# CS120: Computer Networks

## Lecture 7. Multiple Access 2

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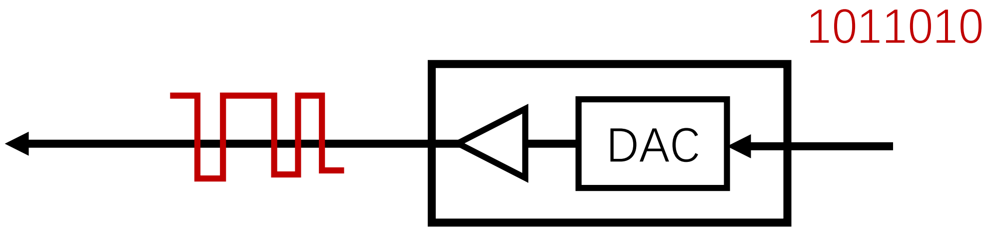
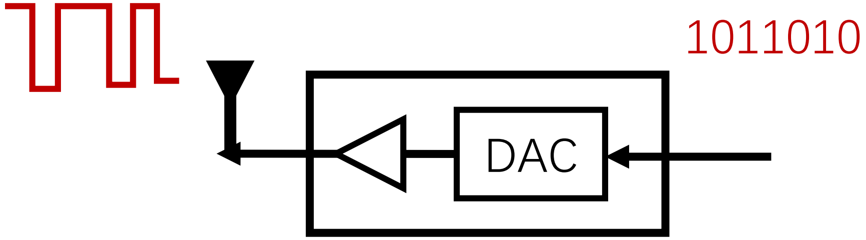
# Outline

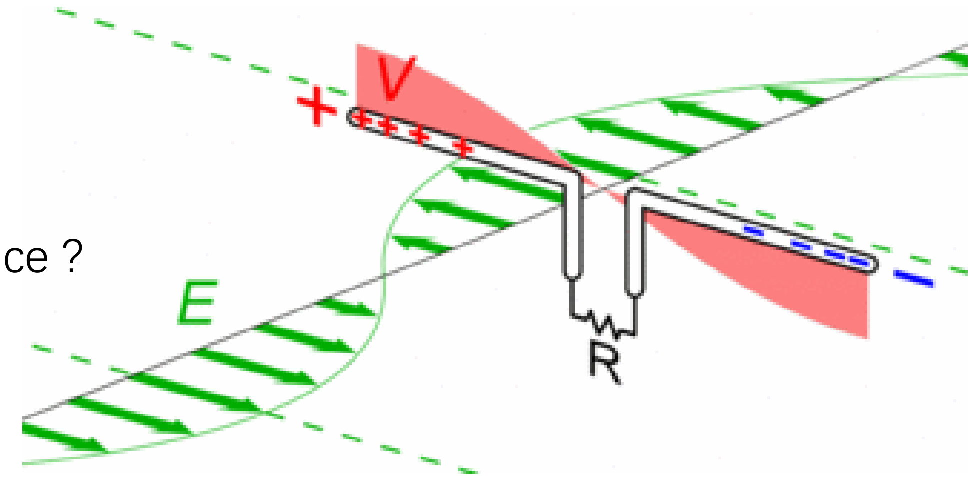
- Wireless MAC
  - Overview of Wireless Technologies
  - WLAN and WLAN MAC
    - CSMA/CD is not feasible
    - Hidden terminal and exposed terminal

# Go to Wireless

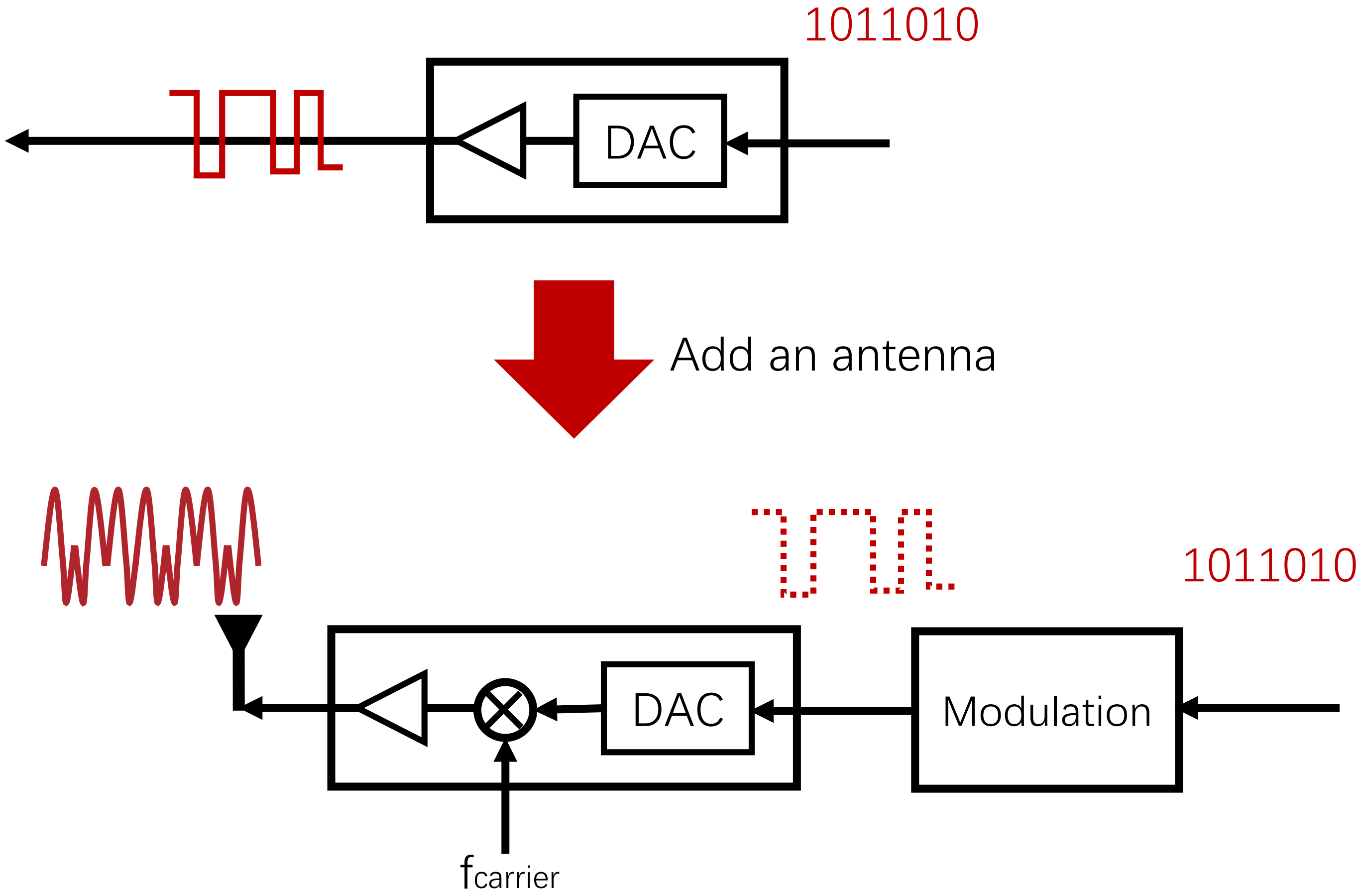



How to transmit out to freespace ?



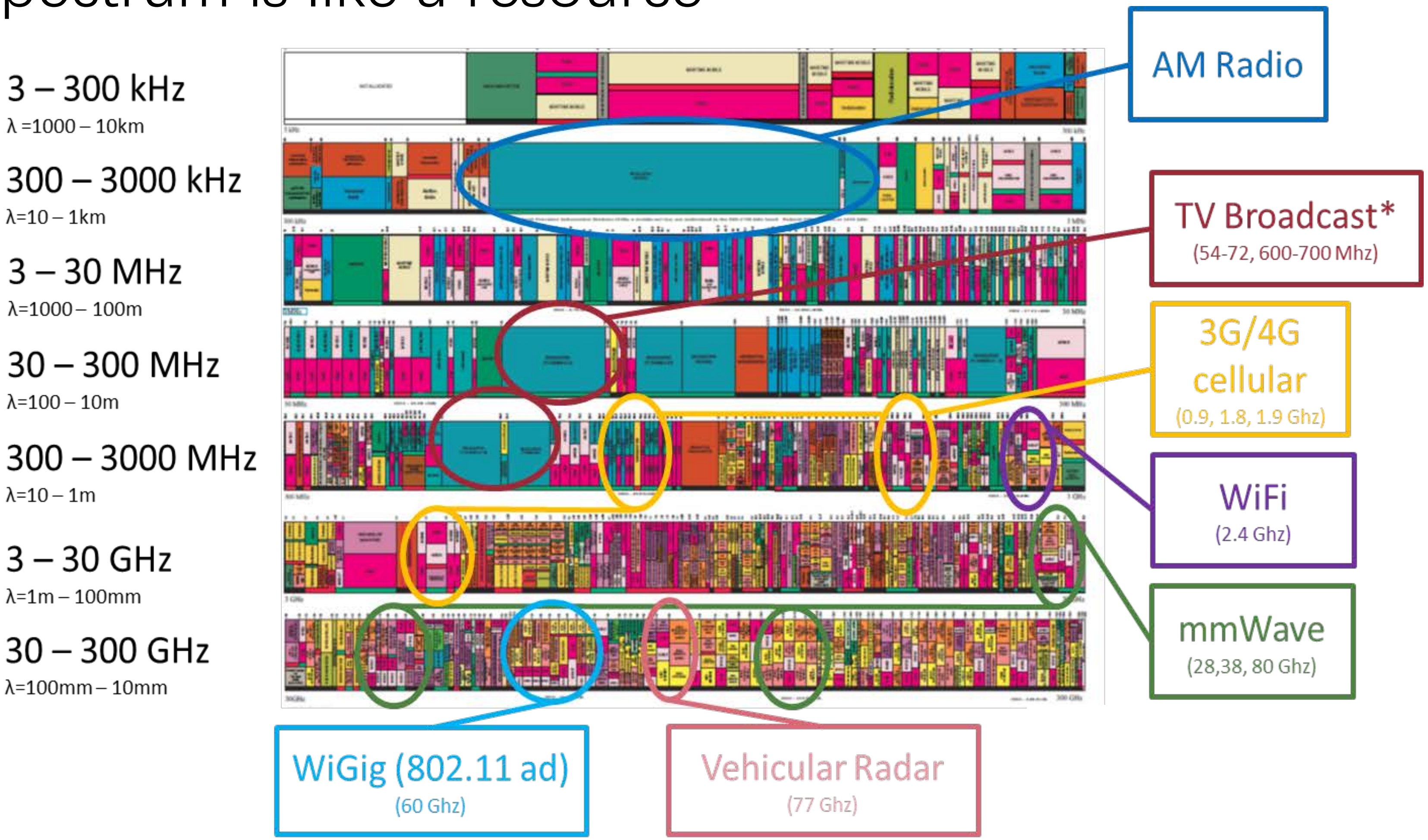
# Go to Wireless




- Two Requirements
  - Antenna
    - Radiate out electromagnetic signal
  - Carrier Wave
    - Choose suitable carrier wave to satisfy communication requirement (coverage, antenna size, spectrum sharing, etc.)
      - Radio: radio band
      - Audio: audio band

