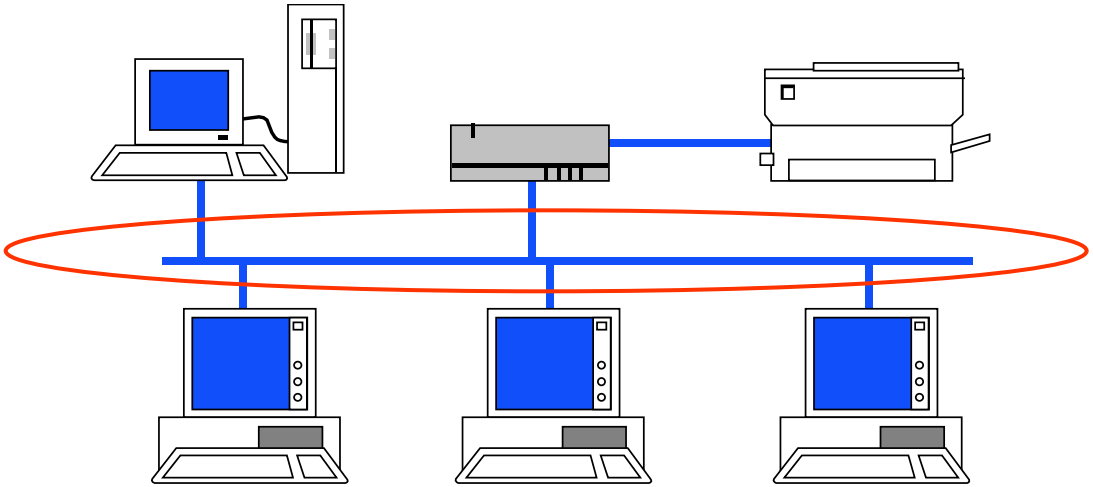
Lecture 7
Wireless Local Area Networks (LANs)

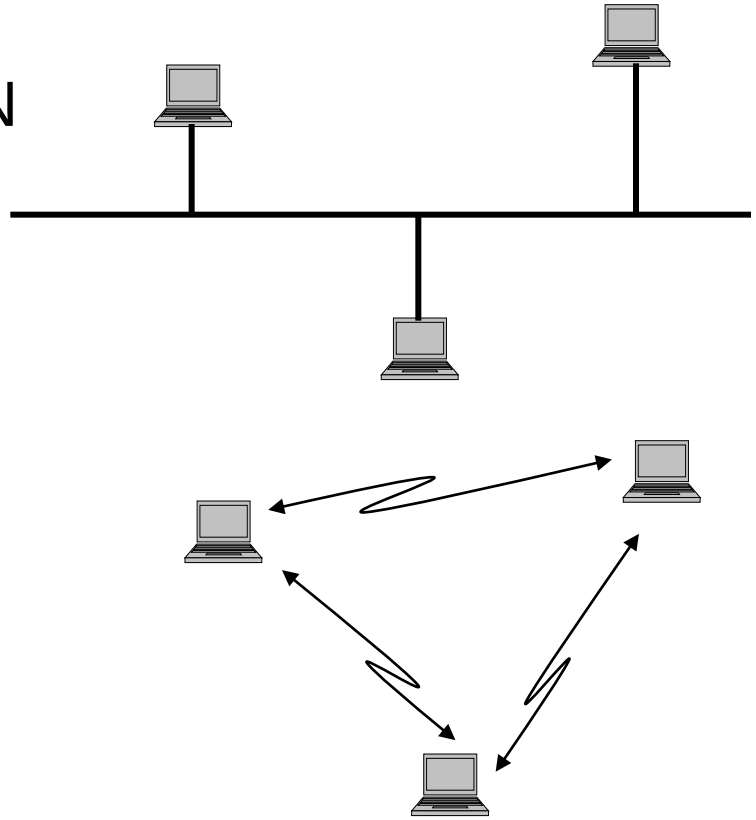
Introduction to Wireless LANs

- Local area networks (LANs)
  - Share resources and information
  - Low-cost, high speed, and almost error-free communications
  - Ethernet; token ring networks



Introduction to Wireless LANs (Cont'd)

- What is wireless LAN?
  - An extension of the wired LAN
  - Compatible
  - Coverage: ~ 100 feet
  - Merits
    - Convenience
    - Fast installation
    - User mobility
  - Challenges
    - Smaller bandwidth
    - Interference/noise → not reliable
    - Broadcast medium → intercepted by snoopers



Wireless LAN Standards

- *HiperLAN* - European Telecommunications Standards Institute (ETSI) @ 5 GHz unlicensed frequency band
- *IEEE 802.11* - IEEE 802.11 Worldwide Standard Group @ 2.4 GHz or 5 GHz unlicensed frequency band

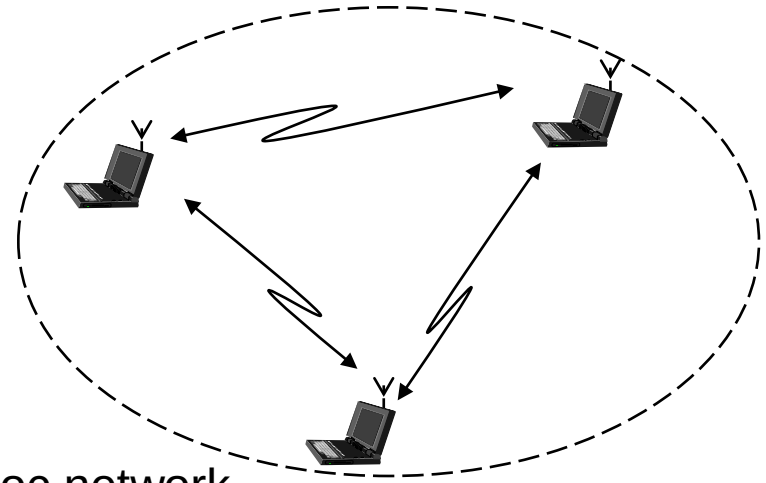
  * IEEE: Institute of Electrical and Electronics Engineers, largest technical professional organization, non-profit.

