Mobile and Wireless Networks

Multiple Access Protocols and IEEE 802.11 Networks

Multiple access protocols

Channel Types

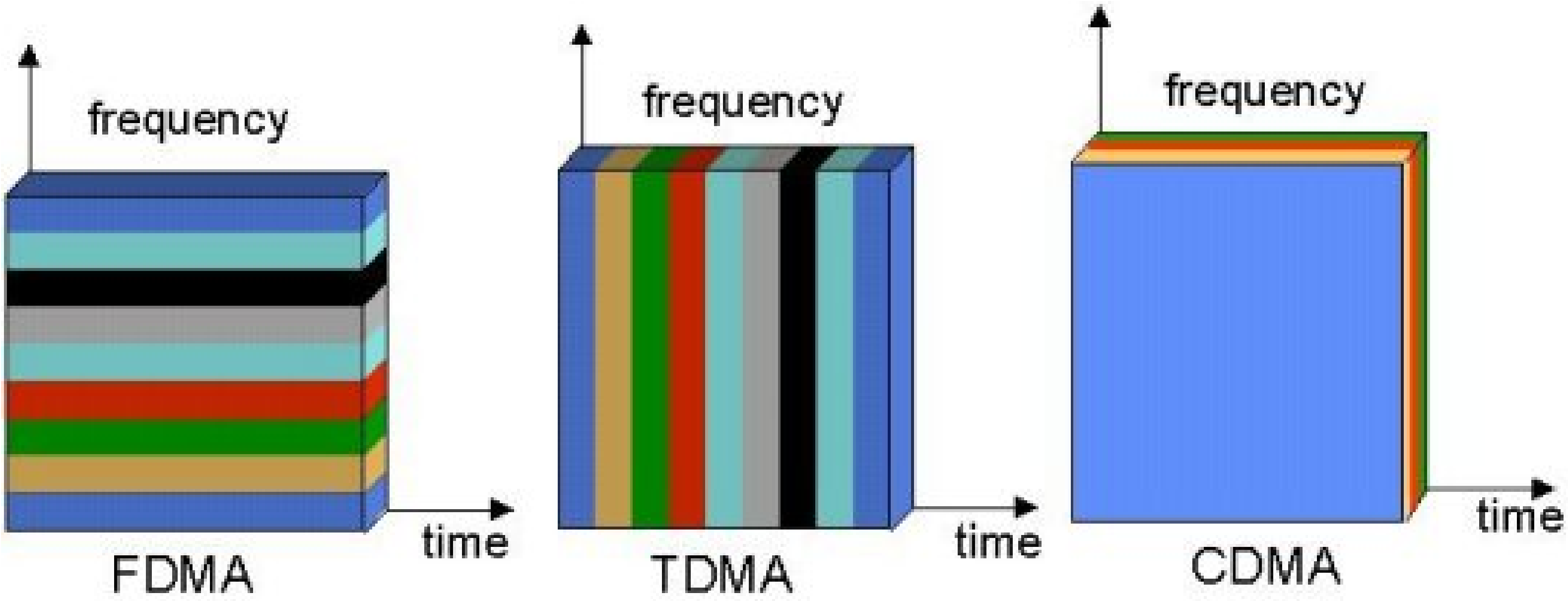
- Broadcast channels
  - (at least) one transmits and (possibly) many receive (simultaneously)
- Multi-access channels
  - Many transmitters use one (single) channel to communicate with (at least) one receiver (not necessarily simultaneously)
  - Possibly communicate between themselves
- Example: Mobile phone and base station
  - Mobile phone ⇒ base station : multiple access channel (many transmitters send to a single receiver)
  - Base station ⇒ mobile phone: the sender boradcasts to many receivers

Multiple Access Control Channels

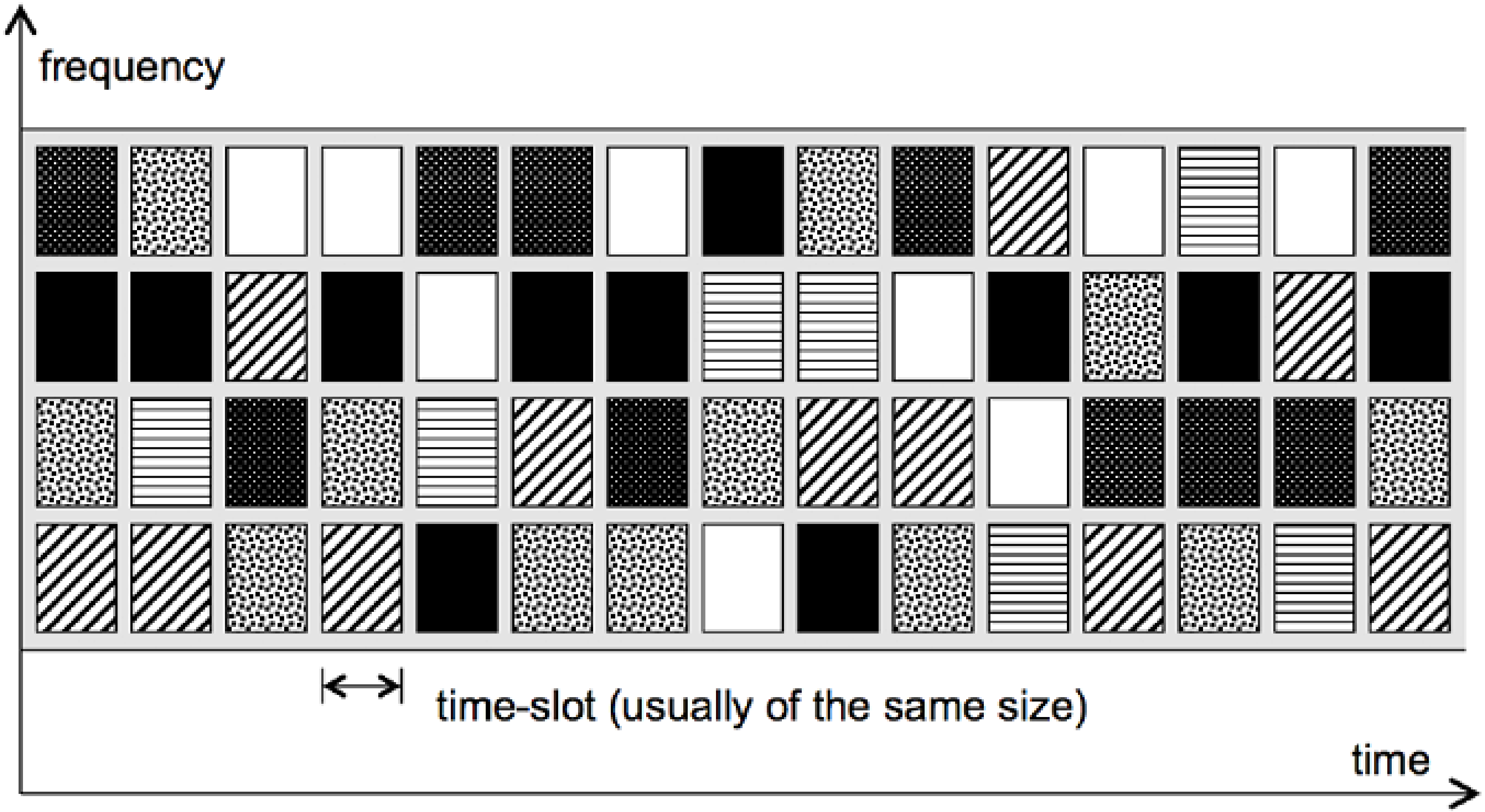
- N independent stations
  - Assumption of limited or unlimited number
  - Poisson arrivals
  - Fixed packet length
- Single Channel
- Collisions are possible
  - Carrier sensing
  - Collision detection
- Time asuumptions
  - Segmented non-continuous time / Synchronous mode
  - Non-segmented continuous time / Asynchronous mode

Multiplexing

- Multiplexing allows parallel transmission from different sources, handling interference.
- Three basic kinds
  - **TDM/TDMA** (Time Division Multiple Access)
  - **FDM/FDMA** (Frequency Division Multiple Access)
  - **CDMA** (Code Division Multiple Access)
  - Combinations of the above

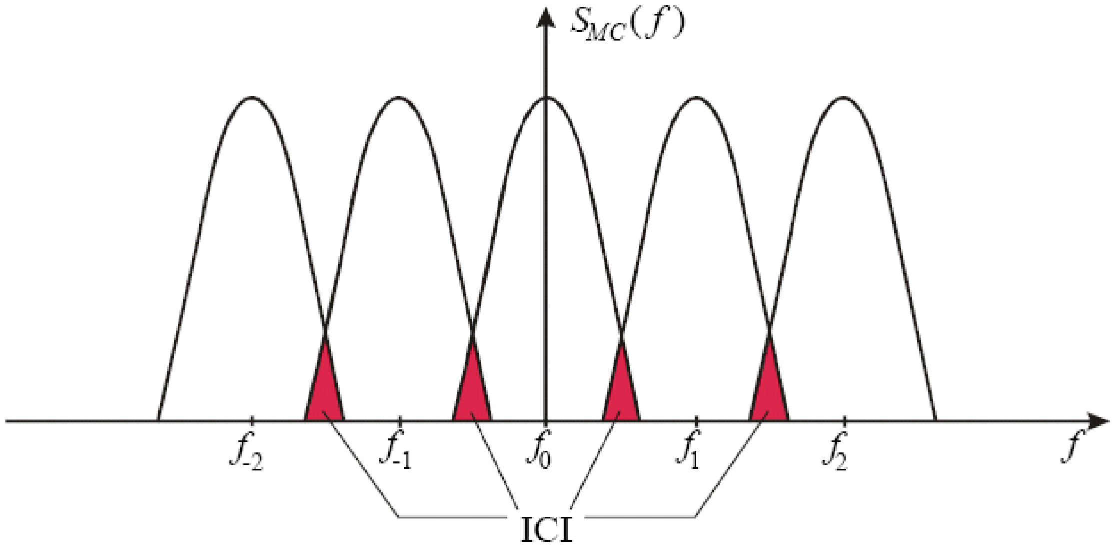

frequency
time
FDMA
frequency
time
TDMA
frequency
time
CDMA

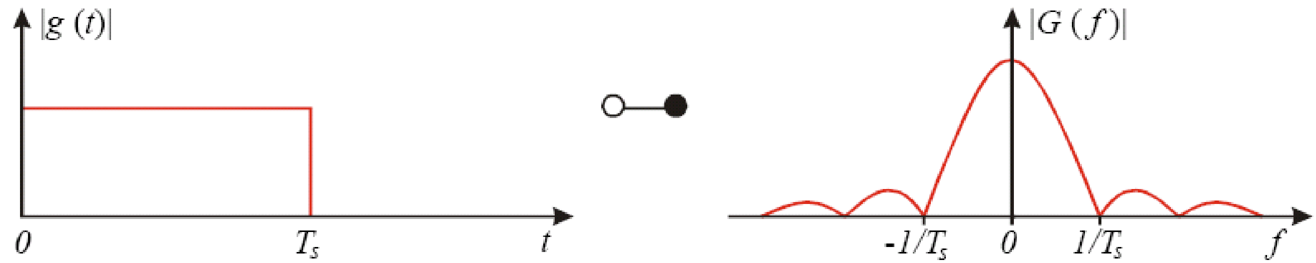
FDMA/TDMA



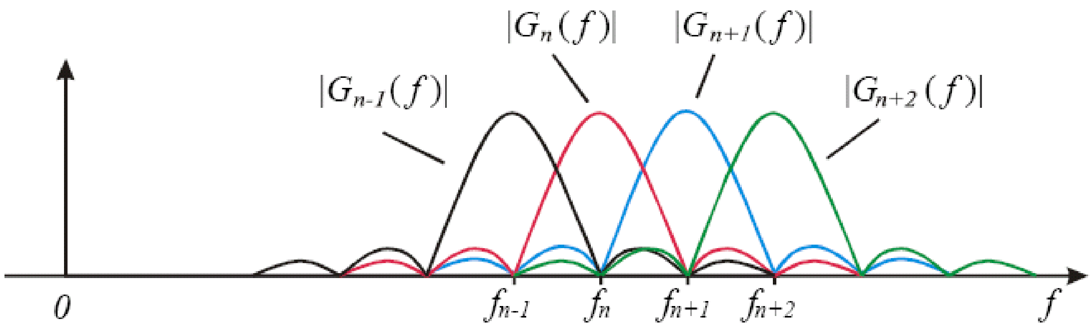
OFDM: Orthogonal Frequency Division Multiplexing