# Radio Spectrum Allocation

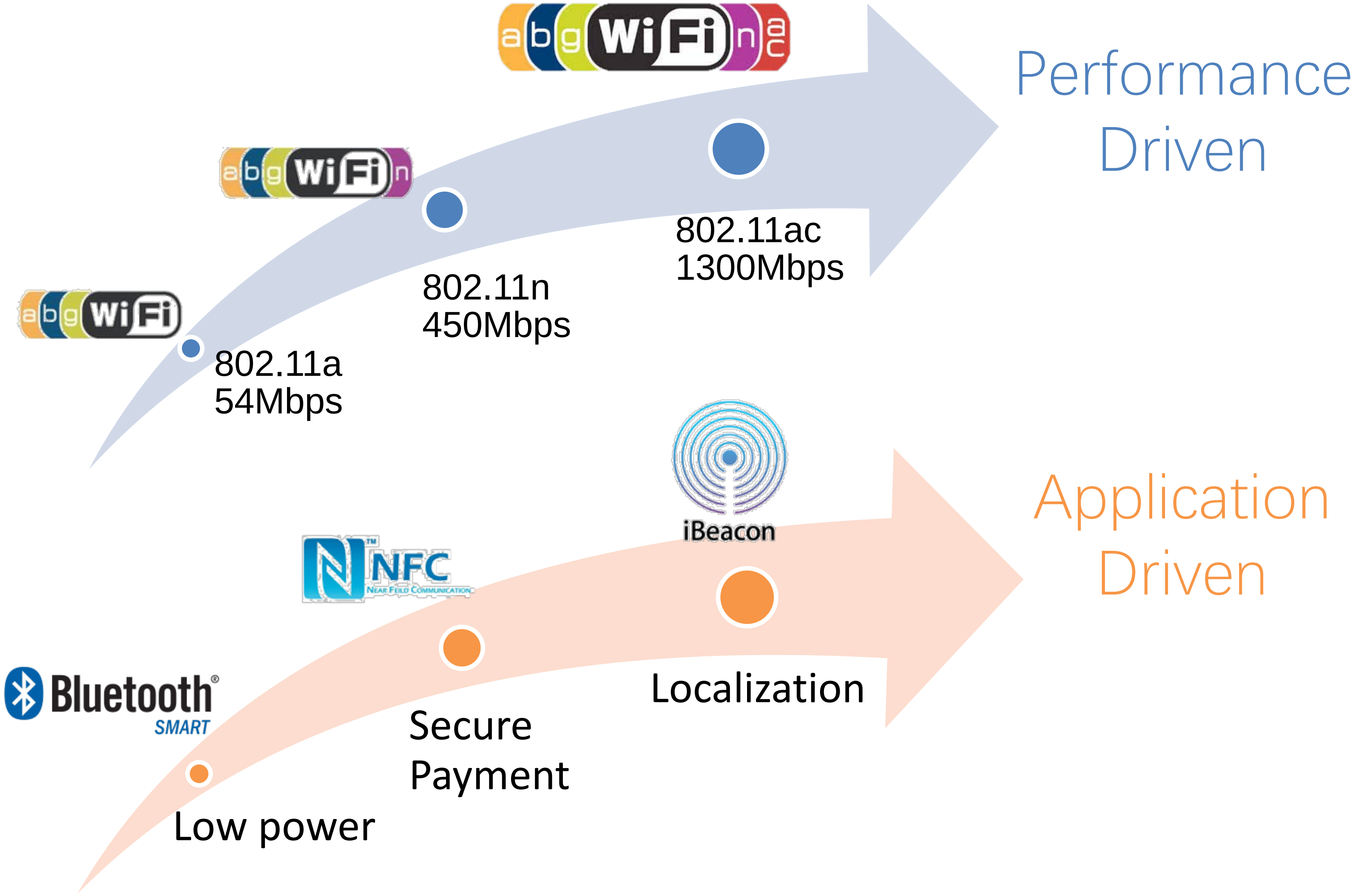
- Radio spectrum is like a resource



# Radio Spectrum Allocation

- Regulation: defines how to use the radio spectrum
  - Price: licensed and unlicensed
  - Frequency bandwidth
  - Power
  - etc.
- Regulatory Agency
  - China: CMIIT
  - U.S.: FCC

# Wireless Technology Overview



# Two Big Players: Wi-Fi and Cellular

**Cellular and Wireless**


| | |
|---|---|
| **Model A1865*** | FDD-LTE (Bands 1, 2, 3, 4, 5, 7, 8, 12, 13, 17, 18, 19, 20, 25, 26, 28, 29, 30, 66) |
| | TD-LTE (Bands 34, 38, 39, 40, 41) |
| | TD-SCDMA 1900 (F), 2000 (A) |
| | CDMA EV-DO Rev. A (800, 1900, 2100 MHz) |
| | UMTS/HSPA+/DC-HSDPA (850, 900, 1700/2100, 1900, 2100 MHz) |
| | GSM/EDGE (850, 900, 1800, 1900 MHz) |
| **All models** | 802.11ac Wi-Fi with MIMO |
| | Bluetooth 5.0 wireless technology |
| | NFC with reader mode |

# Two Big Players: Wi-Fi and Cellular

Telephone



Cellular

Ethernet

WLAN (Wi-Fi)

# Two Big Players: Wi-Fi and Cellular

Telephone

Microcell

Cellular

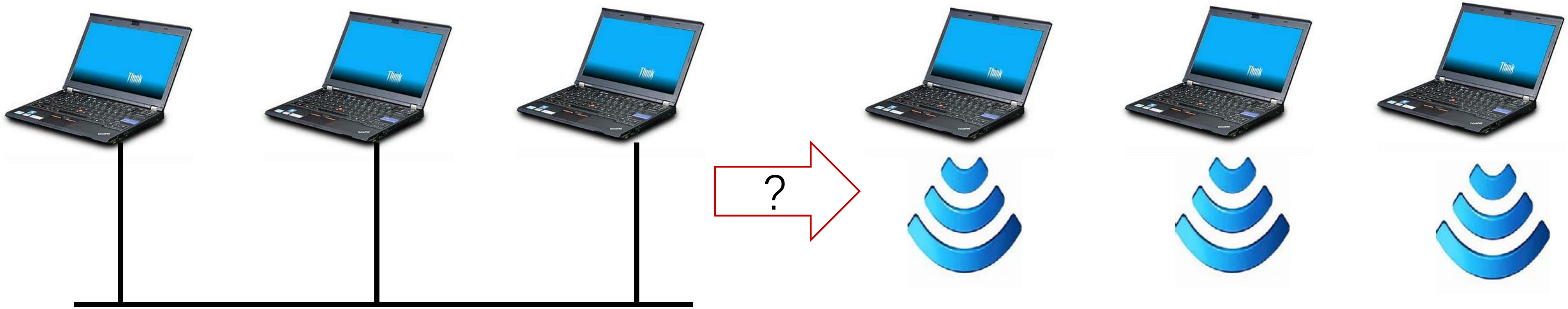
Ethernet

WLAN (Wi-Fi)

WiMAX

# WLAN

- Wireless Local Area Network
  - The original goal is to design a “wireless” LAN



# Reconsider CSMA/CD in Ethernet

- Assumptions:
  - Full Duplex: transceiver can send/receive concurrently
    - To detect collision while transmitting
  - Symmetry: signals are identical at all receivers
    - Collision is detected when transmitting => collision at receiver

Ethernet transceiver can detect collision
when collision occurs at the receiver

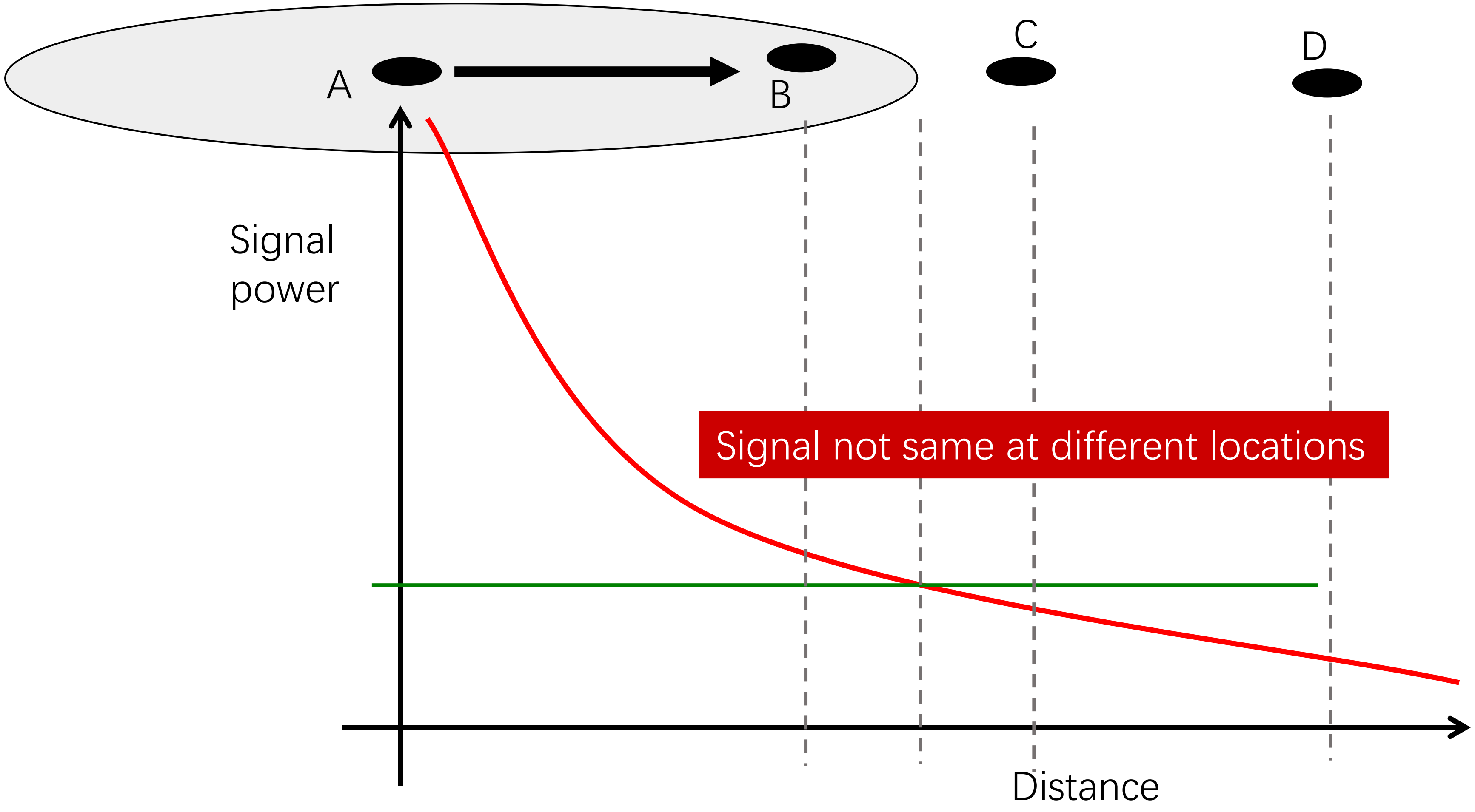
# How about the Wireless Situation

- Assumptions of CSMA/CD
  - ✗ Full Duplex: transceiver can send/receive concurrently
  - ✗ Symmetry: signals are identical at all receivers

Is CSMA possible?

