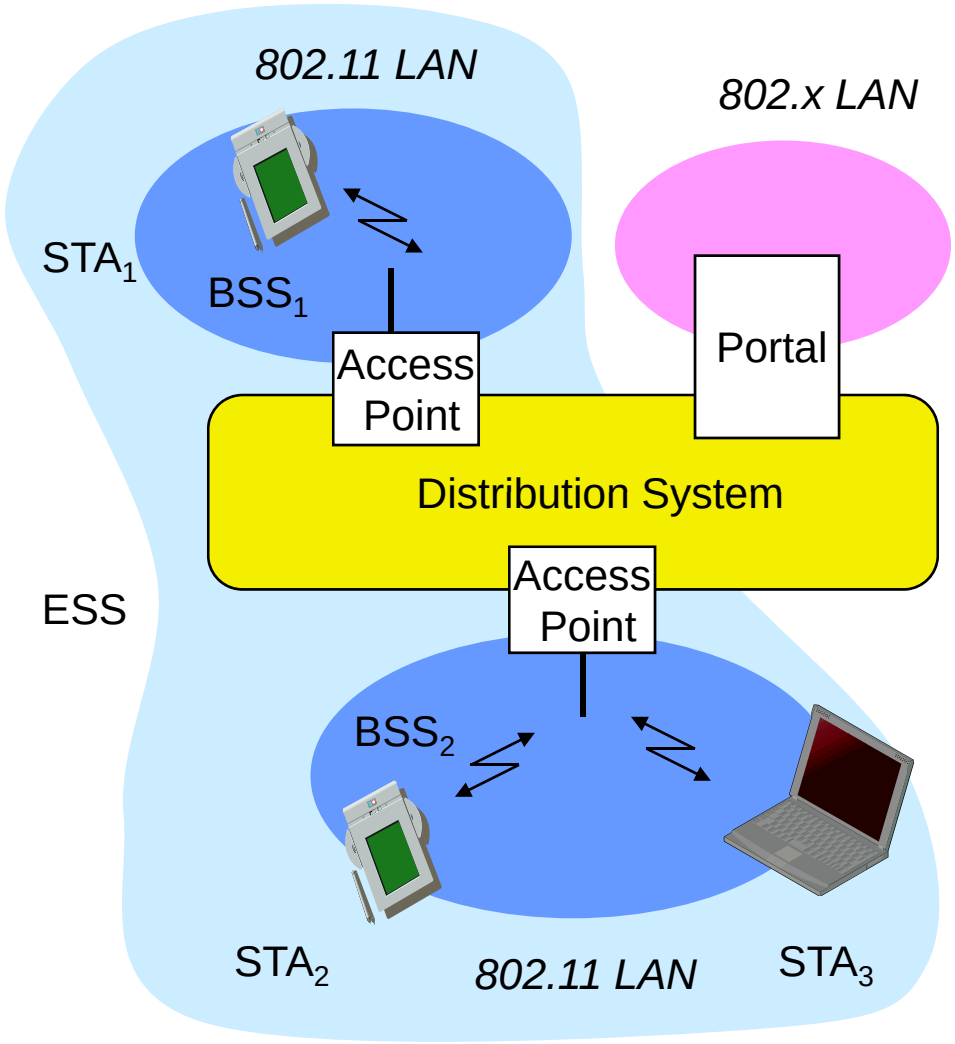
Chapter 2: Introduction to IEEE 802.11

- IEEE 802.11
  - PHY
  - MAC
  - Roaming
  - .11a, b, g, h, i …
- HIPERLAN
  - Standards overview
  - HiperLAN2
  - QoS

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

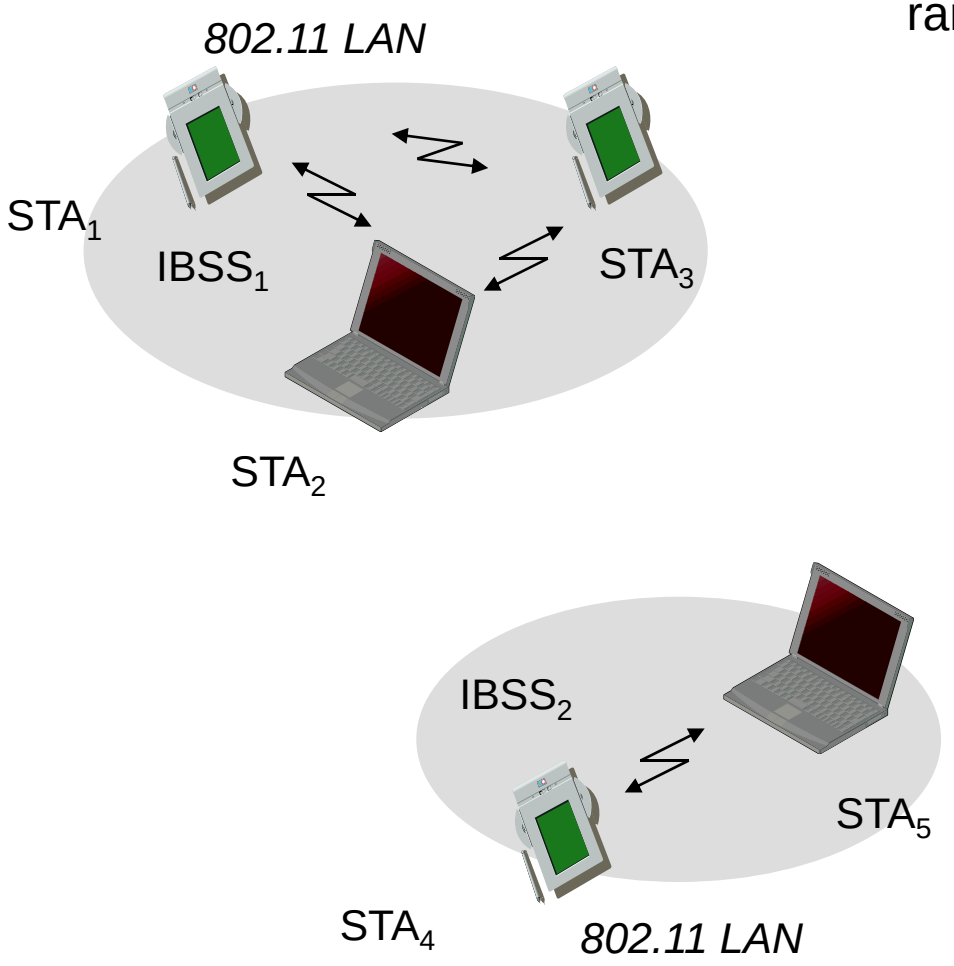
Portal

- bridge to other (wired) networks

Distribution System

- interconnection network to form one logical network (ESS: Extended Service Set) based on several BSS

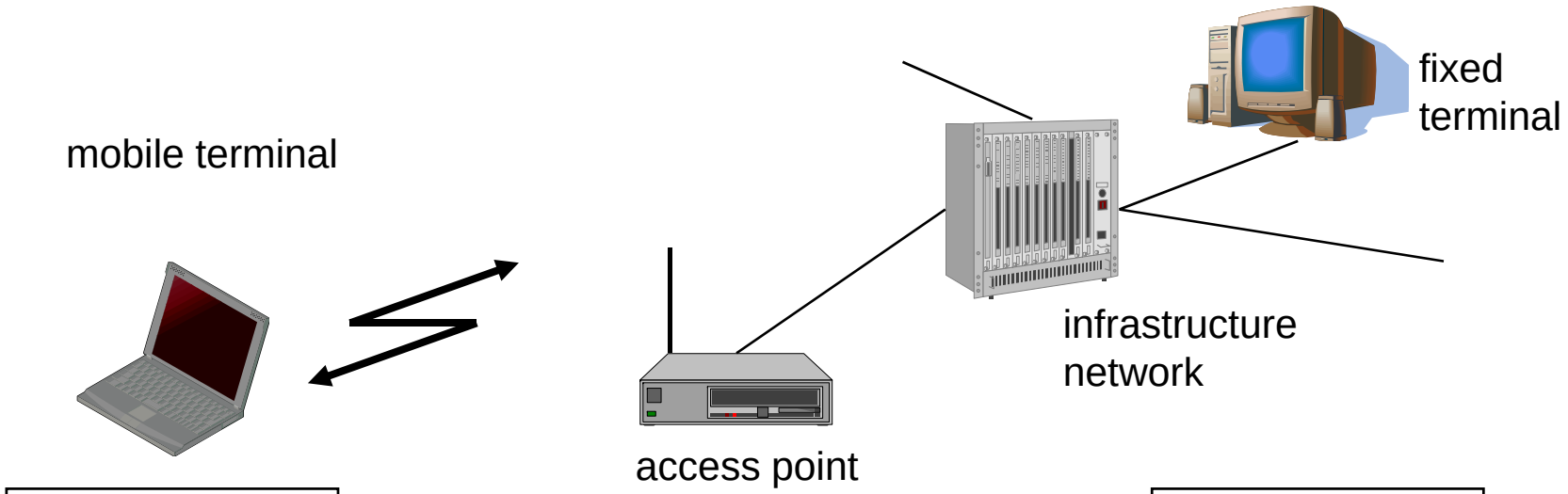
802.11 - Architecture of an ad-hoc network