IEEE 802.11 Family for Wireless LANs

- Specify air interface between APs and stations, or between two stations
- Difference: radio frequency band, transmission speed, modulation scheme
- 802.11
  - original wireless LAN standard
  - 1 - 2 Mbps
- 802.11a
  - Orthogonal frequency division multiplexing (OFDM)
  - 5 GHz radio frequency
  - High speed: up to 54 Mbps
- 802.11b
  - DS-SS at 2.4 GHz
  - Up to 11 Mbps
- 802.11e
  - Support quality-of-service
- 802.11g
  - OFDM
  - High speed standard at 2.4 GHz
  - Up to 54 Mbps

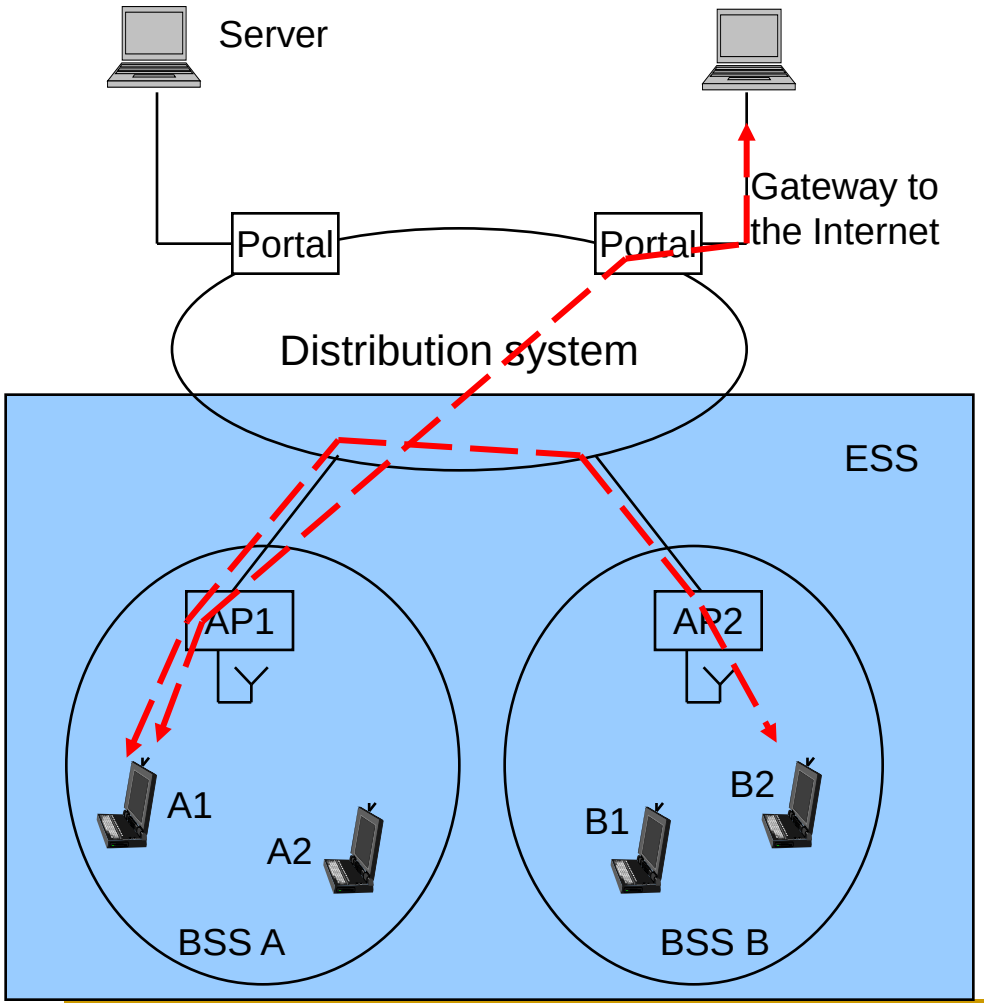
WLAN Architecture

- Two modes: ad hoc networks & Infrastructure networks
- Basic service set (BSS)
  - a group of stations that can communicate with each other
- Ad hoc network
  - No infrastructure; temporary
  - Peer-to-peer
  - Conference meetings, distributed computer games



Ad hoc network

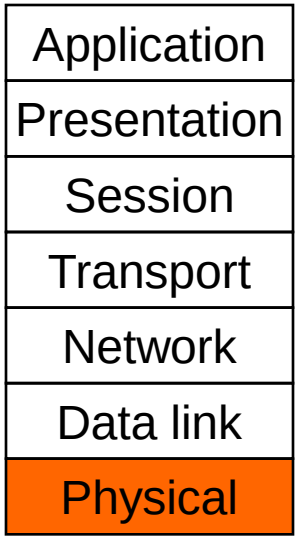
Infrastructure Network



- An access point (AP) in each BSS
- Distribution system: interconnect BSSs to form an extended service set (ESS)
- Portal: bridge to other networks