# CSMA/CD are not Feasible in Wireless Situation

A cannot send and listen in parallel




Signal not same at different locations

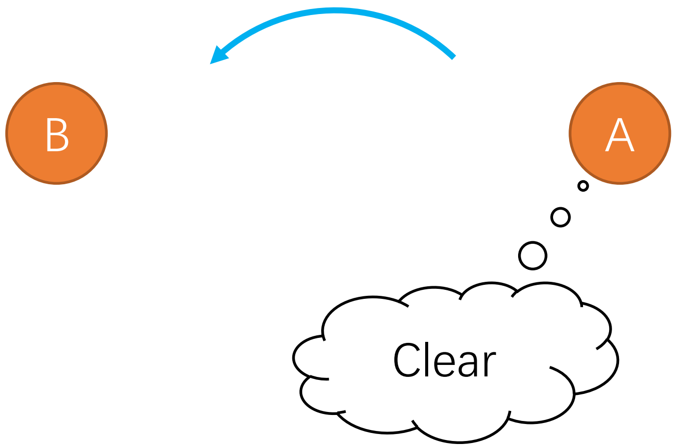
# How about the Wireless Situation

- Assumptions of CSMA/CD
  - ✗ Full Duplex: transceiver can send/receive concurrently
  - ✗ Symmetry: signals are identical at all receivers

How about CSMA?

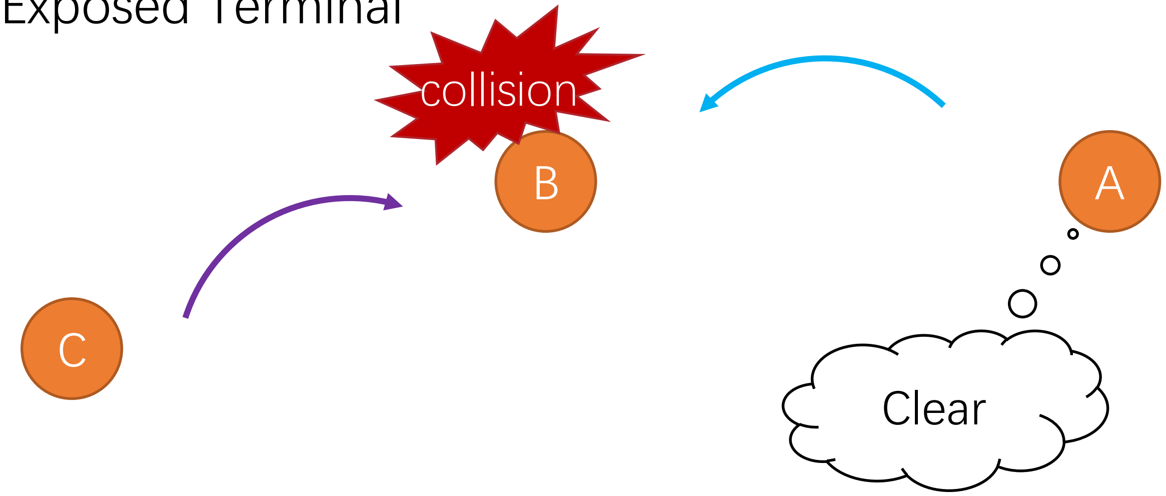
# How about the Wireless Situation

- Consider CSMA in Wireless Situation

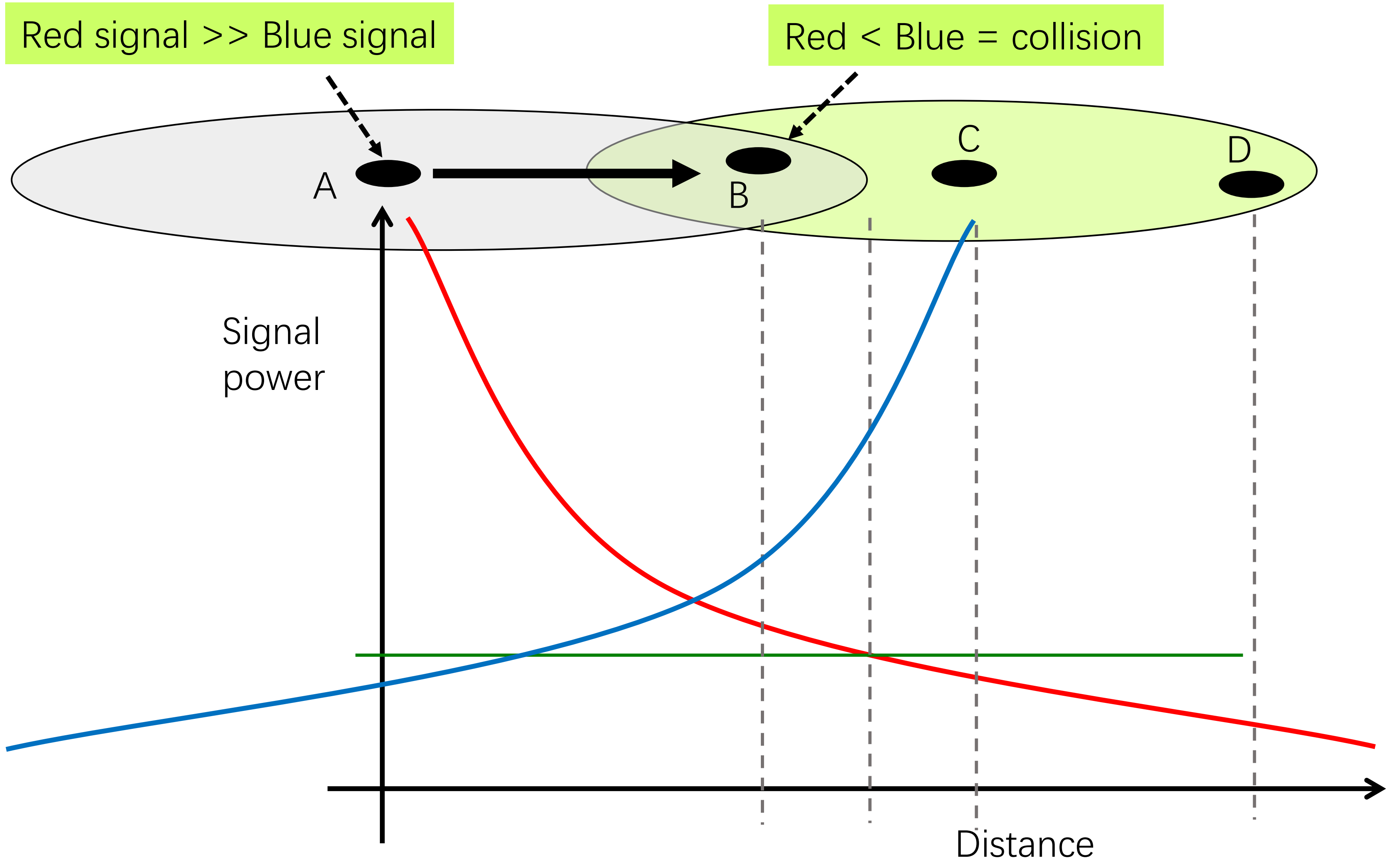


# How about the Wireless Situation

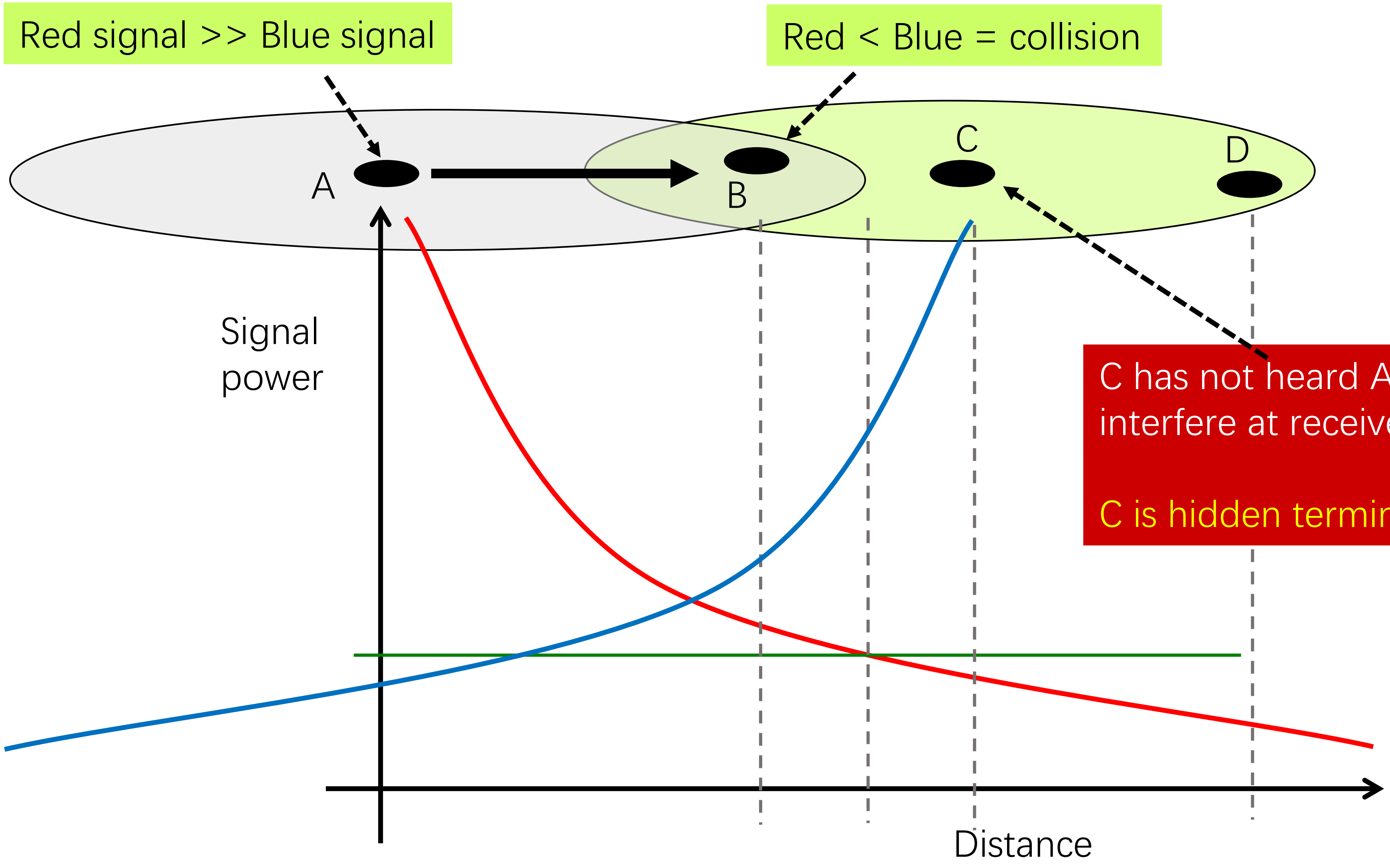
- Consider CSMA in Wireless Situation
  - Not as good as wired situation
    - Hidden Terminal
    - Exposed Terminal