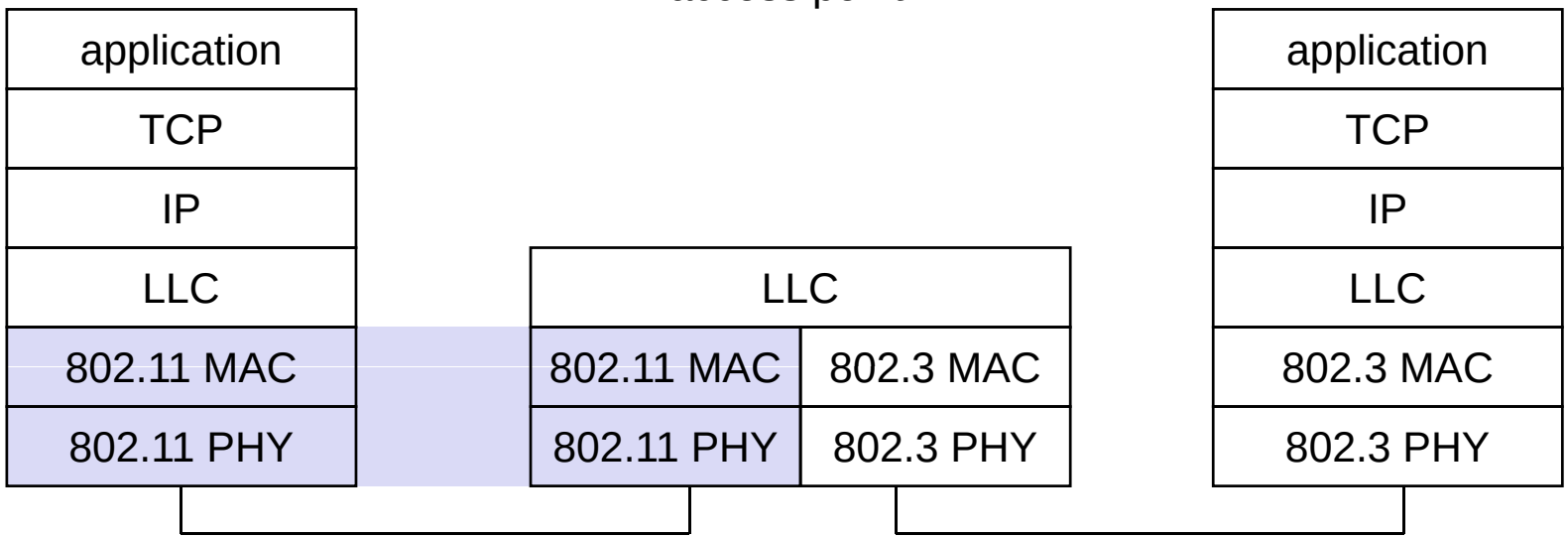


Direct communication within a limited range

- 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





802.11 - Layers and functions

MAC
- access mechanisms, fragmentation, encryption

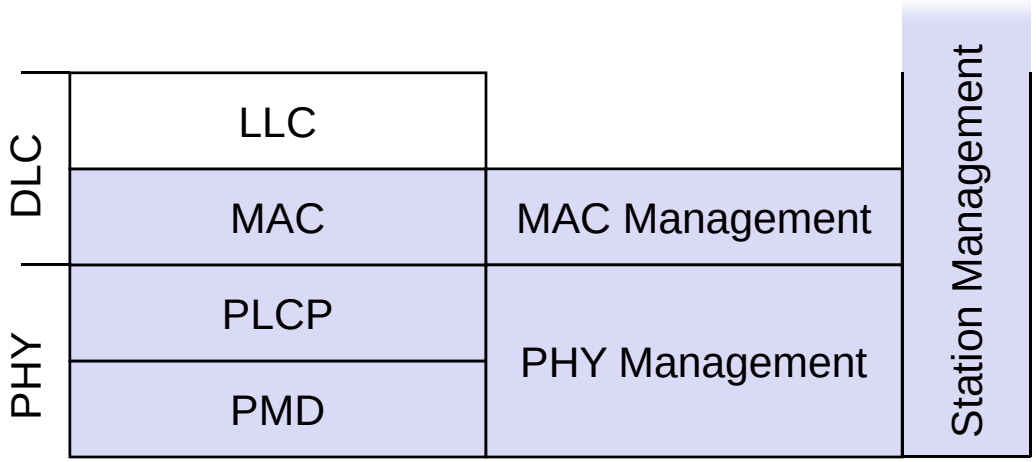
MAC Management
- synchronization, roaming, MIB, power management

PLCP Physical Layer Convergence Protocol
- clear channel assessment signal (carrier sense)

PMD Physical Medium Dependent
- modulation, coding

PHY Management
- channel selection, MIB

Station Management
- coordination of all management functions



802.11 - Physical layer

3 versions: 2 radio (typ. 2.4 GHz), 1 IR

- data rates 1 or 2 Mbit/s

FHSS (Frequency Hopping Spread Spectrum)

- spreading, despreading, signal strength, typ. 1 Mbit/s
- min. 2.5 frequency hops/s (USA), two-level GFSK modulation

DSSS (Direct Sequence Spread Spectrum)

- DBPSK modulation for 1 Mbit/s (Differential Binary Phase Shift Keying), DQPSK for 2 Mbit/s (Differential Quadrature PSK)
- preamble and header of a frame is always transmitted with 1 Mbit/s, rest of transmission 1 or 2 Mbit/s
- chipping sequence: +1, -1, +1, +1, -1, +1, +1, +1, -1, -1, -1 (Barker code)
- max. radiated power 1 W (USA), 100 mW (EU), min. 1mW

Infrared

- 850-950 nm, diffuse light, typ. 10 m range
- carrier detection, energy detection, synchonization

Spread Spectrum Modulation

- Definition: “spread” a signal’s power over a wider band of frequency.

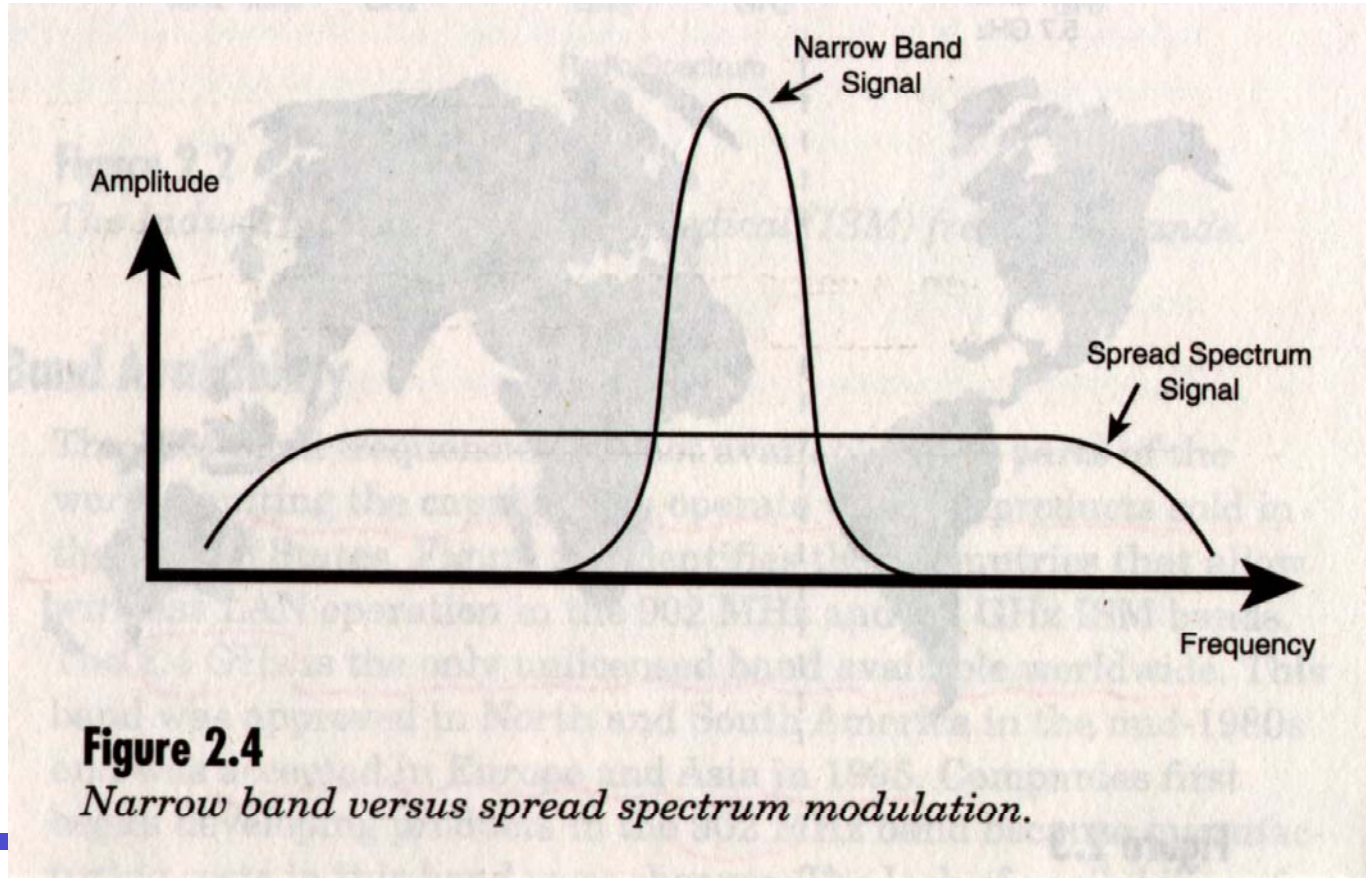


Figure 2.4
Narrow band versus spread spectrum modulation.

展頻(Spread Spectrum, SS)

- **展頻(Spread Spectrum, SS)**是將傳輸訊號的頻譜(spectrum)打散到較其原始頻寬更寬的一種通訊技術，常用於無線通訊領域。比較嚴格的定義則分成兩個部分：
  - 展頻調變之後，其訊號傳輸頻寬應遠大於原始訊號
  - 傳輸端會採用一個獨特的碼(code)，此碼與傳送資料是無關的，接收端也必須使用這個獨特的碼才能解展頻以獲得傳輸端的資料。

優點與用途

- 對背景的雜訊(noise)、干擾(interference)以及自體多路徑干擾(Multipath interference)有免疫力。
- 對人為的刻意干擾(**jamming**)訊號有良好的抵禦能力，這也是展頻最早應用於軍方通訊系統中對抗人為的干擾重要原因其一。
- 較良好的隱密性，通訊過程被截收的可能性較低。這是因為展頻後，單位頻率的功率值降低，截收者不易透過頻譜分析儀獲得敵方通訊的資訊；即使電波被接收了，由於截收者不知道展頻碼的內涵，因此無法回復編碼的資訊。所以展頻通訊亦具有簡單的保密通訊能力。
- 降低電磁干擾(Electromagnetic Interference, EMI)
- 藉由展頻技術，可以達成分碼多工(CDMA)通訊，讓多個用戶能夠獨立地同時使用更大的頻寬。

Direct Sequence Spread Spectrum (DSSS)

- Use bit sequence to represent “zero” and “one” (Fig. 2-5)
- Also referred to as “chipping code”.
- Longer chipping codes are more resilient to noise.
- Minimum length = 10 (by FCC)
- IEEE 802.11 uses 11 chips per data bit.

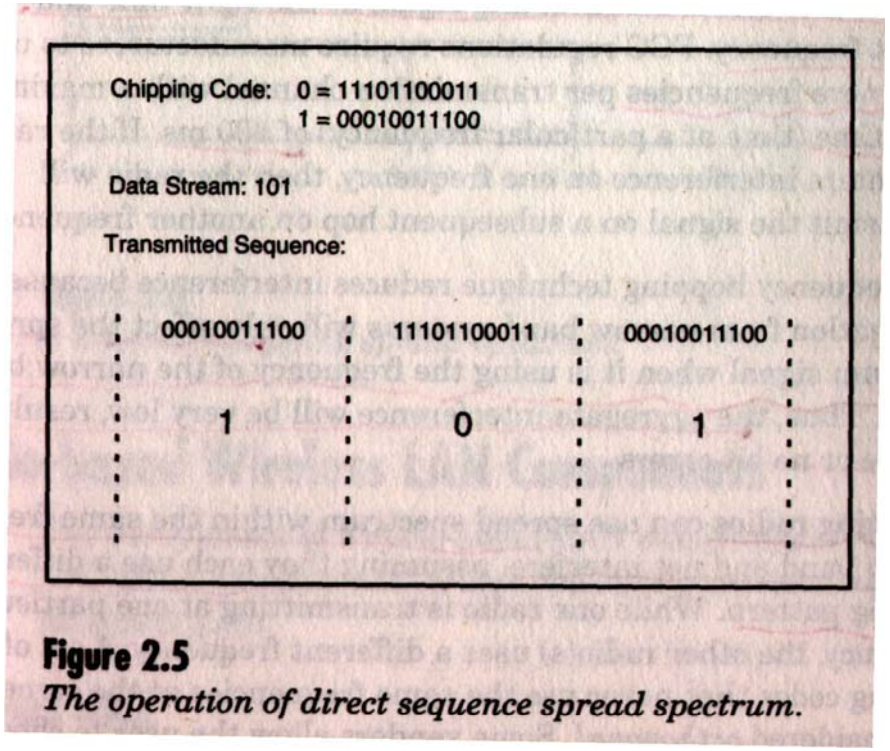


Figure 2.5
The operation of direct sequence spread spectrum.

