CS120: Computer Networks

Lecture 7. Medium Access Control 2

Zhice Yang

Outline

- Medium Access Control in Wireless Networks
  - Introduction to Popular Wireless Networks
  - CSMA/CA
    - CSMA/CD is not feasible
    - Hidden terminal and exposed terminal
  - Wi-Fi MAC

Radio Spectrum Allocation

- Radio spectrum is like a resource

3 – 300 kHz
λ =1000 – 10km

300 – 3000 kHz
λ=10 – 1km

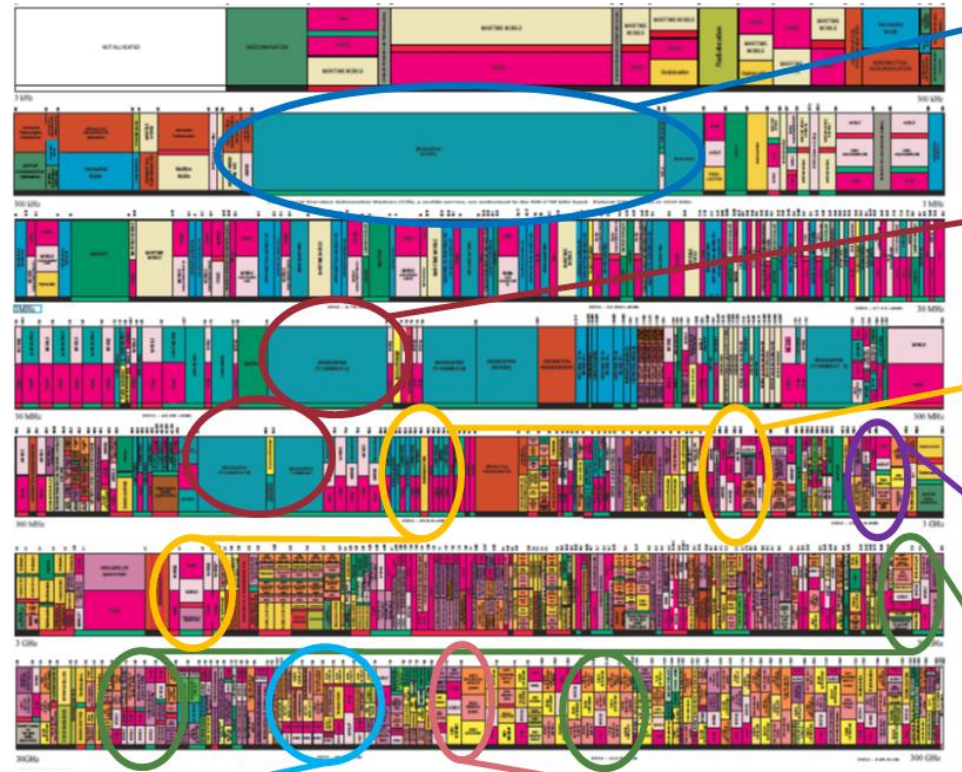
3 – 30 MHz
λ=1000 – 100m

30 – 300 MHz
λ=100 – 10m

300 – 3000 MHz
λ=10 – 1m

3 – 30 GHz
λ=1m – 100mm

30 – 300 GHz
λ=100mm – 10mm



AM Radio

TV Broadcast*
(54-72, 600-700 Mhz)

3G/4G cellular
(0.9, 1.8, 1.9 Ghz)

WiFi
(2.4 Ghz)

mmWave
(28,38, 80 Ghz)

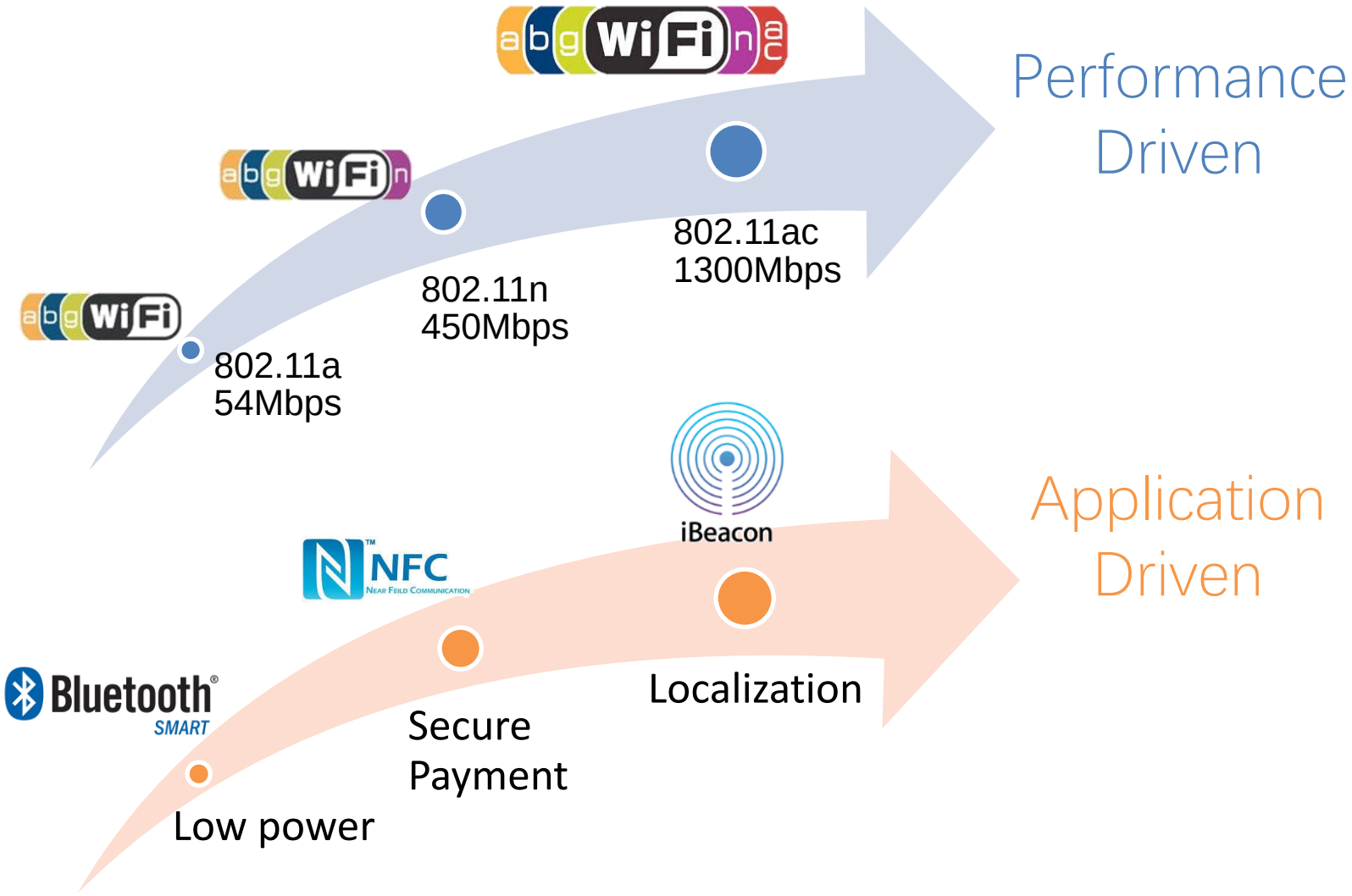
WiGig (802.11 ad)
(60 Ghz)

Vehicular Radar
(77 Ghz)

Radio Spectrum Allocation

- Regulation: defines how to use the radio spectrum
  - licensed and unlicensed, frequency bandwidth, power, etc.
- Regulatory Agency
  - China: CMIIT
  - U.S.: FCC

Popular Wireless Technologies



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

Wi-Fi and Cellular

Telephone

Cellular

Ethernet

WLAN (Wi-Fi)

Wi-Fi and Cellular

Telephone

Microcell

Cellular

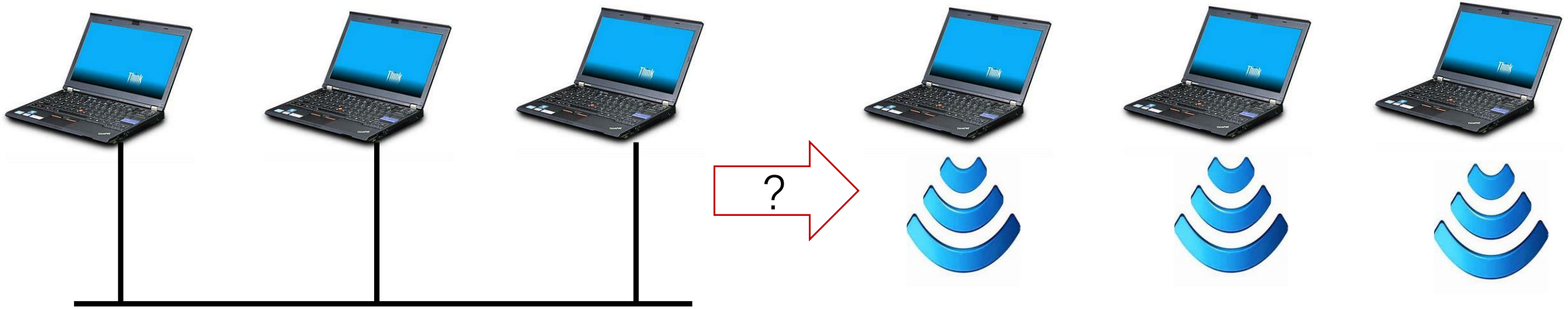
Ethernet

WLAN (Wi-Fi)

