CS120: Computer Networks

Lecture 7. Multiple Access 2

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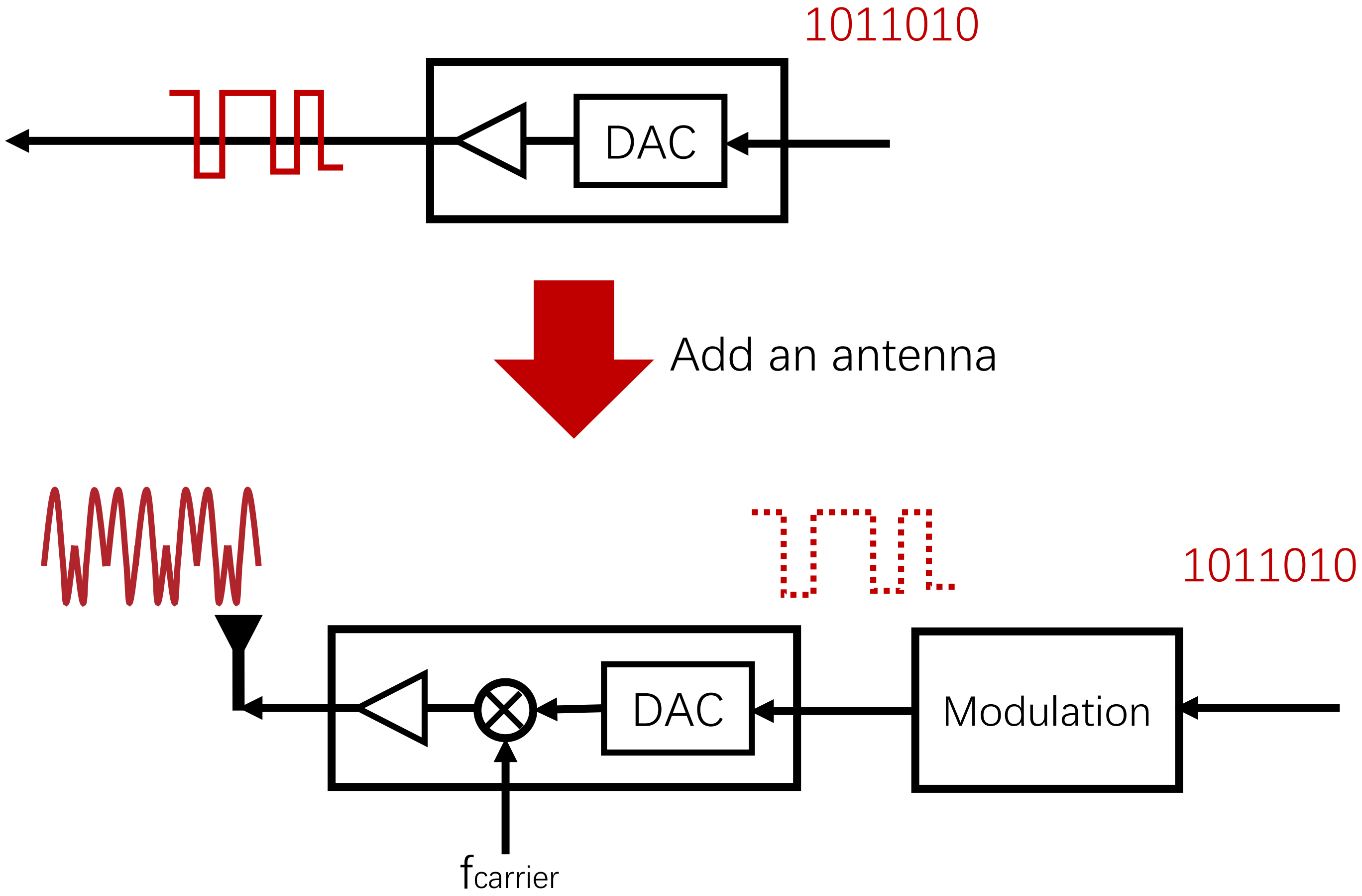
Outline