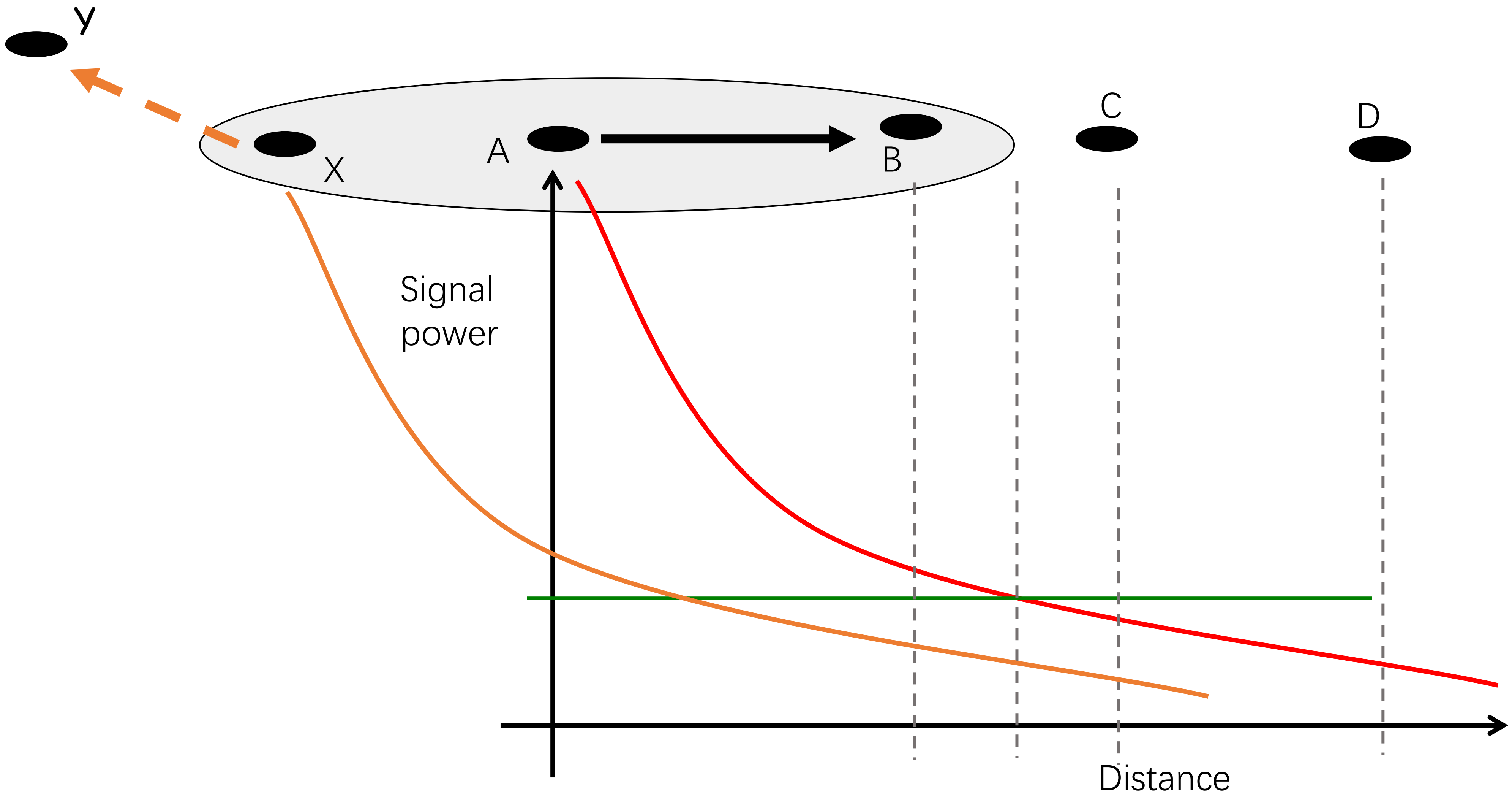
# Hidden Terminal



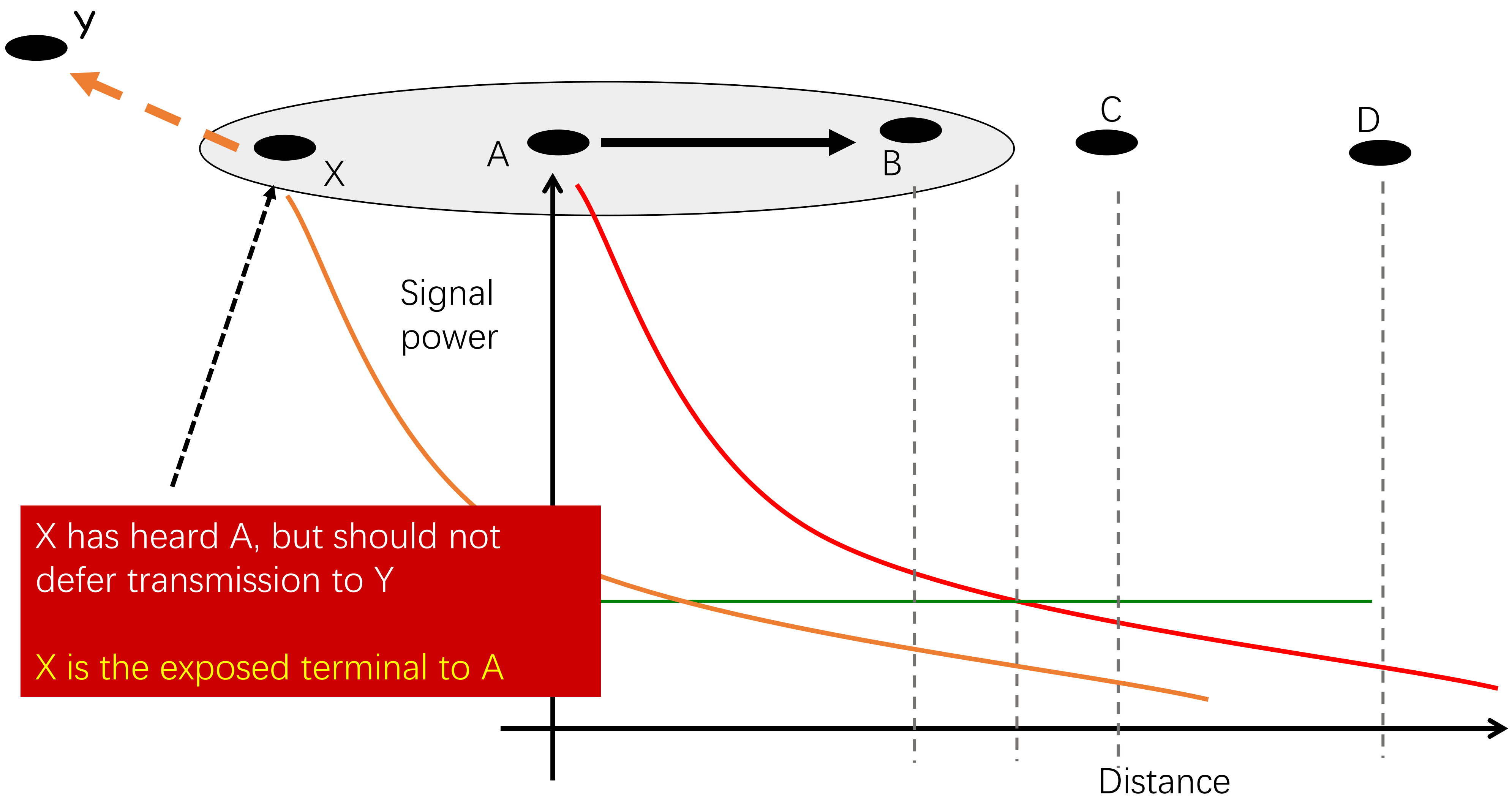
# Hidden Terminal



# Exposed Terminal



# Exposed Terminal




X has heard A, but should not defer transmission to Y

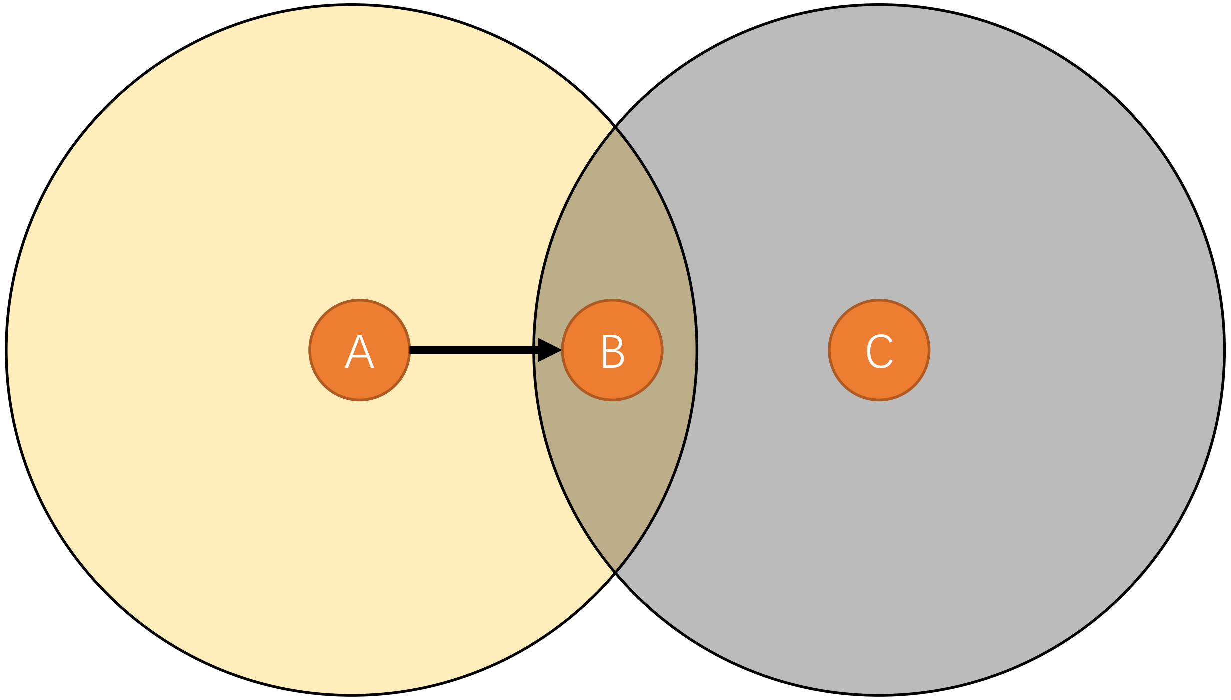
X is the exposed terminal to A

# Wireless LAN MAC

- Consider CSMA in Wireless Situation
  - Not as good as wired situation
    - Hidden Terminal
    - Exposed Terminal
- CSMA/CA
  - CA stands for collision avoidance
    - CTS/RTS scheme