WiMAX

WLAN

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



Outline

- Medium Access Control in Wireless Networks
  - Introduction to Popular Wireless Networks
  - ➢CSMA/CA
    - CSMA/CD is not feasible
    - Hidden terminal and exposed terminal
  - Wi-Fi MAC

Further Thoughts on CSMA/CD

- Important 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

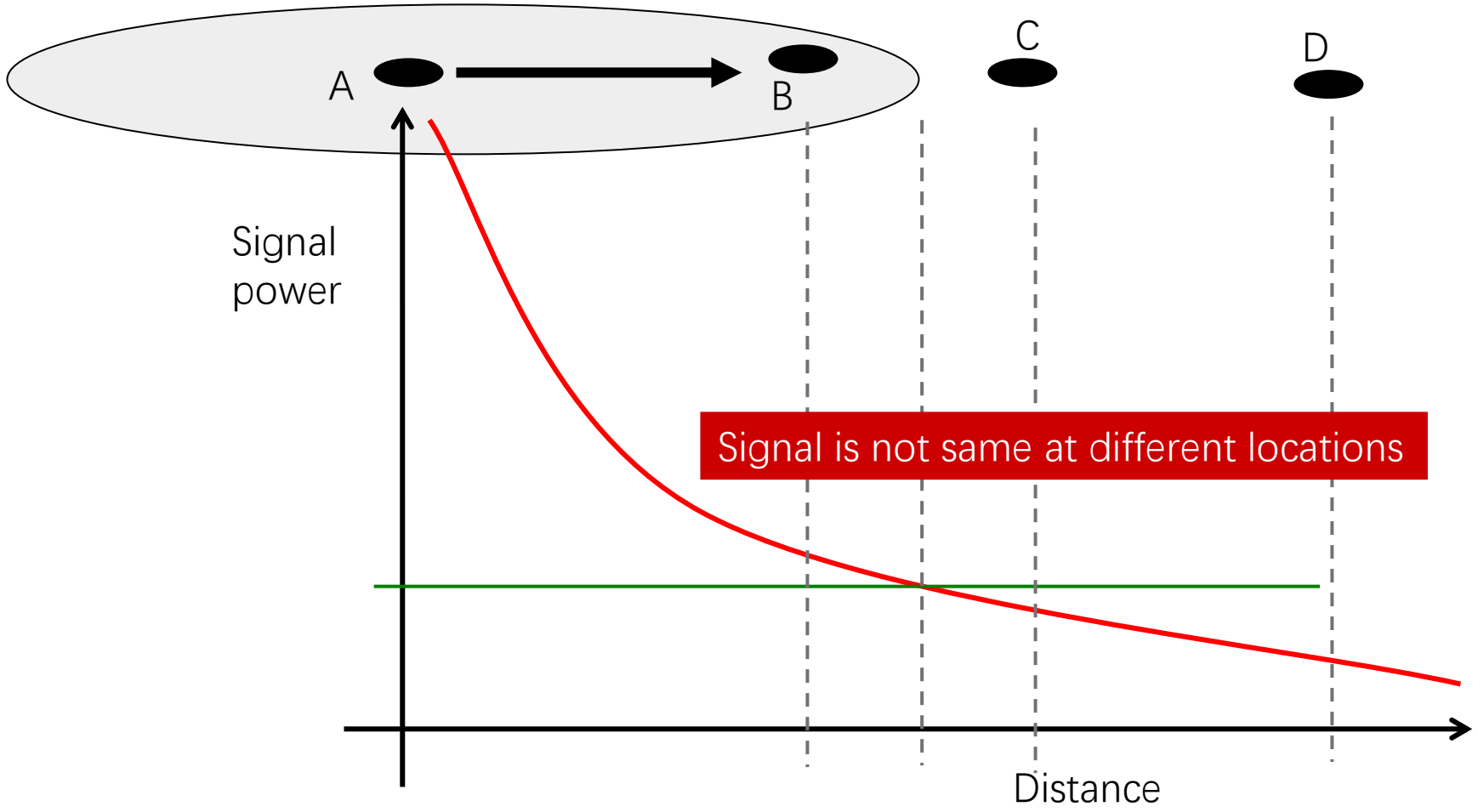
Ethernet transceiver can detect collision when collision occurs at the receiver

Apply CSMA/CD to Wireless Situation ?

- Assumptions no longer hold
  - ✗ Full Duplex: transceiver can send/receive concurrently
  - ✗ Symmetry: signals are identical at all receivers

Why ?

Wireless transceivers cannot send and listen simultaneously



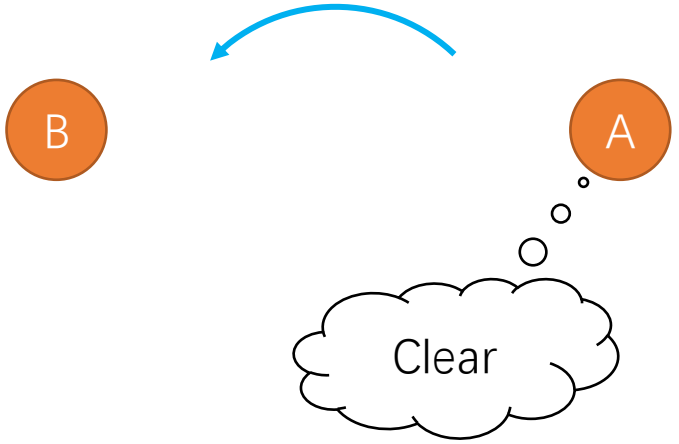
Apply CSMA/CD to Wireless Situation ?

- Assumptions no longer hold
  - ✗ Full Duplex: transceiver can send/receive concurrently
  - ✗ Symmetry: signals are identical at all receivers

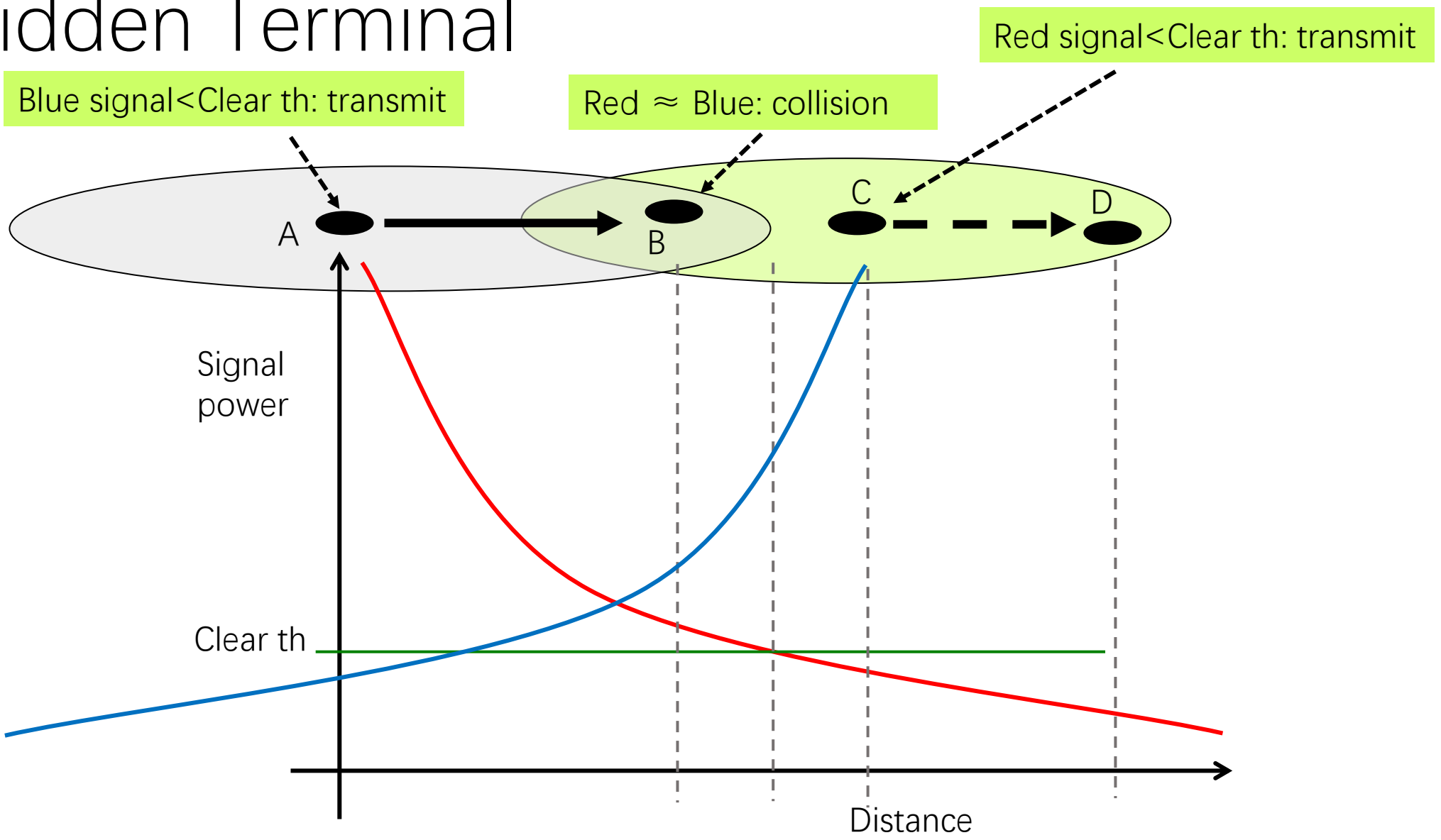
How about applying CSMA alone?