Wireless LAN Physical Layers

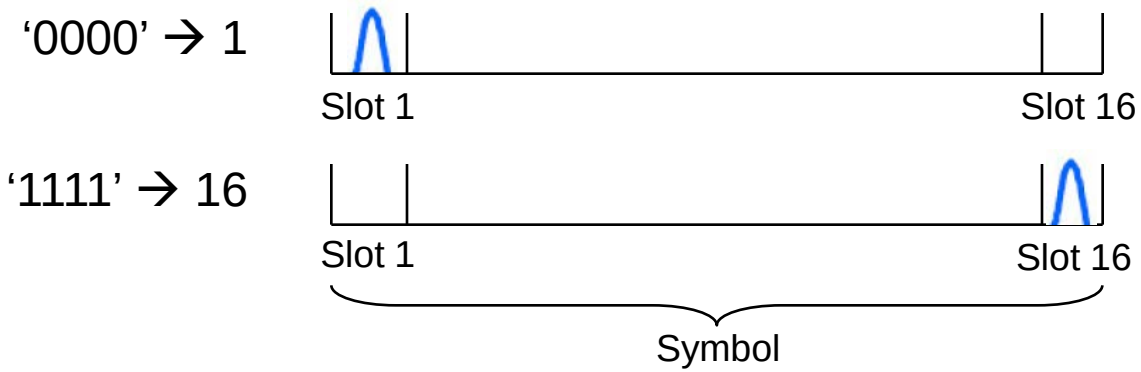
- Physical layer: transfer of bits over a communication channel
- IEEE 802.11 wireless LAN physical layer
  - Infrared
  - Spread spectrum (SS) at 2.4 GHz



OSI model

Infrared Physical Layer

- Coverage: 10 – 20 m
- Pulse-position modulation (PPM)
  - Each transmitted symbol has 16 time slots, one contains a pulse
  - Four bits → integer in [1, 16] (‘0000’→1, ‘1111’→16)
  - The integer determines which slot is used for the pulse
    - An example

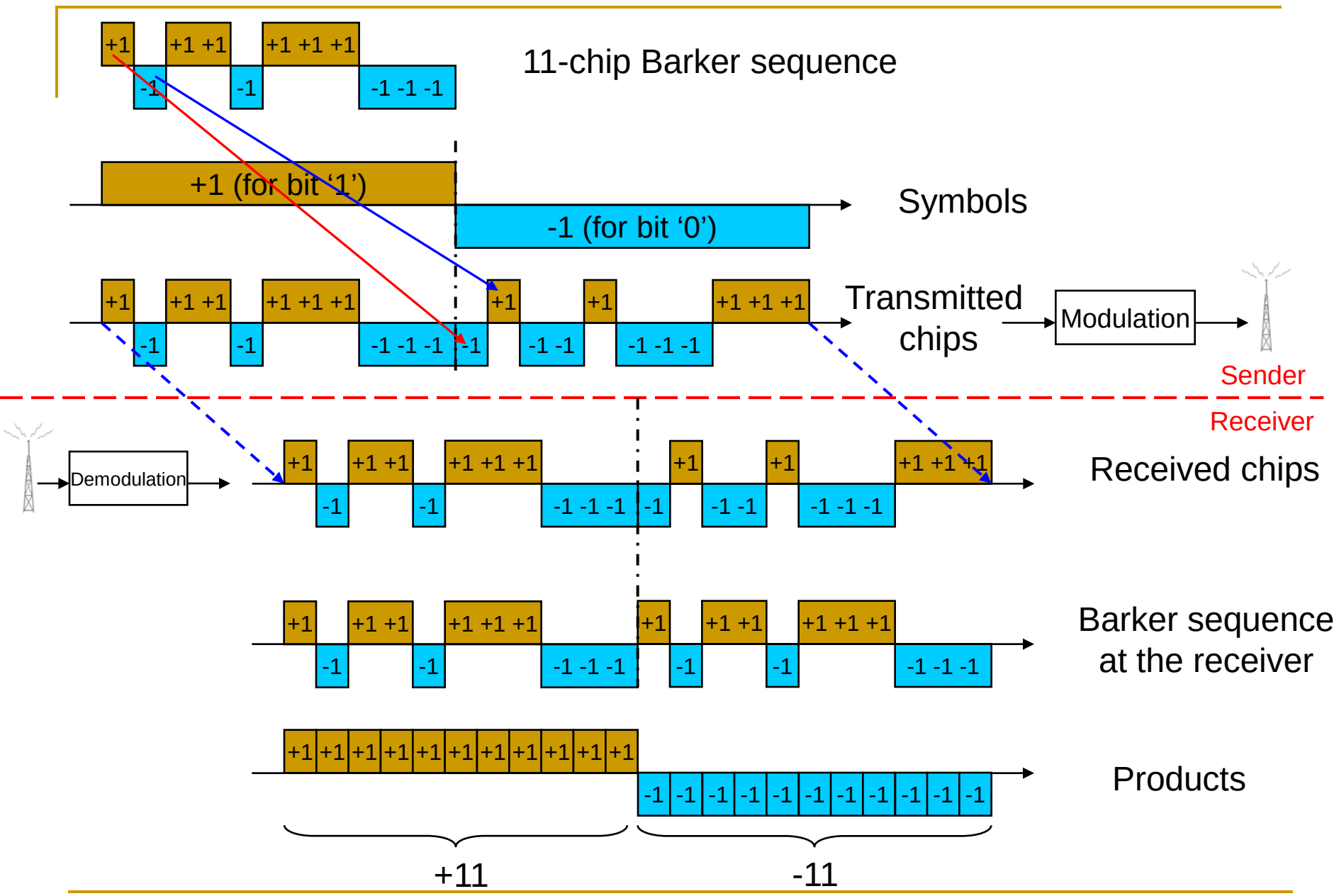


Infrared Physical Layer (Cont'd)