Frequency Hopping Spread Spectrum (FHSS)

- Data is modulated by carrier signals that hop from frequency to frequency as a function of time, over a wide band of frequencies.

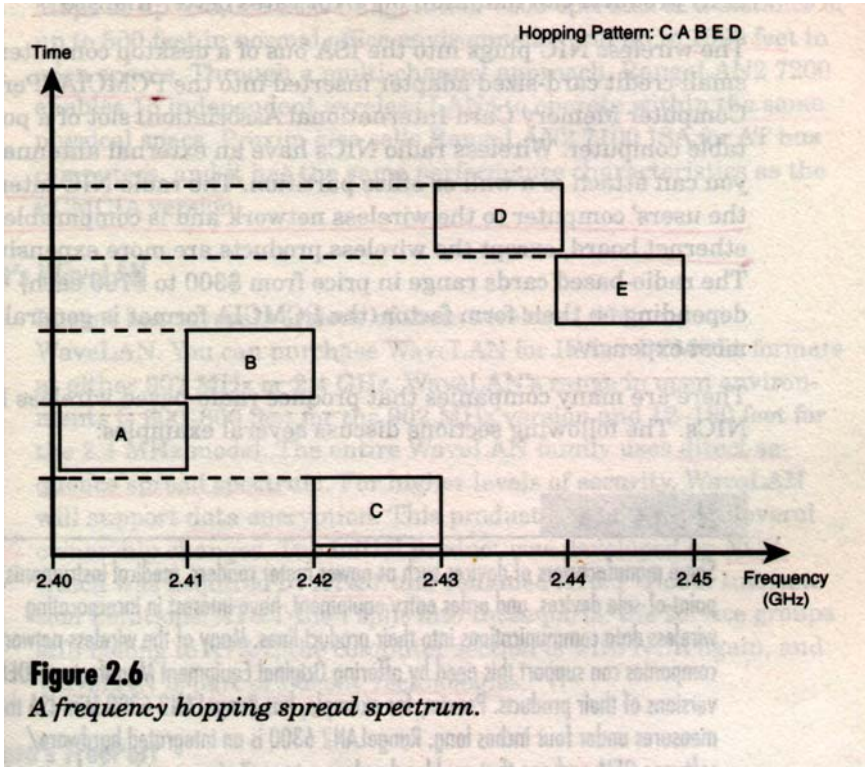


Figure 2.6
A frequency hopping spread spectrum.

Why do we need MAC?

Contention and Collision Avoidance !!!

Why Do We Need MAC?

Fairness !!!

802.11 - MAC layer I – DFWMAC (distributed foundation wireless medium access control)

Traffic services

- 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)

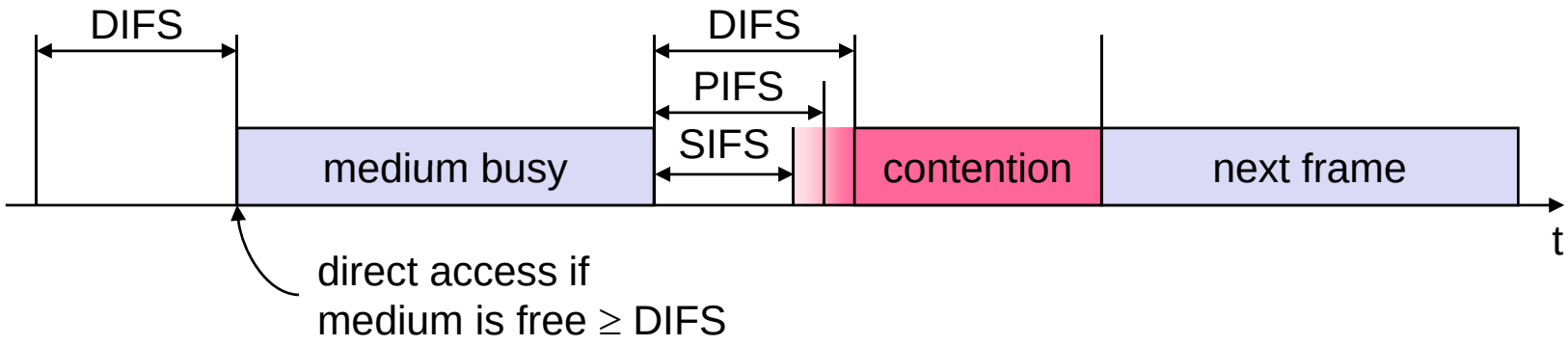
Access methods

- 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

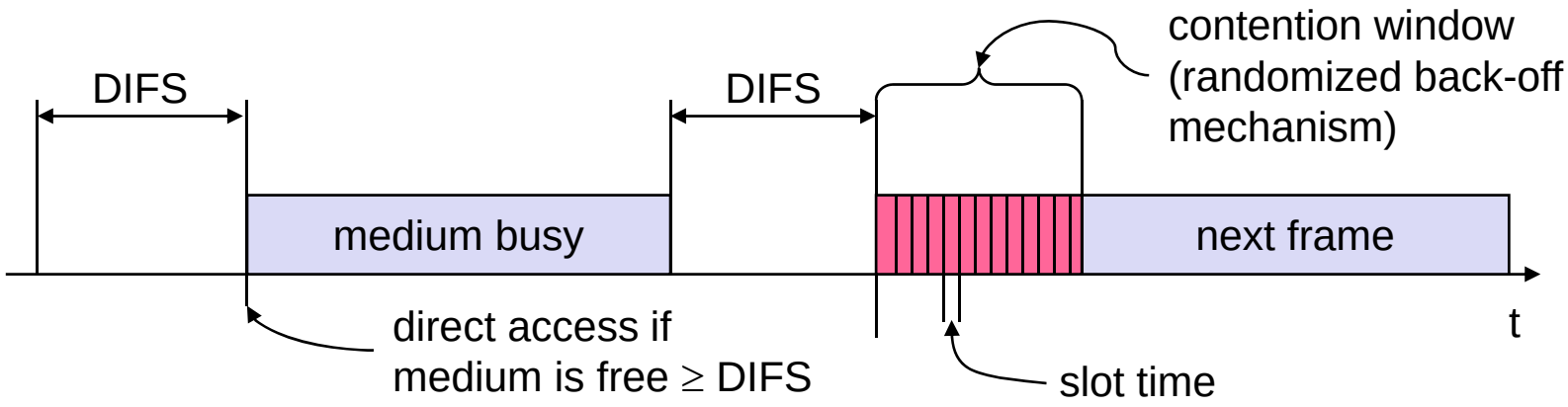
802.11 - MAC layer II

Priorities

- defined through different inter frame spaces
- no 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

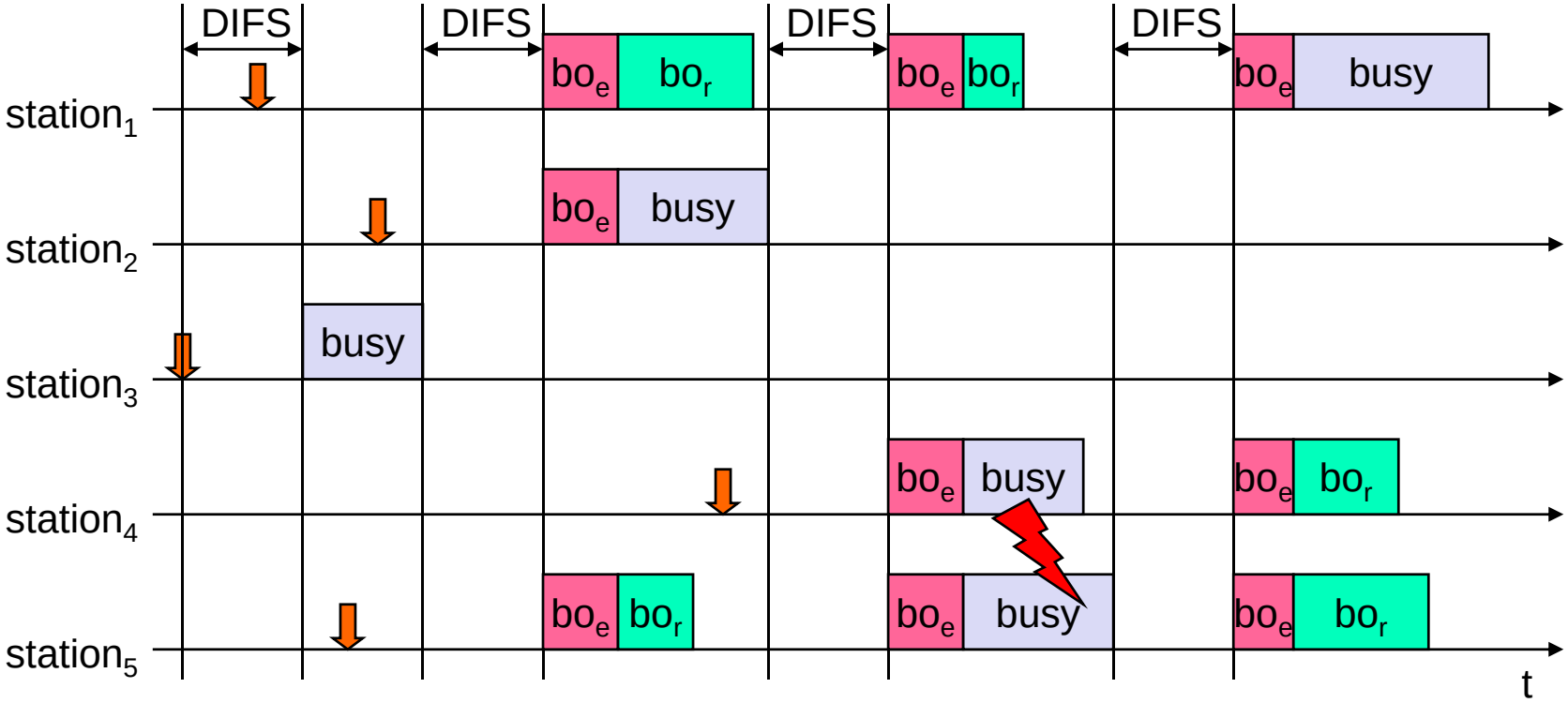


802.11 - CSMA/CA access method I



- 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.)