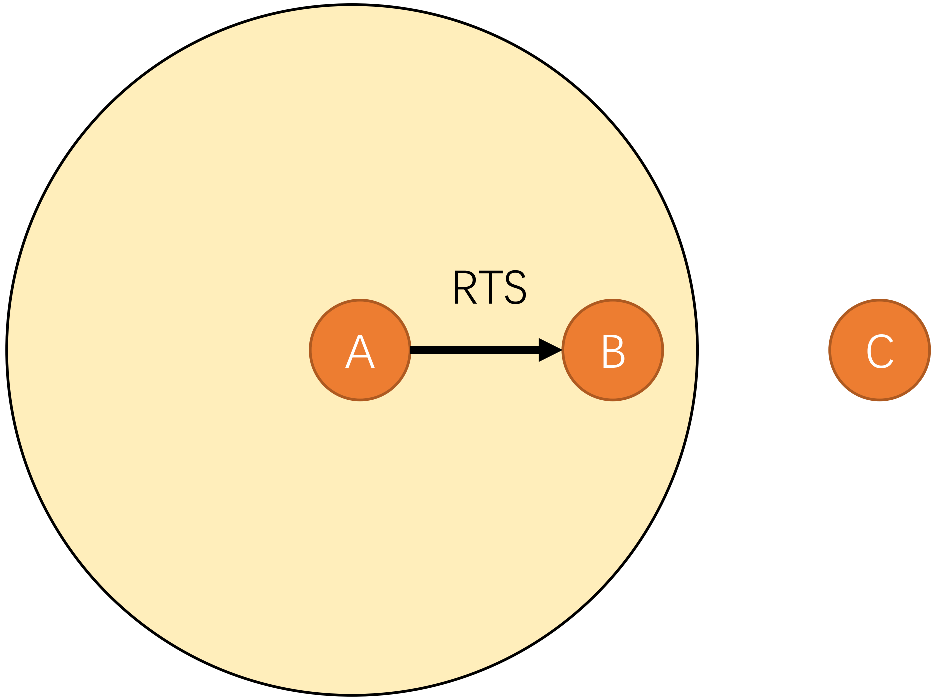
# RTS/CTS

- A wants to transmit to B, but C may interfere B



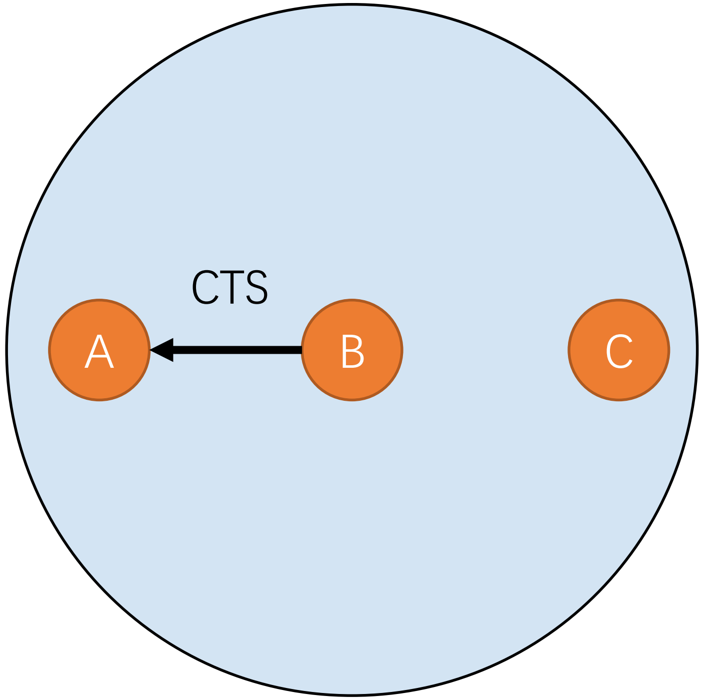
# RTS/CTS

- A transmits a short packet to B and announces the expected transmission duration
  - Request to Send (RTS)



# RTS/CTS

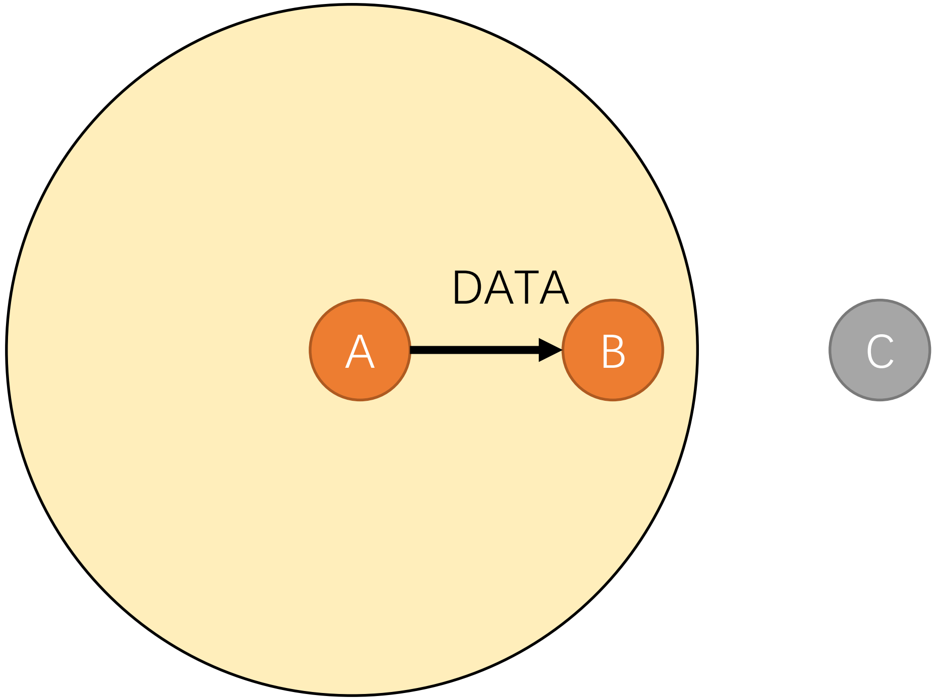
- B transmits a short packet to A and announces the expected transmission duration
  - Clear to Send (CTS)




C can hear CTS and knowns that there will be transmission soon

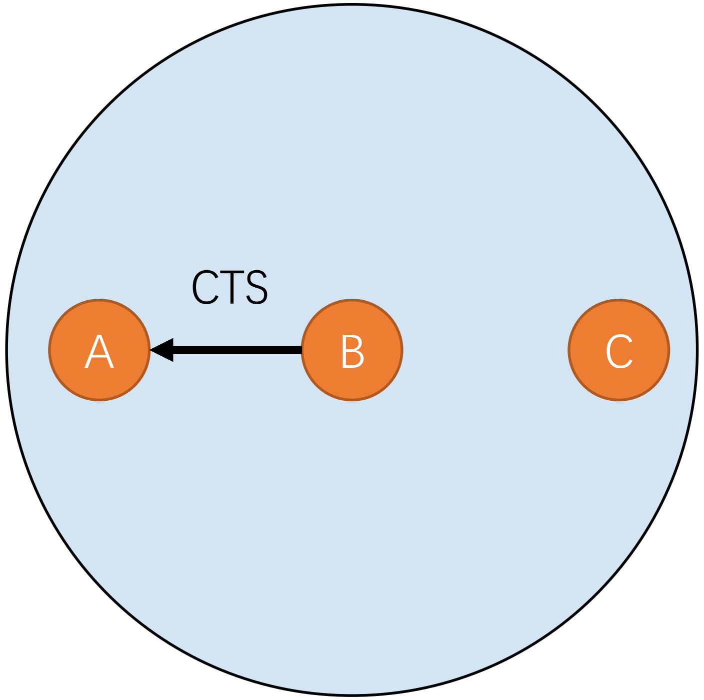
# RTS/CTS

- C knows the expected transmission duration from CTS and defers
  - Avoids the hidden terminal problem



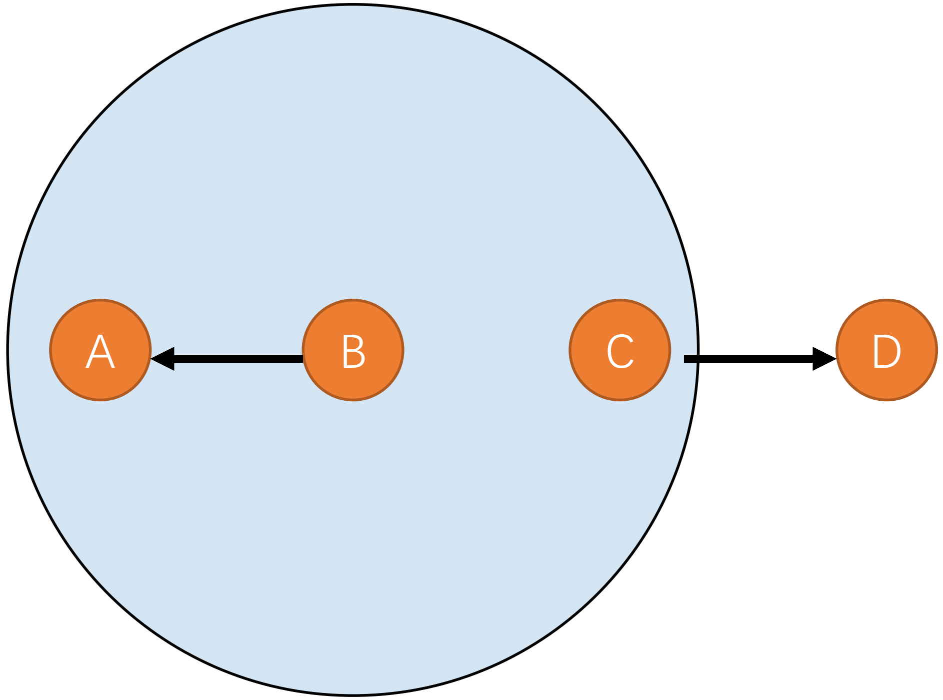
# RTS/CTS

- However
  - If CTS is lost at C, C can still interfere B



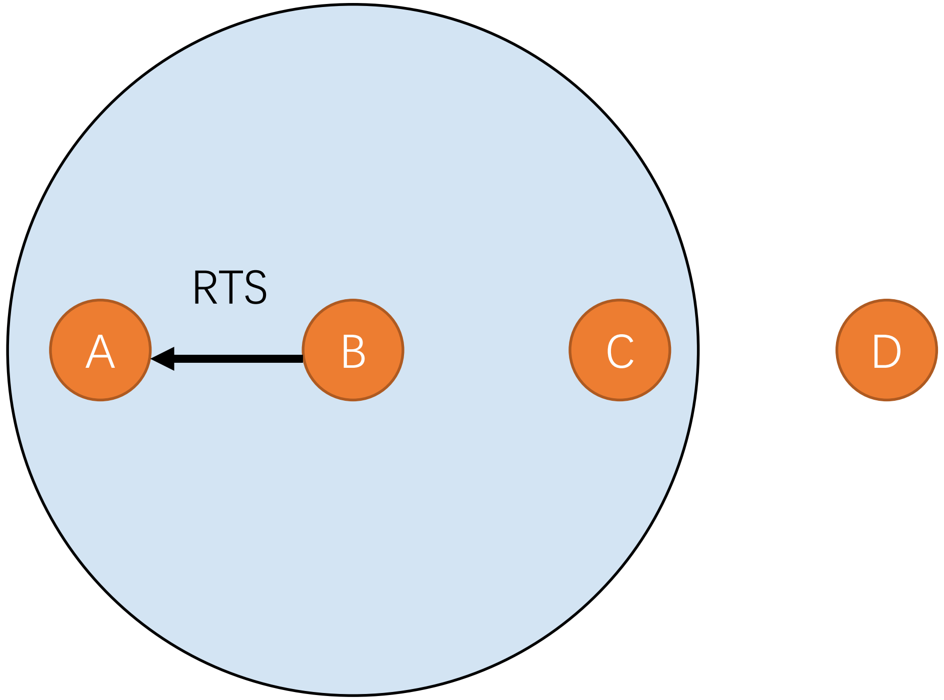
# RTS/CTS

- C wants to transmit to D, but B may interfere C.