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

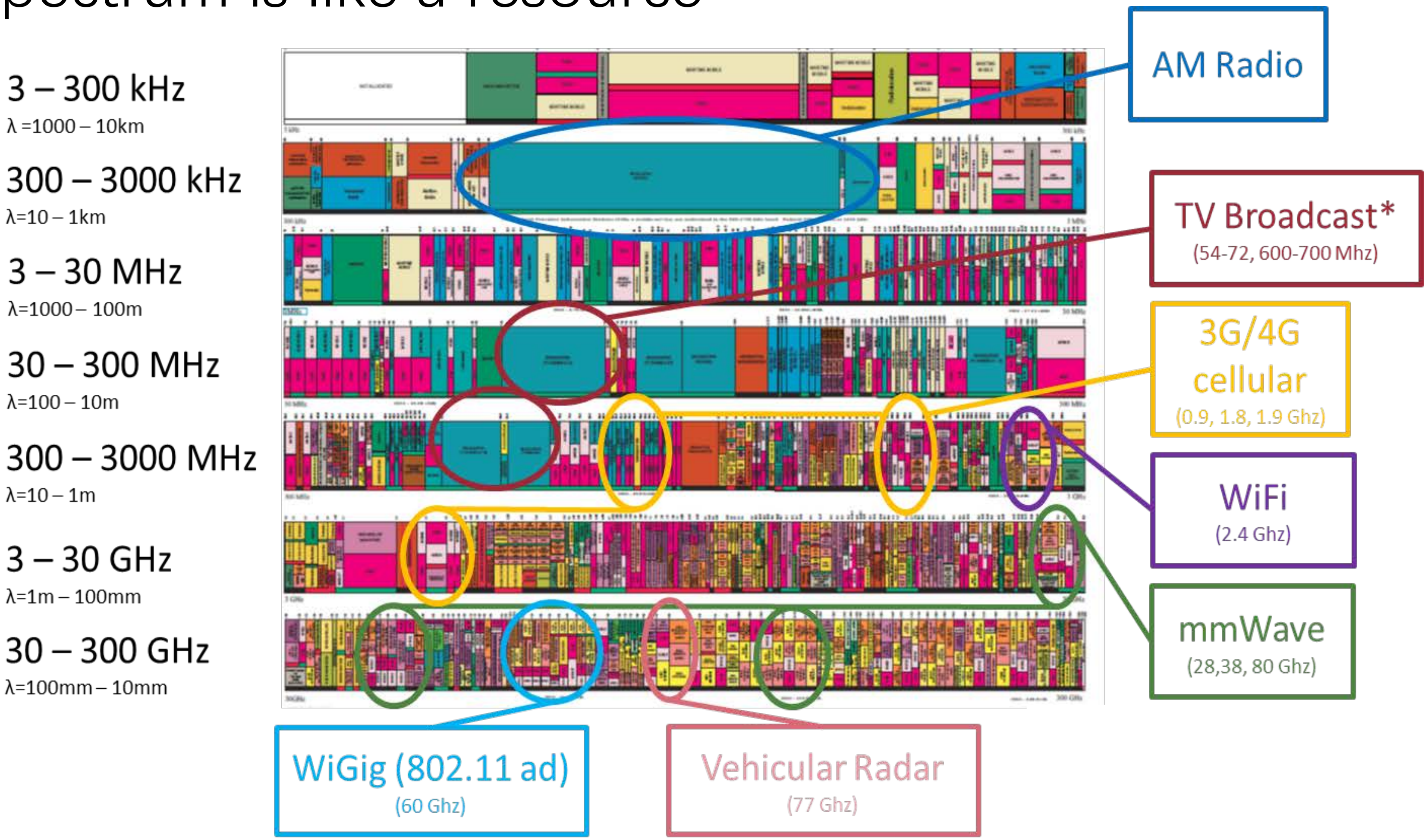
Go to Wireless



- 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

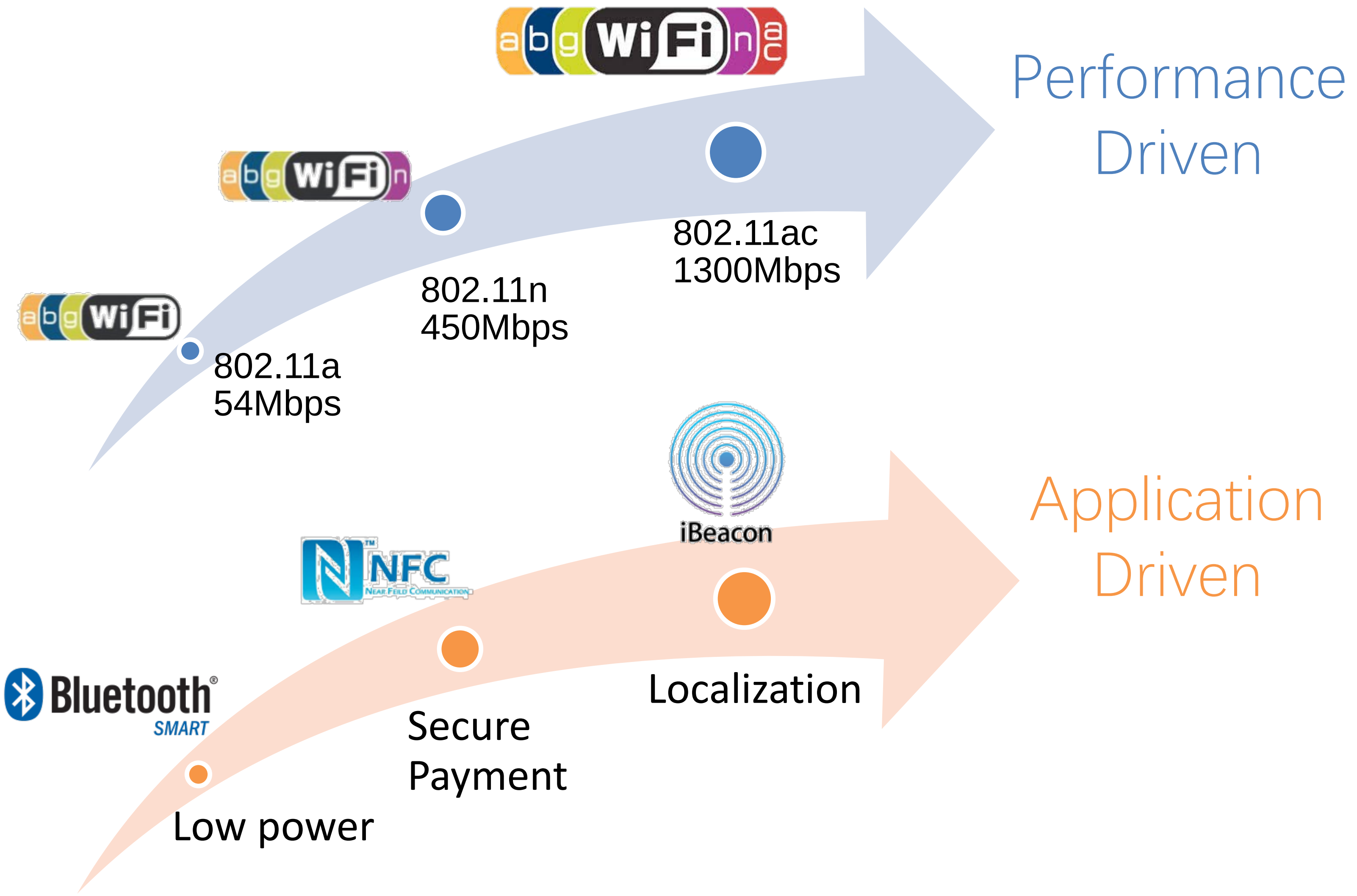
- Radio spectrum is like a resource



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

Model A2651*	5G NR (Bands n1, n2, n3, n5, n7, n8, n12, n14, n20, n25, n26, n28, n29, n30, n38, n40, n41, n48, n53, n66, n70, n71, n77, n78 n79)
	5G NR mmWave (Bands n258, n260, n261)
	FDD-LTE (Bands 1, 2, 3, 4, 5, 7, 8, 12, 13, 14, 17, 18, 19, 20, 25, 26, 28, 29, 30, 32, 66, 71)
	TD-LTE (Bands 34, 38, 39, 40, 41, 42, 46, 48, 53)