Traditional FDM



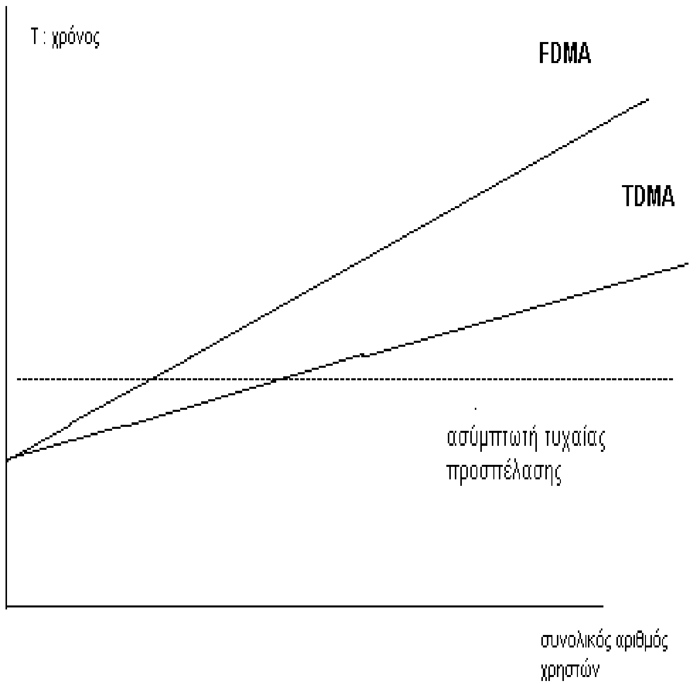


OFDM



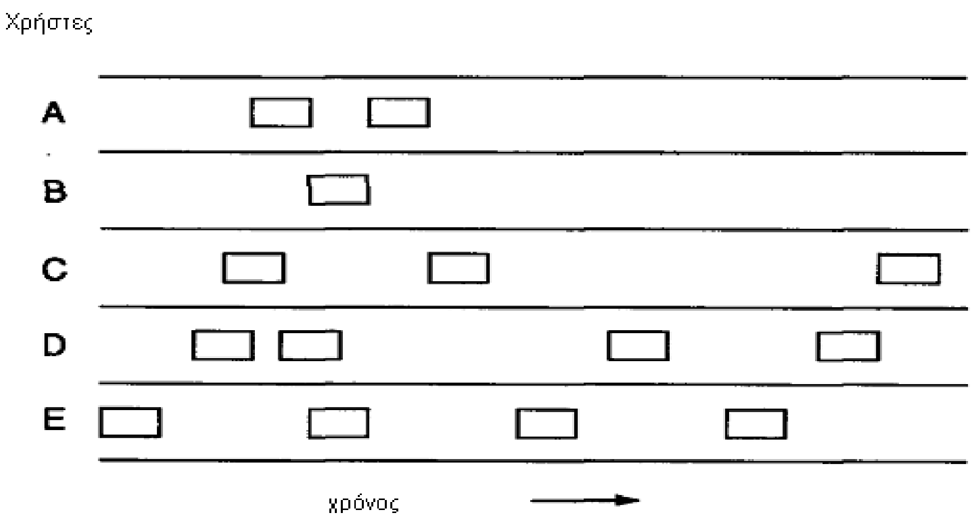
Random Access Protocols

- For continuous unpredictable traffic
- Packet delay independent to the number of transmitters
- Delay depends on the amount of traffic
- On the contrary, in fixed capacity division delay increases linearly to the number of transmitters
- More efficient for variable traffic



Pure ALOHA

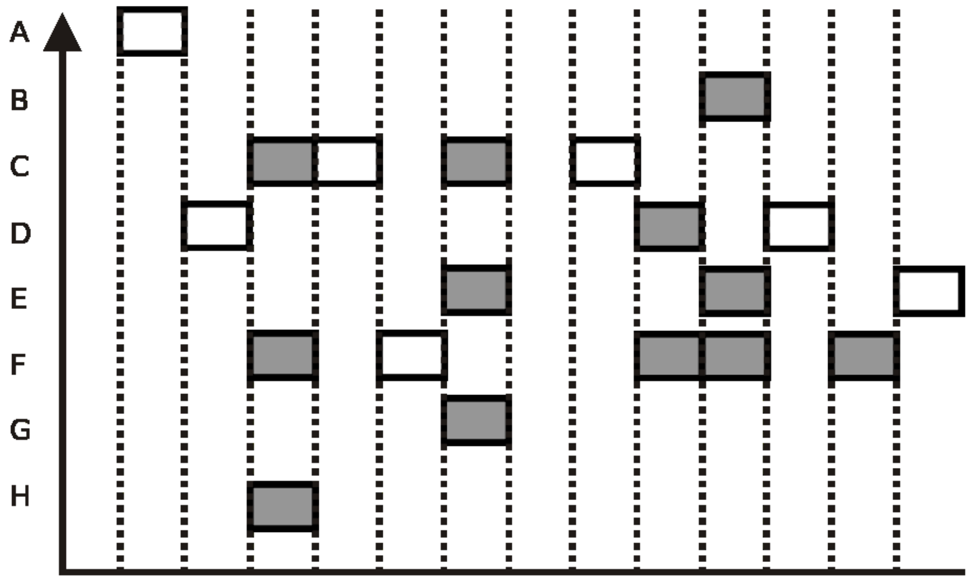
- Continuous time, transmission at any moment.
- No synchronization, packet transmission upon arrival at the queue.
- On collision, the packet is retransmitted after random time.



στο καθαρό aloha τα πλαίσια μεταδίδονται σε τελείως αυθαίρετούς χρόνους

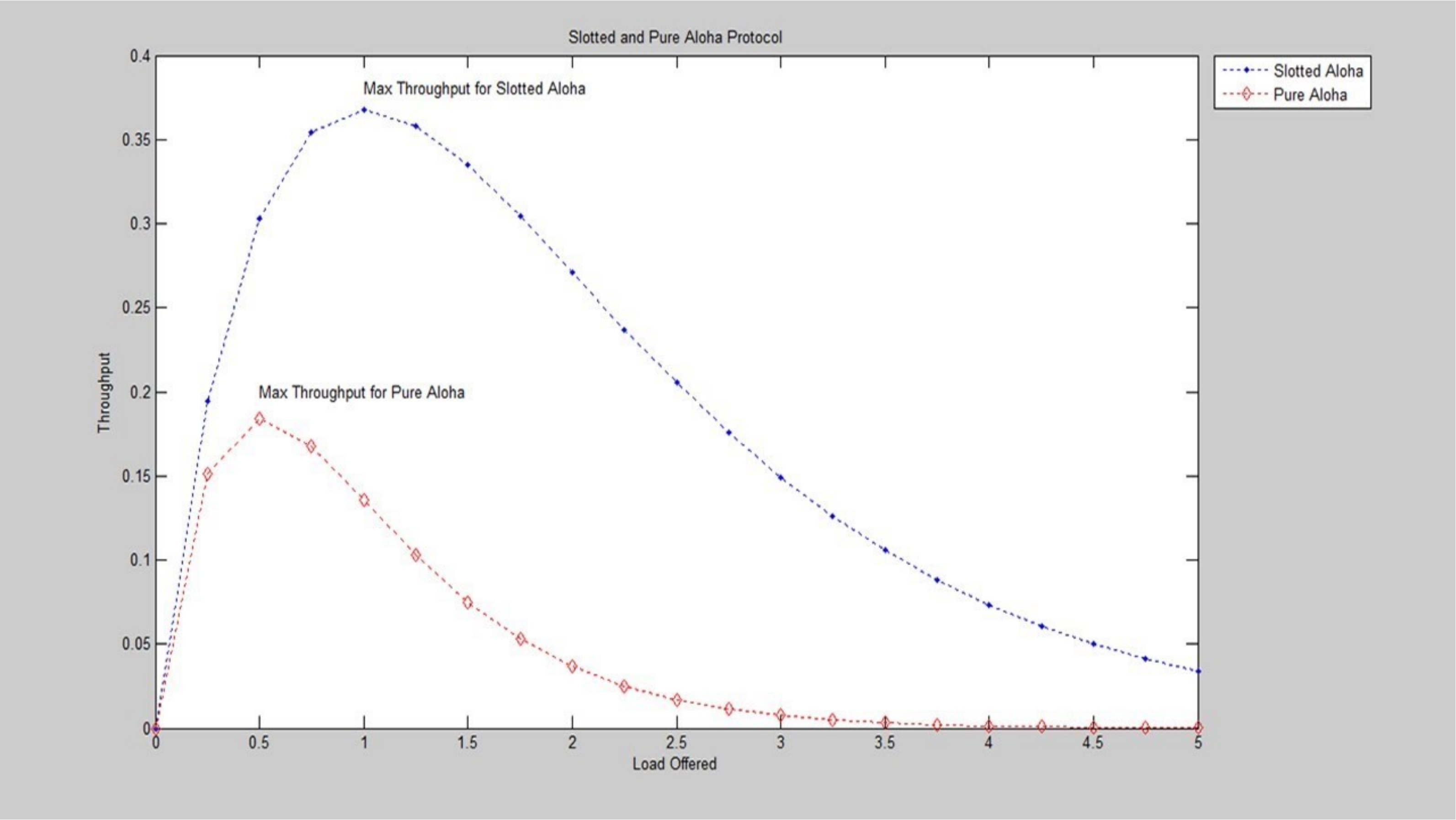
Slotted ALOHA

- Fixed packet length
- Timeslot=packet transmission time
- Each packet is transmitted at the first timeslot after arrival
- Synchronization is required
- On collision, the packet is retransmitted after random timeslots



Slotted ALOHA protocol (shaded slots indicate collision)

Throughput



Slotted and Pure Aloha Protocol
Slotted Aloha
Pure Aloha
Max Throughput for Slotted Aloha
Max Throughput for Pure Aloha
Throughput
Load Offered
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

ALOHA performance

- Unstable behavior: one packet can have low or high delay for the same throughput
- Low throughput = 18% ή 36%
- But
  - Very simple to implement
  - Low delay for low traffic
  - Delay independent to the total number of nodes

Carrier Sense Multiple Access(CSMA)

- One node can listen if other nodes transmit (this a small delay depending on distance
- Transmission can be postponed, if a collision is going to happen
- Not all collisions are avoided due to delay in signal propagation

CSMA PROTOCOLS

Non-persistent CSMA

- Packets arriving in empty slots are transmitted instantaneously
- If the slot is busy, the transmission is rescheduled after random time (virtual collision)
- Good throughput
- Good distribution of traffic in time
- Delay is increasing for higher traffic

CSMA PROTOCOLS

1-persistent CSMA

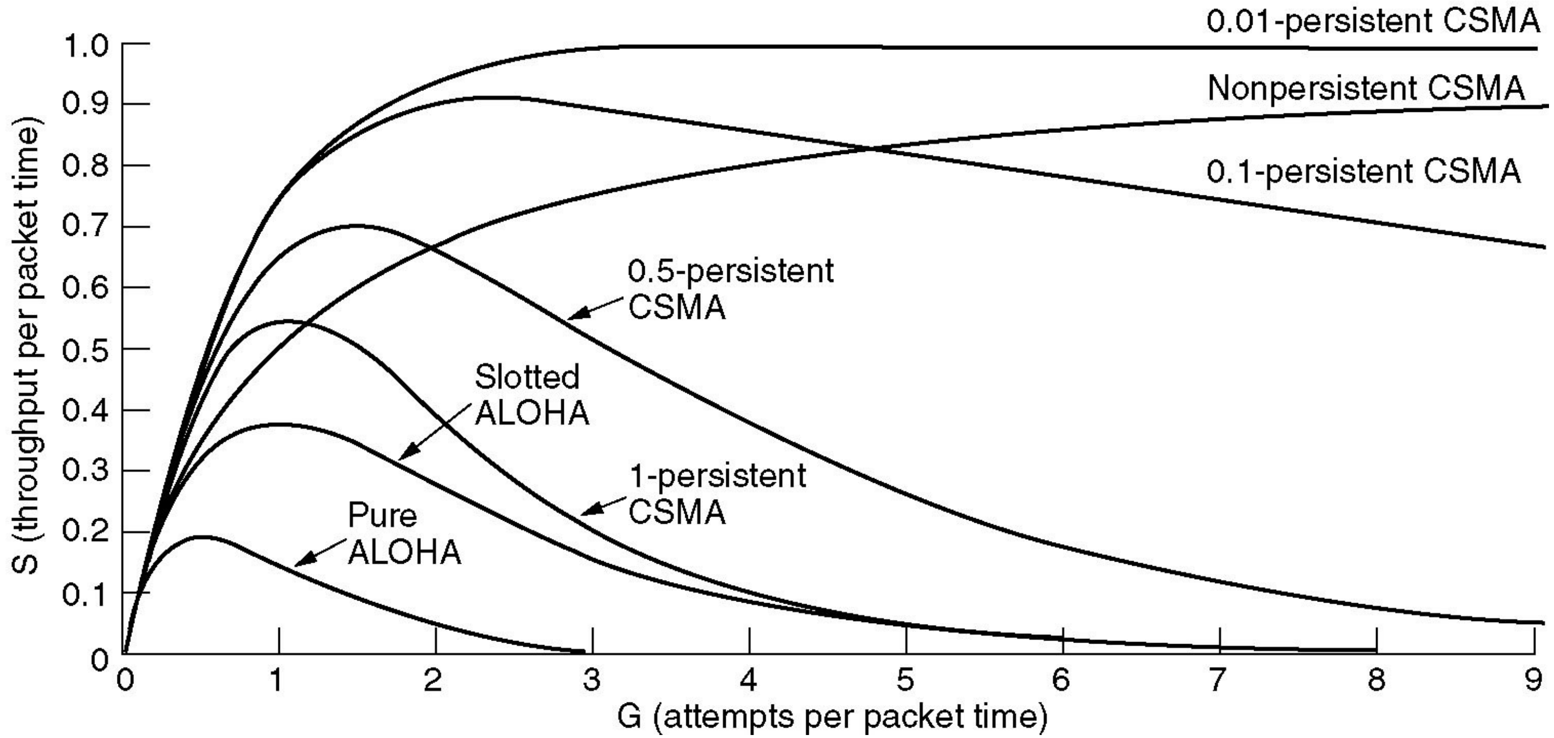
- Packets arriving in empty slots are transmitted instantaneously
- If the slot is busy, wait until the next empty slot and transmit
- Low delay in low traffic
- Max throughput not that impressive
- At the end of an existing transmission, collision probability if high