packet arrival at MAC

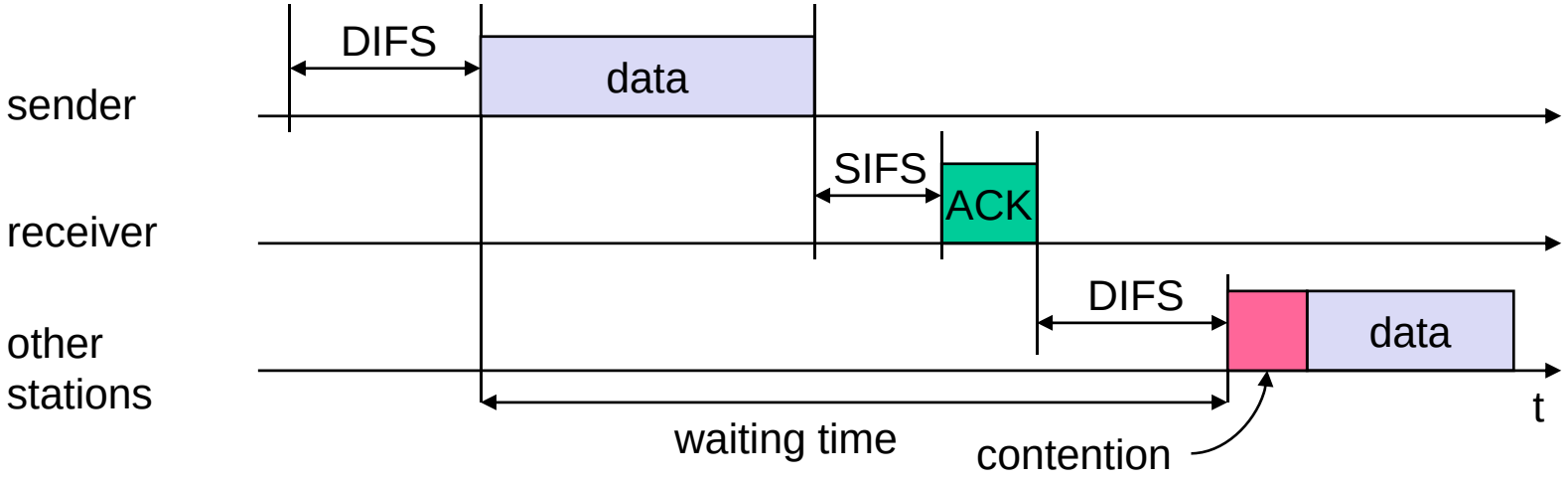
bo_e — elapsed backoff time

bo_r — residual backoff time

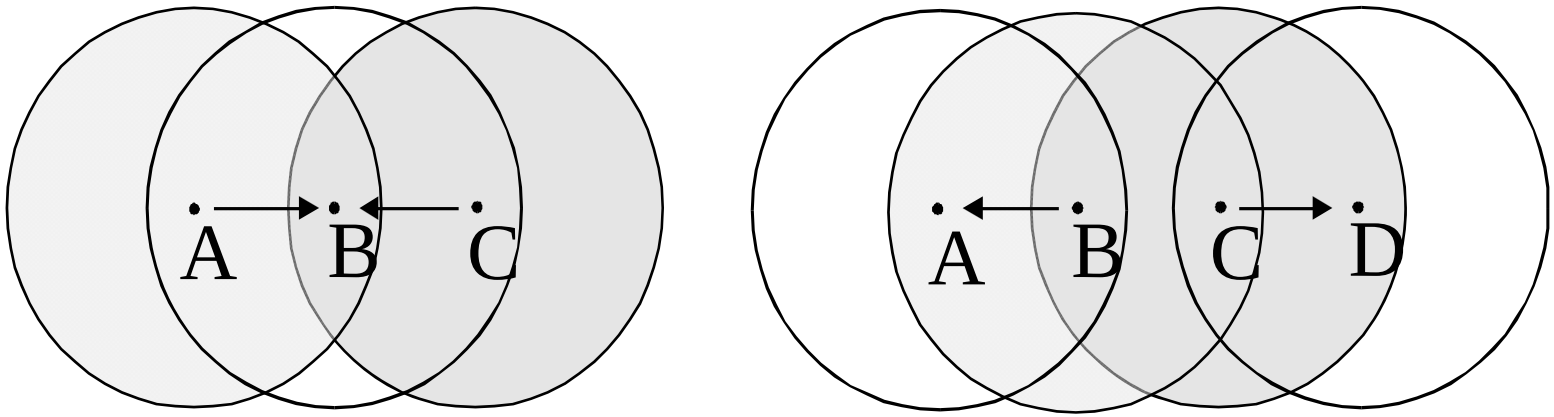
802.11 - CSMA/CA access method II

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



Hidden-Terminal and Exposed-Terminal Problems



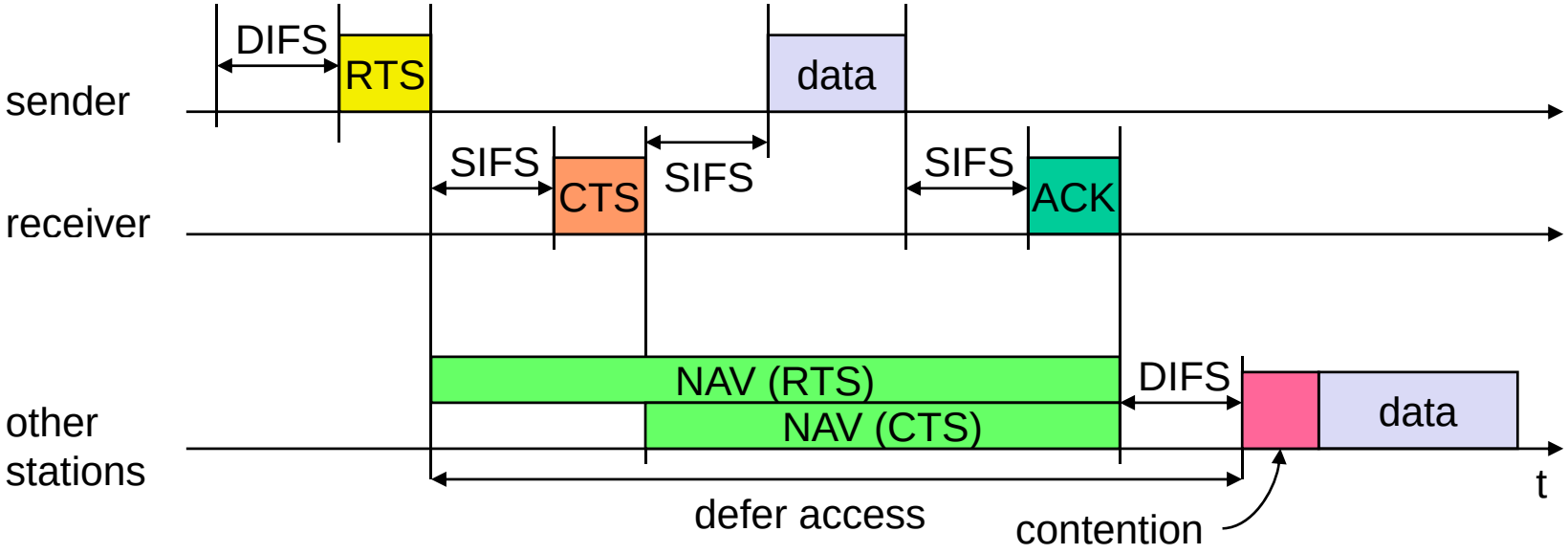
(a) (b)