	UMTS/HSPA+/DC-HSDPA (850, 900, 1700/2100, 1900, 2100 MHz)
	GSM/EDGE (850, 900, 1800, 1900 MHz)
All models	5G (sub-6 GHz and mmWave) with 4x4 MIMO[8]
	Gigabit LTE with 4x4 MIMO and LAA[8]
	Wi-Fi 6 (802.11ax) with 2x2 MIMO
	Bluetooth 5.3
	Ultra Wideband chip for spatial awareness[9]
	NFC with reader mode
	Express Cards with power reserve

Two Big Players: Wi-Fi and Cellular

Telephone

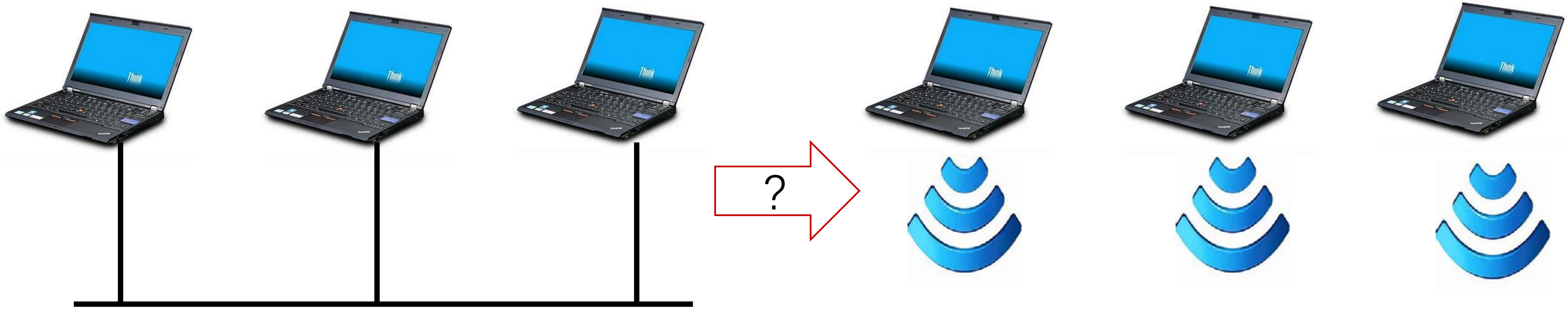
Cellular

Ethernet

WLAN (Wi-Fi)

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 at transmitter => collision at receiver

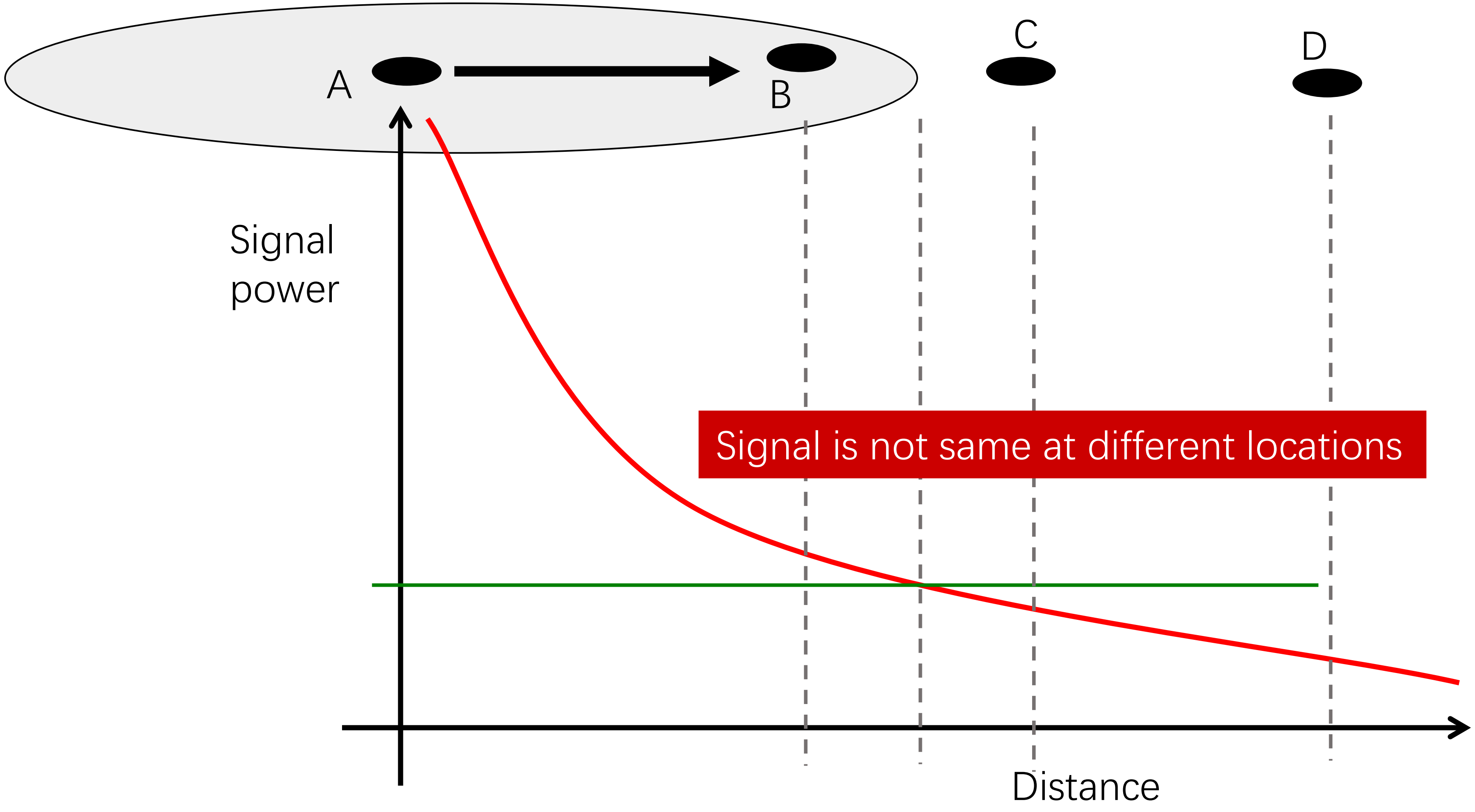
Ethernet transceiver can detect collision when collision occurs at the receiver