CSMA in Wireless Situation

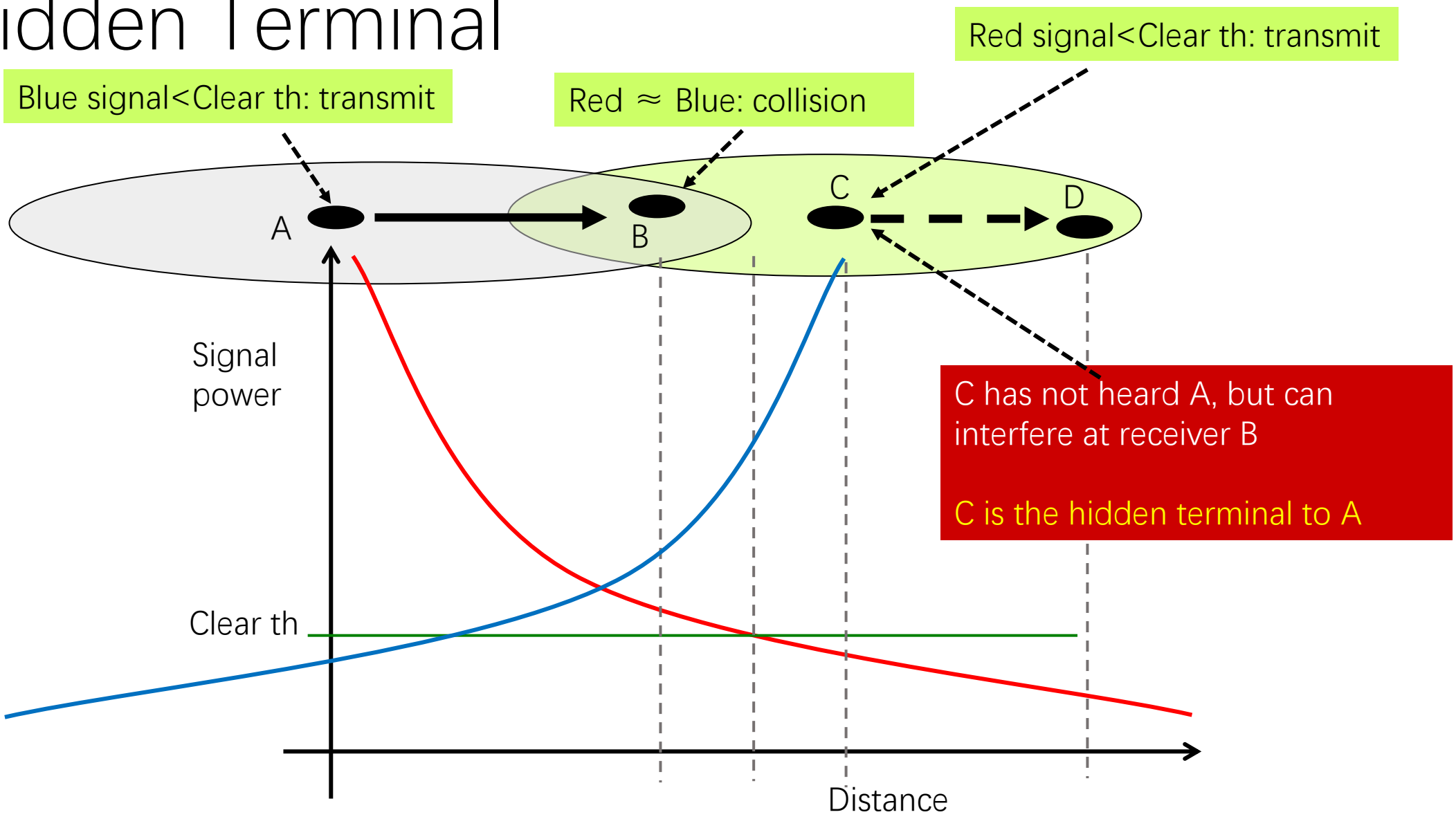
- Not as good as the wired situation
  - Hidden Terminal
  - Exposed Terminal