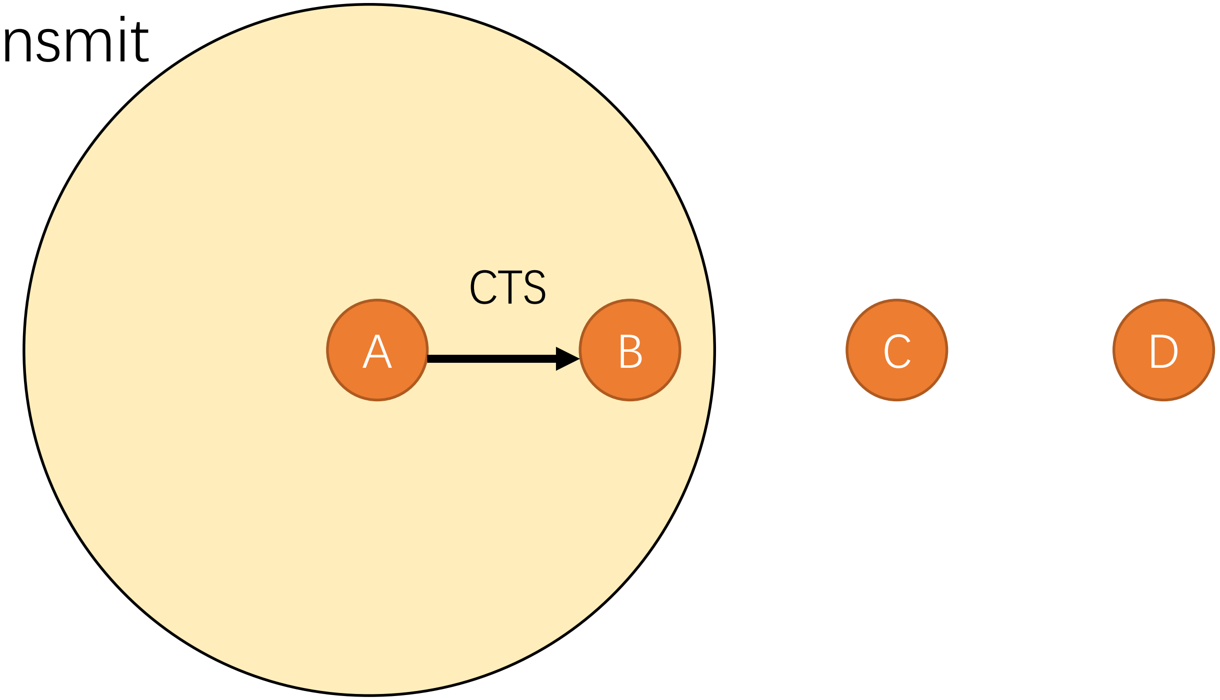
# RTS/CTS

- B sends RTS. C waits CTS packet.
  - CTS packets must be replied within a short period of time



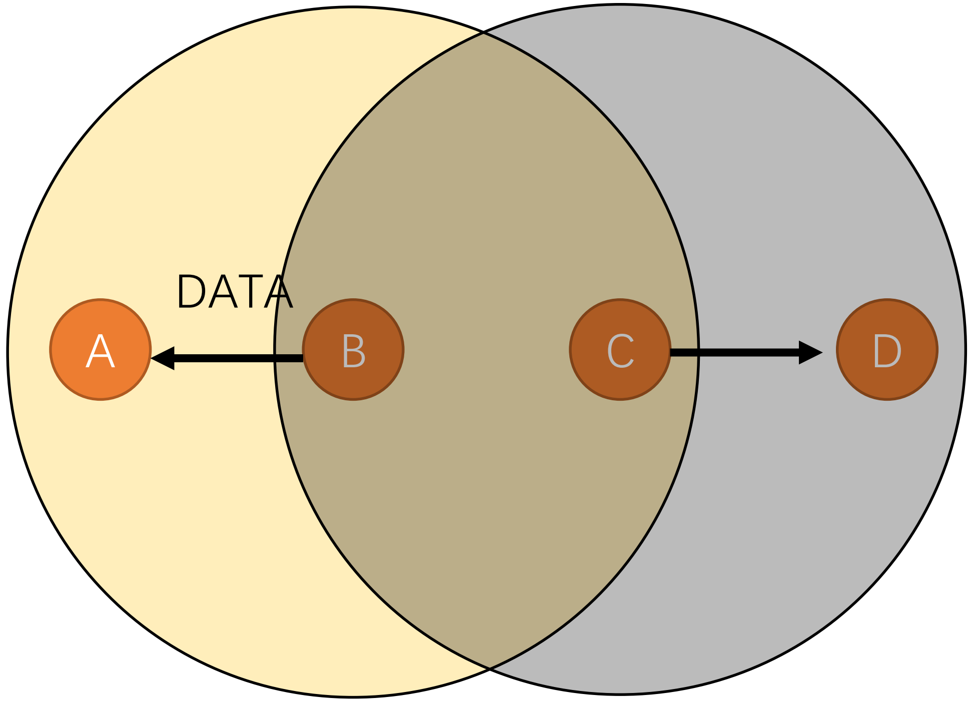
# RTS/CTS

- C does not hear CTS packet.
  - C is not in the coverage of B's receiver (A)
  - B's receiver (A) is not in the coverage of C
  - C can transmit



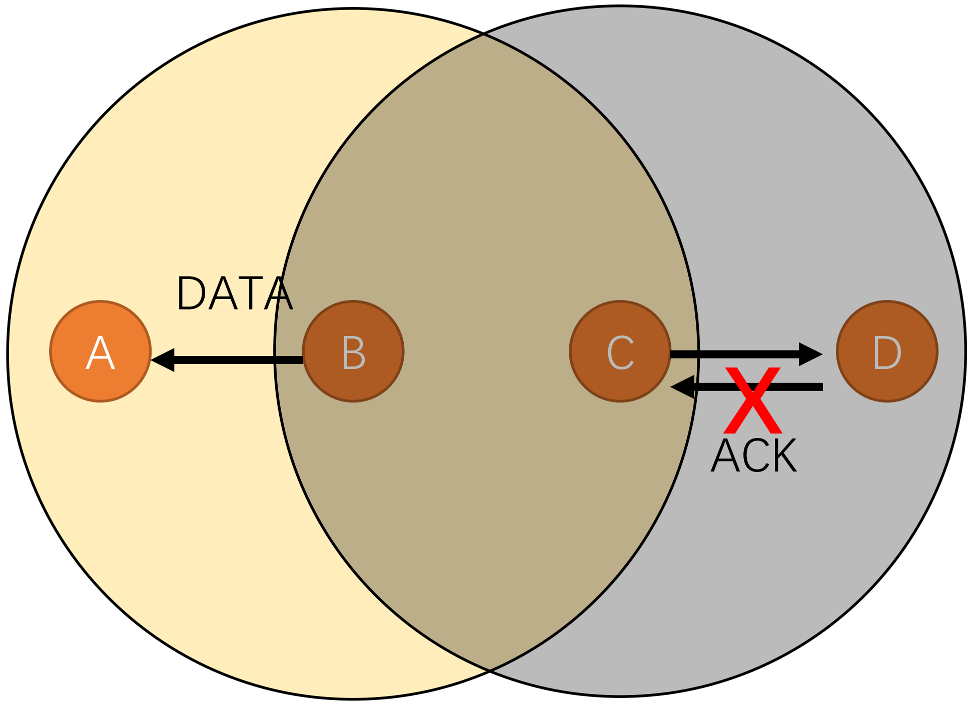
# RTS/CTS

- C transmits to D
  - Avoids the exposed terminal problem



# RTS/CTS

- However
  - ACK is interfered

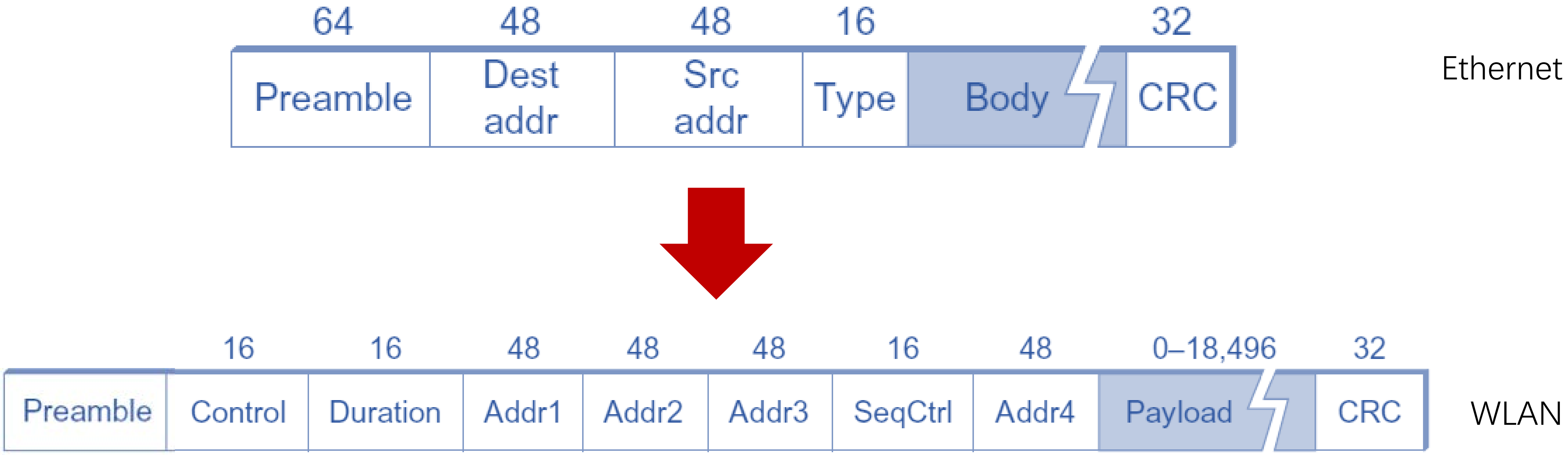


# RTS/CTS

- RTS/CTS does not solve hidden terminal and exposed terminal completely
- Designing Wireless MAC is non-trivial