Apply CSMA/CD to Wireless Situation

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

Why ?

A cannot send and listen in parallel



Signal is not same at different locations

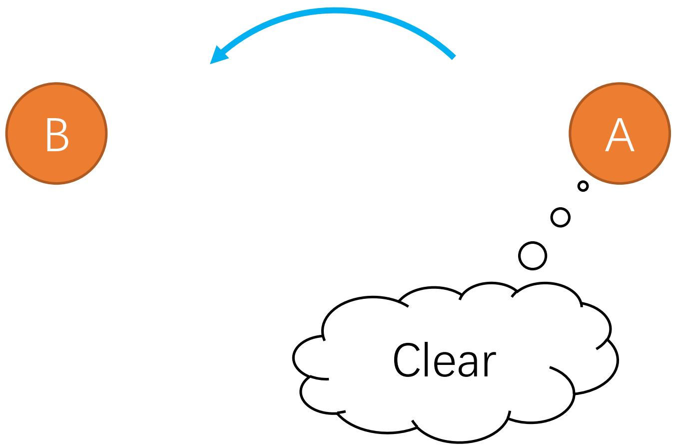
How about the Wireless Situation

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

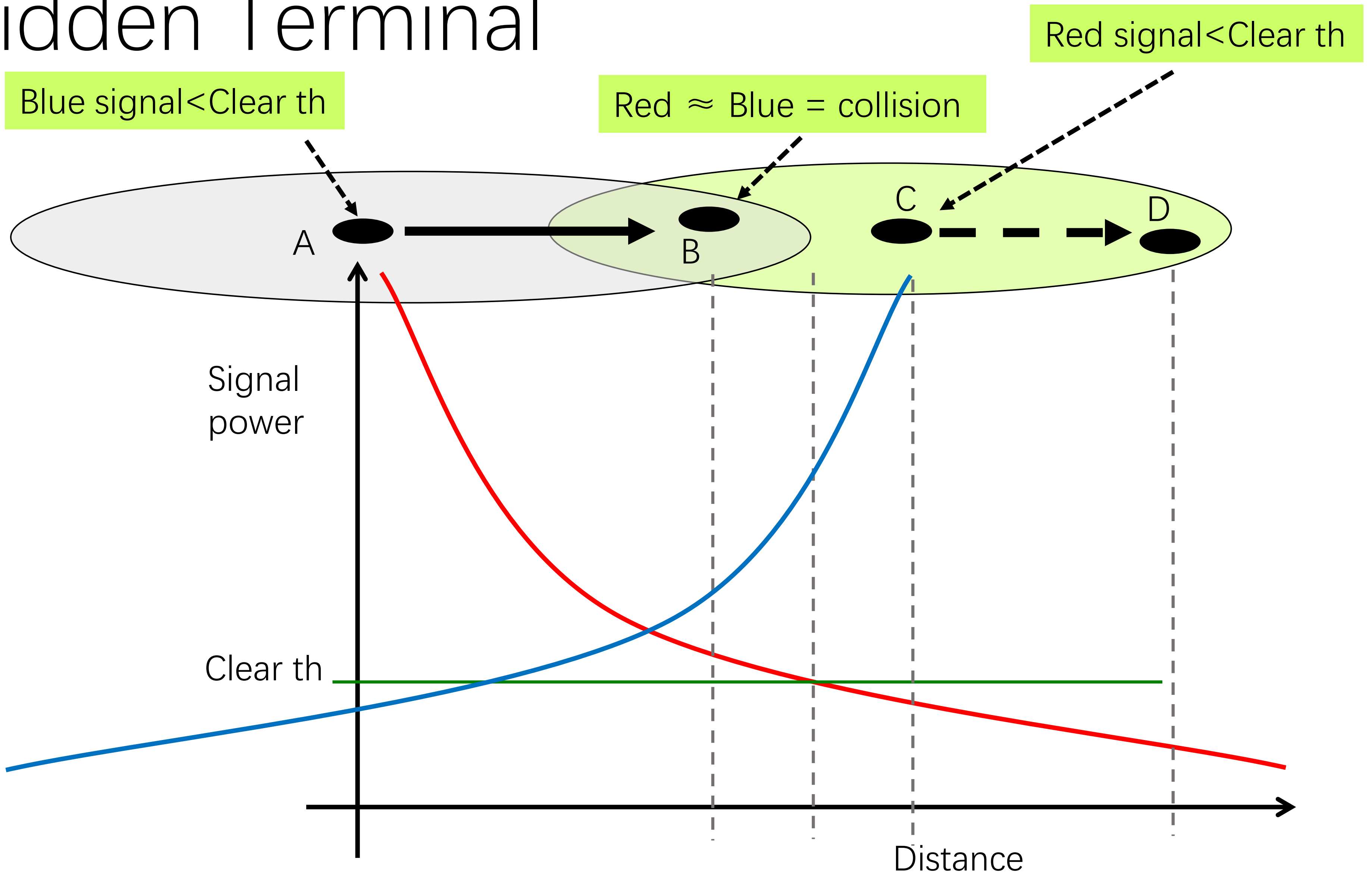
How about CSMA?

CSMA in Wireless Situation

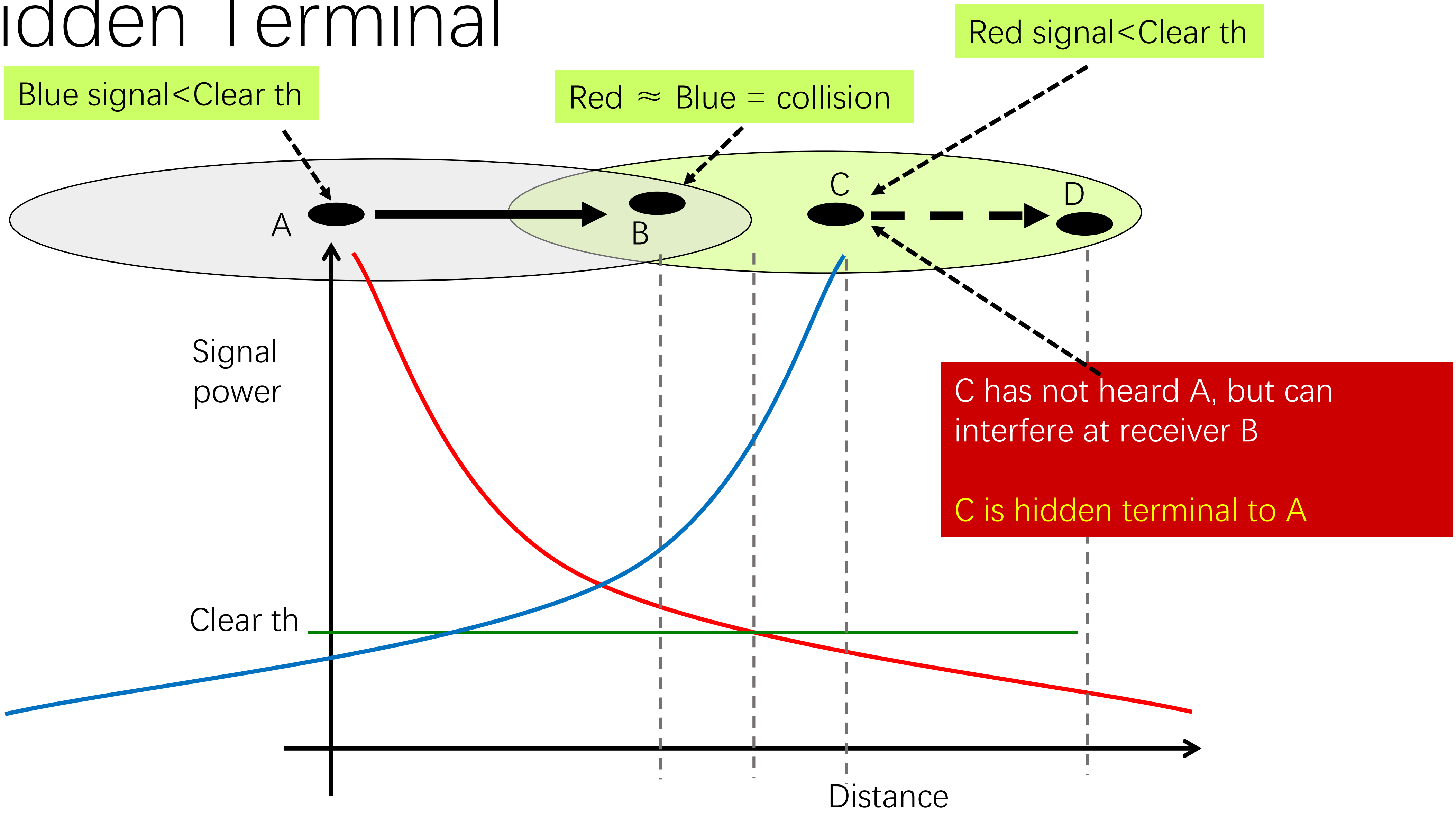
- Not as good as the wired situation
  - Hidden Terminal
  - Exposed Terminal