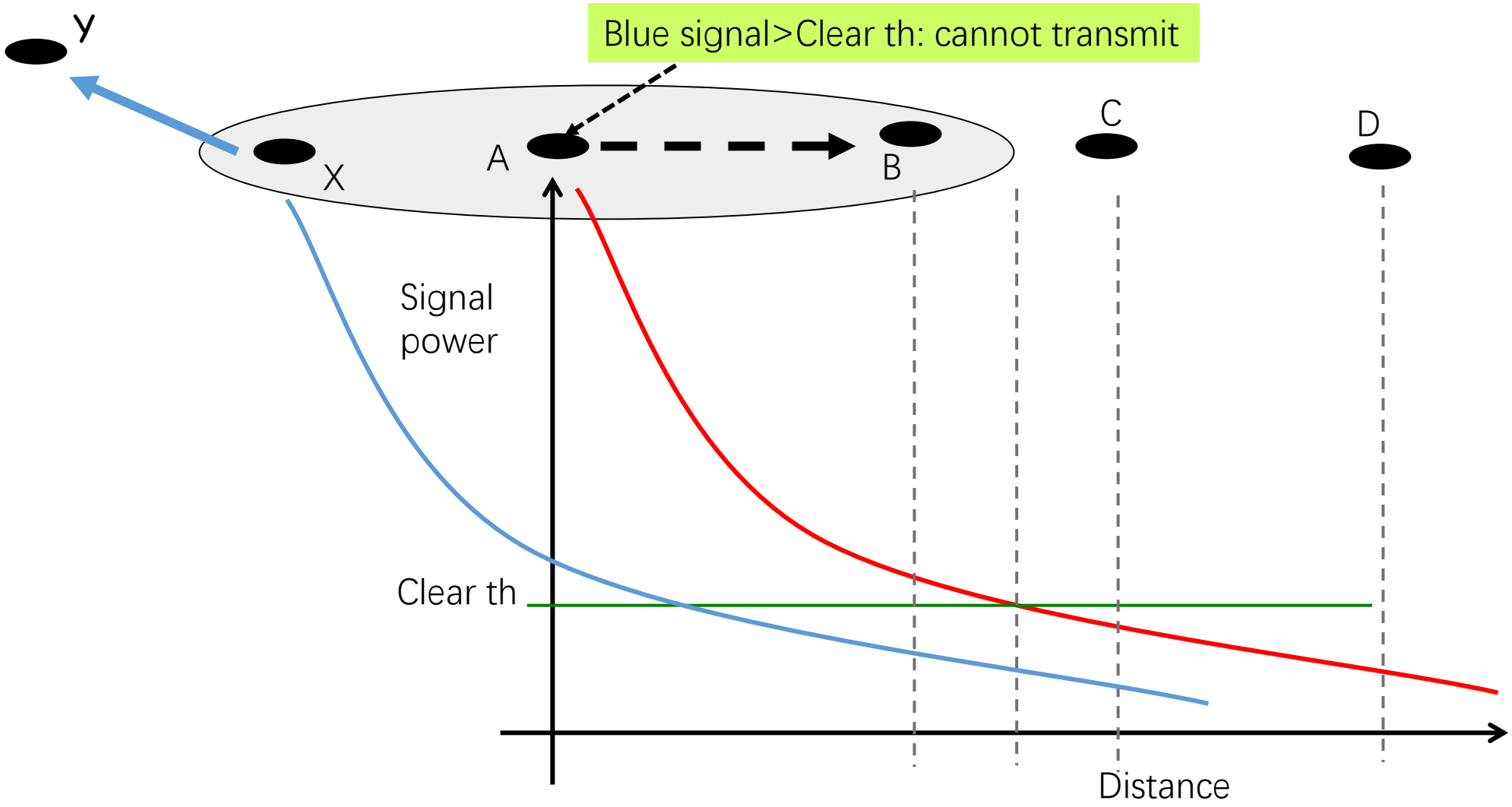
Hidden Terminal



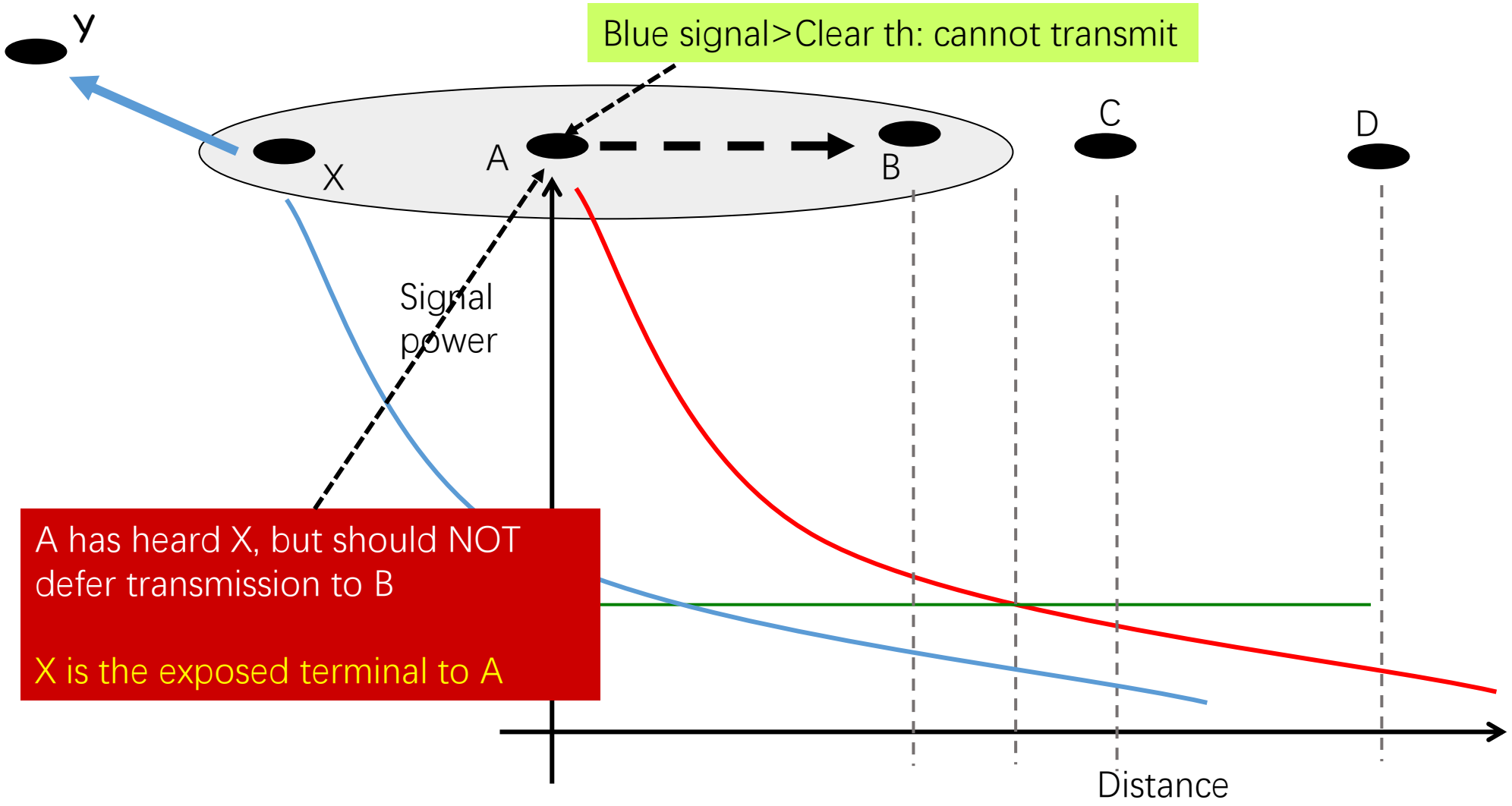
Hidden Terminal



Exposed Terminal



Exposed Terminal



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

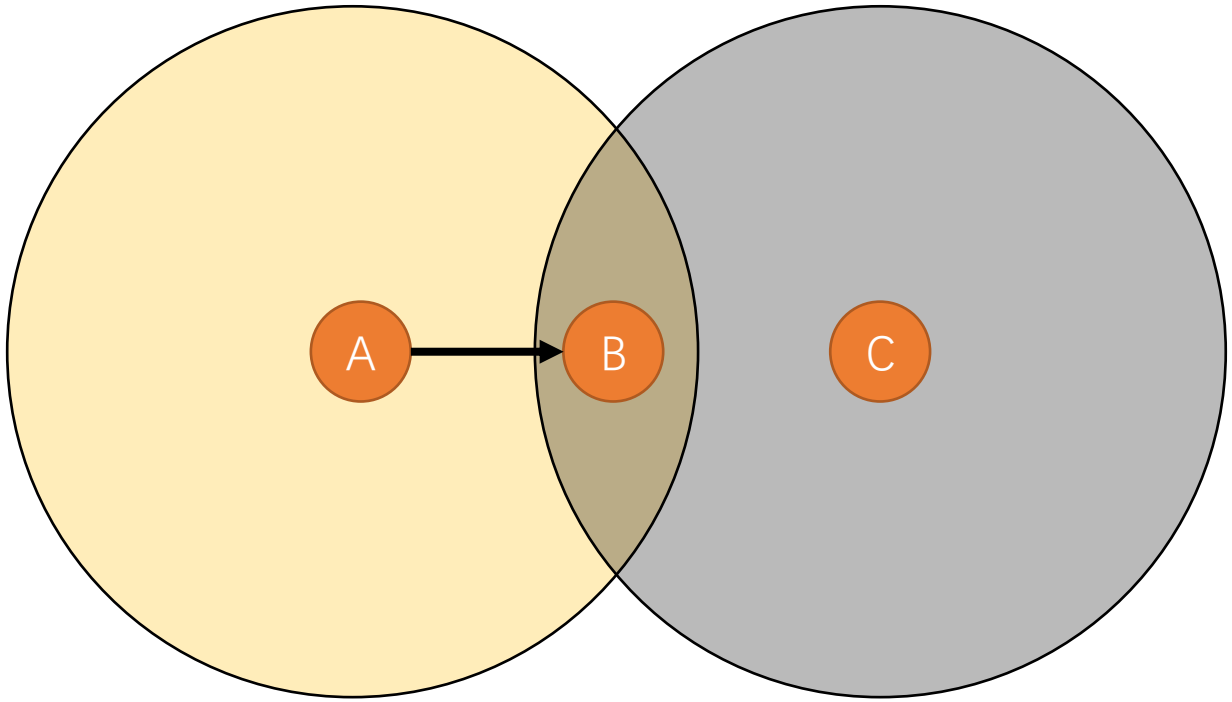
X is the exposed terminal to A

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

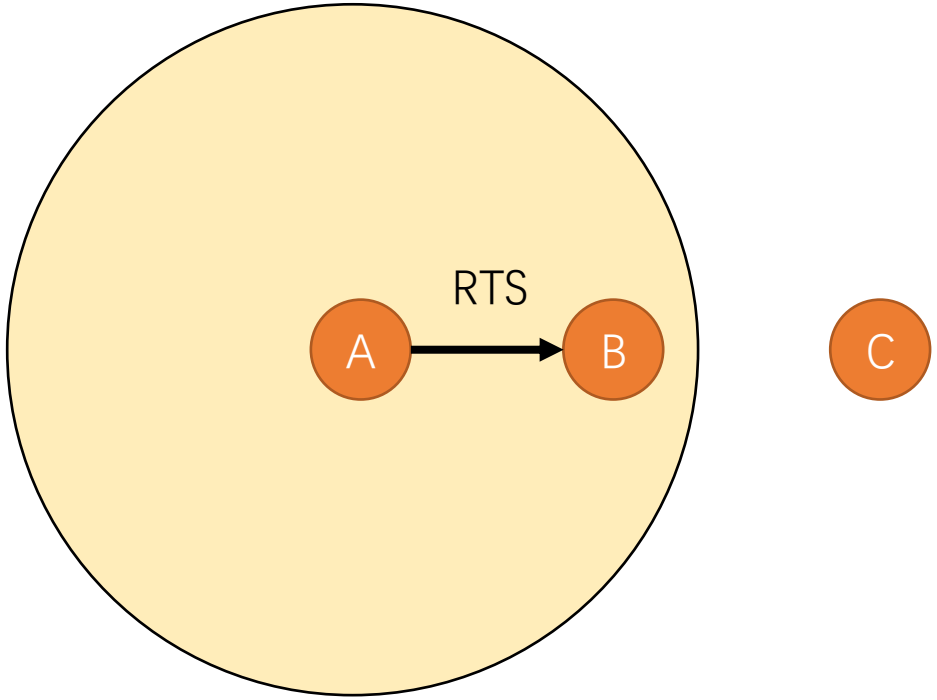
RTS/CTS

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



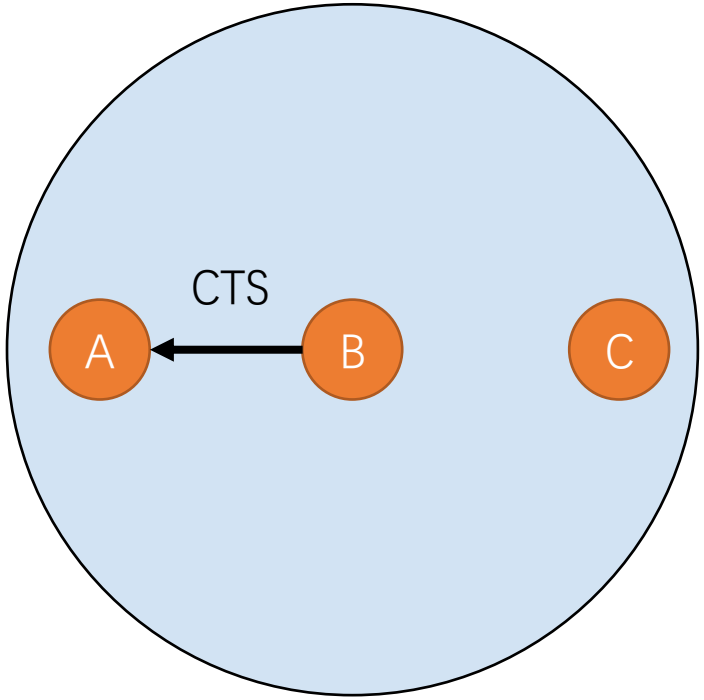
RTS/CTS

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



RTS/CTS

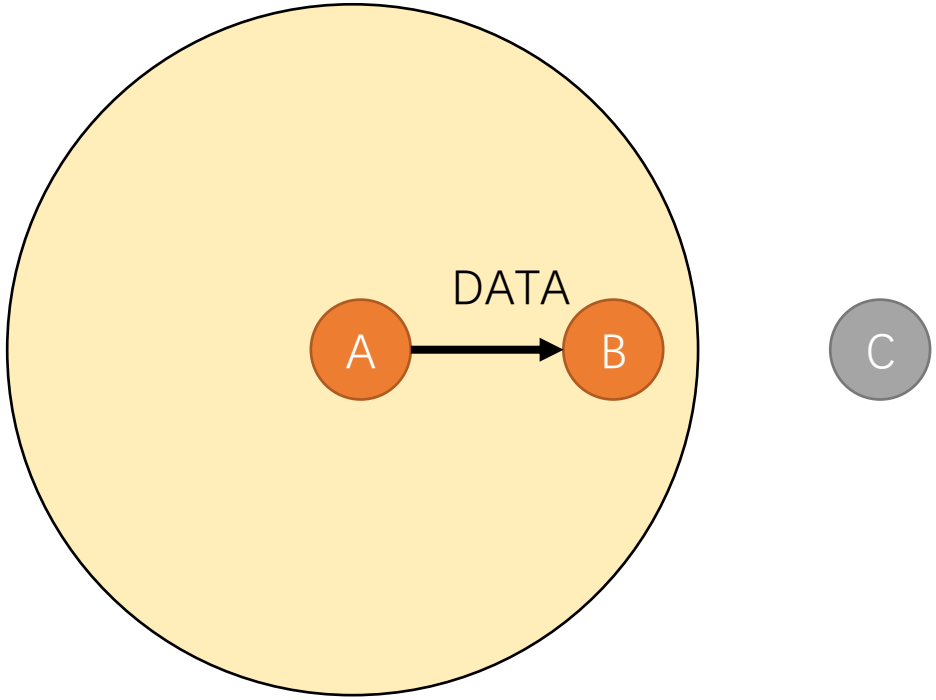