Fig. 1: (a) the hidden terminal problem,
(b) the exposed terminal problem

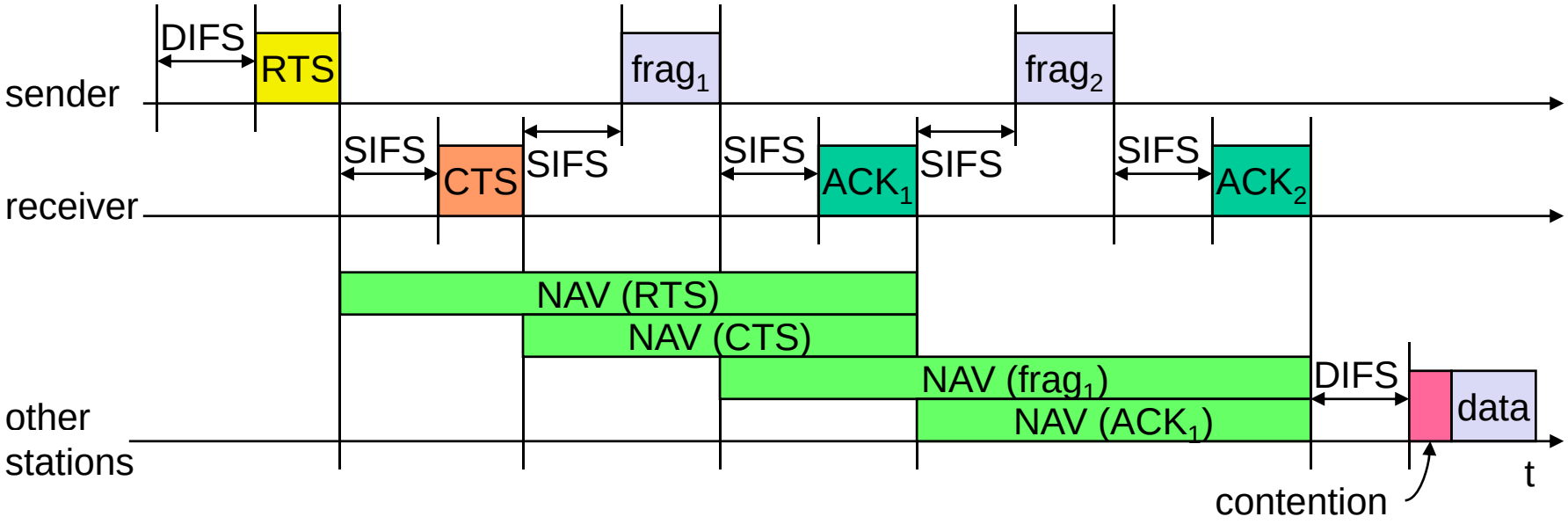
802.11 - DFWMAC

Sending unicast packets

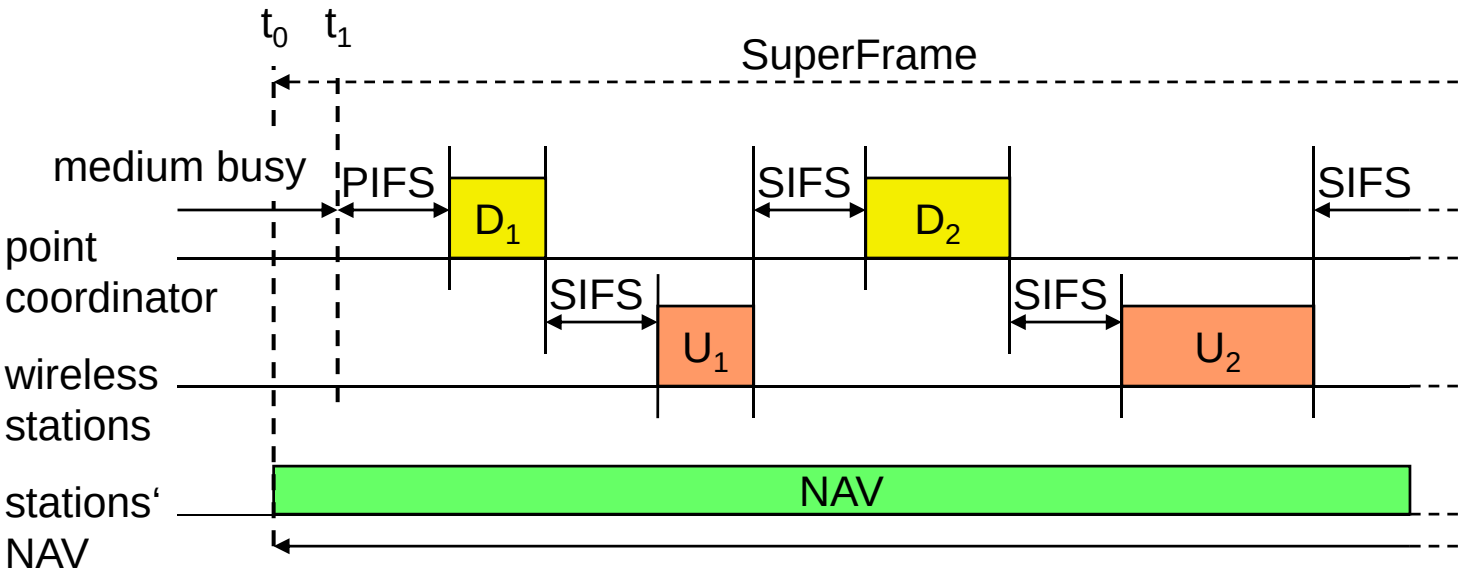
- station can send RTS with reservation parameter after waiting for DIFS (reservation determines amount of time the data packet needs the medium)
- acknowledgement via CTS after SIFS by receiver (if ready to receive)
- sender can now send data at once, acknowledgement via ACK
- other stations store medium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



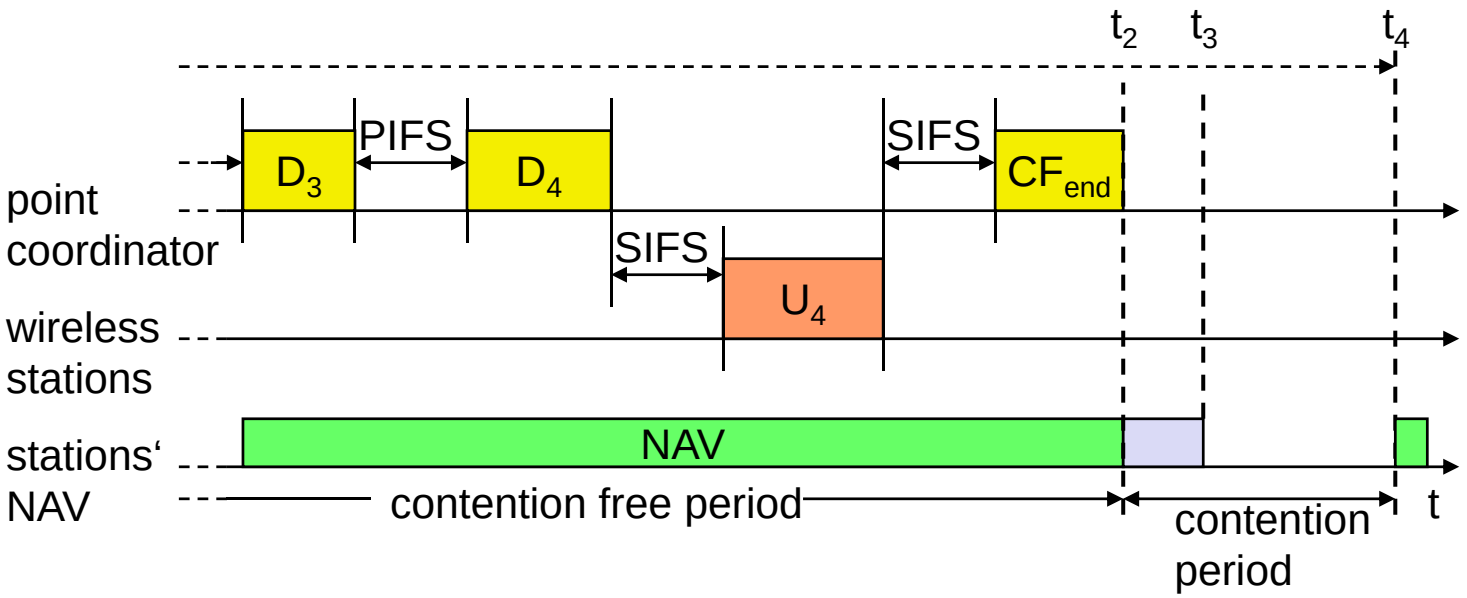
Fragmentation



DFWMAC-PCF I



DFWMAC-PCF II



802.11 - Frame format

Types

- control frames, management frames, data frames

Sequence numbers

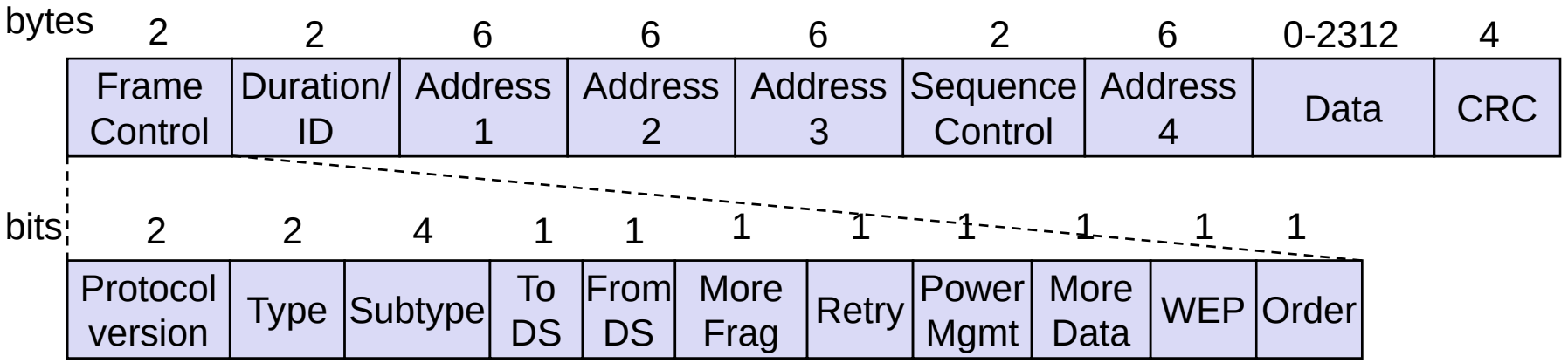
- important against duplicated frames due to lost ACKs

Addresses

- receiver, transmitter (physical), BSS identifier, sender (logical)

Miscellaneous

- sending time, checksum, frame control, data



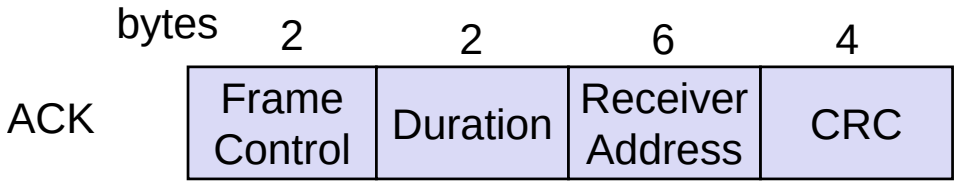
MAC address format

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

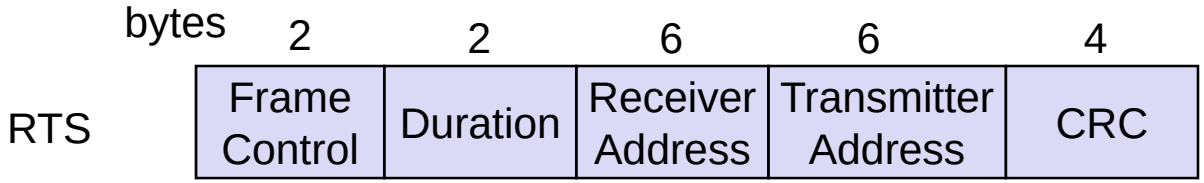
DS: Distribution System
AP: Access Point
DA: Destination Address
SA: Source Address
BSSID: Basic Service Set Identifier
RA: Receiver Address
TA: Transmitter Address

Special Frames: ACK, RTS, CTS

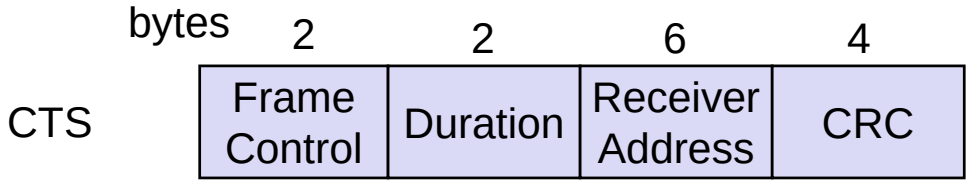
Acknowledgement



Request To Send



Clear To Send



802.11 - MAC management

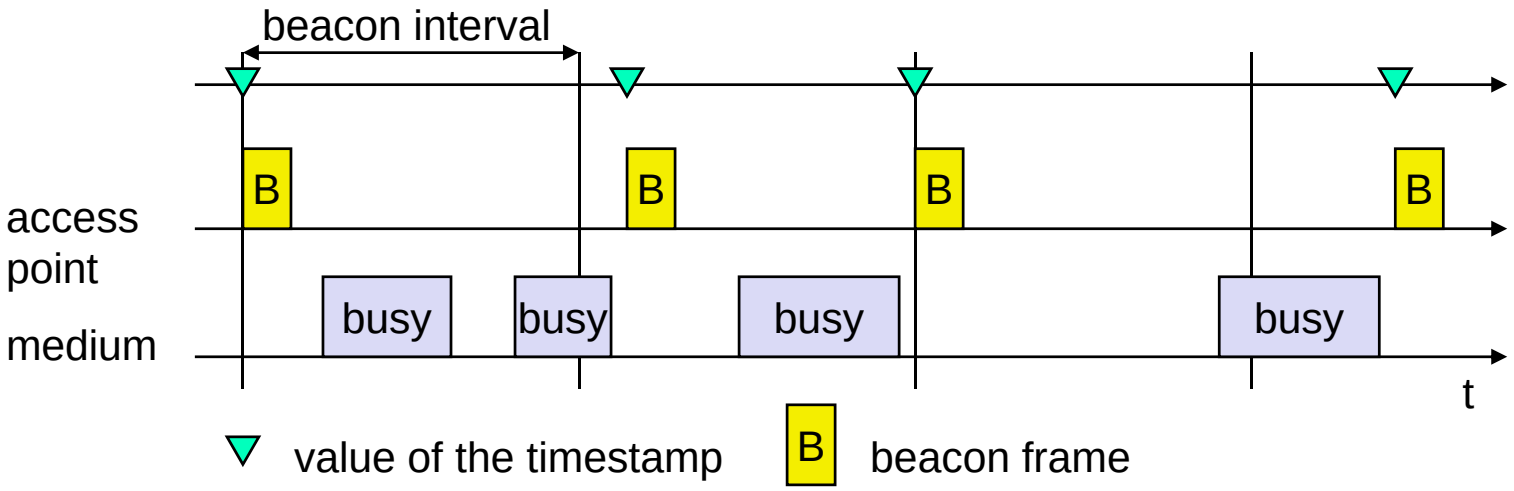
Synchronization
- try to find a LAN, try to stay within a LAN
- timer etc.