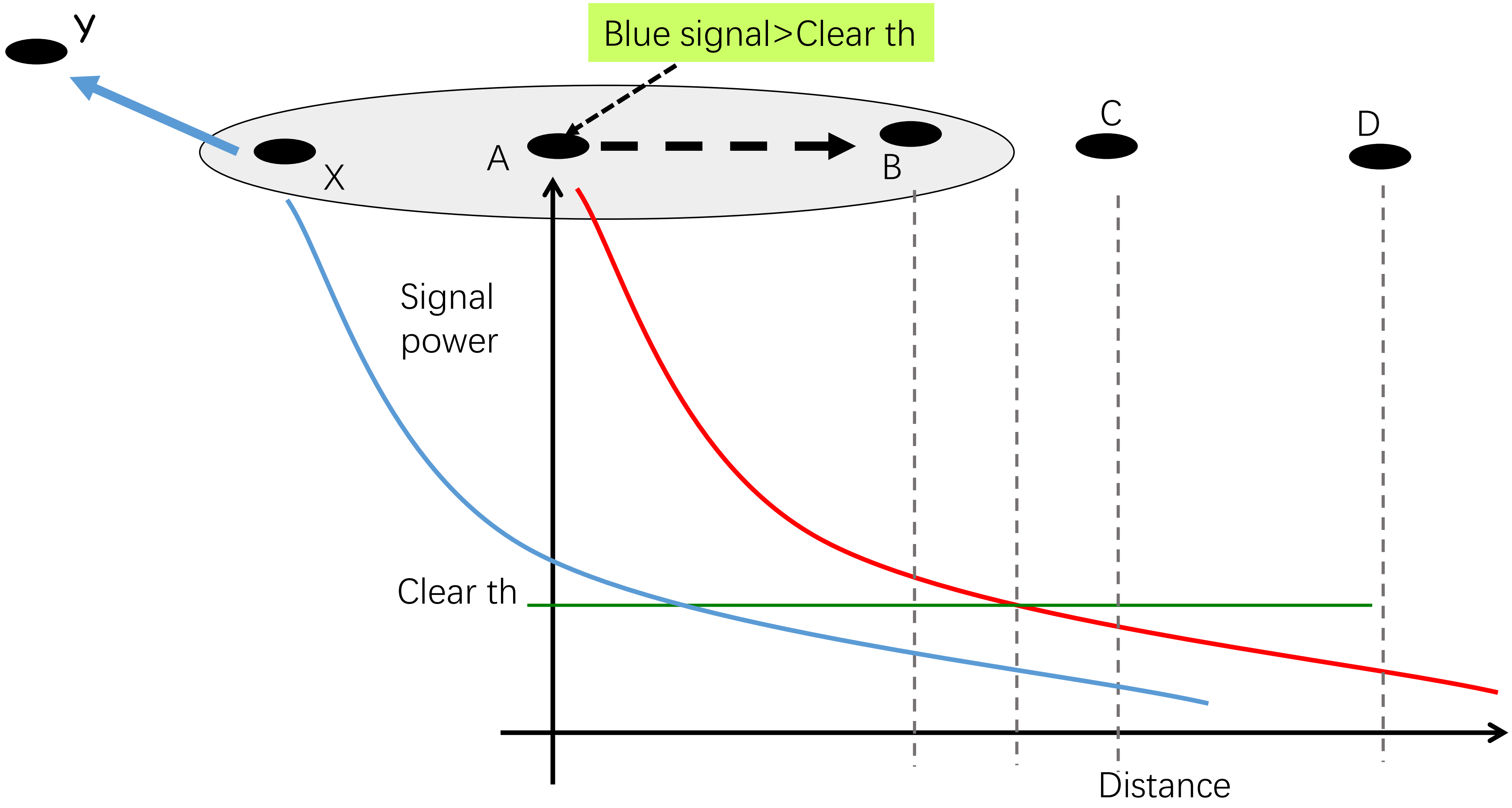
Hidden Terminal



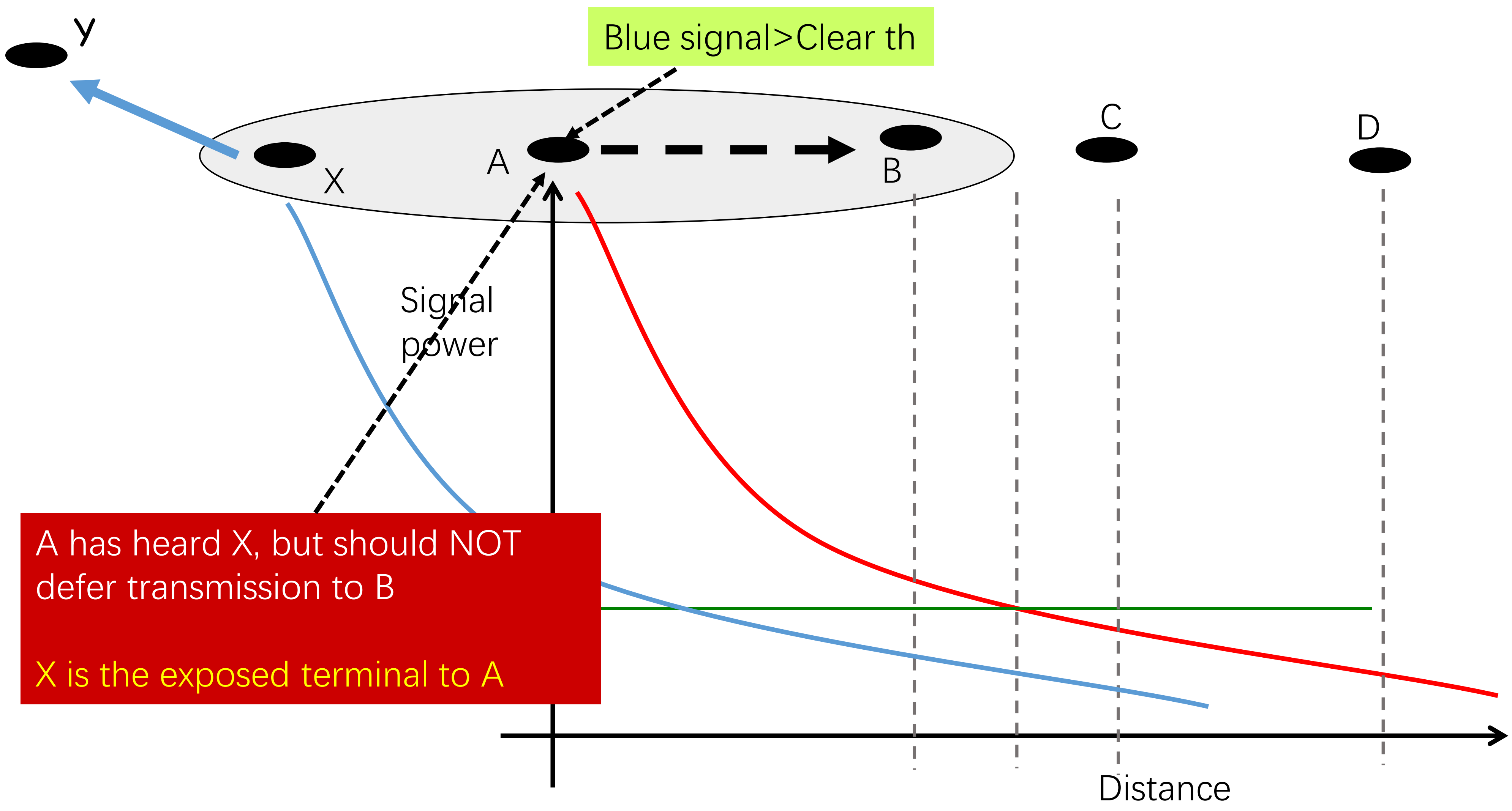
Hidden Terminal



Exposed Terminal



Exposed Terminal



A has heard X, but should NOT defer transmission to B

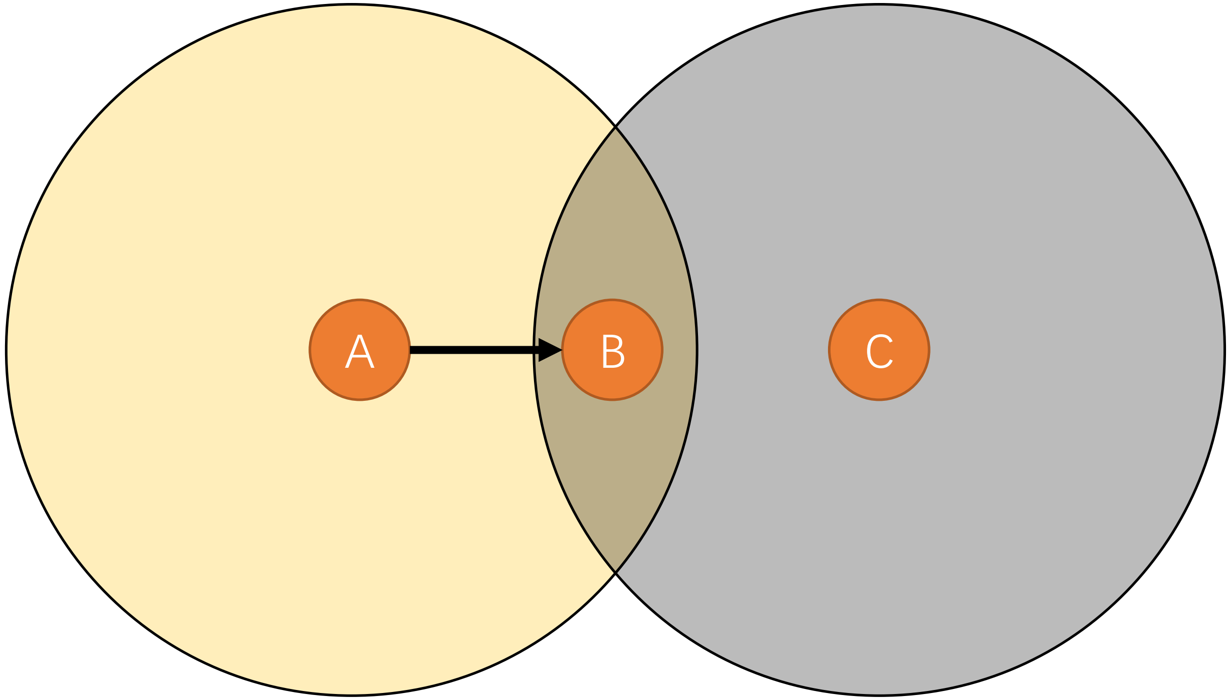
X is the exposed terminal to A

CSMA in Wireless Situation

- Not as good as the wired situation
  - Hidden Terminal
  - Exposed Terminal
- => CSMA/CA
  - CA stands for collision avoidance
    - CTS/RTS scheme