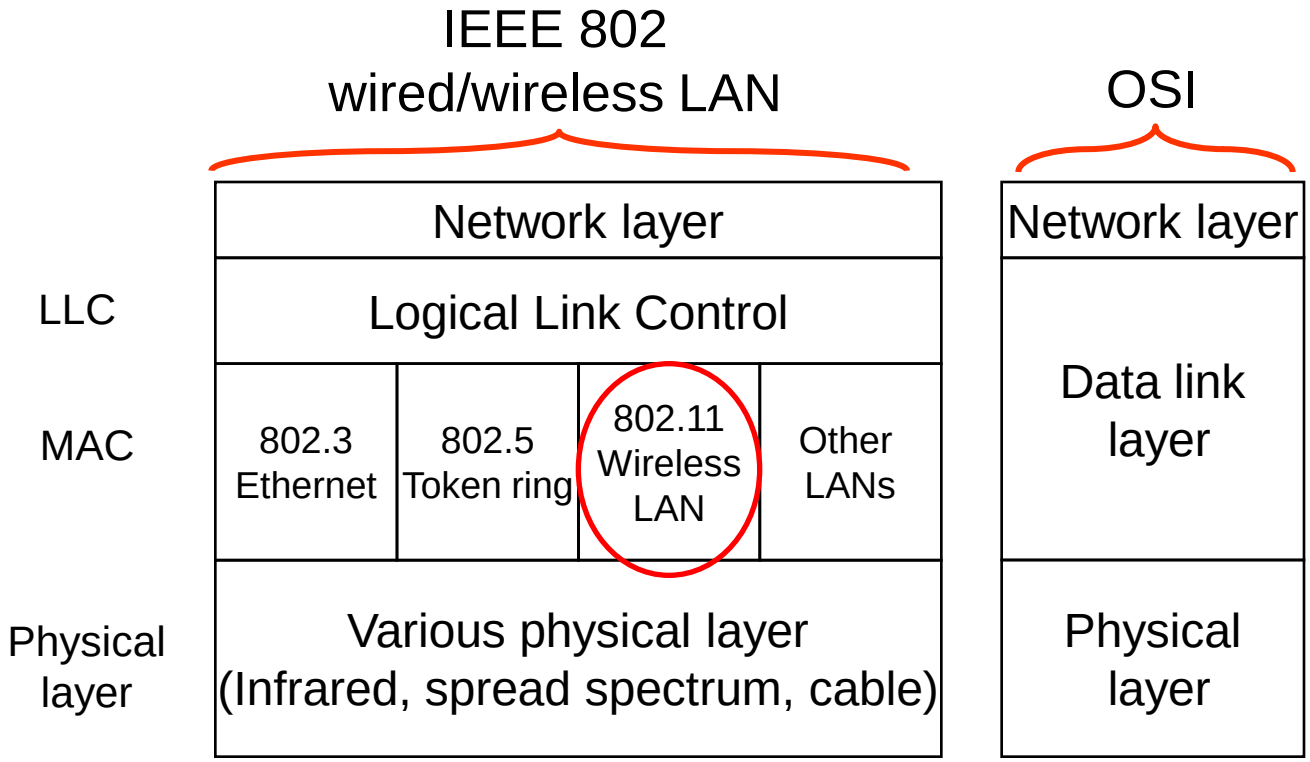
- Advantages
  - Simple & inexpensive
  - Constrained by walls → Secured against eavesdropping, low interference
- Disadvantages
  - Interference (sunlight, indoor lighting)
  - Limited range
    - Not popular

Spread Spectrum Physical Layer

- Spread spectrum: spread the signal energy over a wide frequency band
- Frequency hopping (FP) & direct sequence (DS) (802.11b)


11-chip Barker sequence
+1
+1 +1
+1 +1 +1
-1
-1
-1 -1 -1
+1 (for bit '1')
-1 (for bit '0')
Symbols
Transmitted chips
Modulation
Sender
Receiver
Demodulation
Received chips
Barker sequence at the receiver
Products
+11
-11

Where is MAC in OSI Model?



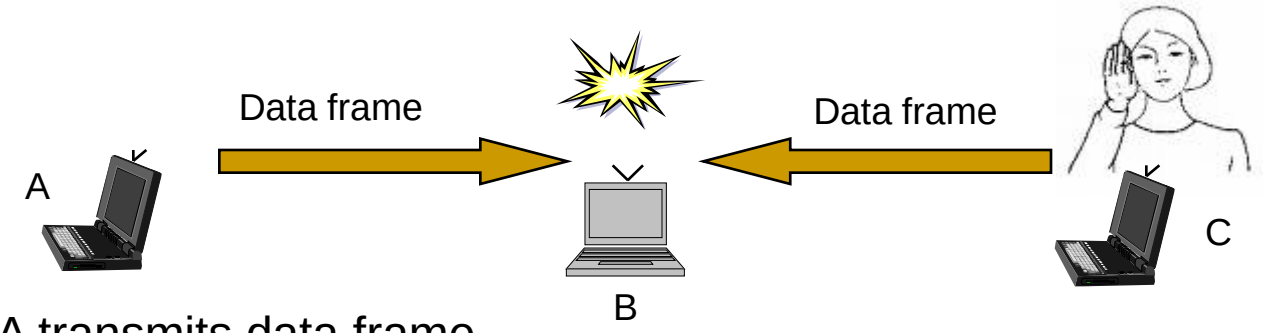
- Data link layer: logic link control (LLC) + MAC
- MAC: coordinating the access to the shared medium.
- LLC: operate over all MAC standards (802.3, 802.5, and 802.11), and offer the network layer a standard set of services