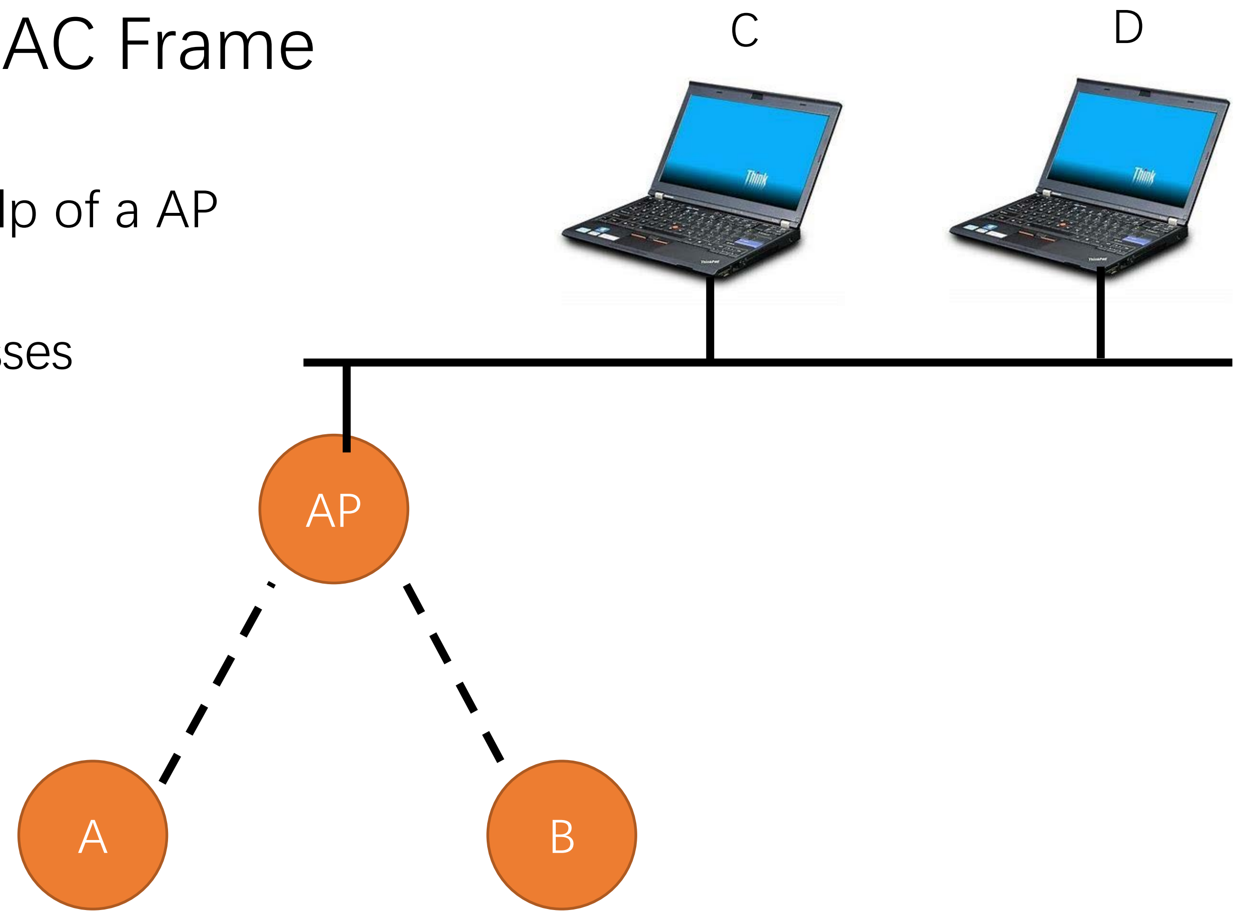
# IEEE 802.11 MAC

- The Wireless LAN is standard by IEEE 802.11
  - “Wi-Fi” is a certification trademark of IEEE 802.11



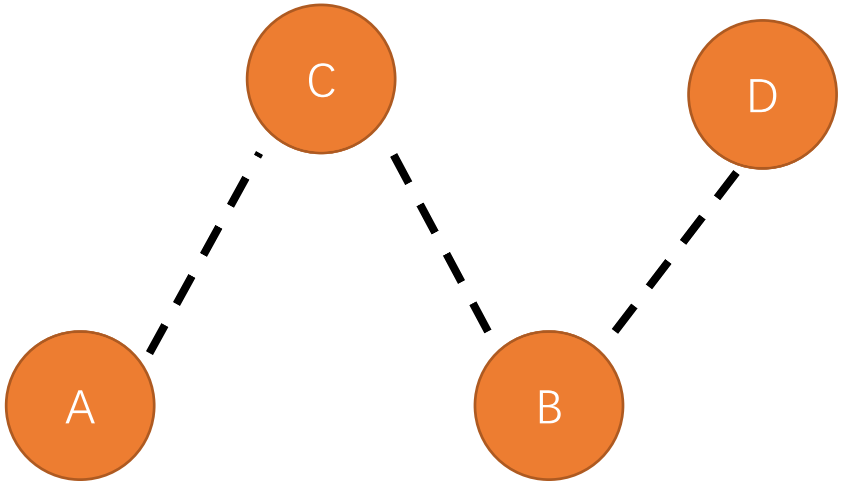
# IEEE 802.11 MAC

- Four Address Fields in MAC Frame
  - AP mode
    - Communicate with the help of a AP
    - A -> AP: two addresses
    - A -> AP->B: three addresses



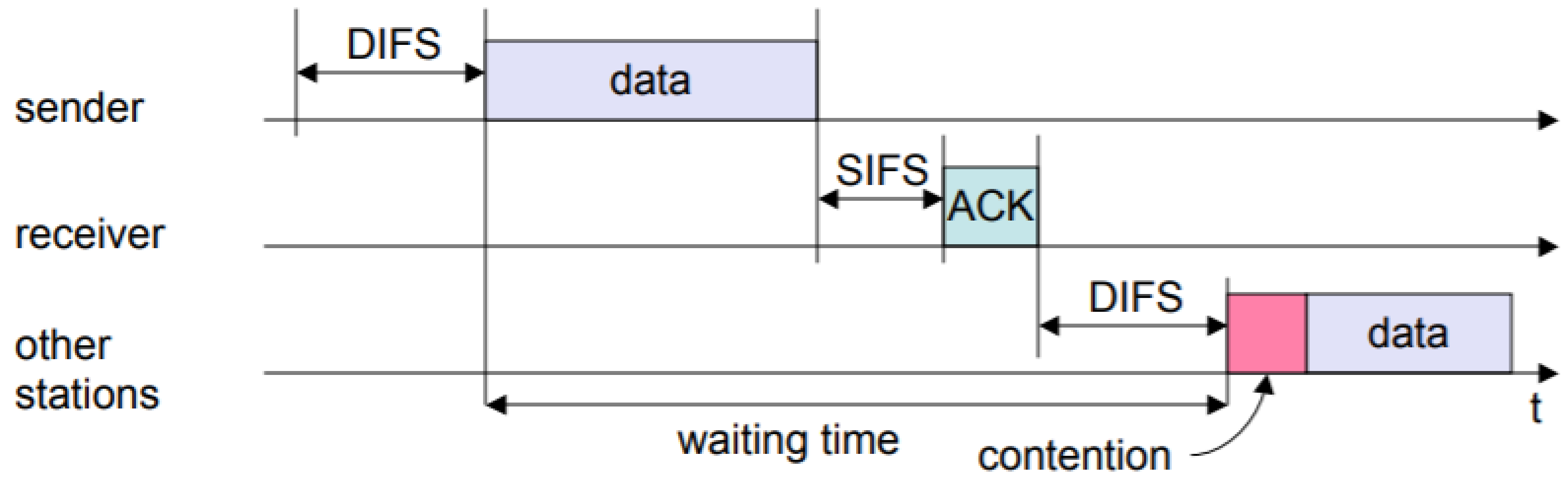
# IEEE 802.11 MAC

- Four Address Fields in MAC Frame
  - AP mode
    - Communicate with the help of a AP
    - A -> AP: two addresses
    - A -> AP->B: three addresses
  - ad-hoc mode
    - Directly communicate with each peer
    - A -> C -> B->D: four addresses



# IEEE 802.11 MAC

- Sender has to wait for DIFS before sending data
- Receivers acknowledge at once (after waiting for SIFS) if the packet was received correctly (CRC)

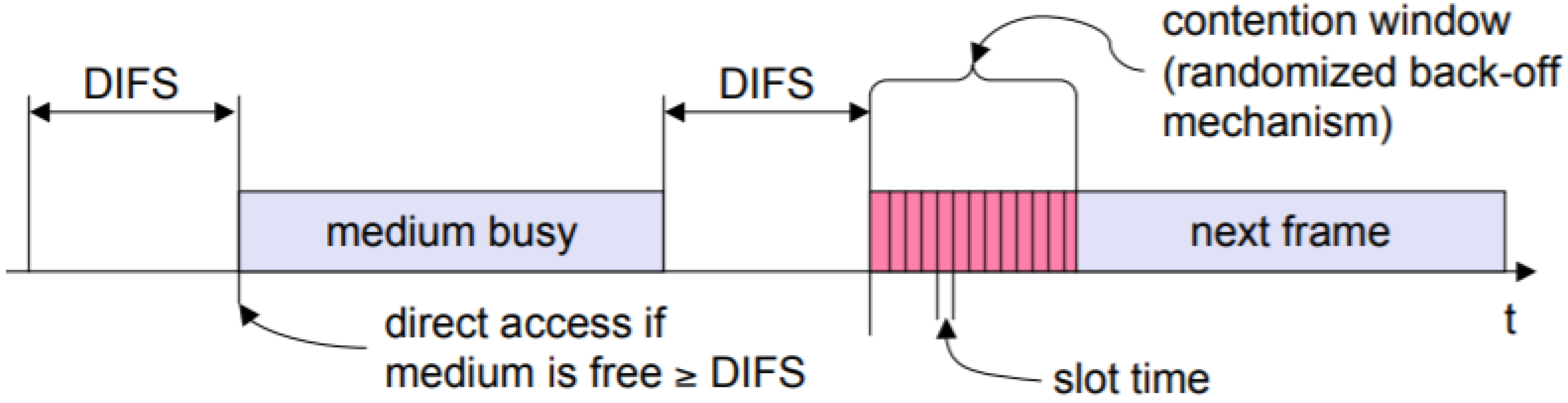


# SIFS & DIFS

- Short Inter Frame Space (SIFS)
  - SIFS = round trip propagation delay + processing delay
  - Ensure nodes at coverage edge can correctly send and receive ACK
- DCF Inter Frame Space (DIFS)
  - DISF = SIFS+2*slots
  - Ensure frames transmit with SIFS, eg, ACK, RTS, etc., will not be interfered

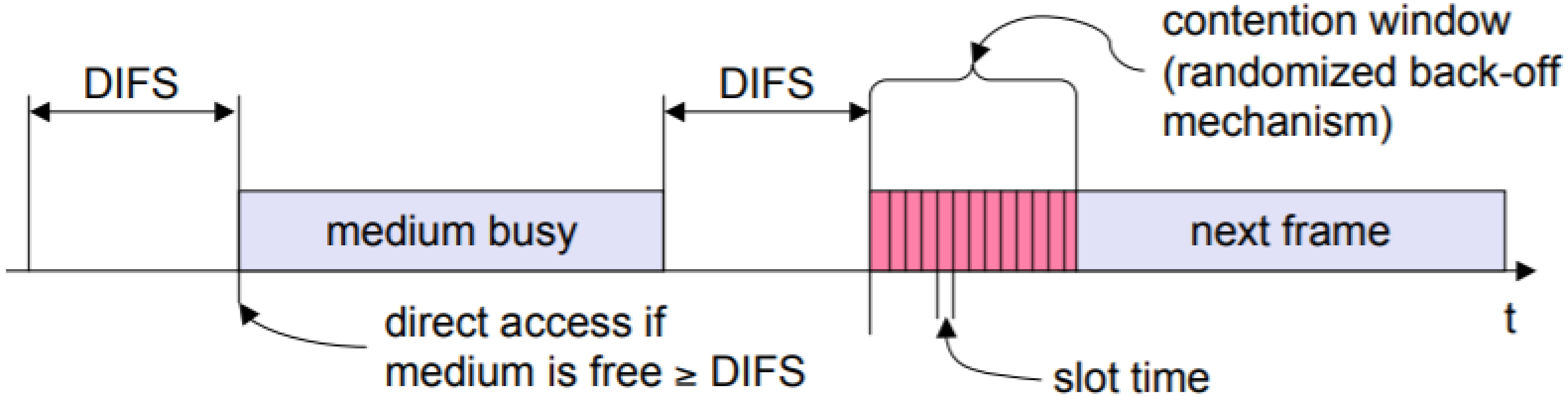
# Exponential Backoff

- All backlogged nodes choose a random number
  - R = rand (0, CW_min)
- Each node counts down R
  - Continue carrier sensing while counting down
  - Once carrier busy, freeze countdown
- Whoever reaches ZERO sends data
  - Neighbors freeze countdown