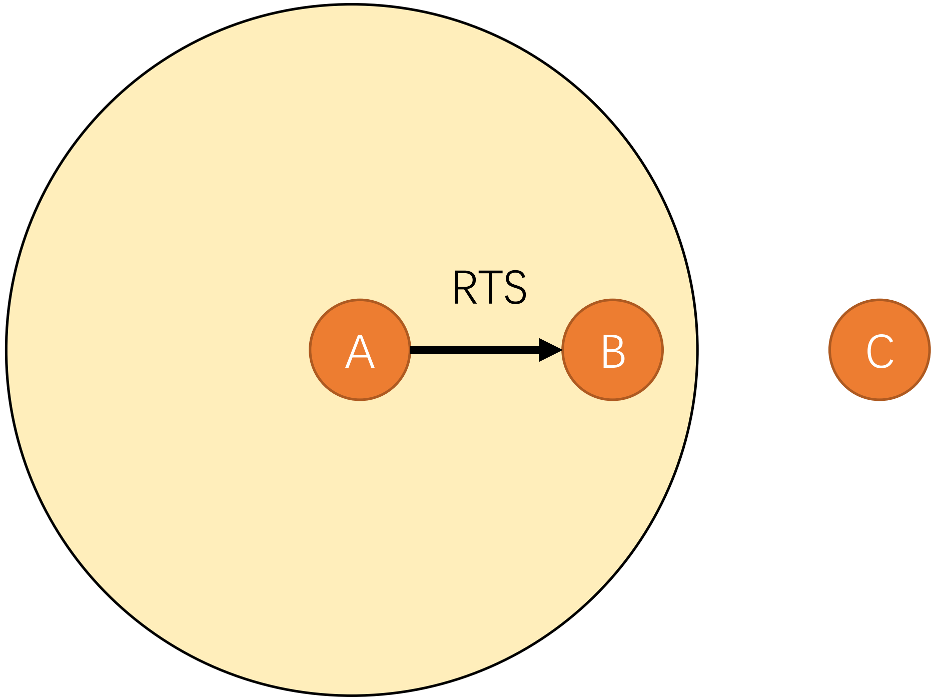
RTS/CTS

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



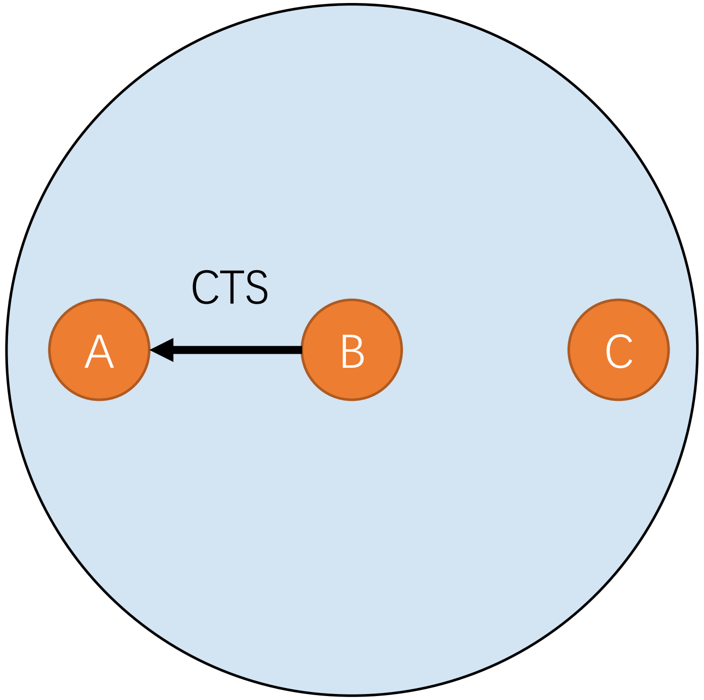
RTS/CTS

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



RTS/CTS

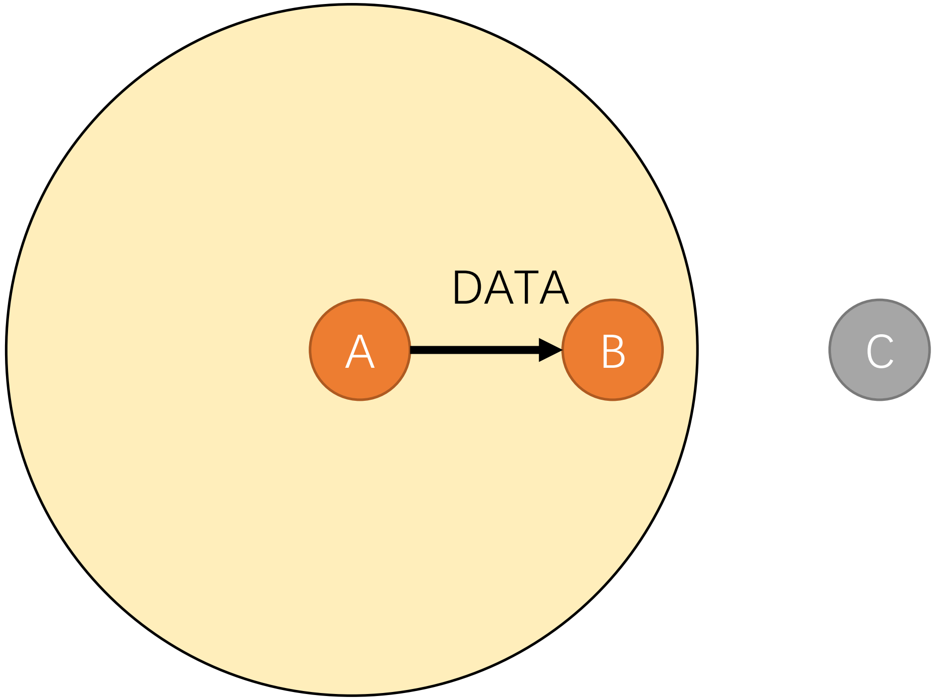
- B transmits a short packet to A and announces the expected transmission duration
  - Clear to Send (CTS)