Distributed Coordination Function (DCF)

- Mandatory in IEEE 802.11
- Distributed manner
- Asynchronous data transfer & best effort
- All stations contend
- Recall: Ethernet has carrier sensing multiple access with collision detection (CSMA-CD)
- Why not use CSMA-CD in wireless LANs?
  - Sense the channel before transmission
  - Channel busy → persistent methods
  - During transmission, continue to sense (detect collision)
  - Collision detected → abort
    - transmit and sense at the same time

Distributed Coordination Function (DCF) (Cont'd)

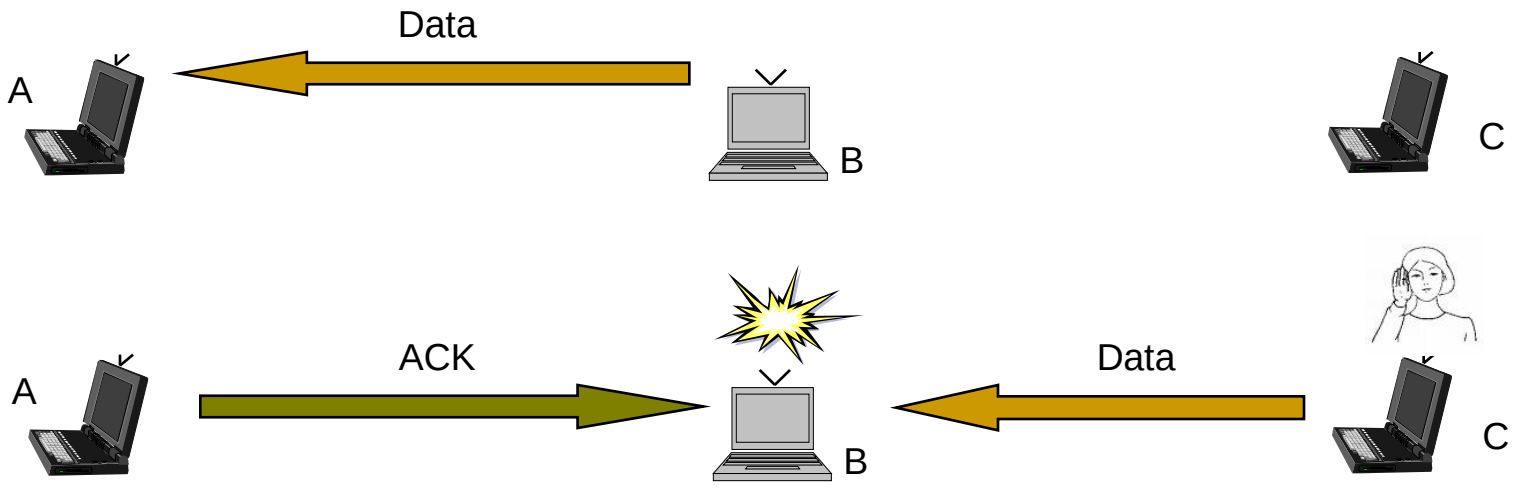
- Drawbacks of CSMA-CD over wireless LANs
  - *"Collision detection" problem*: half-duplex → unable to transmit and sense simultaneously at the same frequency band
  - *"Hidden-station" problem* (also called *"hidden-terminal" problem*)



    - A transmits data frame
    - C senses medium; hears nothing
    - C transmits data frame
    - C collides with A at B
- A new MAC: CSMA with collision avoidance (CSMA-CA)

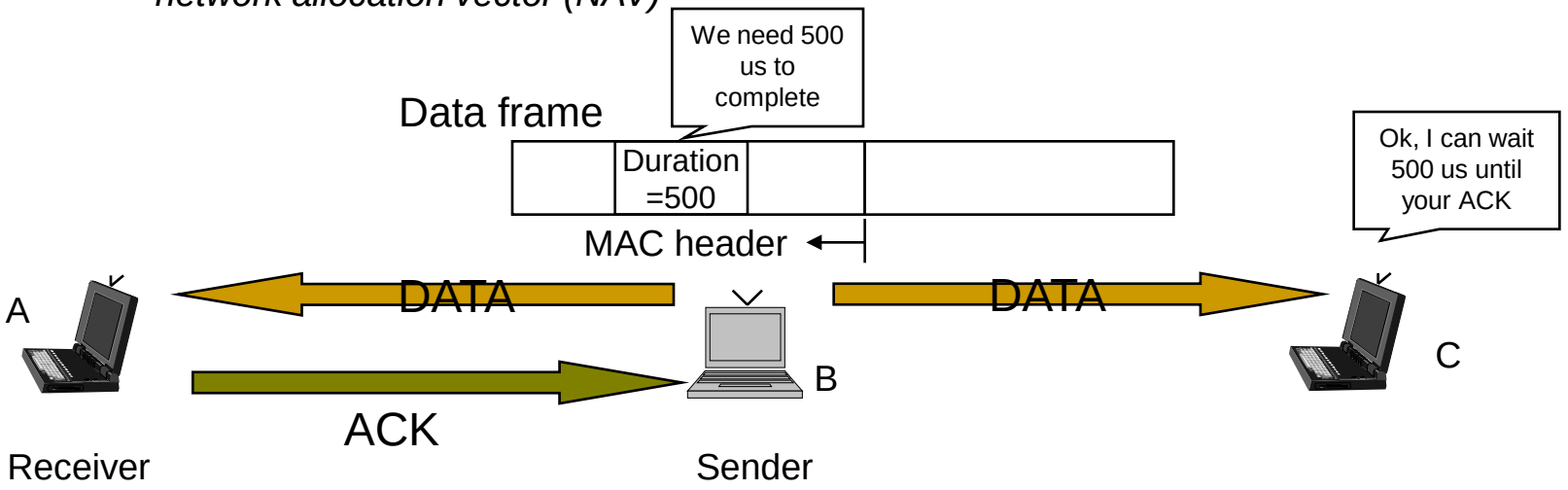
Solution to "Collision Detection" Problem