Power management
- sleep-mode without missing a message
- periodic sleep, frame buffering, traffic measurements

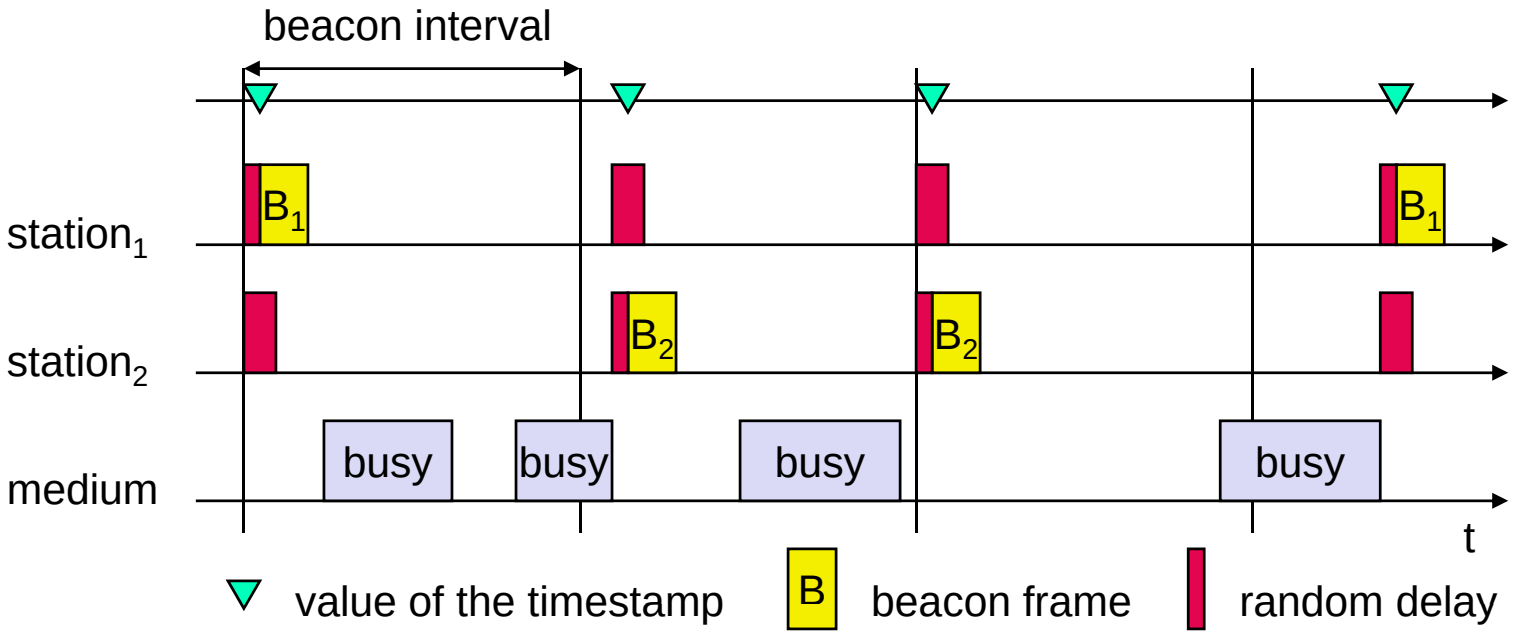
Association/Reassociation
- integration into a LAN
- roaming, i.e. change networks by changing access points
- scanning, i.e. active search for a network

MIB - Management Information Base
- managing, read, write

Synchronization using a Beacon (infrastructure)



Synchronization using a Beacon (ad-hoc)



Power management

Idea: switch the transceiver off if not needed

States of a station: sleep and awake

Timing Synchronization Function (TSF)

- stations wake up at the same time

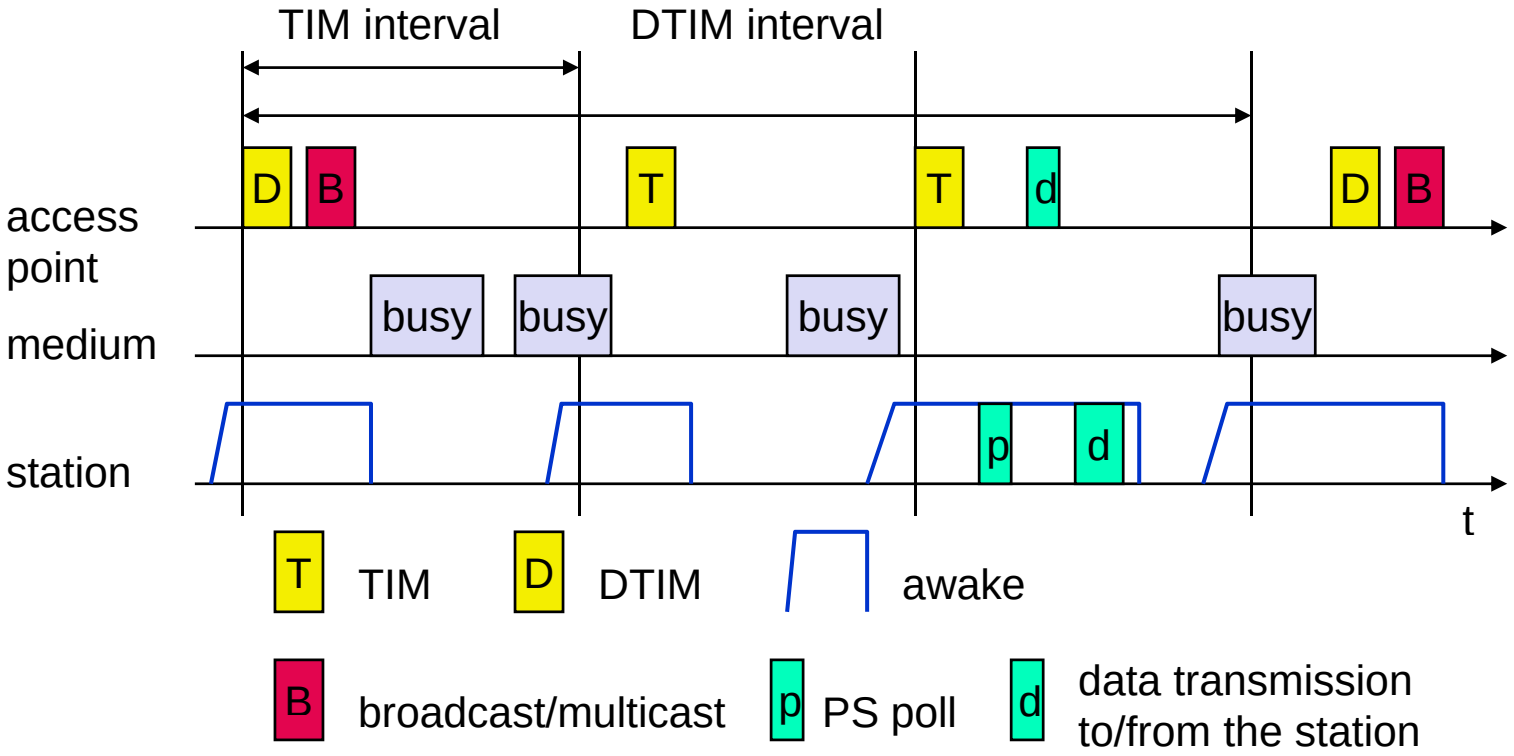
Infrastructure

- Traffic Indication Map (TIM)
  - list of unicast receivers transmitted by AP
- Delivery Traffic Indication Map (DTIM)
  - list of broadcast/multicast receivers transmitted by AP

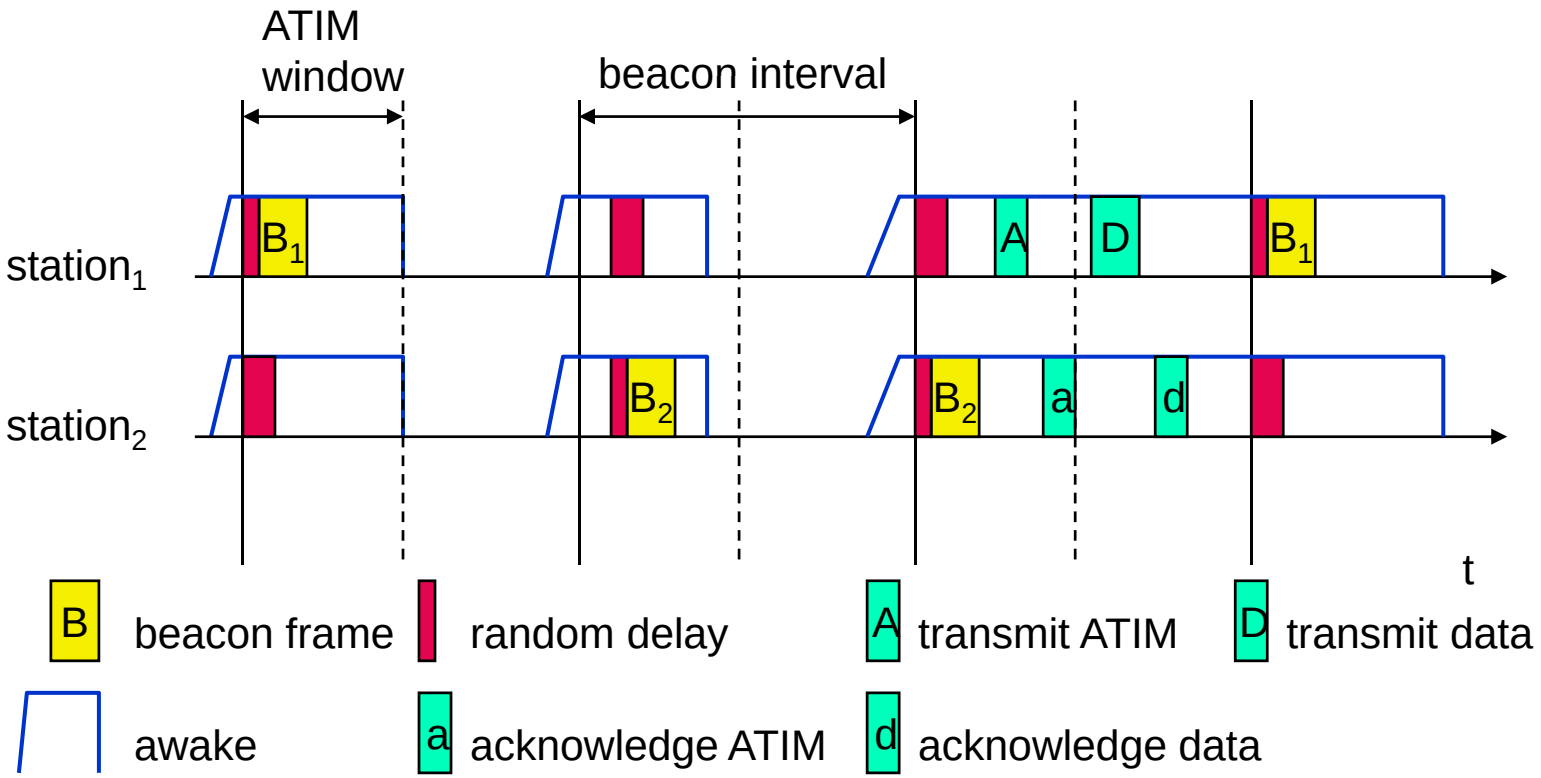
Ad-hoc

- Ad-hoc Traffic Indication Map (ATIM)
  - announcement of receivers by stations buffering frames
  - more complicated - no central AP
  - collision of ATIMs possible (scalability?)