- B transmits a short control message (CTS) to A and announces the expected transmission duration
  - Clear to Send (CTS)



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

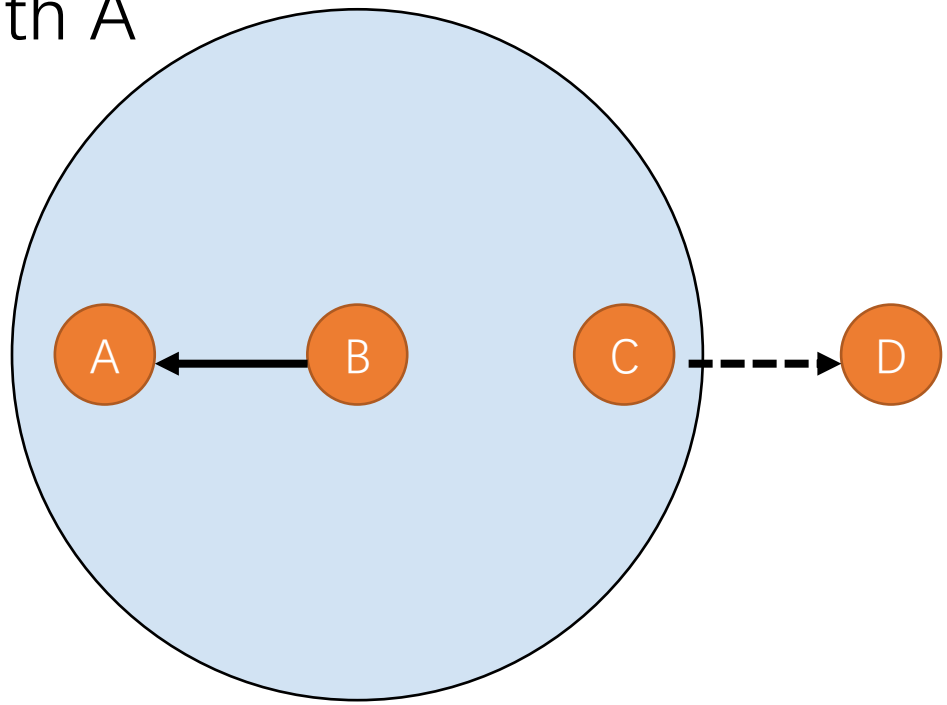
RTS/CTS

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



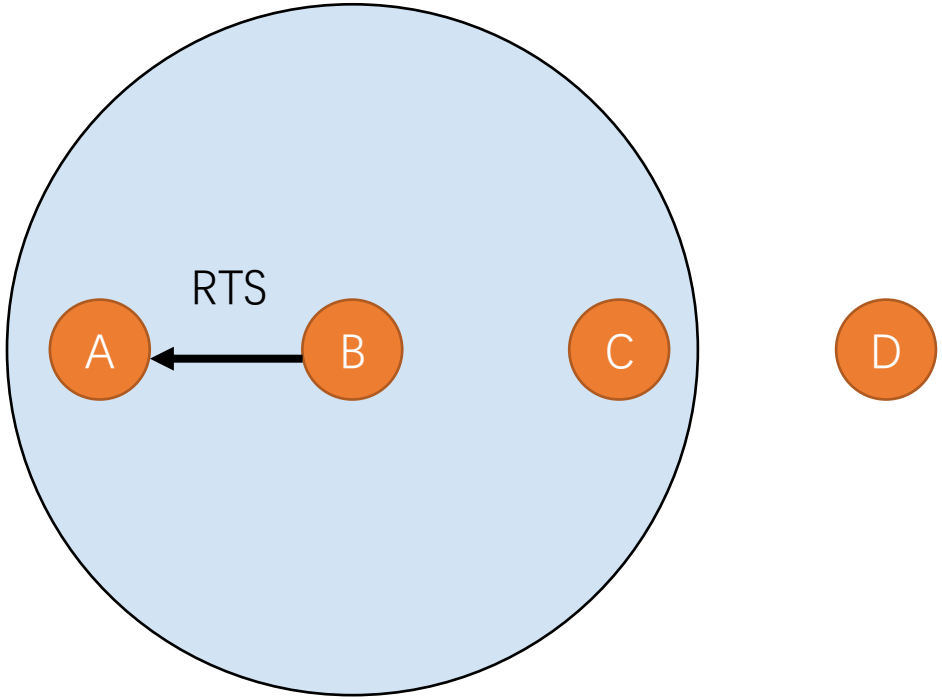
RTS/CTS

- B is transmitting to A, and C wants to transmit to D. However, as C is within the coverage of B, it cannot transmit due to CSMA (C's transmissions may interfere with A)
- If B uses RTS/CTS, C can determine whether its transmissions will actually interfere with A