- Acknowledgement (ACK)
  - No ACK → collision
- Information exchange handshake: Data + ACK
- New problem: ACK collision



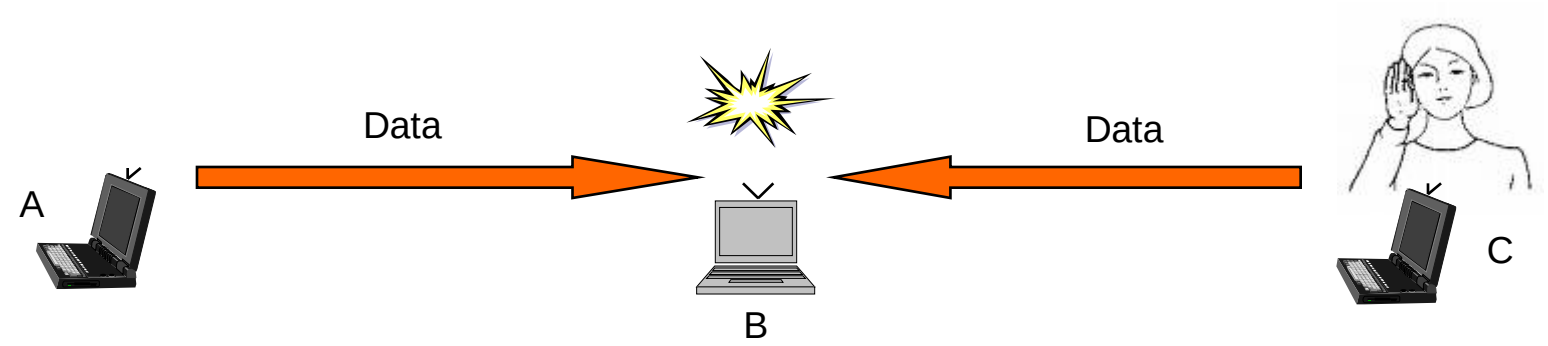
Solution to "Collision Detection" (Cont'd)

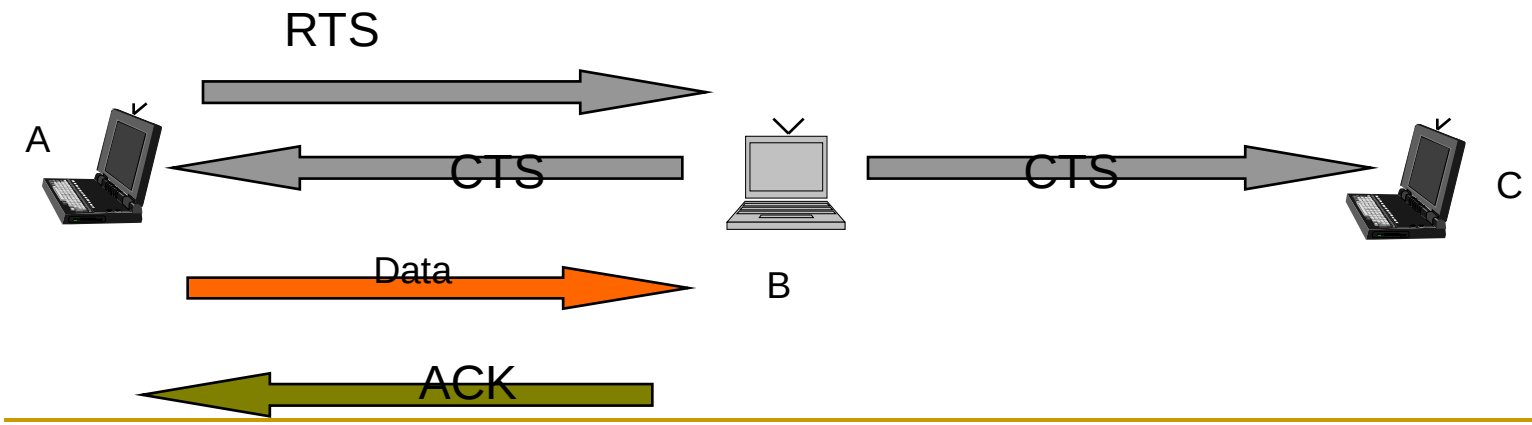
- Two kinds of carrier sensing
  - Physical carrier sensing
  - Virtual carrier sensing: tell others how long I need
    - Sender: set *duration field* in the MAC header of the transmitted frames
      - Indicate the amount of time needed to complete the Data-ACK handshake
    - Other stations wait until the completion of the exchange, and the waiting time is called *network allocation vector (NAV)*