CSMA PROTOCOLS

P-persistent CSMA

- Packets arriving in empty slots are transmitted instantaneously
- If the slot is busy, wait until the next empty slot and transmit with probability P
- With probability 1-P repeat the procedure in the next slot

A comparison of simple protocols



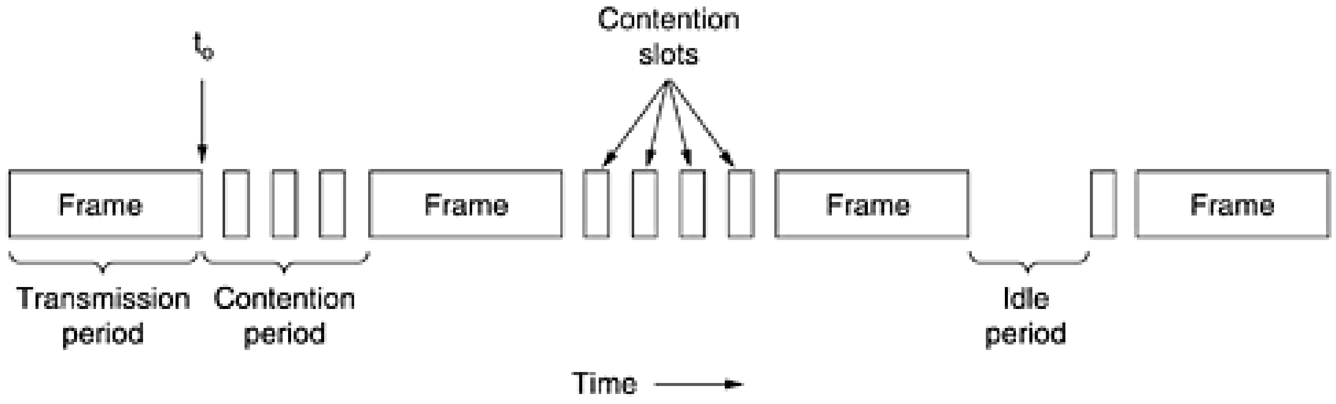
Carrier Sense Multiple Access Collision Detection (CSMA/CD)

- each node can listen to the medium **before transmission, while the channel allows listening while transmitting**
- On collision detection:

    quits transmission

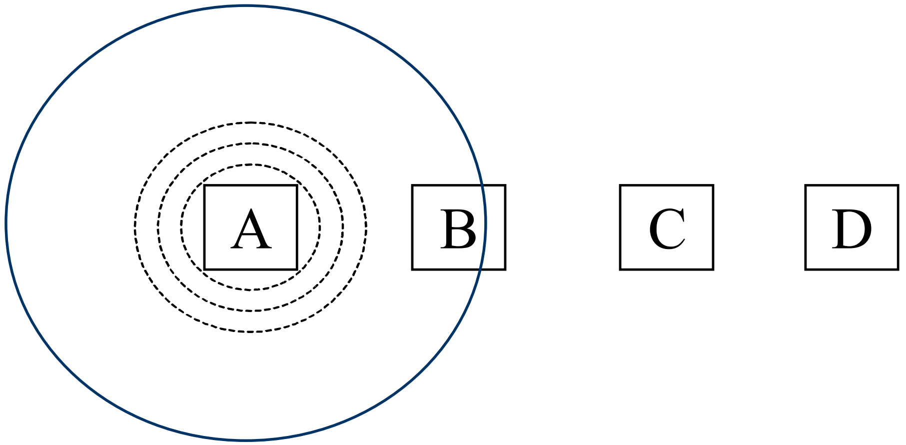
    waits a random time period and retries

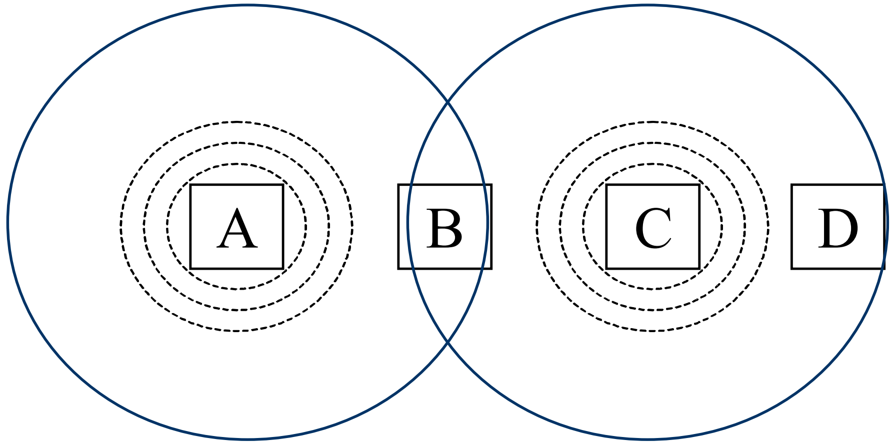
- **hard to implement in wireless communications**
- Used in Ethernet



Hidden station problem

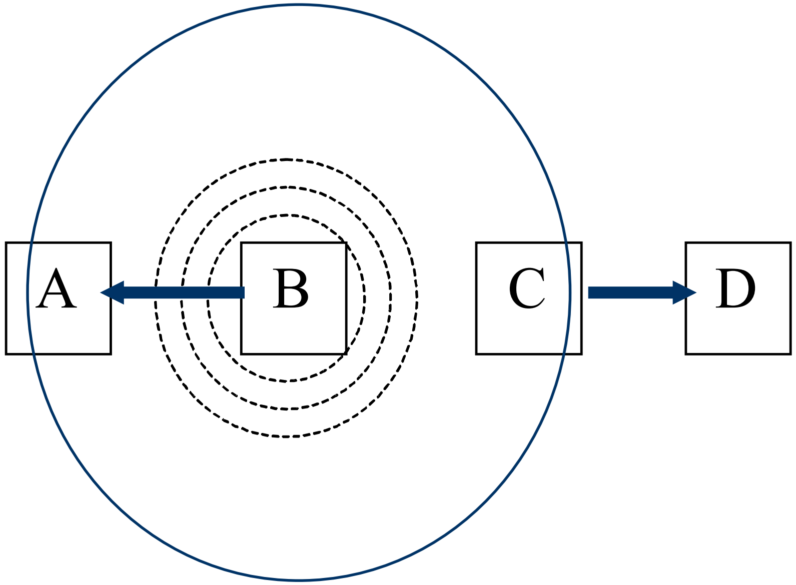
- A sends to B
- C does not listen to A
- C sends to B
- Collision at B
- A and C does not detect collision
- CSMA/CD not efficient in wireless
- Better performance for CSMA/CA





Visible station problem

- B sends to A
- C wants to send to D
- but
  - C listens to B
  - C does not transmit to D (while he could)

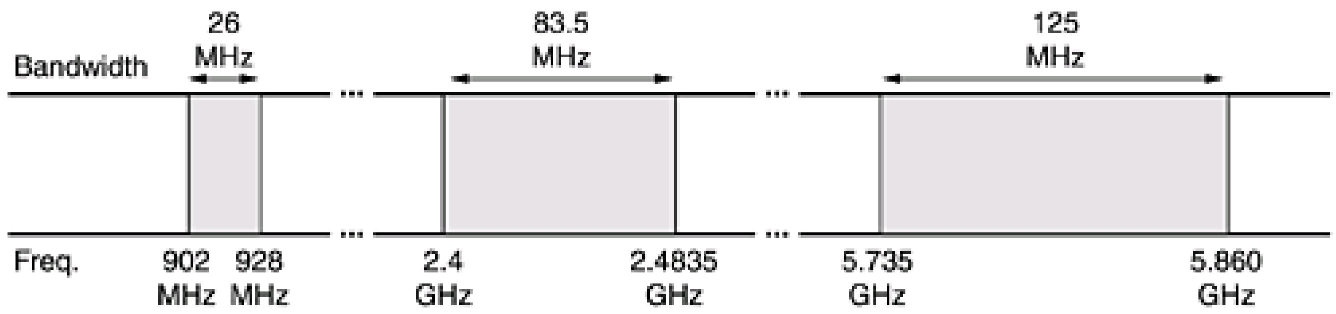


Δίκτυα τύπου IEEE 802.11

Introduction

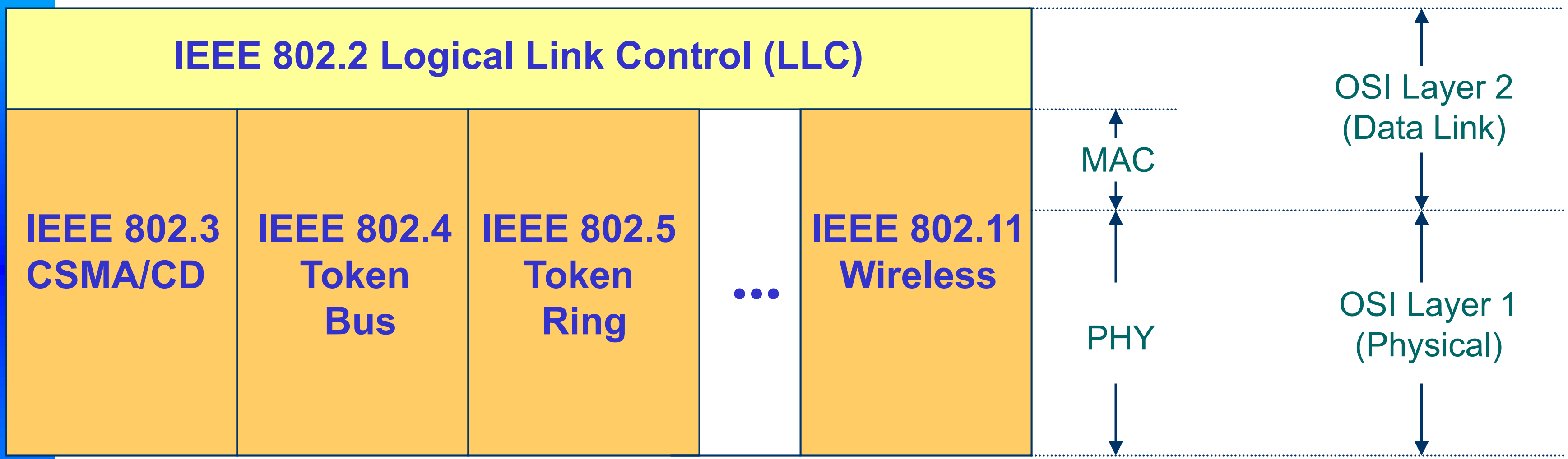
- At 1997 IEEE issued standard IEEE Std. 802.11-1997 for wireless local transmissions at the ISM band.
- The standard defines MAC and PHY layers for wireless local environments.
- Standard 802.11 provides 2Mbps at 2,4GHz ('97).
- Extension 802.11b provides 11Mbps at 2,4GHz ('99).
- Extension 802.11a provides 54Mbps at 5GHz ('99) through OFDM.
- Extension 802.11g offers 54Mbps at 2,4GHz ('02) through OFDM.
- Extension 802.11n offers up to 600Mbps at 2,4/5GHz through MIMO.

ISM Band (Industrial Scientific Medical)