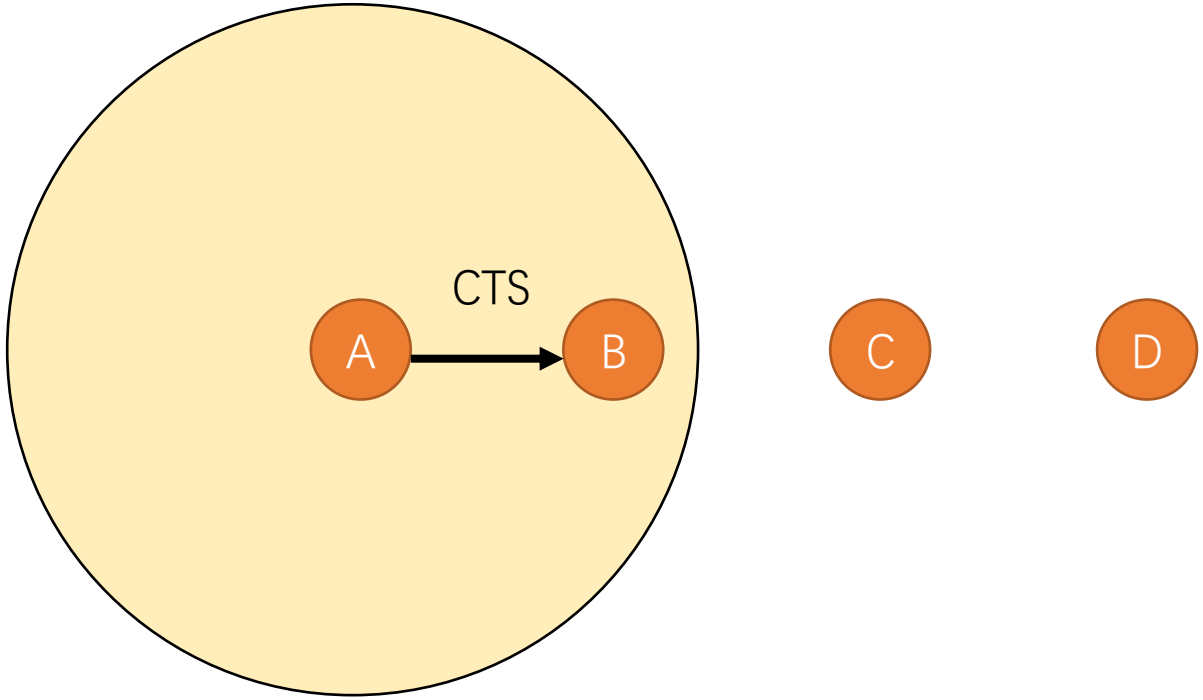
RTS/CTS

- B sends RTS. C waits the RTS recipient's CTS reply.
  - CTS must be replied within a short period of time



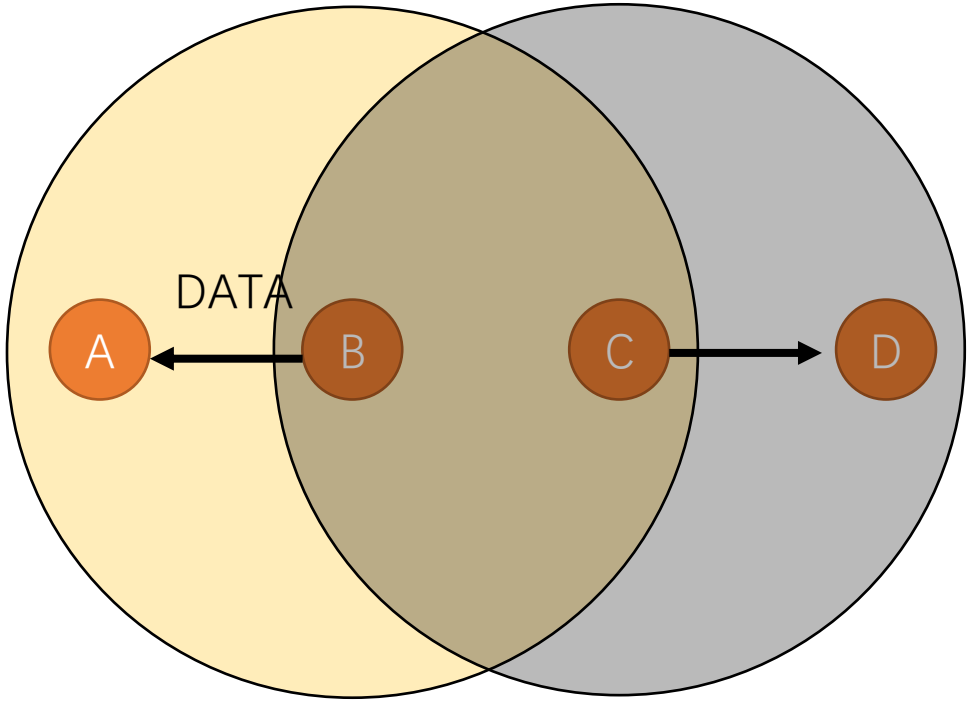
RTS/CTS

- C does not hear CTS message.
  - 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 even when B is transmitting



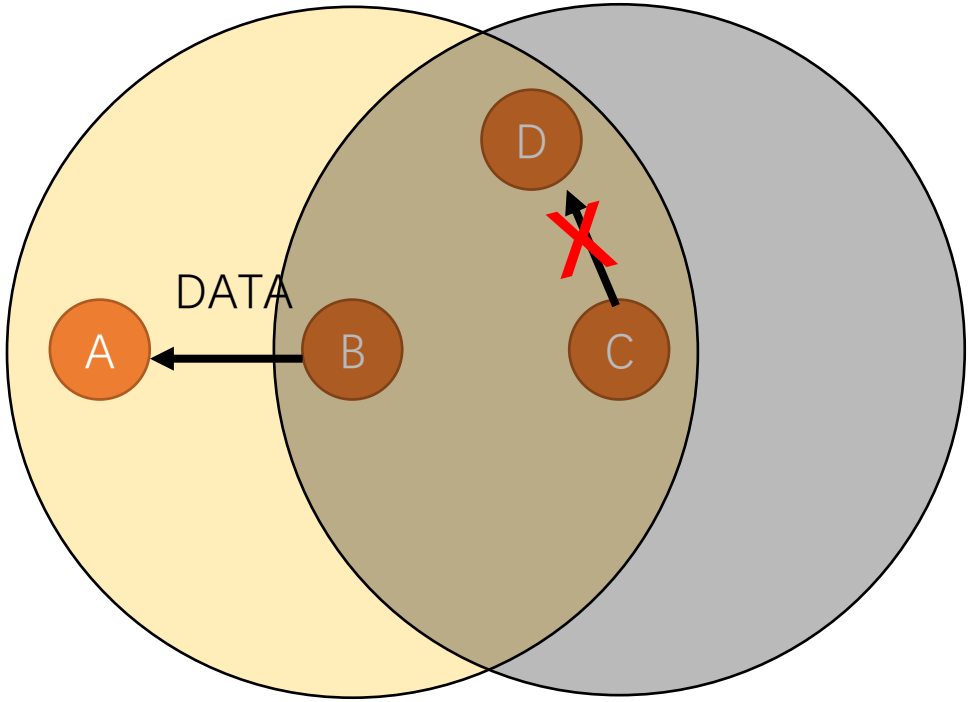
RTS/CTS

- B and C can transmit concurrently
  - Utilize the transmission opportunities in exposed terminals