Solution to "Hidden-Station" Problem

- Request-to-send (RTS)/clear-to-send (CTS) handshake
- Four-way handshake: RTS-CTS-Data-ACK

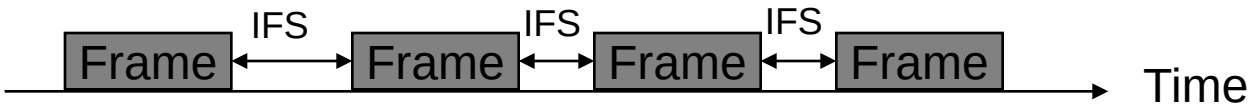




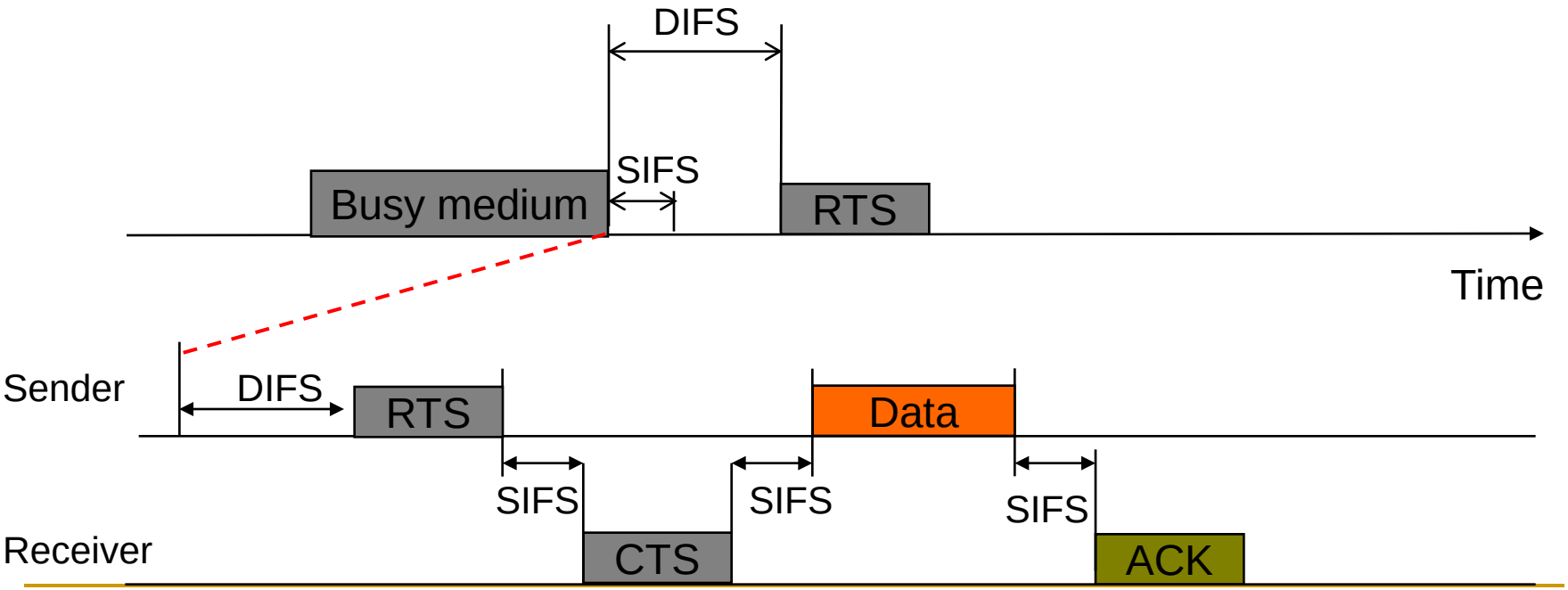
Data frame: up to 1500 bytes; RTS: 20 bytes
The duration field in CTS tells C to wait.

Basic CSMA-CA Operation

- Interframe space (IFS): “idle gap” between two frame transmissions

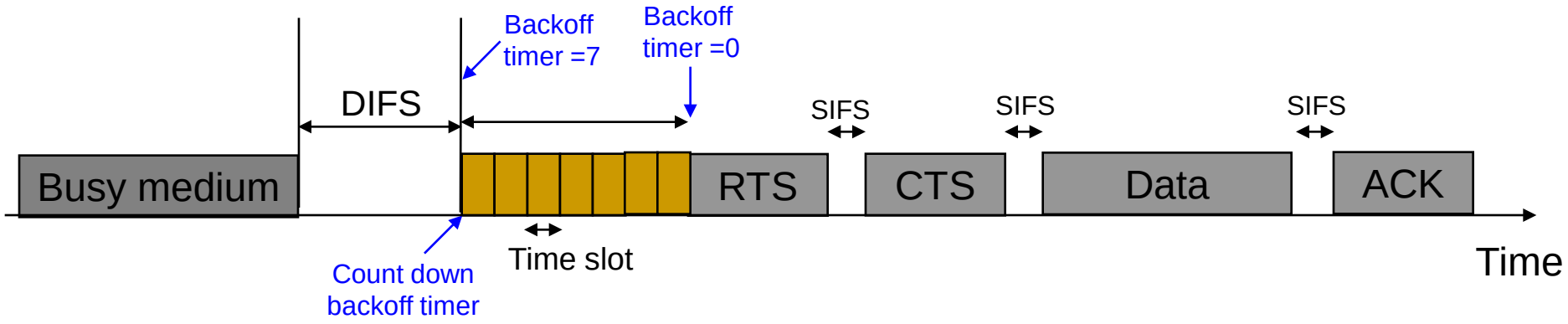


  - *Short IFS (SIFS)*: High-priority frames (such as CTS, ACK)
  - *DCF IFS (DIFS)* : RTS