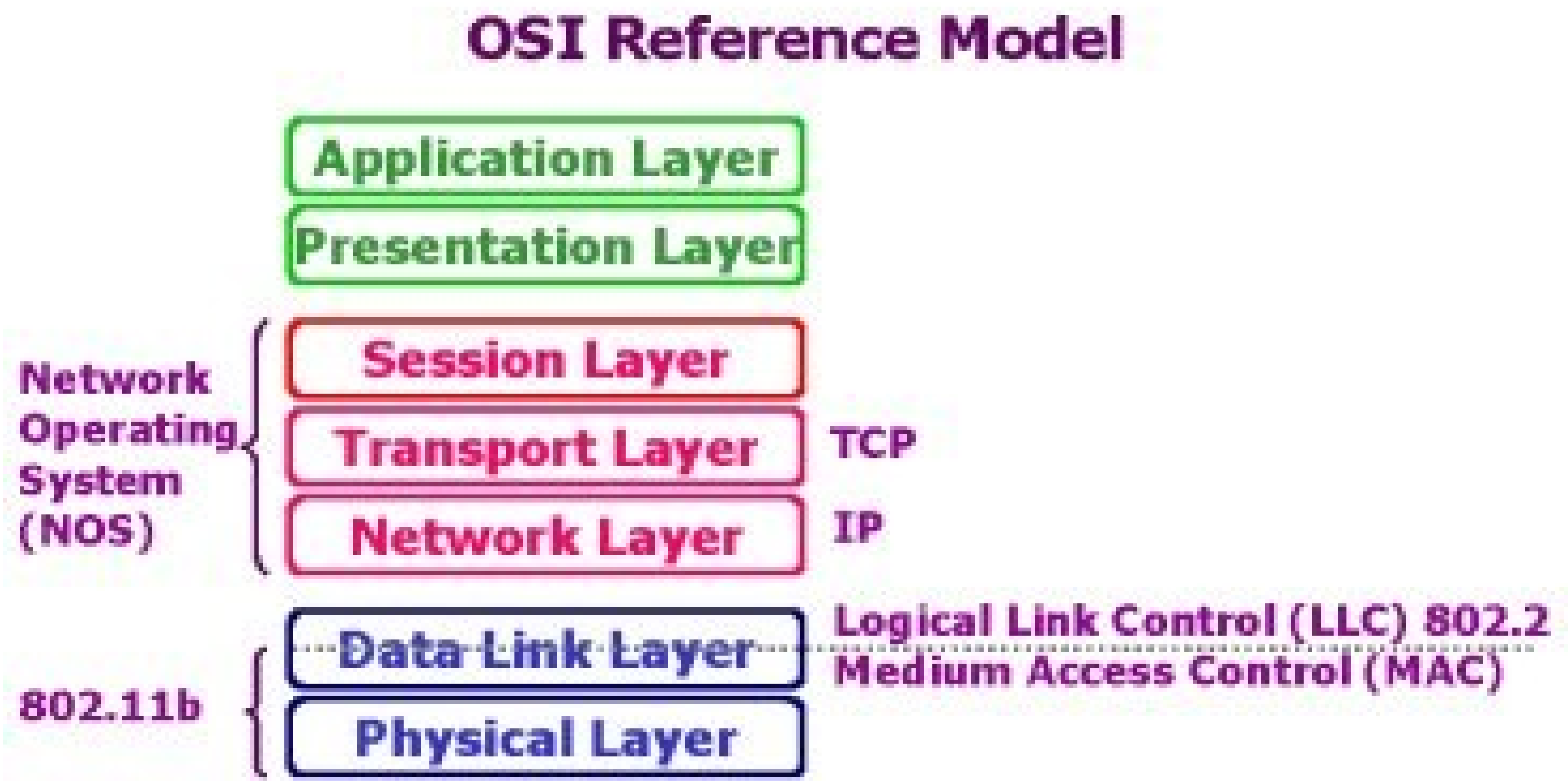


- Free to use without the need for a license
- Used mainly for WLANS

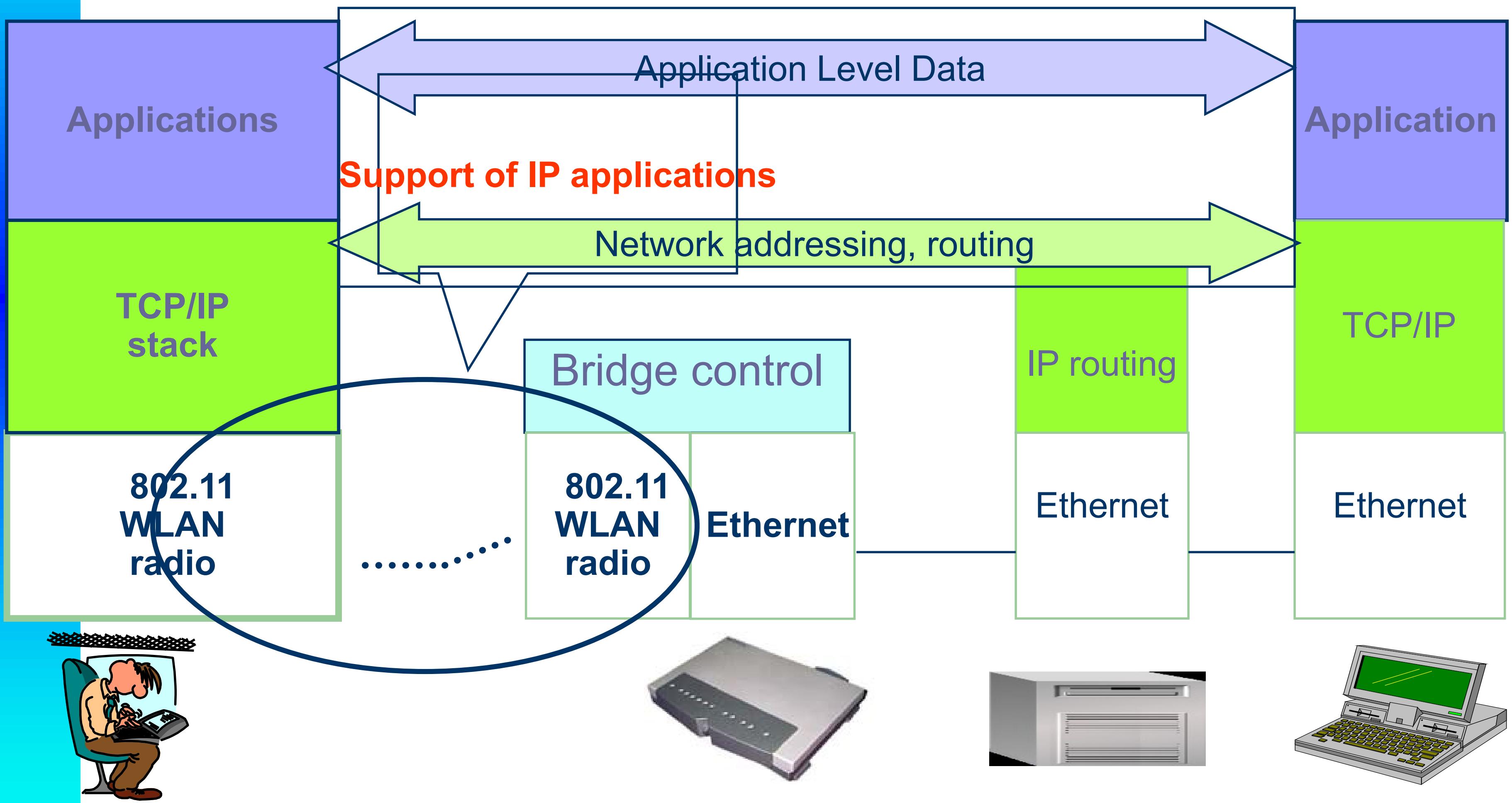
The 802.x family of standards



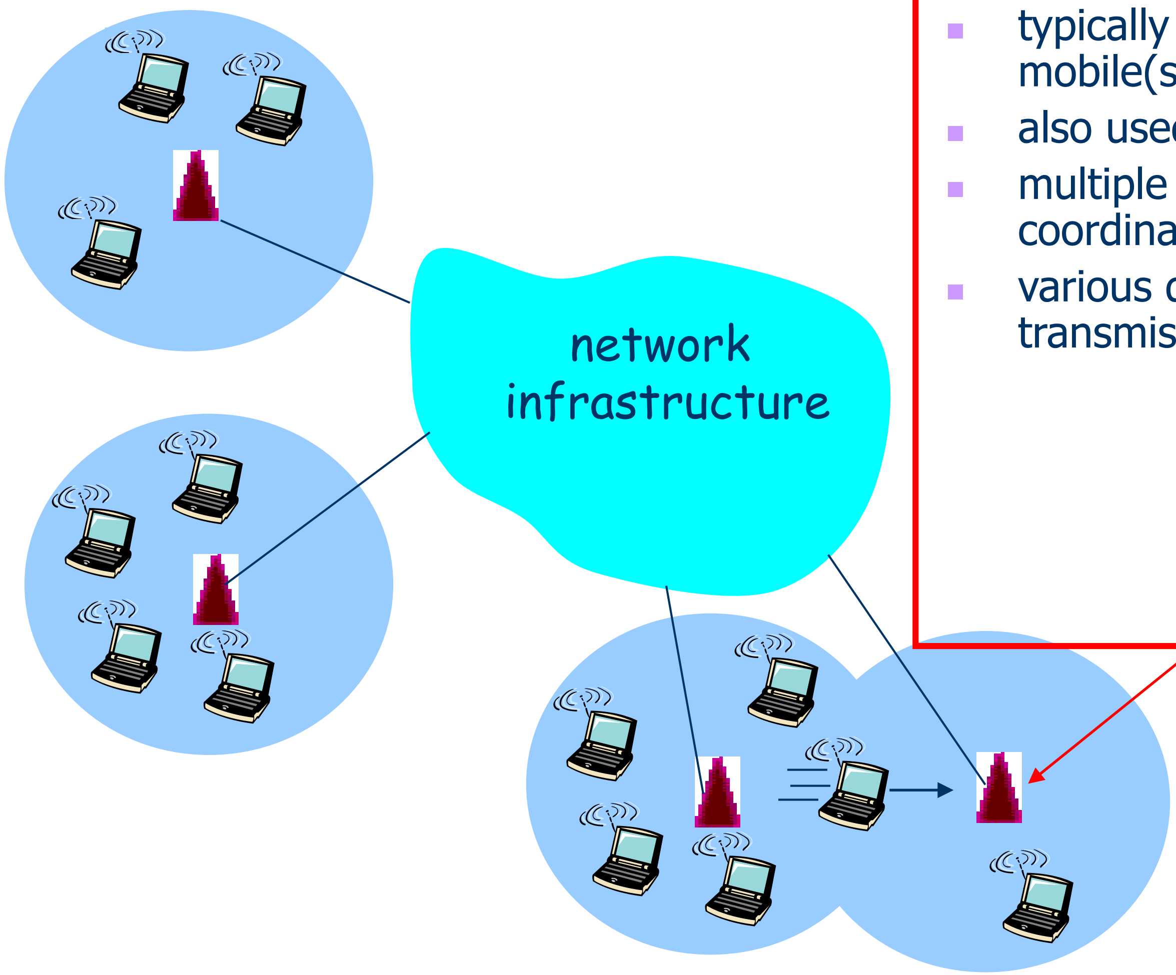
The 802.11 protocol stack



802.11 – Wireless Ethernet



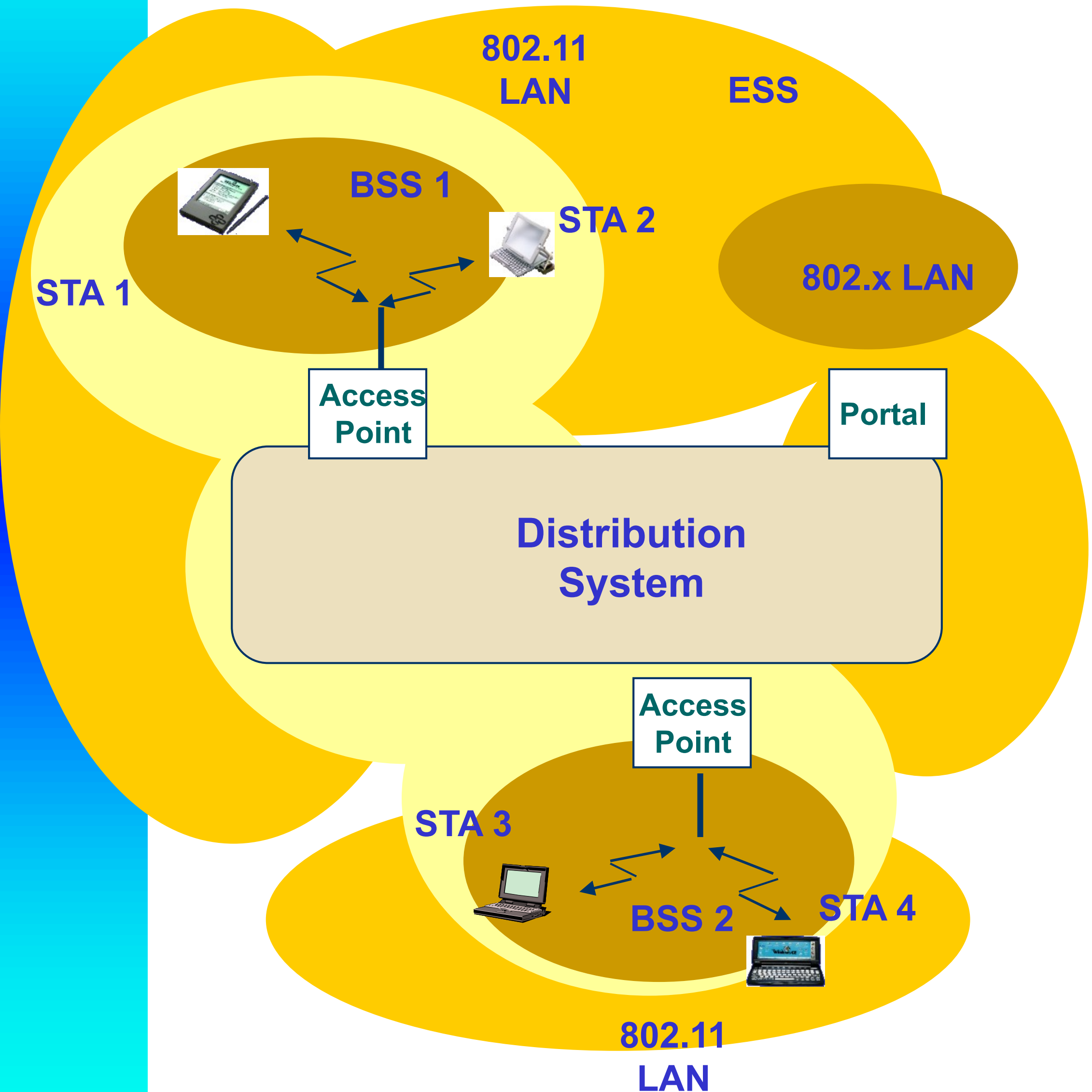
Elements of a wireless network



wireless link

- typically used to connect mobile(s) to base station
- also used as backbone link
- multiple access protocol coordinates link access
- various data rates, transmission distance

802.11 Infrastructure based



Station (STA)

Terminal with capabilities to communicate with the AP Access Point

Basic Service Set (BSS)

Group of stations using the same radio frequency

Access Point

A station that communicates both with the wireless LAN and the distribution system