Power saving with wake-up patterns (infrastructure)



Power saving with wake-up patterns (ad-hoc)



802.11 - Roaming

No or bad connection? Then perform:

Scanning

- scan the environment, i.e., listen into the medium for beacon signals or send probes into the medium and wait for an answer

Reassociation Request

- station sends a request to one or several AP(s)

Reassociation Response

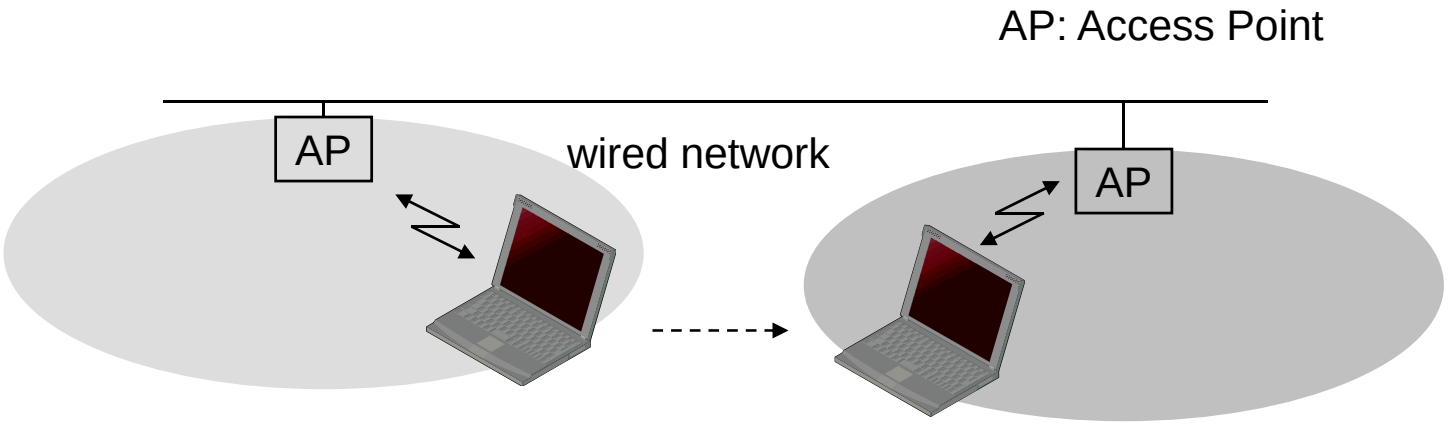
- success: AP has answered, station can now participate
- failure: continue scanning

AP accepts Reassociation Request

- signal the new station to the distribution system
- the distribution system updates its data base (i.e., location information)
- typically, the distribution system now informs the old AP so it can release resources

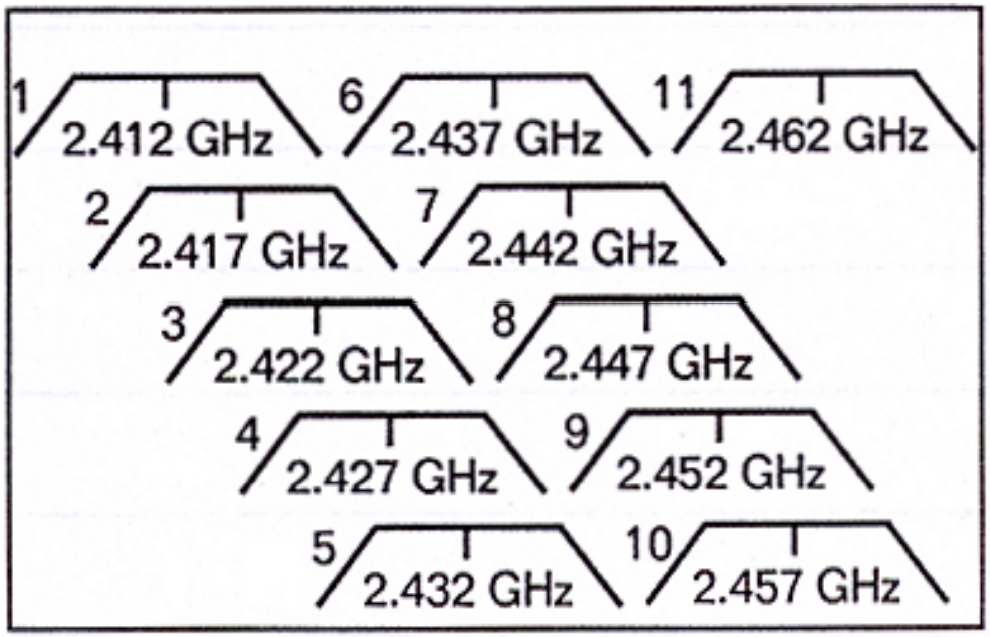
Layer-2 handoff

infrastructure network

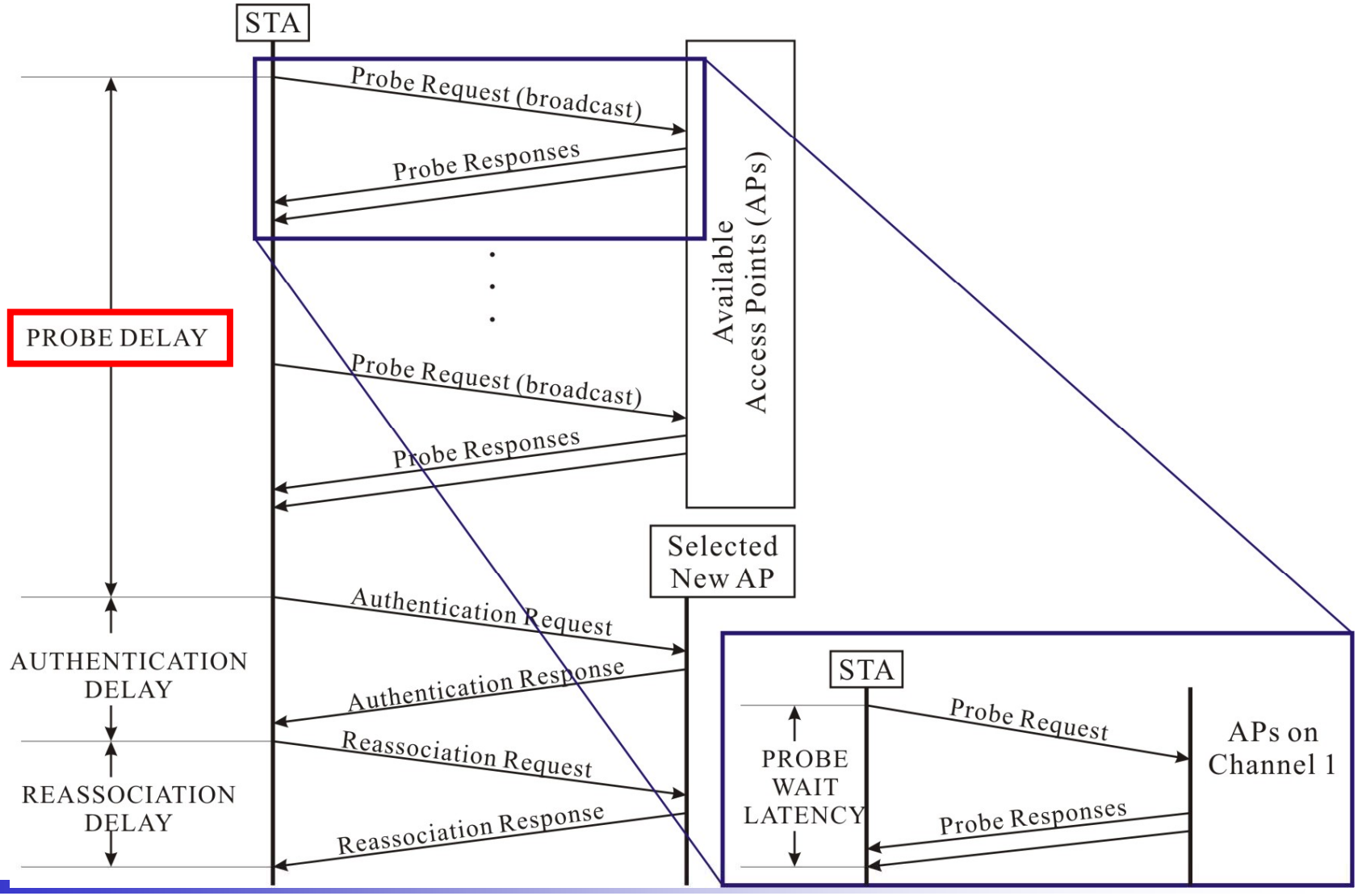


Scope

- To develop a medium access (MAC) and physical layer (PHY) specification for wireless connectivity for fixed, portable, and moving stations within a local area.
- 11 channels in 2.4 GHz
  - 3 separate, clean channels for simultaneous usage



Layer-2 handoff procedure in WLAN



Paper studying

Yuh-Shyan Chen, Ming-Chin Chuang, and Chung-Kai Chen, "DeuceScan: Deuce-Based Fast Handoff Scheme in IEEE 802.11 Wireless Networks," ***IEEE Trans. on Vehicular Technology***, March 2008.

802.11 Task Groups

- **802.11**
  - The objective of this group was to develop MAC layer and physical specification for wireless connectivity for fixed, portable, and mobile nodes within a local area.
  - The 802.11 standard was first published in 1997.
- **802.11a**
  - This group created a standard for wireless LAN operations in the 5 GHz frequency band
  - Data rates of up to 54 Mbps
  - The 802.11a standard was ratified in 1999.

802.11 Task Groups (cont.)

- **802.11b**
  - This group created a standard for wireless LAN operations in the 2.4 GHz Industrial, Scientific, and Medical (ISM) band
  - This standard is popularly referred to as Wi-Fi, standing for Wireless-Fidelity
  - It can offer data rates of up to 11 Mbps
  - The 802.11b standard was ratified in 1999.
- **802.11c**
  - Manufactures use this standard while developing bridges and access points.
  - The 802.11c standard was first published in 1998.