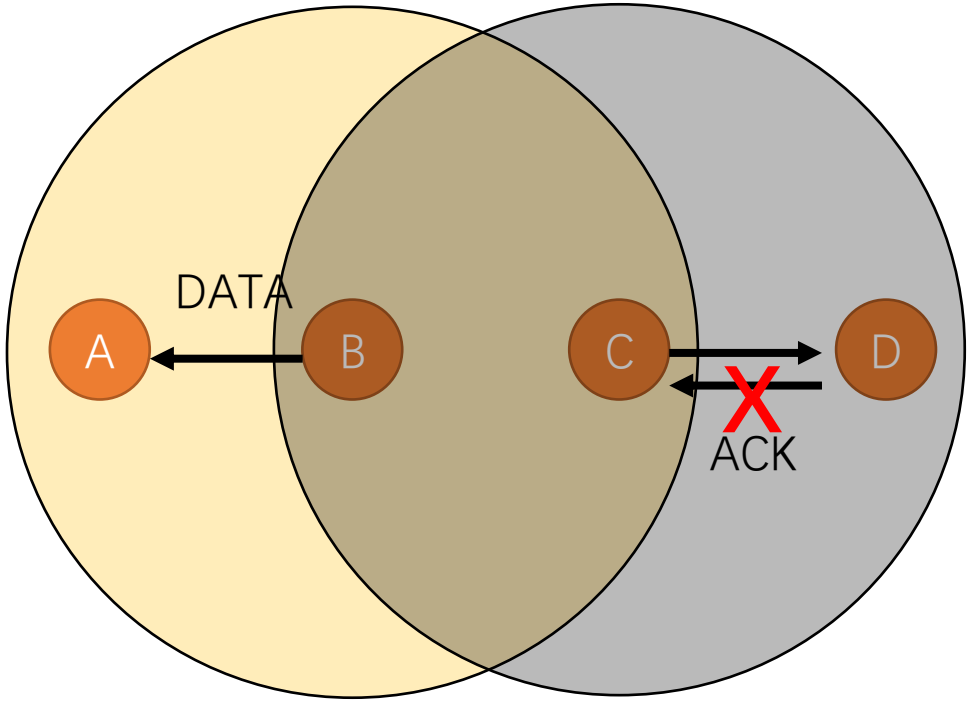
RTS/CTS

- However
  - No guarantee on D's successful reception



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

Outline

- Medium Access Control in Wireless Networks
  - Introduction to Popular Wireless Networks
  - CSMA/CA
    - CSMA/CD is not feasible
    - Hidden terminal and exposed terminal
  - ➢Wi-Fi MAC

Wi-Fi MAC Frame

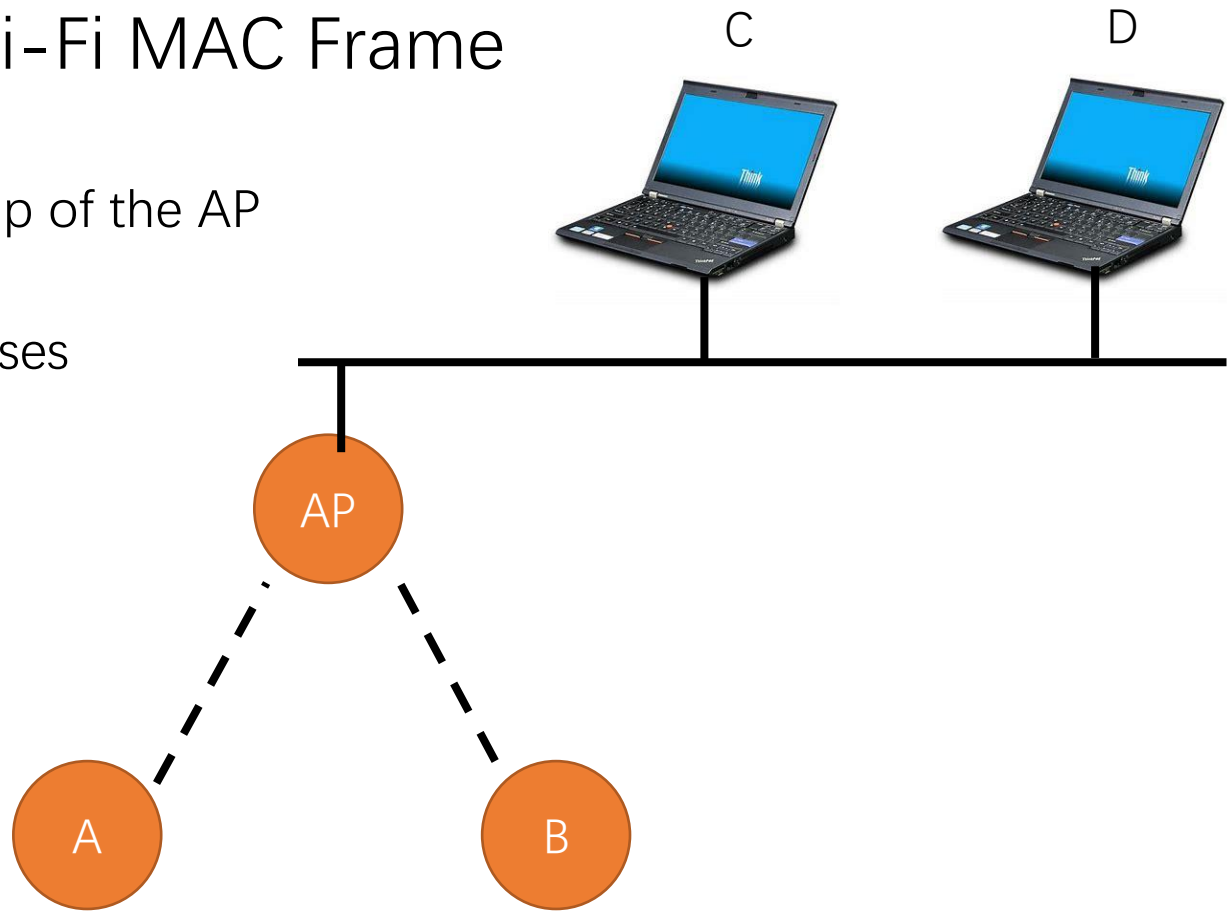
- Wireless LAN is standard by IEEE 802.11
  - "Wi-Fi" is a certification trademark of IEEE 802.11

Ethernet

Wi-Fi

Wi-Fi MAC Frame

- Four Address Fields in Wi-Fi MAC Frame
  - Access Point (AP) mode
    - Communicate with the help of the AP
    - A -> AP: two addresses
    - A -> AP->B: three addresses

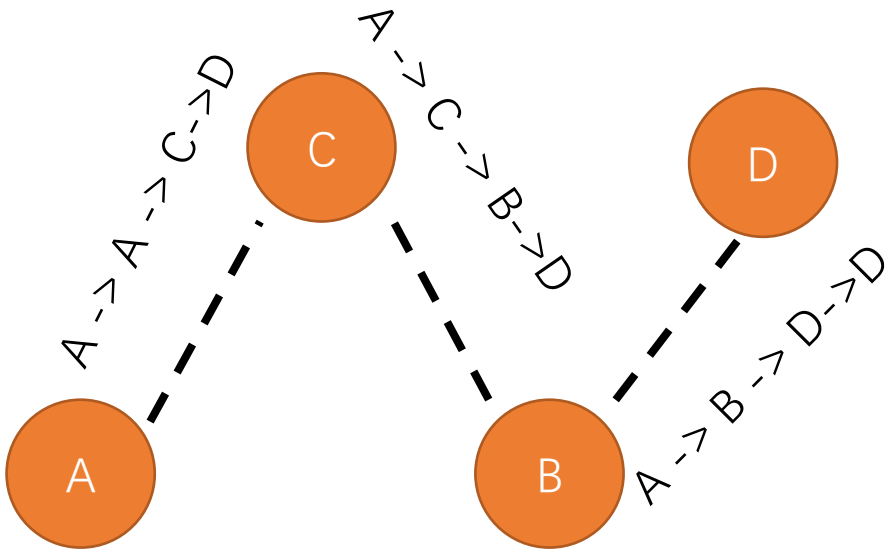


Wi-Fi MAC Frame

- Four Address Fields in Wi-Fi MAC Frame
  - Access Point (AP) mode
    - Communicate with the help of the AP
    - A -> AP: two addresses
    - A -> AP->B: three addresses
  - ad-hoc mode
    - network without infrastructure, i.e., APs
    - Directly communicate with each peer
    - A -> X -> XX->D: four addresses