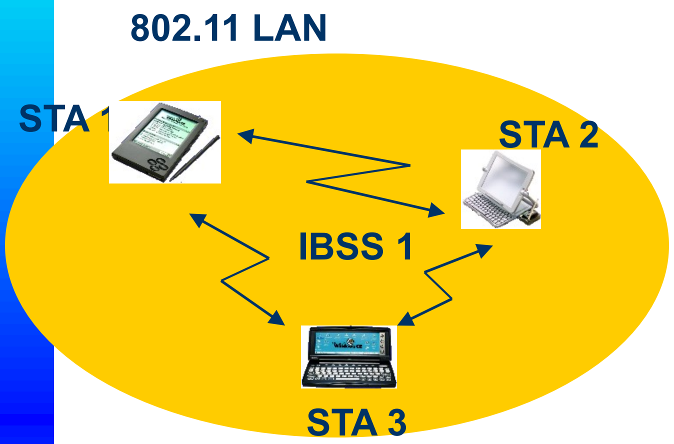
Portal

Bridge between the distribution system and external networks

Distribution System

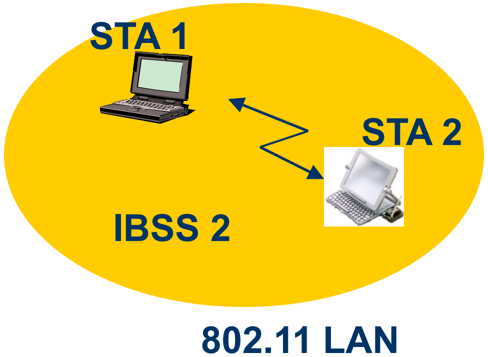
Network connection multiple BSSs in one ESS (Extended Service Set)

802.11 Ad-Hoc



Station (STA)

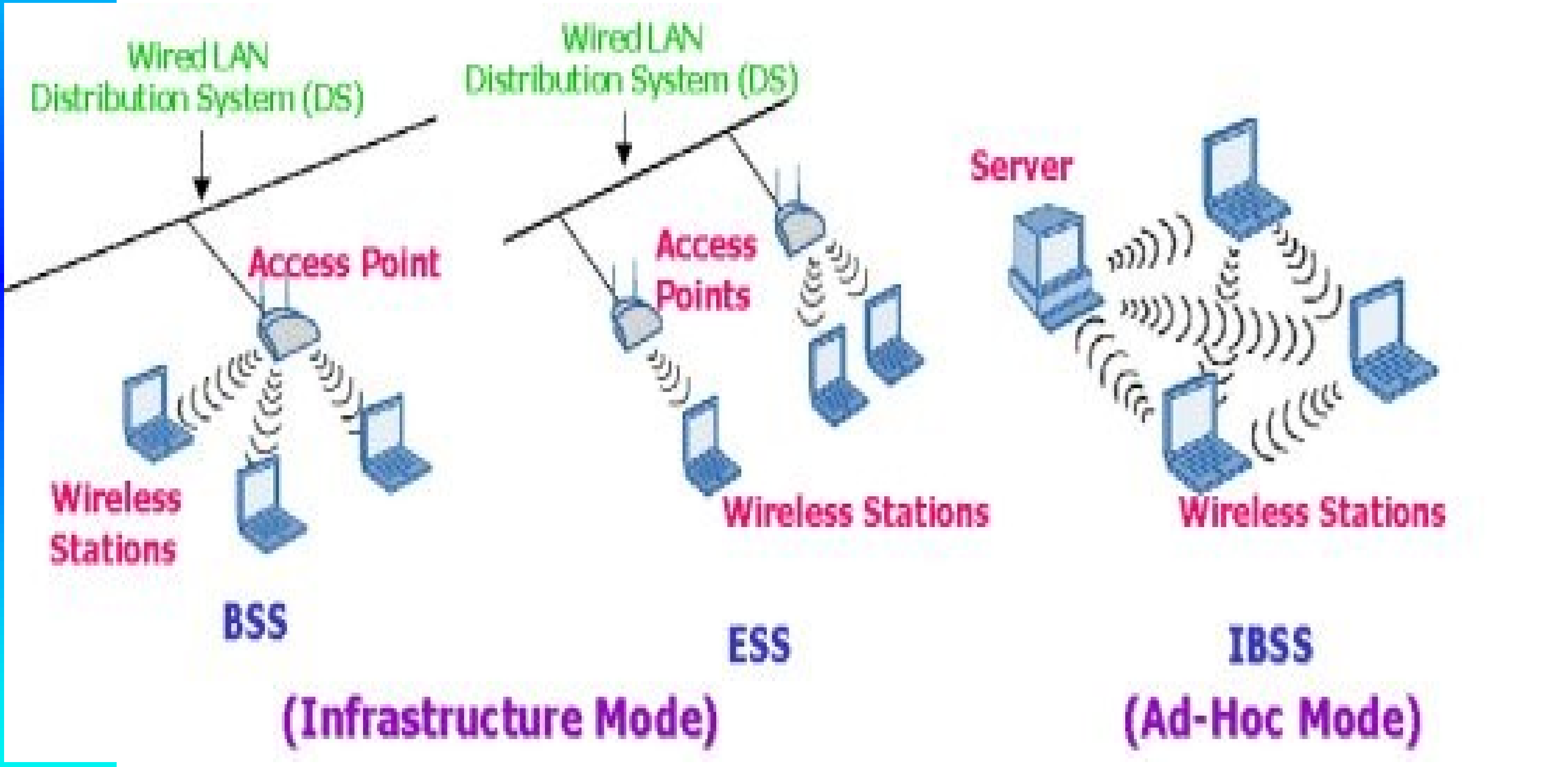
Terminal with capabilities to communicate with the AP Access Point



Independent Basic Service Set (IBSS)

Group of stations communicating at the same frequency without the need for an AP

Two modes of operation



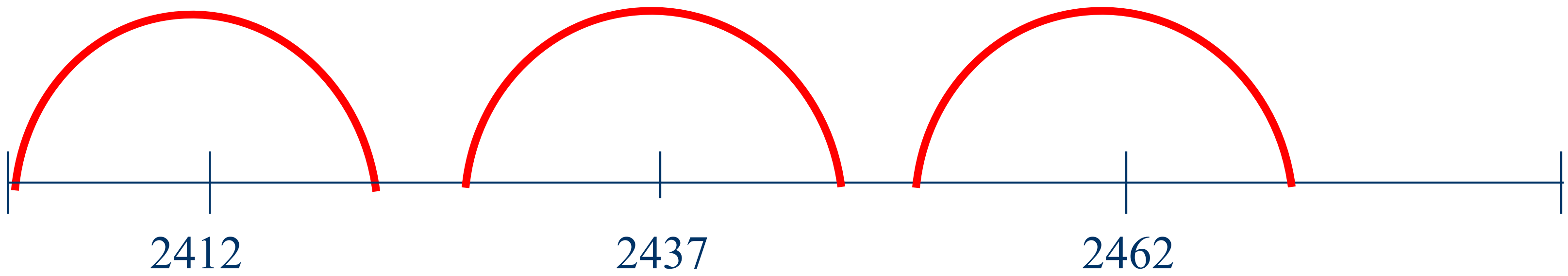
Protocol stack of 802.11

802.2			Data Link Layer
802.11 MAC			
FH	DS	IR	PHY Layer

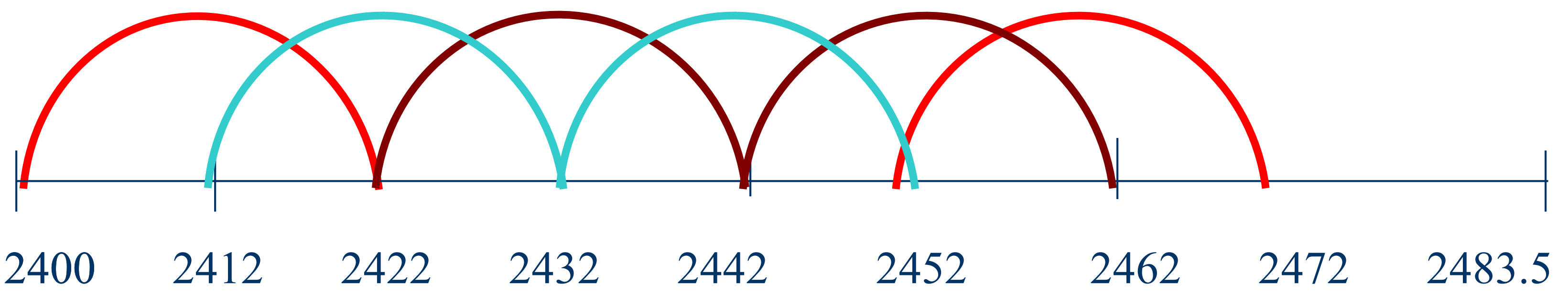
802.11b transmission channels

- PHY of 802.11b has 14 channels, 22MHz each, placed 5MHz one next to the other
- Channel one is at 2.412 GHz, channel 2 at 2.417 GHz, etc, until channel 14 at 2.477 GHz
- 3 non overlapping channels

Non overlapping channels



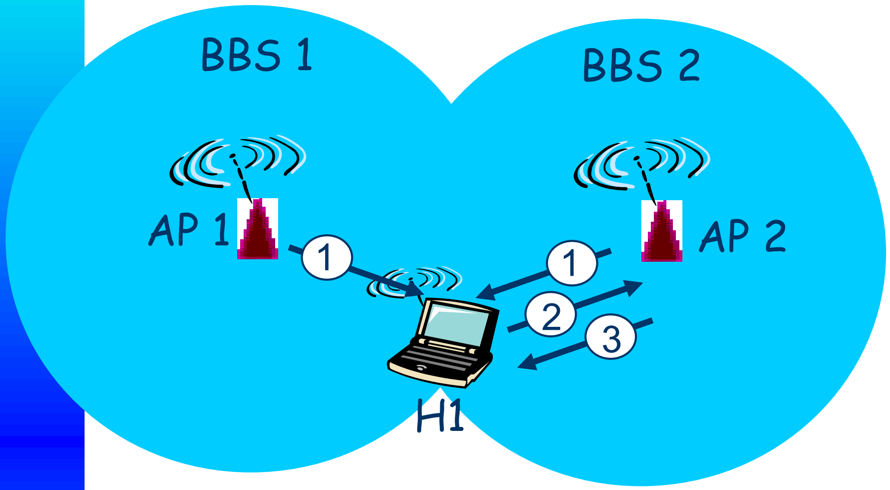
Overlapping channels

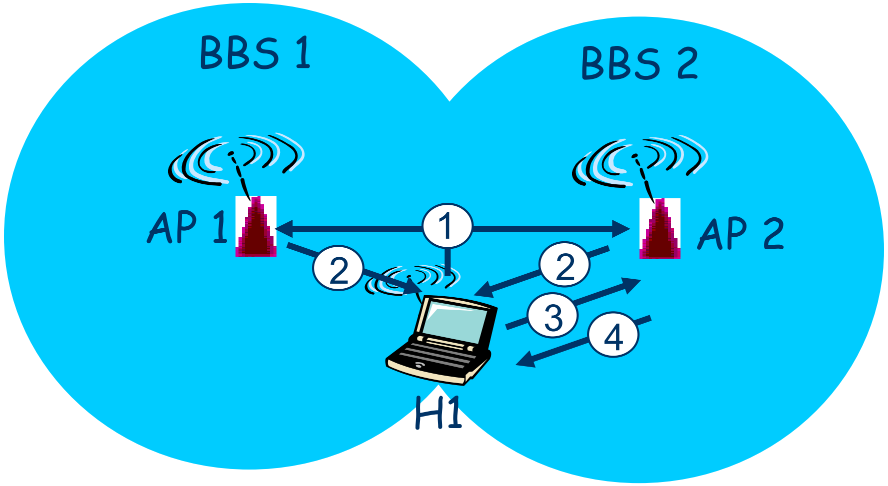


802.11: Channels, association

- 802.11b: 2.4GHz-2.488GHz spectrum divided into 14 channels at different frequencies
  - AP admin chooses frequency for AP
  - interference possible: channel can be same as that chosen by neighboring AP!
- host: must *associate* with an AP
  - scans channels, listening for *beacon frames* containing AP's name (SSID) and MAC address
  - selects AP to associate with
  - may perform authentication
  - will typically run DHCP to get IP address in AP's subnet

802.11: passive/active scanning





Passive Scanning:

(1) beacon frames sent from APs

(2) association Request frame sent: H1 to selected AP

(3) association Response frame sent: H1 to selected AP

Active Scanning:

(1) Probe Request frame broadcast from H1

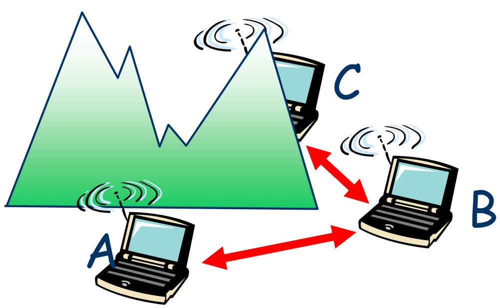
(2) Probes response frame sent from APs

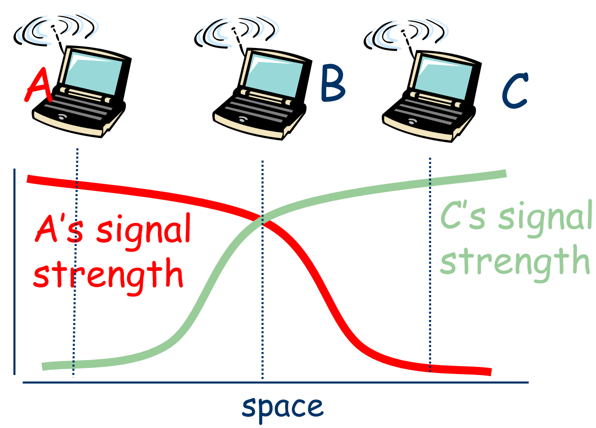
(3) Association Request frame sent: H1 to selected AP