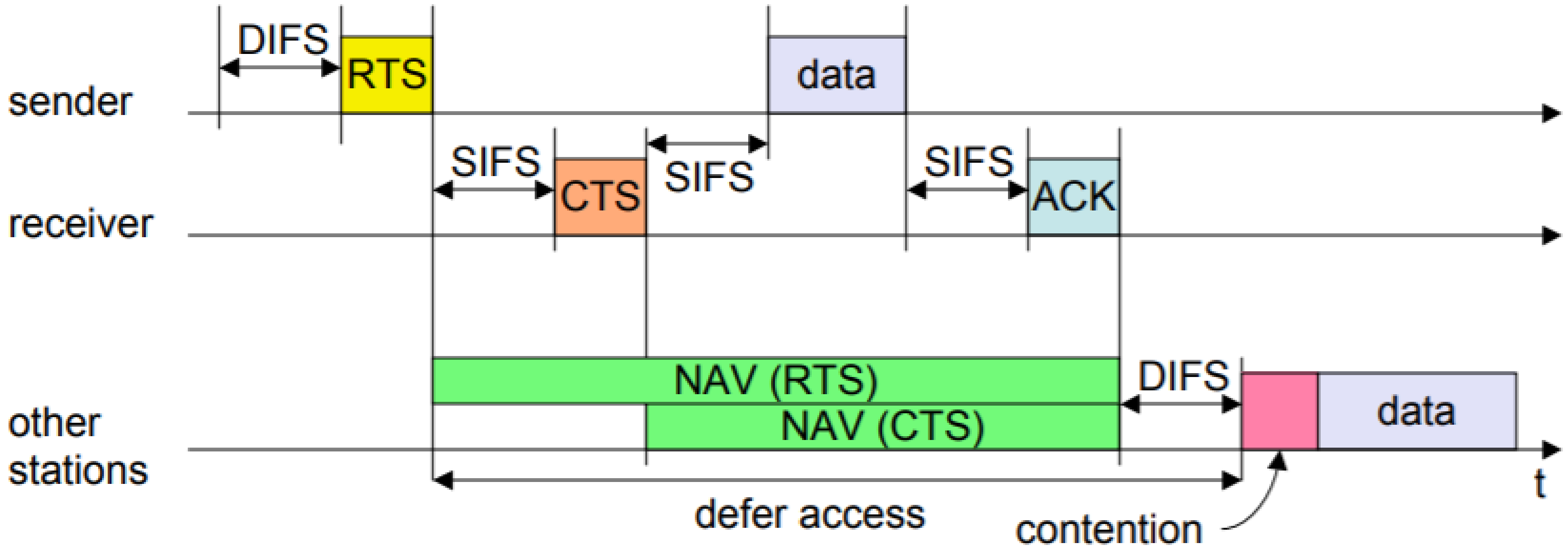
# Exponential Backoff

- Receiver replies with ACK
  - After ACK, everyone initiates remaining countdown
  - Tx chooses new R = rand (0, CW_min)
- If DATA collides, i.e. no ACK
  - Chooses new random number R = rand (0, 2*CW_min)

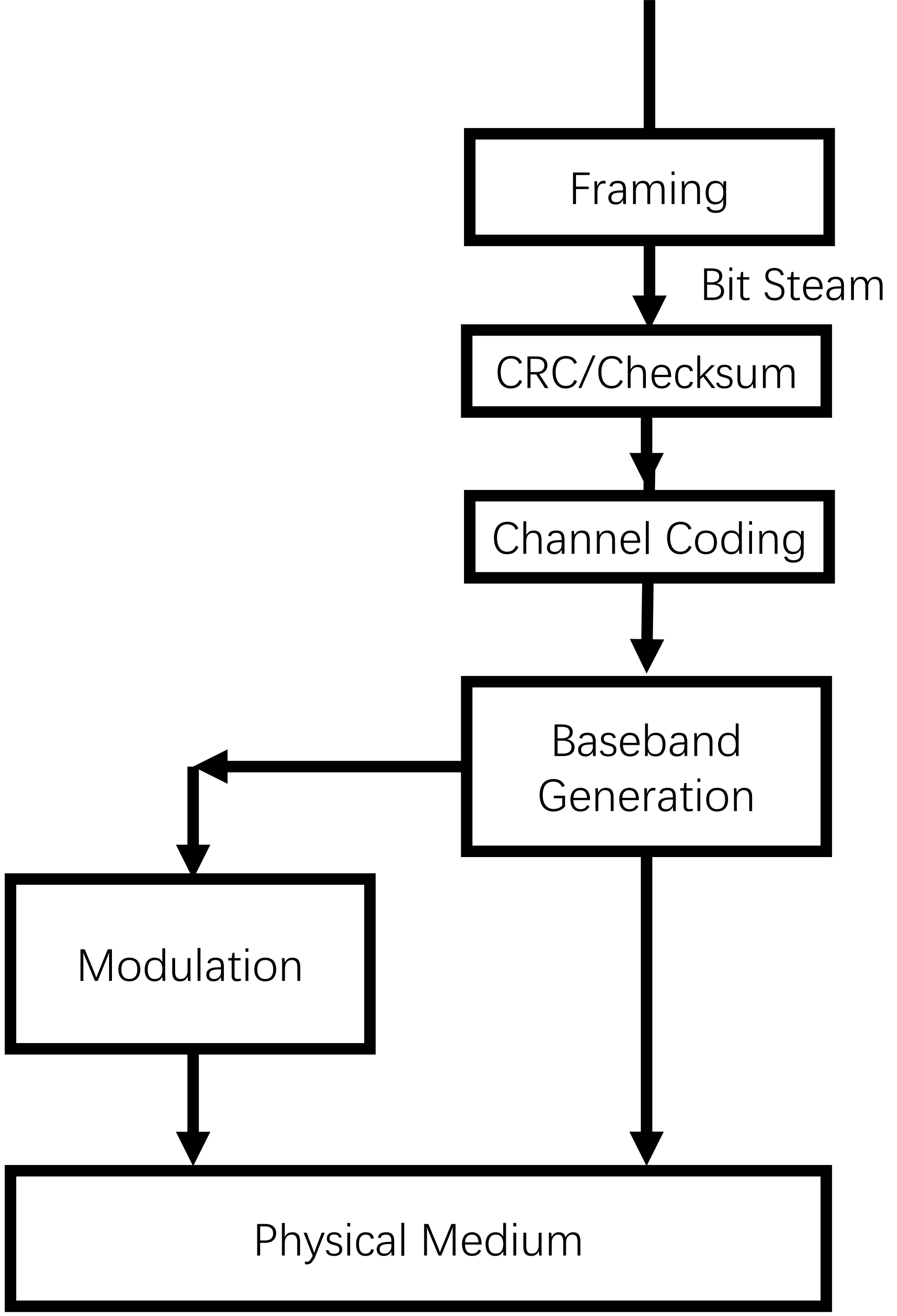


# IEEE 802.11 MAC

- With RTS/CTS

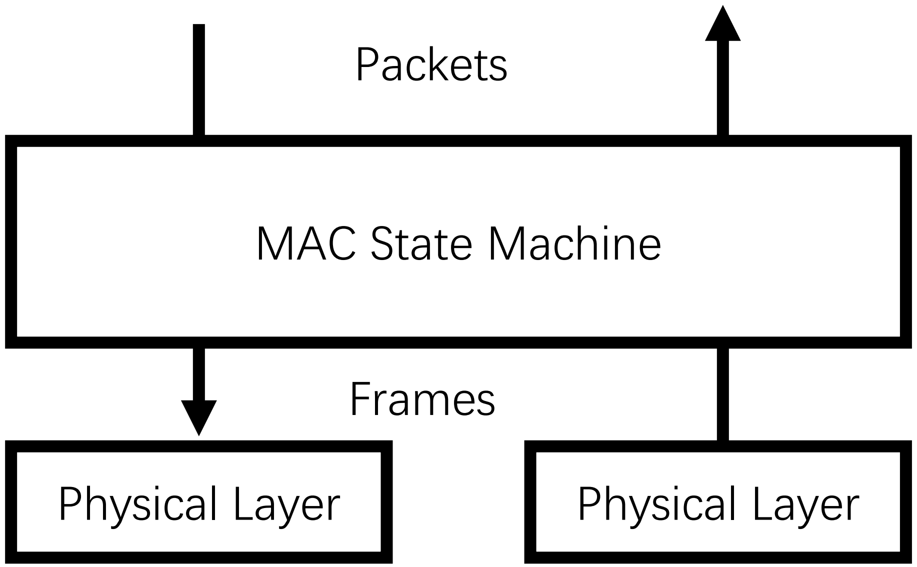


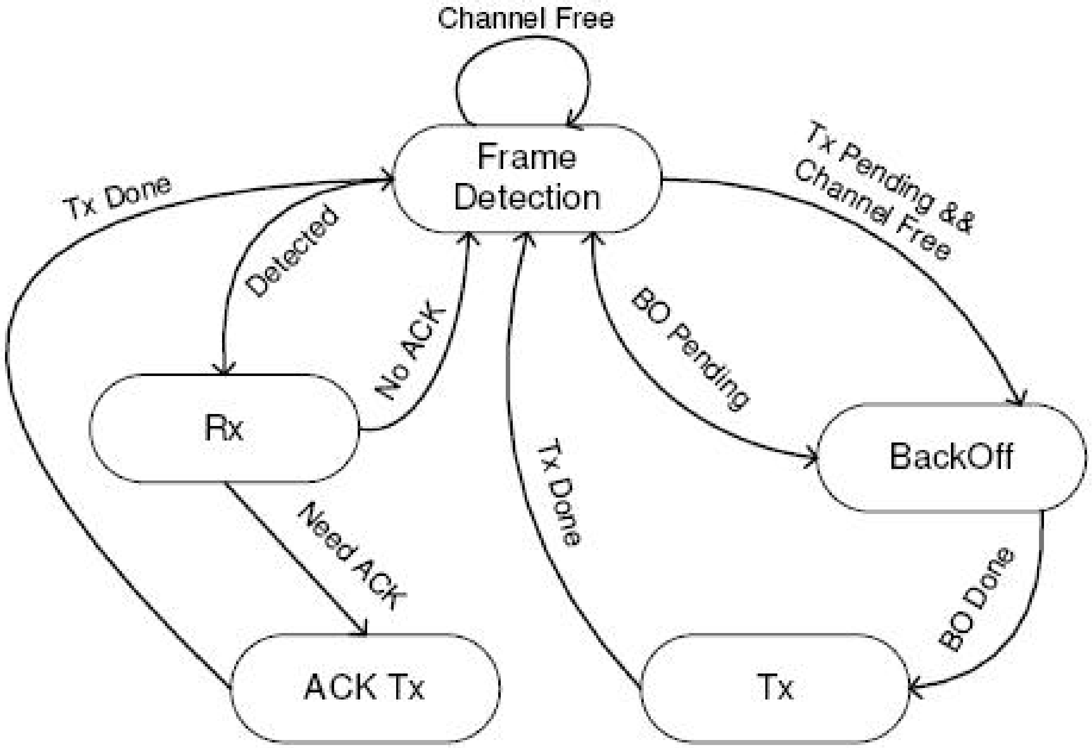
# By Now



Framing
Bit Steam
CRC/Checksum
Channel Coding
Baseband Generation
Modulation
Physical Medium

# By Now


Packets
MAC State Machine
Frames
Physical Layer
Physical Layer


Channel Free
Frame Detection
Tx Done
Detected
No ACK
Tx Pending && Channel Free
BO Pending
Rx
BackOff
Need ACK
Tx Done
BO Done
ACK Tx
Tx