802.11 Task Groups (cont.)

- **802.11d**
  - This group's main objective is publishing definitions and requirements for enabling the operation of the 802.11 standard in countries that are not currently served by the standard.
  - The 802.11d standard was ratified in 2001.
- **802.11e**
  - This group's main objective is to define an extension of the 802.11 standard for quality of service (QoS) provisioning and service differentiation in wireless LANs.
  - Works is in progress.

802.11 Task Groups (cont.)

- **802.11f**
  - This group is created for developing specification for implementing access points and distribution systems following the 802.11 standard, so that interoperability problems between devices manufactured by different vendors do not arise.
  - The 802.11f standard was ratified in 2003.
- **802.11g**
  - This group was involved in extending the 802.11b standard to support high-speed transmissions of up to 54 Mbps in the 5 GHz frequency band, while maintaining backward compatibility with current 802.11 devices.
  - The 802.11g standard was ratified in 2003.

802.11 Task Groups (cont.)

- **802.11h**
  - It was developed in order for the MAC layer to comply European regulations for 5 GHz wireless LANs.
  - The 802.11h standard was ratified in 2003.
- **802.11i**
  - This group is working on mechanisms for enhancing security in the 802.11 standard
- **802.11j**
  - This task group is working on mechanisms for enhancing the current 802.11 MAC physical layer protocols to additionally operate in the newly available Japanese 4.9 GHz and 5 GHz bands

WLAN: IEEE 802.11b

Data rate
- 1, 2, 5.5, 11 Mbit/s, depending on SNR
- User data rate max. approx. 6 Mbit/s

Transmission range
- 300m outdoor, 30m indoor
- Max. data rate ~10m indoor

Frequency
- Free 2.4 GHz ISM-band

Security
- Limited, WEP insecure, SSID

Cost
- 100€ adapter, 250€ base station, dropping

Availability
- Many products, many vendors

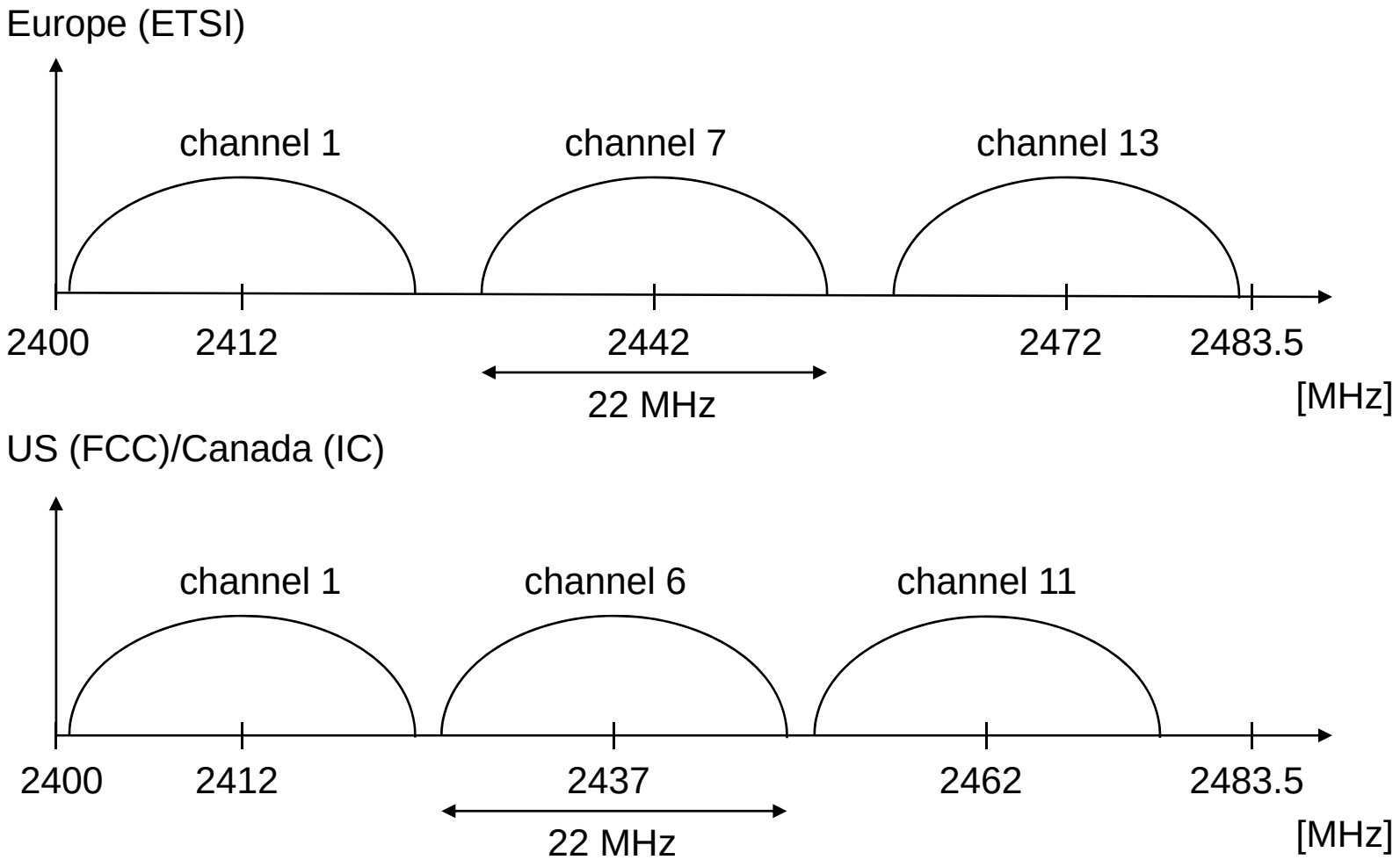
Connection set-up time
- Connectionless/always on

Quality of Service
- Typ. Best effort, no guarantees (unless polling is used, limited support in products)

Manageability
- Limited (no automated key distribution, sym. Encryption)

Special Advantages/Disadvantages
- Advantage: many installed systems, lot of experience, available worldwide, free ISM-band, many vendors, integrated in laptops, simple system
- Disadvantage: heavy interference on ISM-band, no service guarantees, slow relative speed only

Channel selection (non-overlapping)



WLAN: IEEE 802.11a

Data rate
- 6, 9, 12, 18, 24, 36, 48, 54 Mbit/s, depending on SNR
- User throughput (1500 byte packets): 5.3 (6), 18 (24), 24 (36), 32 (54)
- 6, 12, 24 Mbit/s mandatory

Transmission range
- 100m outdoor, 10m indoor
  - E.g., 54 Mbit/s up to 5 m, 48 up to 12 m, 36 up to 25 m, 24 up to 30m, 18 up to 40 m, 12 up to 60 m

Frequency
- Free 5.15-5.25, 5.25-5.35, 5.725-5.825 GHz ISM-band

Security
- Limited, WEP insecure, SSID

Cost
- 280€ adapter, 500€ base station

Availability
- Some products, some vendors

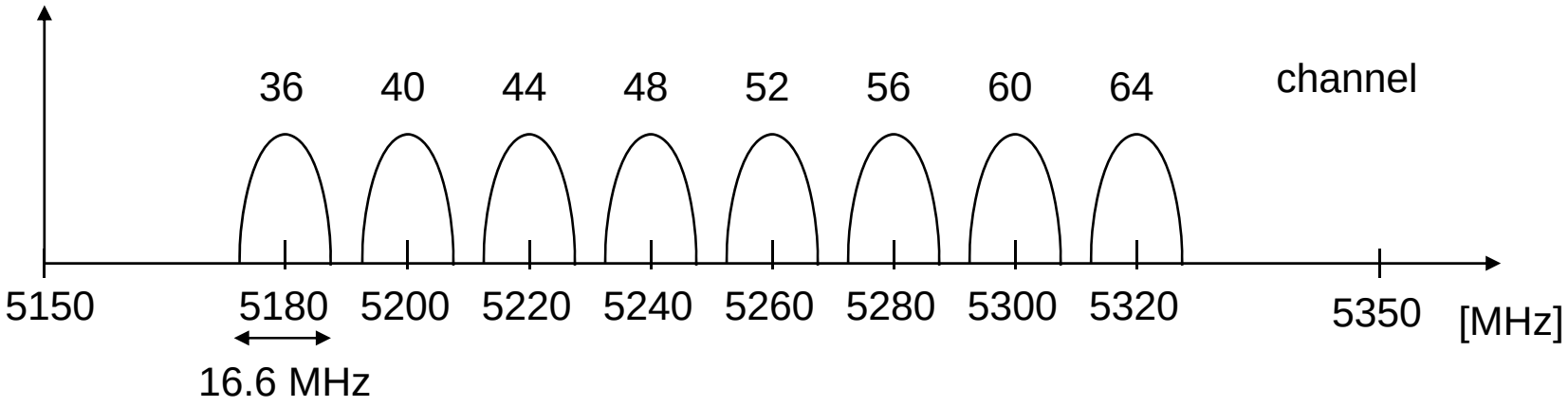
Connection set-up time
- Connectionless/always on

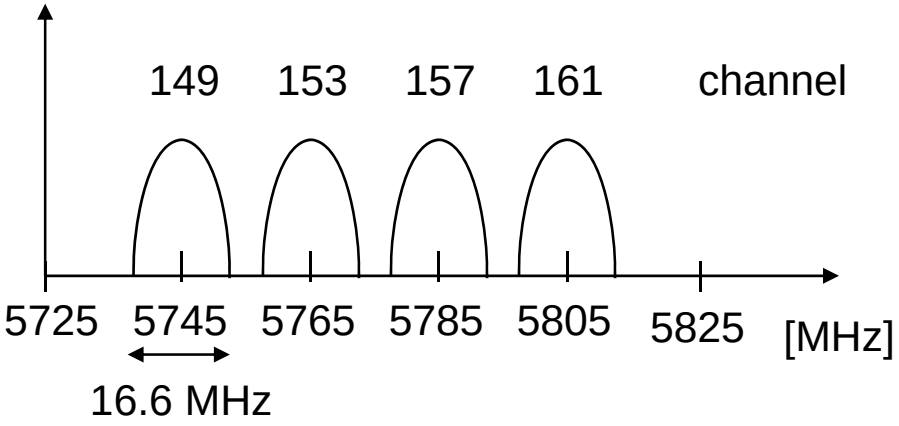
Quality of Service
- Typ. best effort, no guarantees (same as all 802.11 products)

Manageability
- Limited (no automated key distribution, sym. Encryption)

Special Advantages/Disadvantages
- Advantage: fits into 802.x standards, free ISM-band, available, simple system, uses less crowded 5 GHz band
- Disadvantage: stronger shading due to higher frequency, no QoS

Operating channels for 802.11a / US U-NII





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

Homework #2

1. What's the hidden-terminal and exposed-terminal problems occurred in DFWMAC-DCF CSMA/CA ?
2. How to use RTS/CTS messages (DFWMAC-DCF w/ RTS/CTS) to **reduce** the hidden-terminal problem ?
3. How the PCF (Point Coordination Function) works ?
4. What's the main operations of IEEE 802.11 roaming (layer-2 handoff procedure) ?
5. What's the power management in infrastructure and ad hoc modes ?