(4) Association Response frame sent: H1 to selected AP

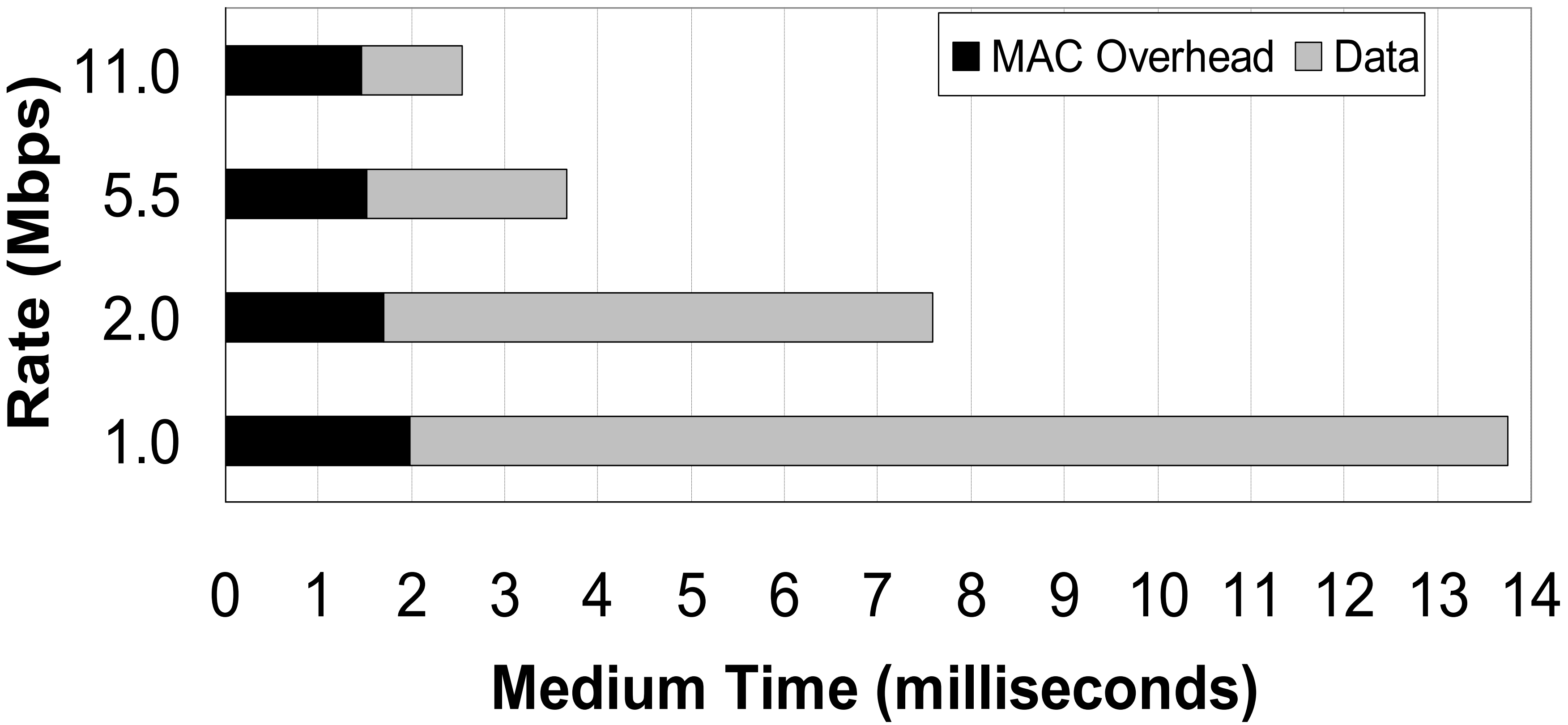
IEEE 802.11: multiple access

- avoid collisions: 2⁺ nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - don't collide with ongoing transmission by other node
- 802.11: *no* collision detection!
  - difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - can't sense all collisions in any case: hidden terminal, fading
  - goal: *avoid collisions:* CSMA/C(ollision)A(voidance)





MAC Overhead



MAC responsible for

- ✓ Channel allocation
- ✓ Addressing
- ✓ Transmission frame structure
- ✓ Error control (retransmissions)
- ✓ Fragmentation/reassembly

Three kinds of frames:

- ✓management (association, synchronization, authentication)
- ✓control (acks, end of contention-free period)
- ✓data

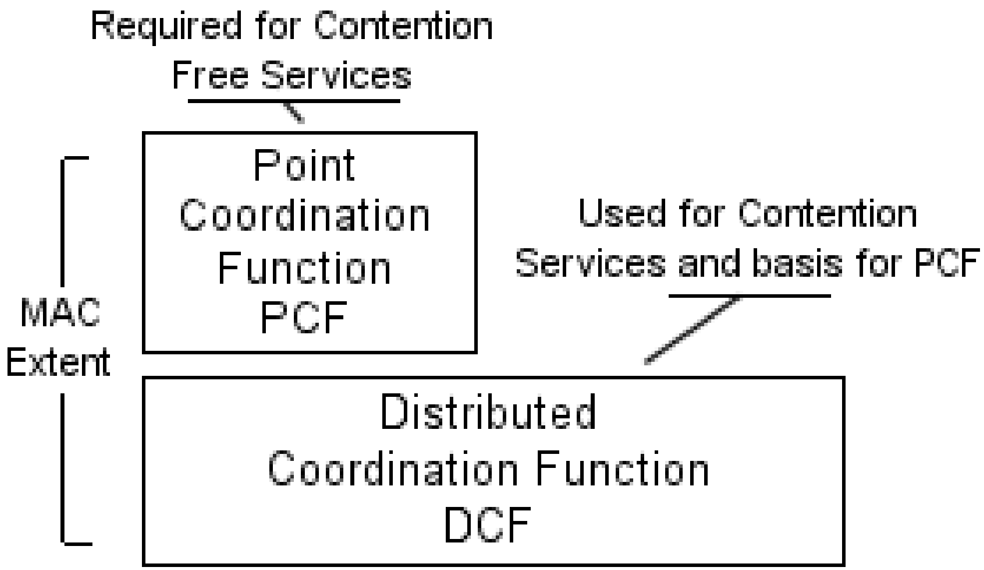
Access Methods

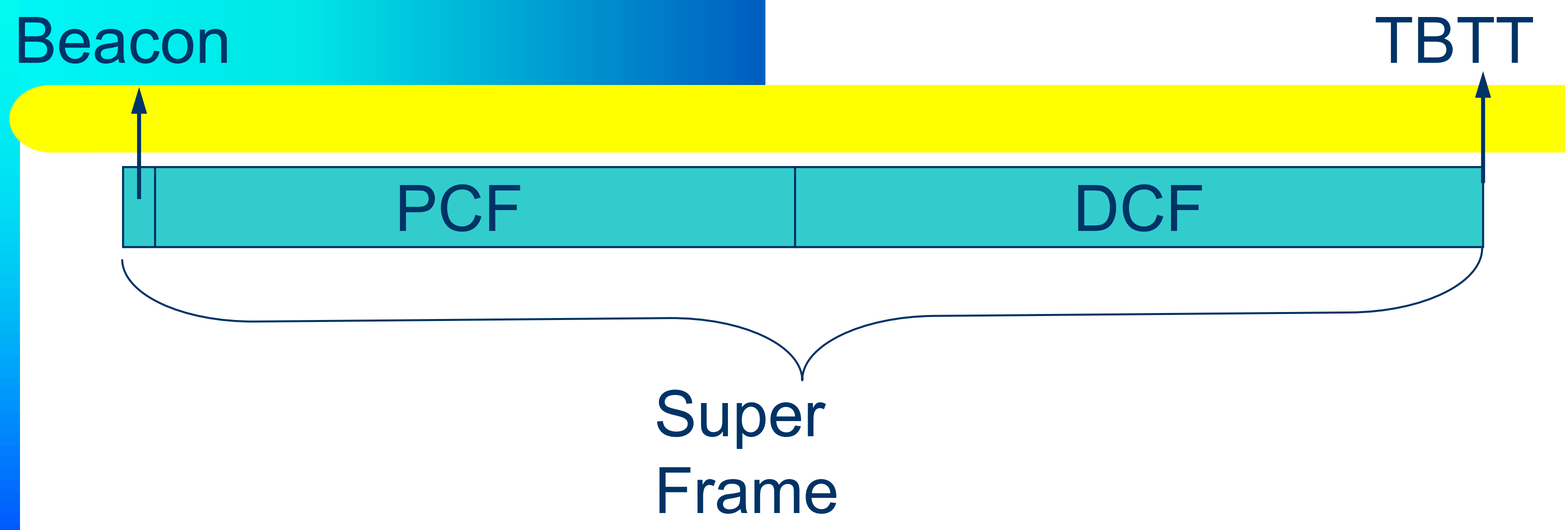
Distributed Coordination Function (DCF)

- Mandatory
- Main access mode
- Contention-based

Point Coordination Function (PCF)

- Optional
- Contention-free
- Lower delays in high traffic
- Only in infrastructure mode





DCF - Distributed Coordinated Function

(**Contention Period** - *Ad-hoc Mode*)

PCF - Point Coordinated Function

(**Contention Free Period** – *Infrastructure BSS*)

Beacon - Management Frame

Synchronization of Local timers

Delivers protocol related parameters (e.g., version)

TBTT (Target Beacon Transition Time)

IEEE 802.11 MAC Protocol: CSMA/CA

802.11 sender

1 if sense channel idle for **DIFS** then

transmit entire frame (no CD)

2 if sense channel busy then

start random backoff time

timer counts down while channel idle

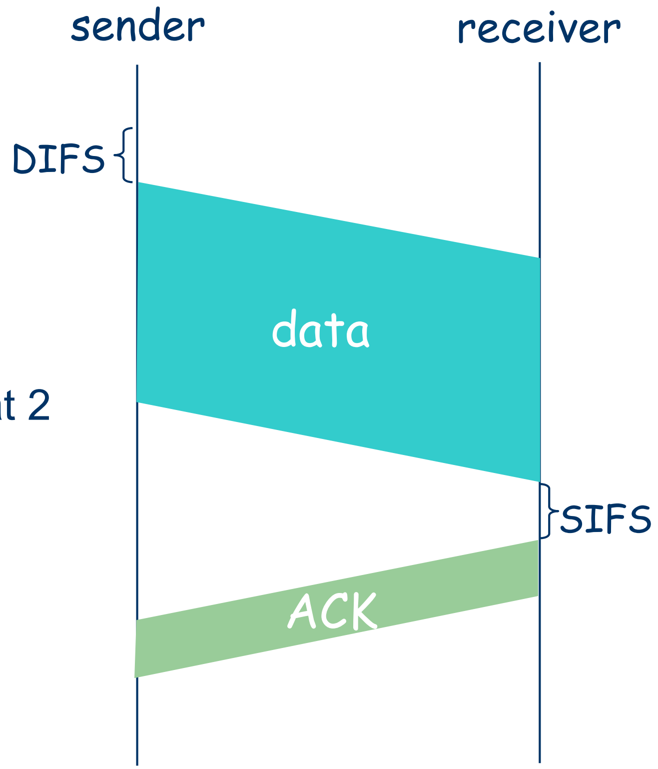
transmit when timer expires

if no ACK, increase random backoff interval, repeat 2

802.11 receiver

- if frame received OK

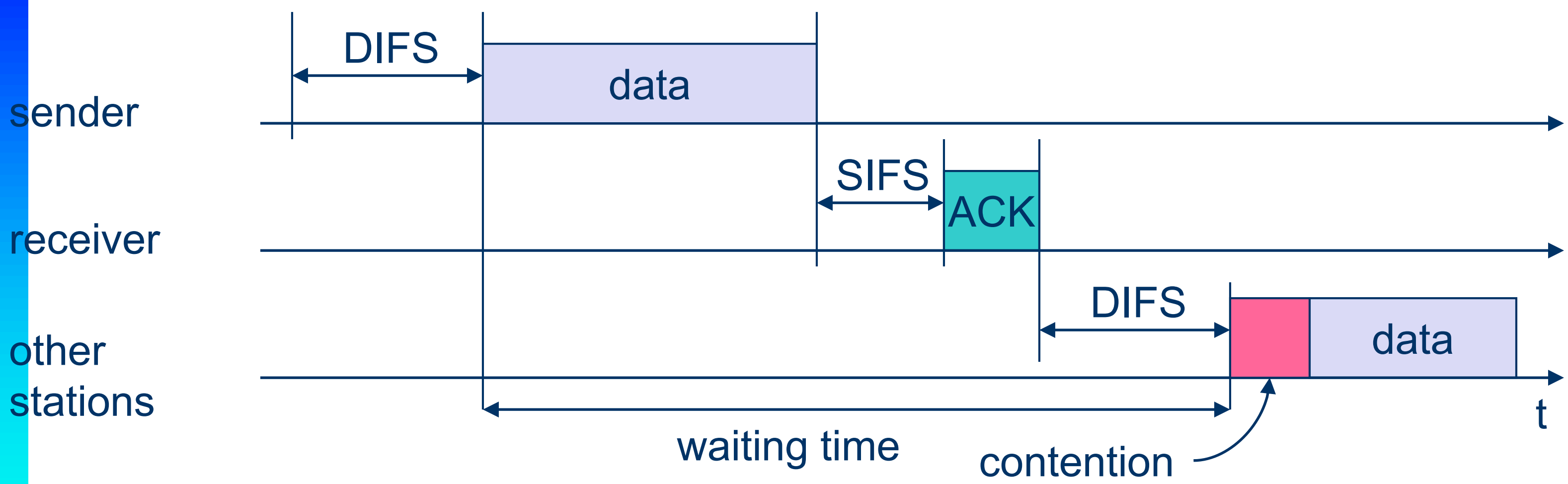
return ACK after **SIFS** (ACK needed due to hidden terminal problem)