Backoff Procedure

- If a station has a frame to send
  - Schedule a random *backoff timer* from a window [0, 31] (called contention window)
  - After DIFS channel idle, count down the backoff timer by one when the channel continues to be idle for one more time slot
  - Transmit when the backoff timer reaches 0
  - Access time: after DIFS + random backoff time
  - Can collisions be eliminated completely?
    - If two stations have the same backoff time?

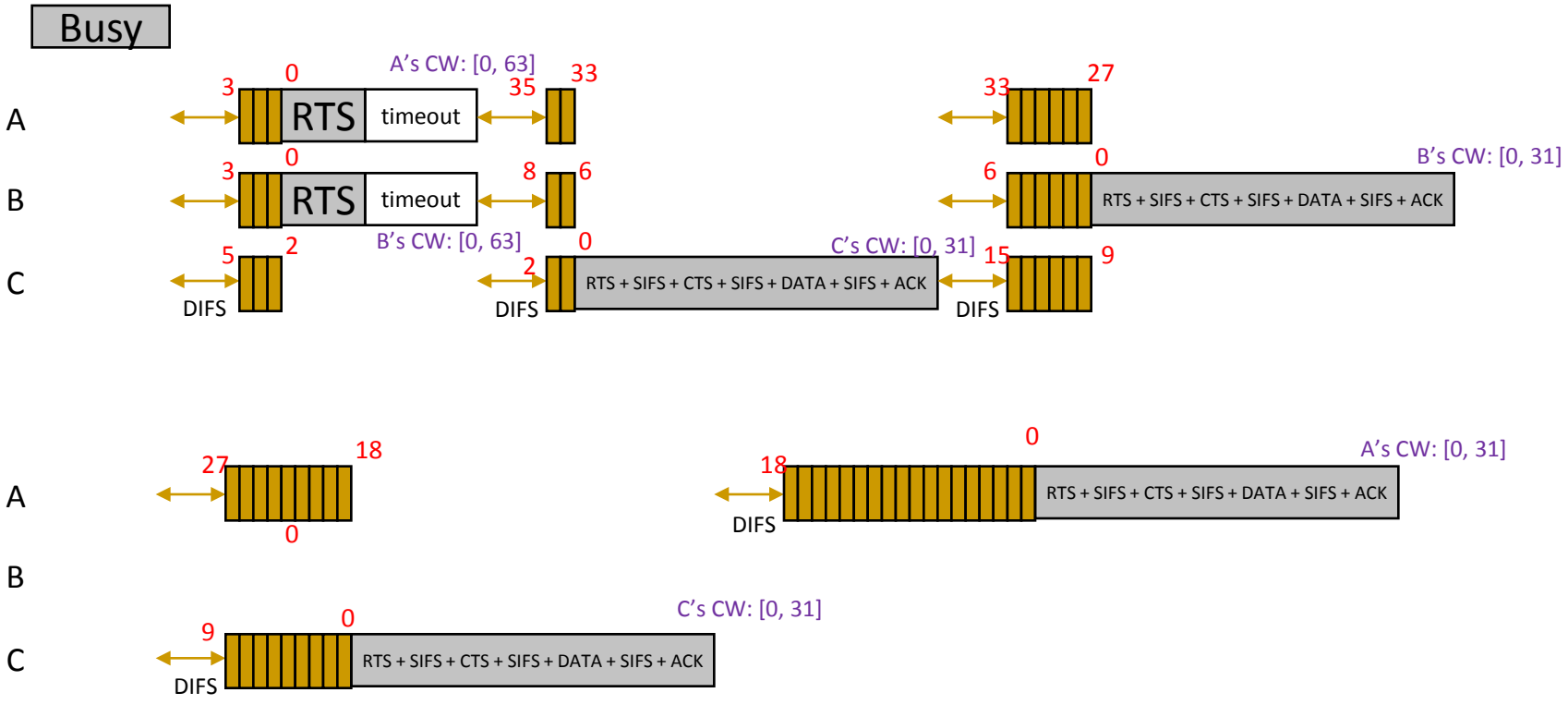


Collisions and Retransmissions

- Each sender
  - If non-arrival of CTS or ACK, interpret as a collision, and double the contention window, [0, 31] → [0, 63]
  - Schedule a new backoff timer from the new contention window
  - Retransmit when the backoff timer counts down to 0
  - If collided again, double contention window again
  - Until ACK arrives or the maximum attempt number is reached
    - *binary exponential backoff*
  - After a successful transmission, contention window is reset to initial window [0, 31].

Red font: backoff timer

CW: contention window



Summary of CSMA-CA Mechanisms

Mechanism	Objective
ACK	“Collision detection” problem
RTS/CTS	“Hidden station” problem
Binary exponential backoff	Collision avoidance and resolution