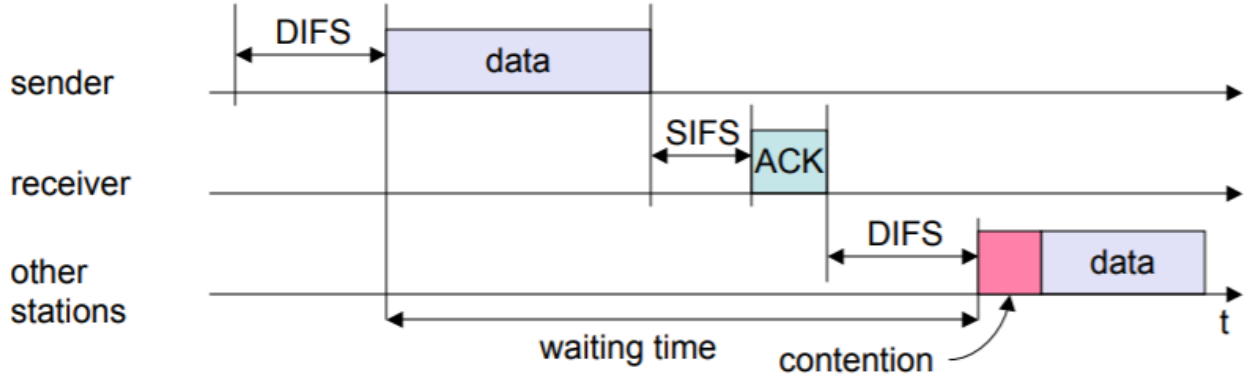
Intermediate Destination

Intermediate Source



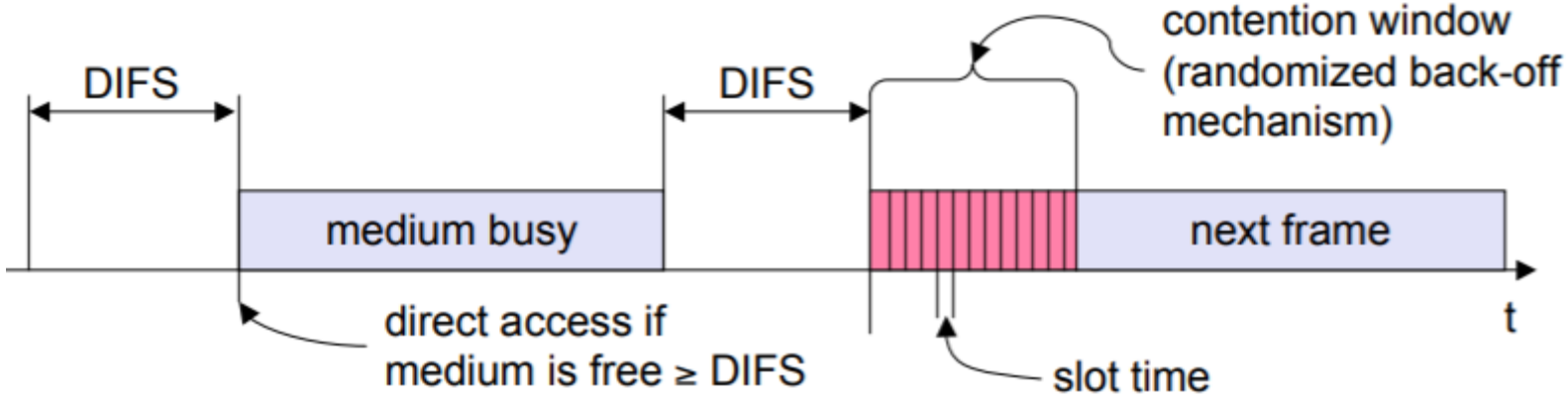
Wi-Fi MAC Protocol

- Based on CSMA
- Not able to detect collisions
  - Use ACK to confirm correctness
- Sender has to wait for DIFS before sending data
  - DIFS and SIFS are used to differentiate priority, e.g., ACK > data
- Receiver acknowledges at once (after waiting for SIFS) if the frame was received correctly (CRC)



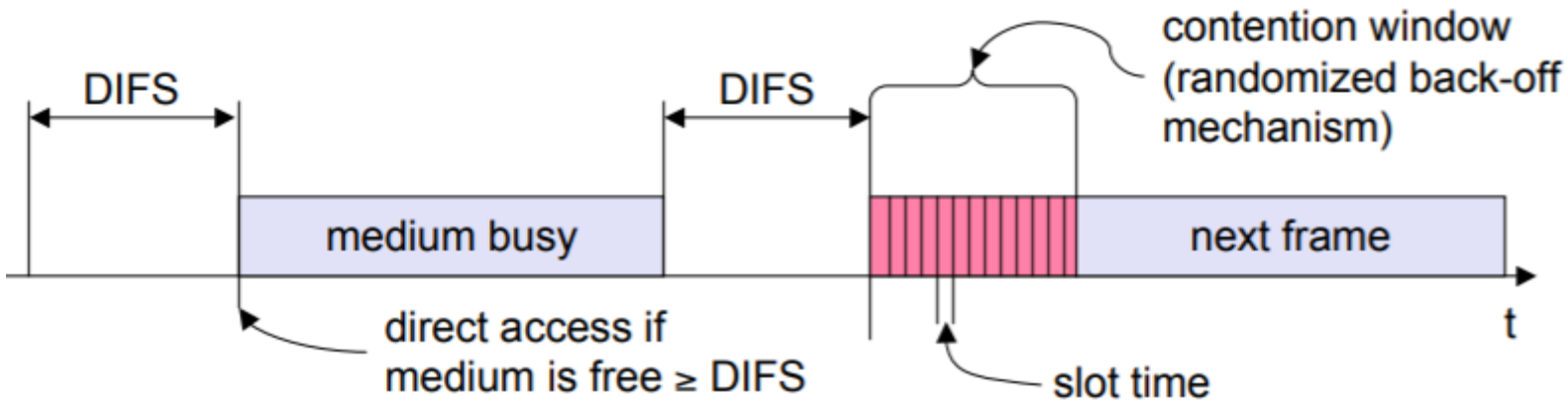
Contention

- 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



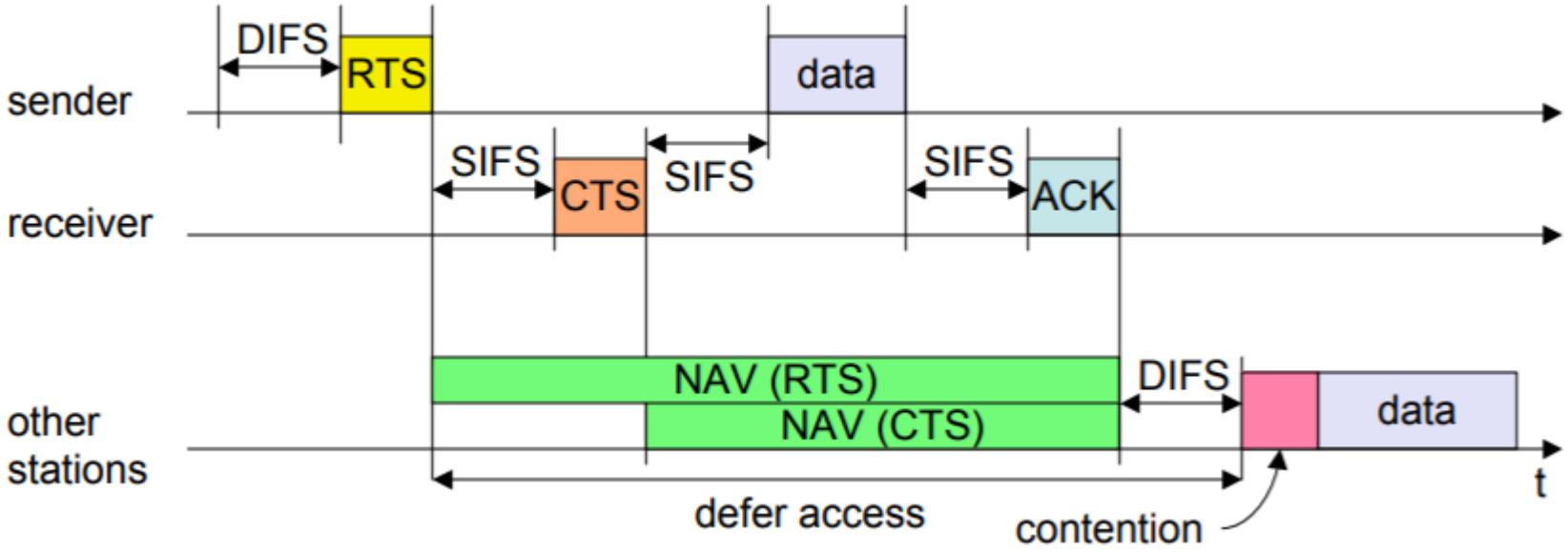
Exponential Backoff

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



Wi-Fi MAC

- With RTS/CTS



Wi-Fi Protocol Stack