SIFS<DIFS

802.11 - CSMA/CA access method

- 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



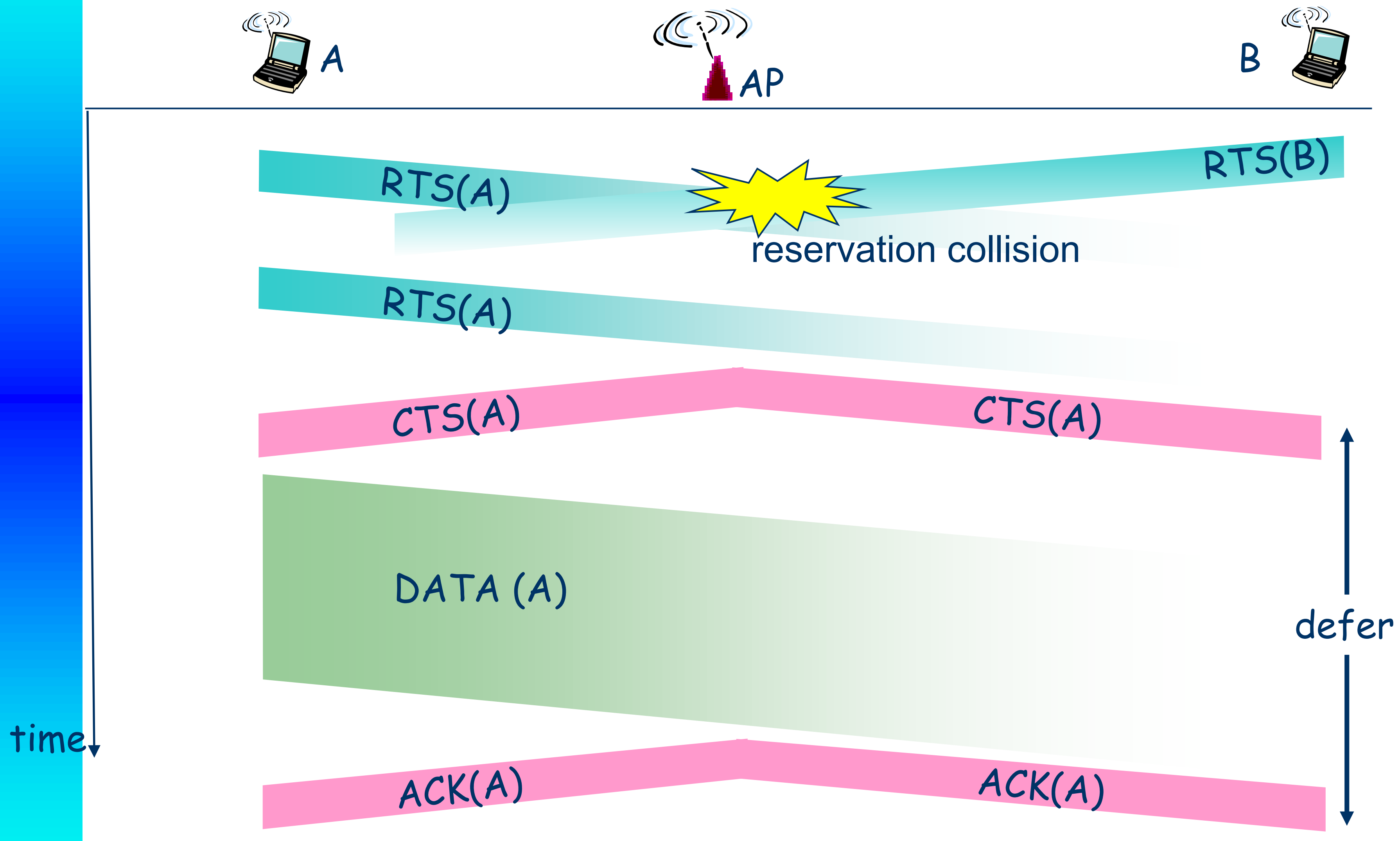
Avoiding collisions

idea: allow sender to “reserve” channel rather than random access of data frames: avoid collisions of long data frames

- sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they’re short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

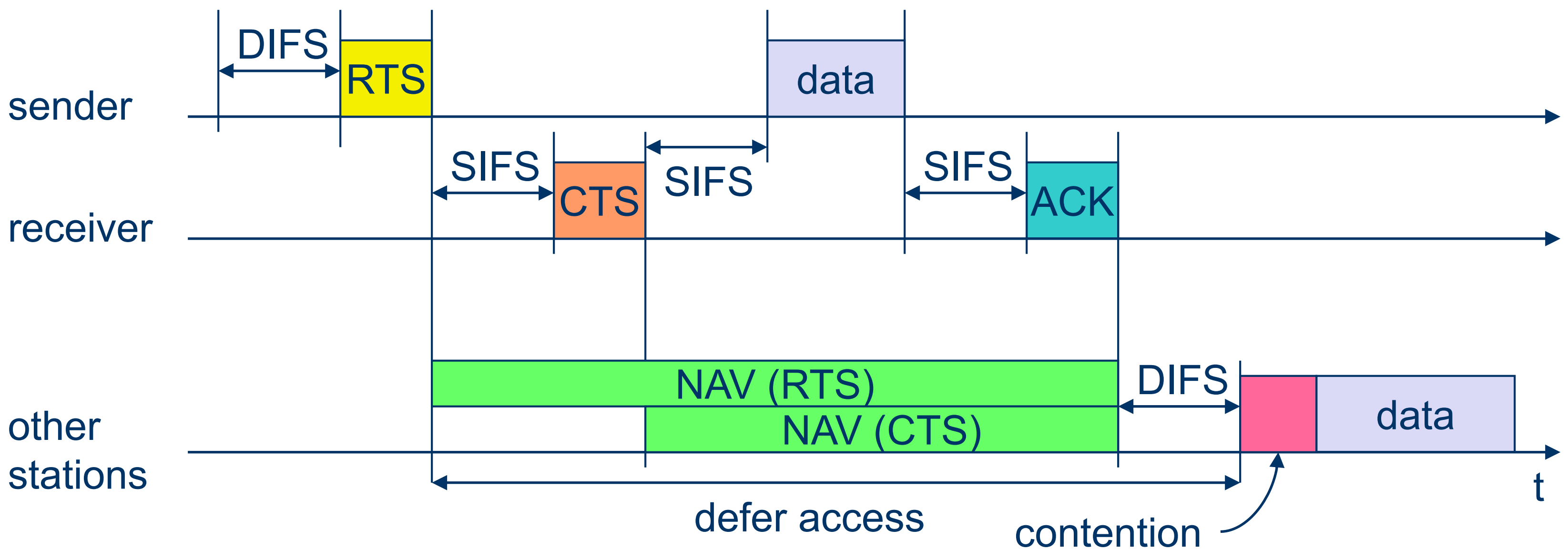
avoid data frame collisions completely
using small reservation packets!