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

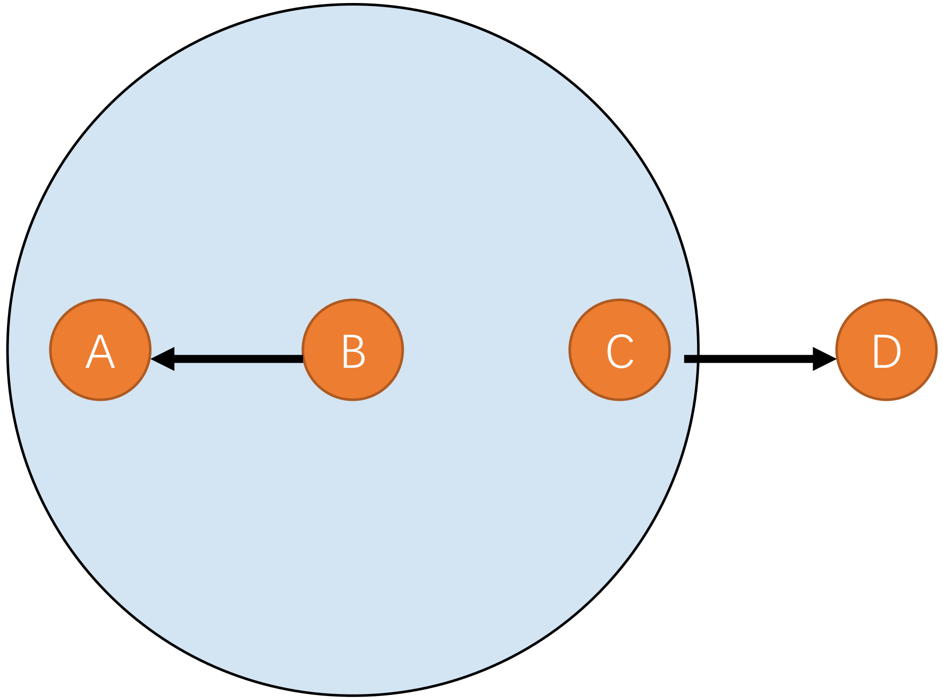
RTS/CTS

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



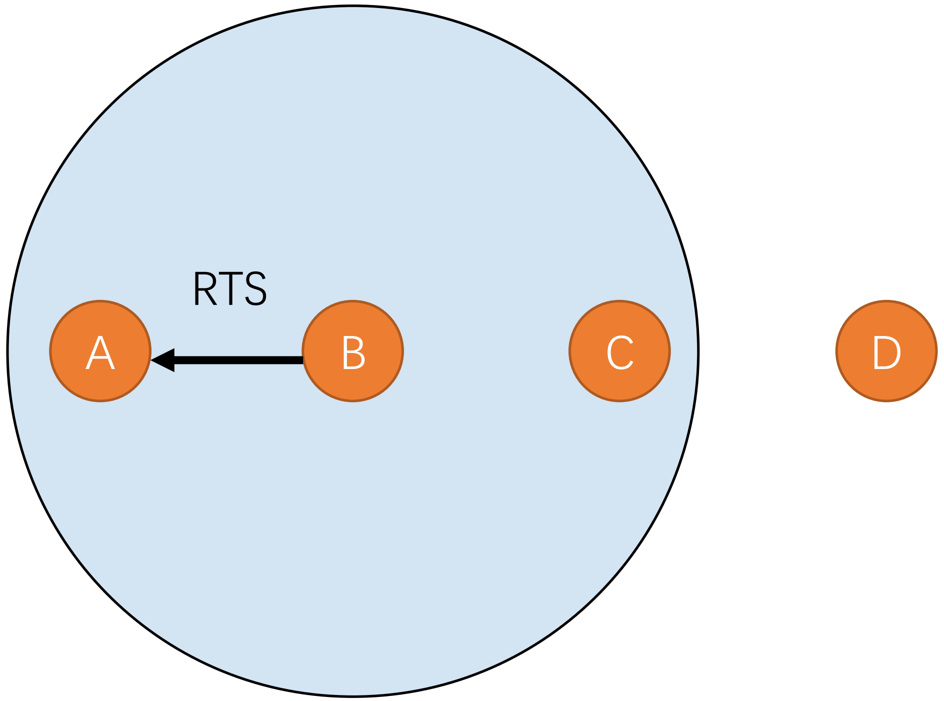
RTS/CTS

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



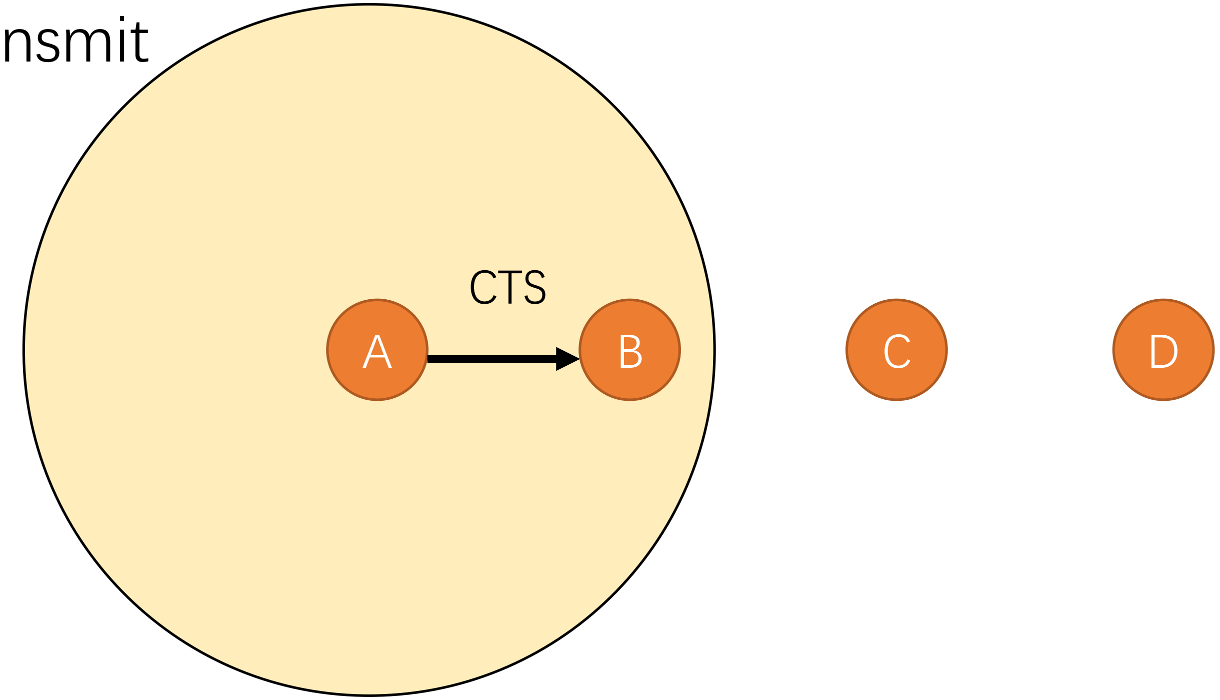
RTS/CTS

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



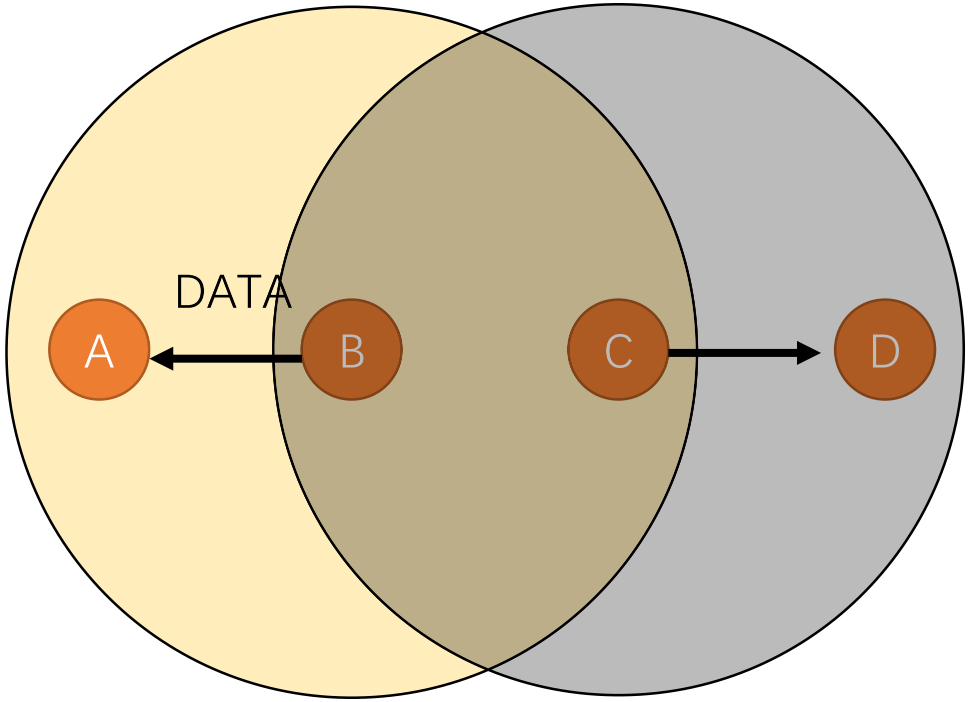
RTS/CTS

- 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



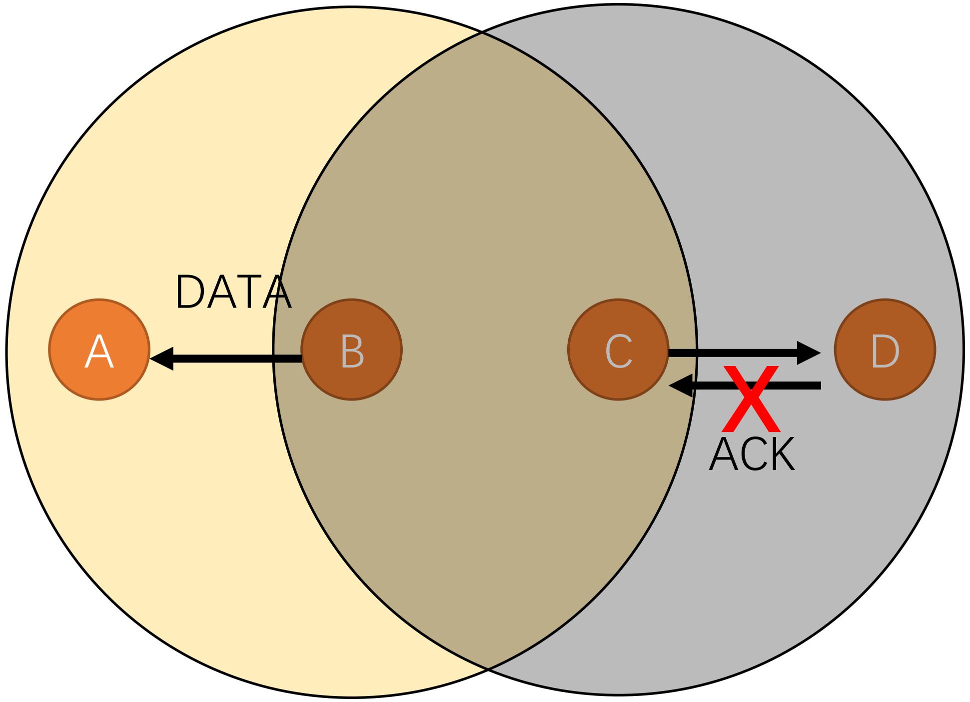
RTS/CTS

- C transmits to D
  - Avoids the exposed terminal problem



RTS/CTS

- However
  - ACK should be better handled

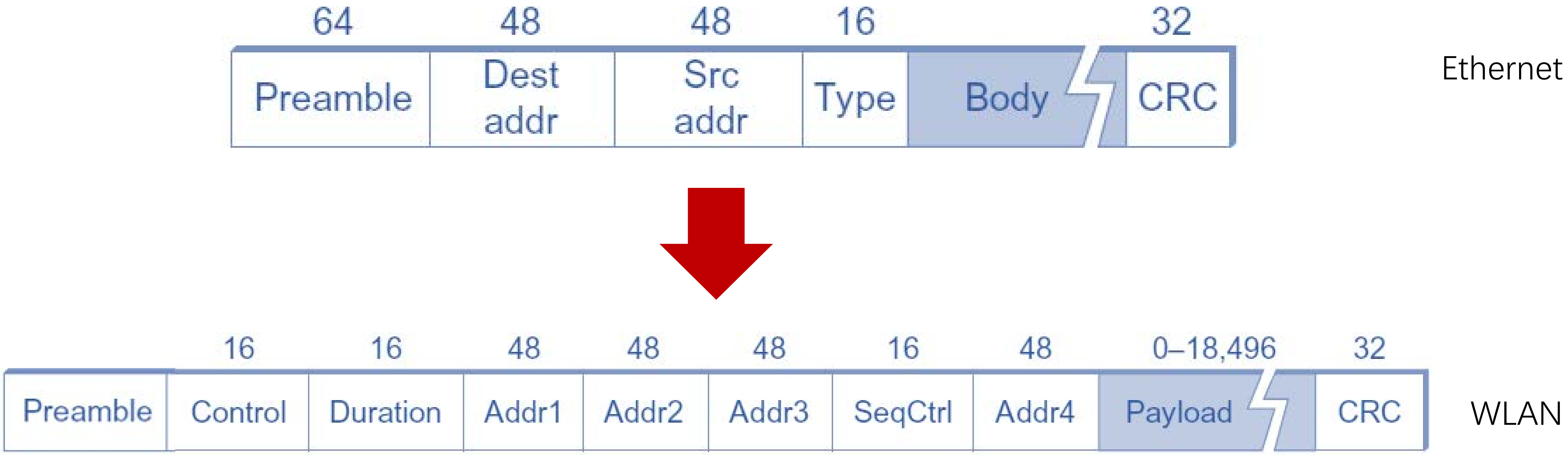


RTS/CTS

- RTS/CTS does not solve the hidden terminal and exposed terminal completely
  - and also degrade spatial utilization
  - have been used by but is *not* the default option of Wi-Fi