Collision Avoidance: RTS-CTS exchange

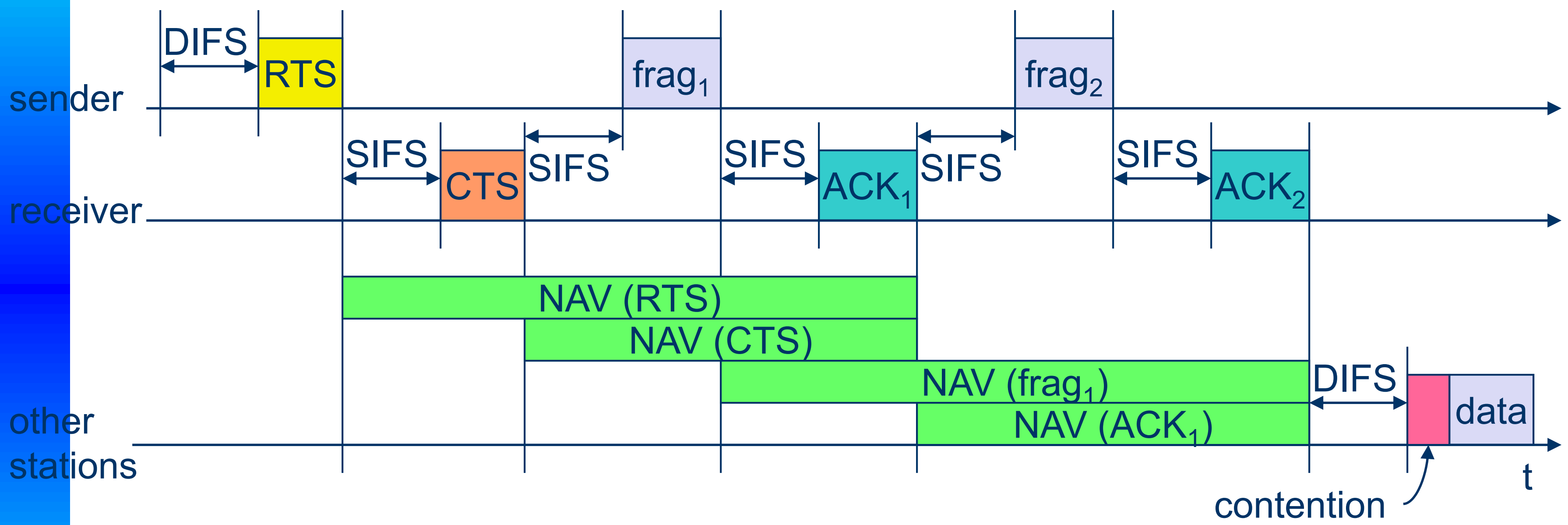


Collision Avoidance: RTS-CTS exchange

- 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

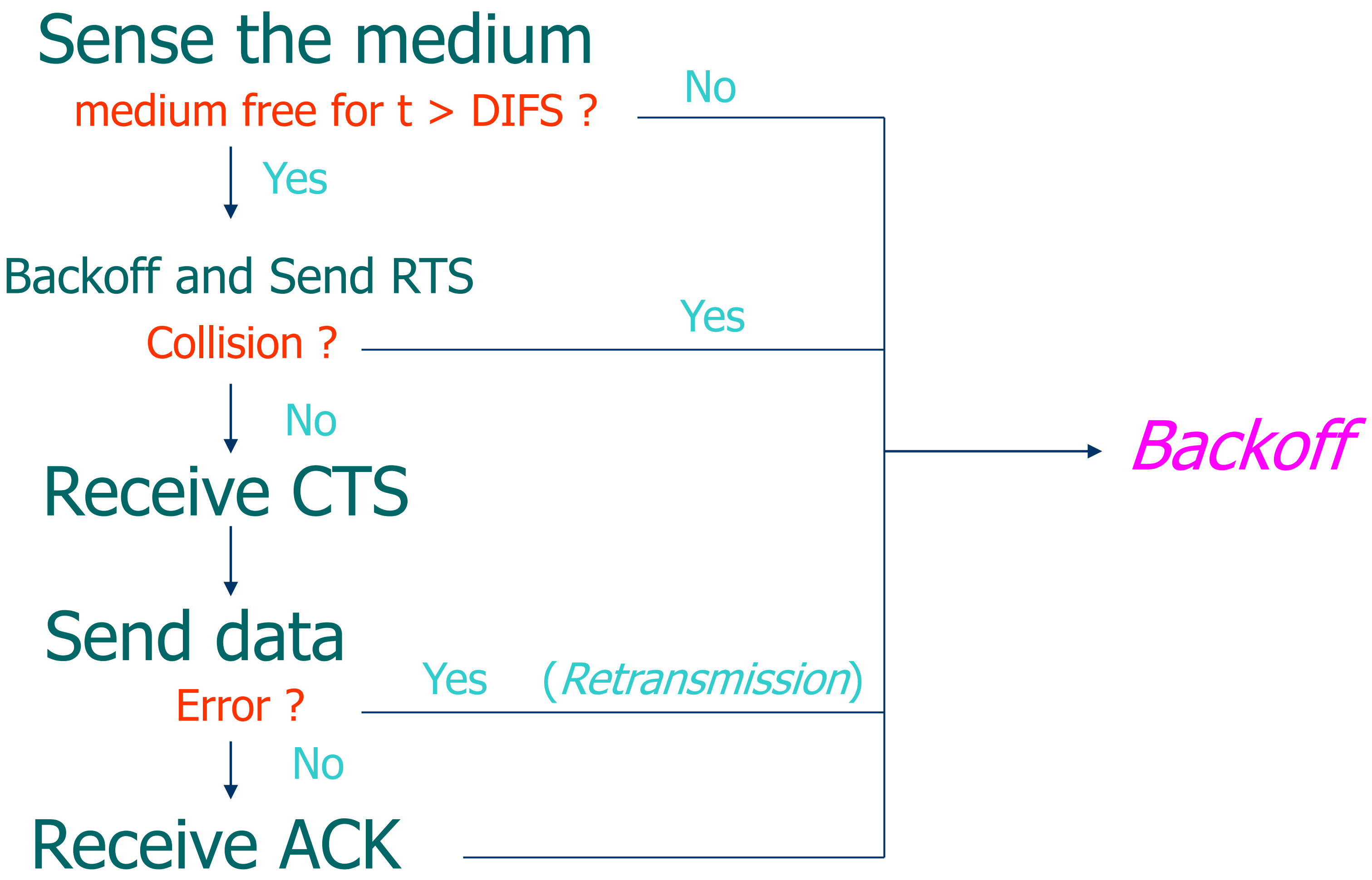


Fragmentation



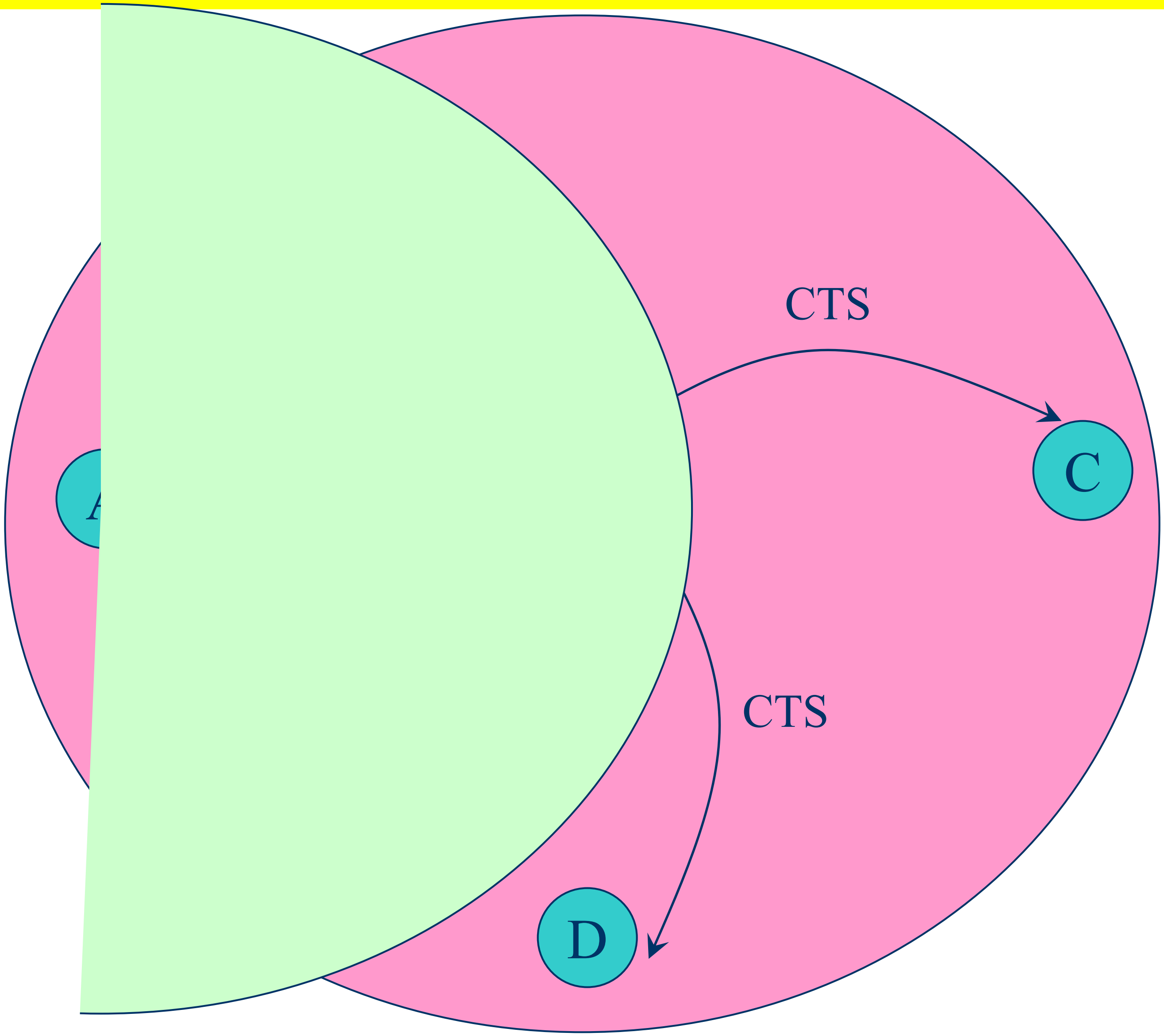
Why fragment?

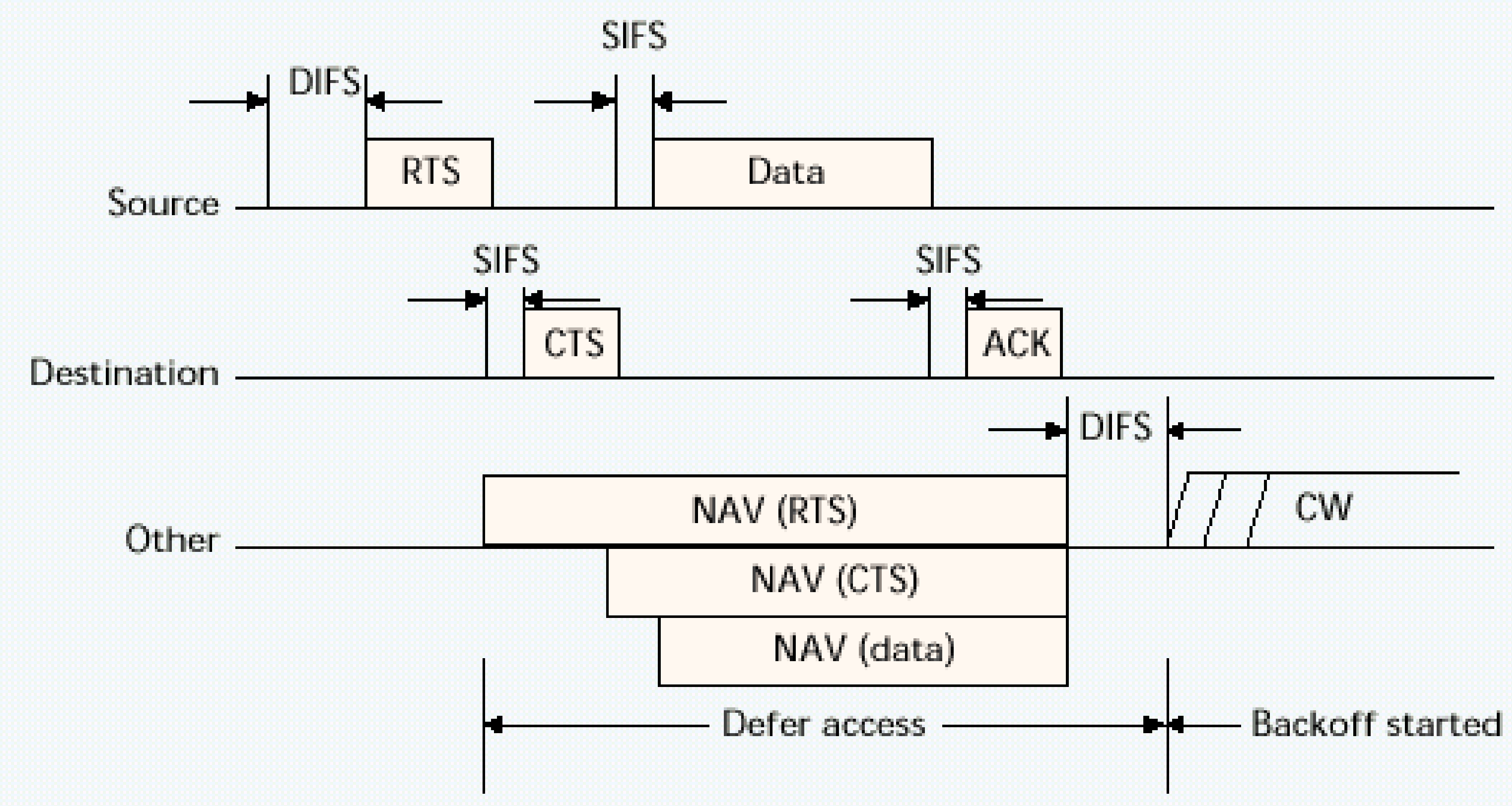
Distributed Coordination Function



DIFS: DCF Interframe Space

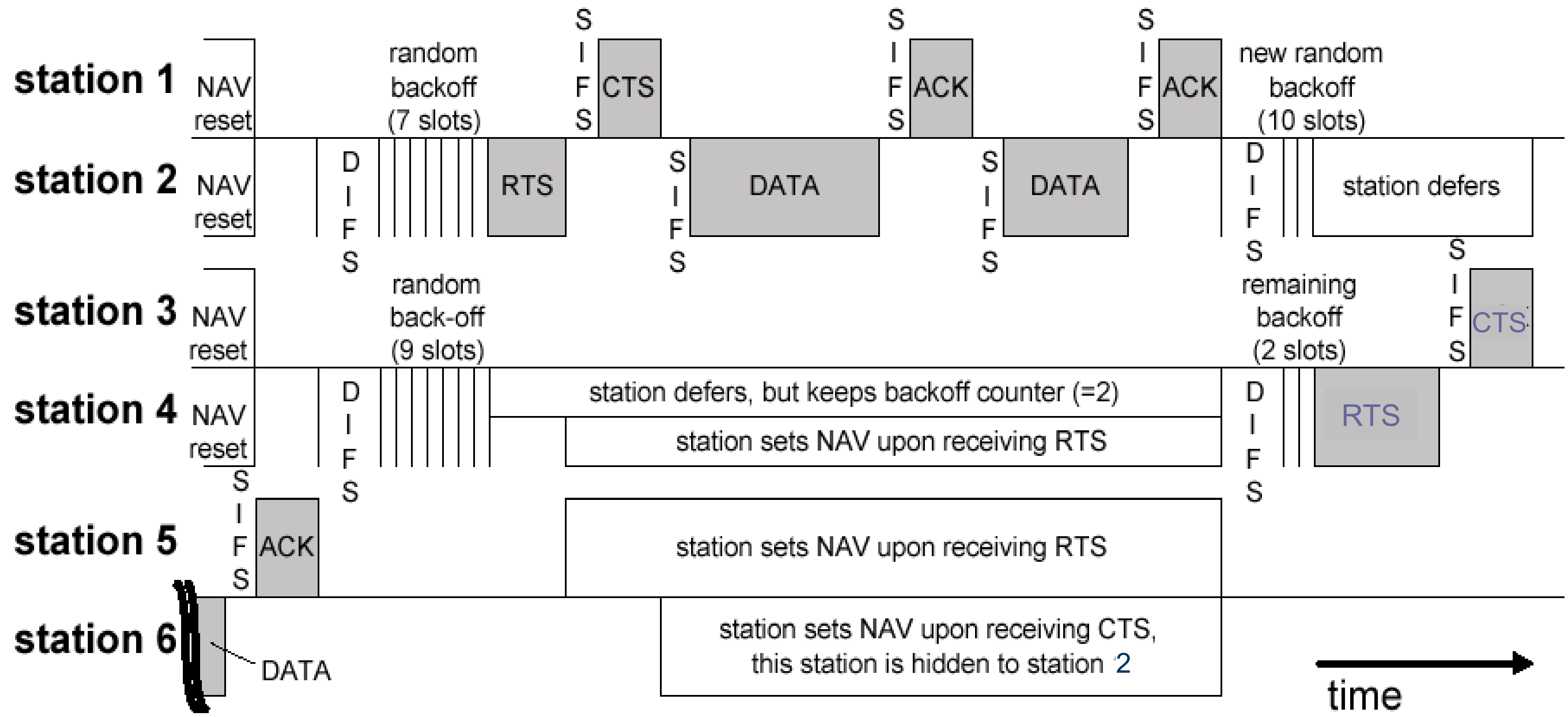
Collision avoidance at B





- Always SIFS<DIFS
- Updating of NAVs (Network Allocation Vectors) very important through RTS/CTS/data packets to use power saving

Example of DCF transmission



CW doubles after each collision

- Initial CW -> 3 (backoff 0-3)
- CW after Collision 1 → 7 (backoff 0-7)
- CW after Collision 2 → 15 (backoff 0-15)
- CW after Collision 3 → 31 (backoff 0-31)
- CW after Collision 4 → 63 (backoff 0-63)

How the Contention Window works

- Whenever a backoff occurs the backoff time is uniformly chosen in the range $[0, W-1]$
- After each unsuccessful transmission the backoff windows size is doubled, up to a maximum value
- Once the backoff window size reaches its maximum value it will stay at that value until it is reset
- The value of W will be reset after every successful transmission of a data or RTS packet, or when a retry counter reaches its limit

Disadvantages of DCF

- Unpredictable collision number
- Unpredictable delay of successful transmission
- Unpredictable throughput
- Uncontrolled selection of station to transmit

And one advantage:

- Low transmission delay and good performance for low traffic