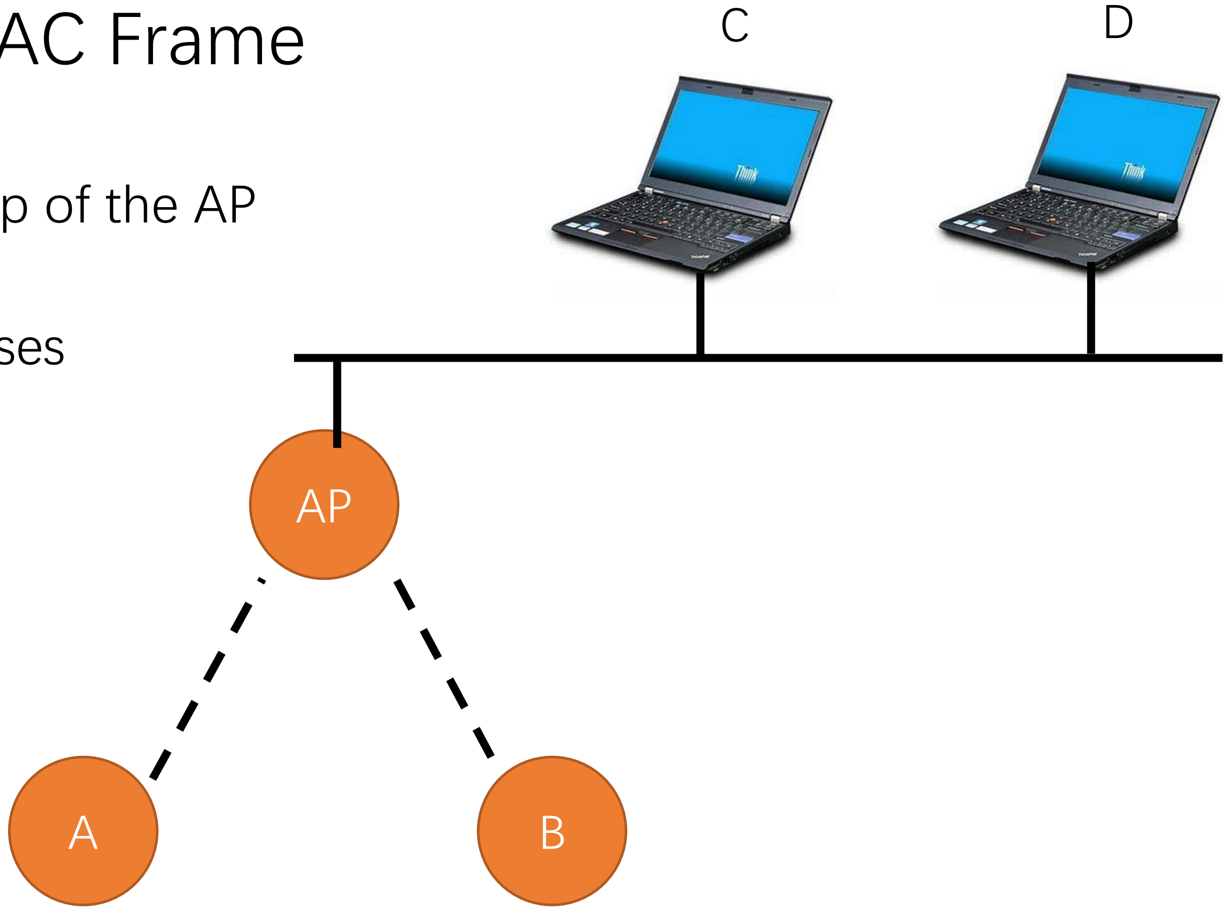
Wi-Fi MAC

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



Wi-Fi MAC

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

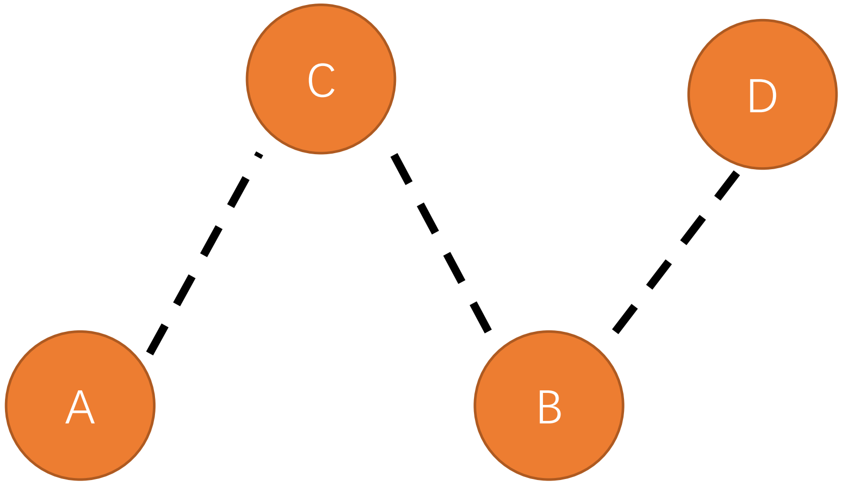


Wi-Fi MAC

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

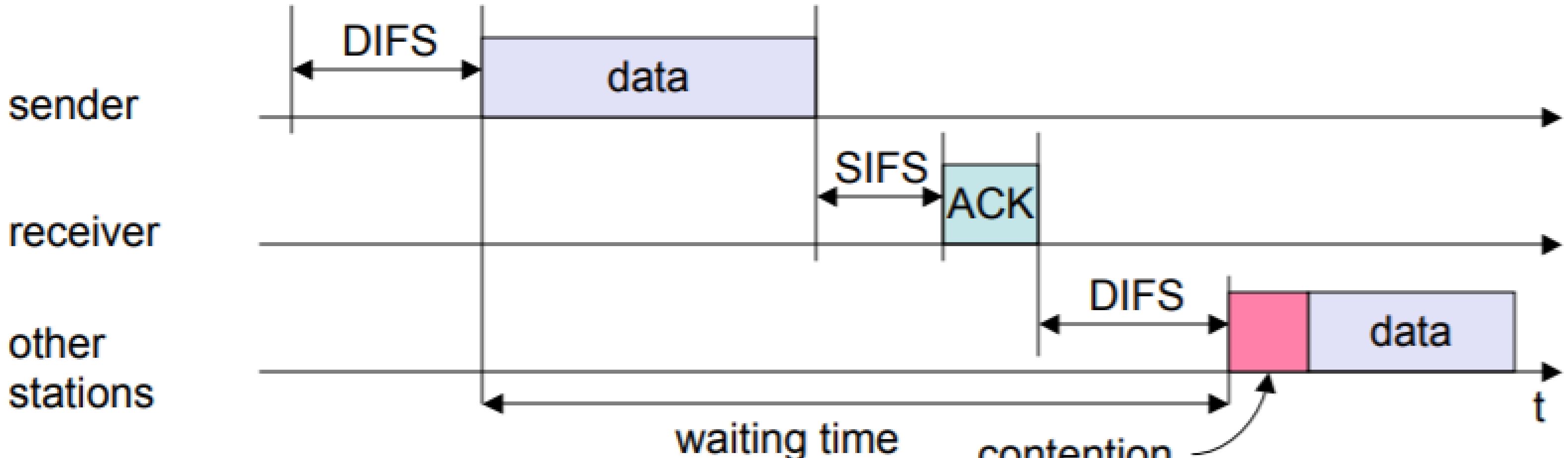
Intermediate Destination

Intermediate Source



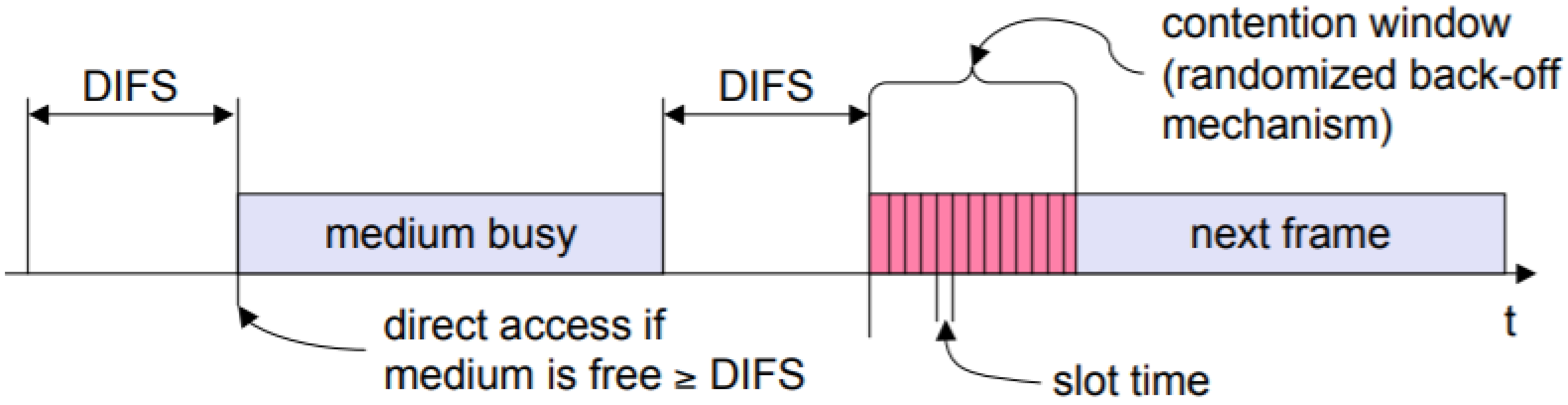
Wi-Fi MAC

- Based on CSMA
- Sender has to wait for DIFS before sending data
  - DIFS and SIFS are used to differentiate packet priority, e.g., ACK > data
- Receiver acknowledges at once (after waiting for SIFS) if the packet was received correctly (CRC)
  - Use ACK rather than collision detection



Contention

- 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



Wi-Fi MAC

- With RTS/CTS