Case Study: 802.11 MAC (Based on CSMA/CA)

Kameswari Chebrolu

MAC

- 802.11 specifies
  - **DCF: Distributed Coordination Function (distributed); employs CSMA/CA MAC**
  - PCF: Point Coordination Function (centralized)
- Background: Get familiarized with Ethernet MAC -- CSMA/CD

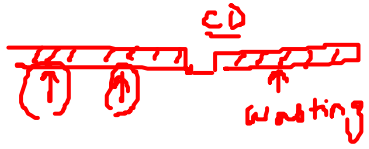
Quick Recap - Ethernet MAC: CSMA/CD

- CSMA/CD: Carrier-Sense Multiple Access with Collision Detection
  - Listen before transmit (CS)
  - Tx when (as soon as) medium is free (1-persistent)
  - Collision Detection (CD)
  - Backoff (exponential) on collision

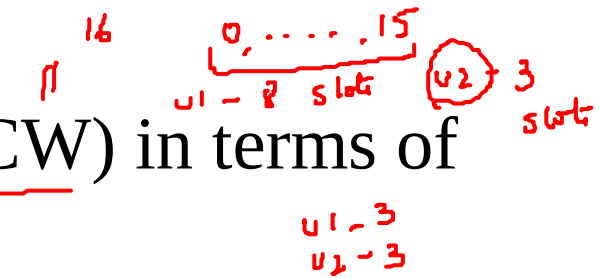
Collision Detection

- What causes collisions?
  - Simultaneous transmissions
  - Near simultaneous transmissions can cause collisions due to propagation delay
- Collision detection very difficult in wireless
  - Tx power is relatively very high near the transmitter

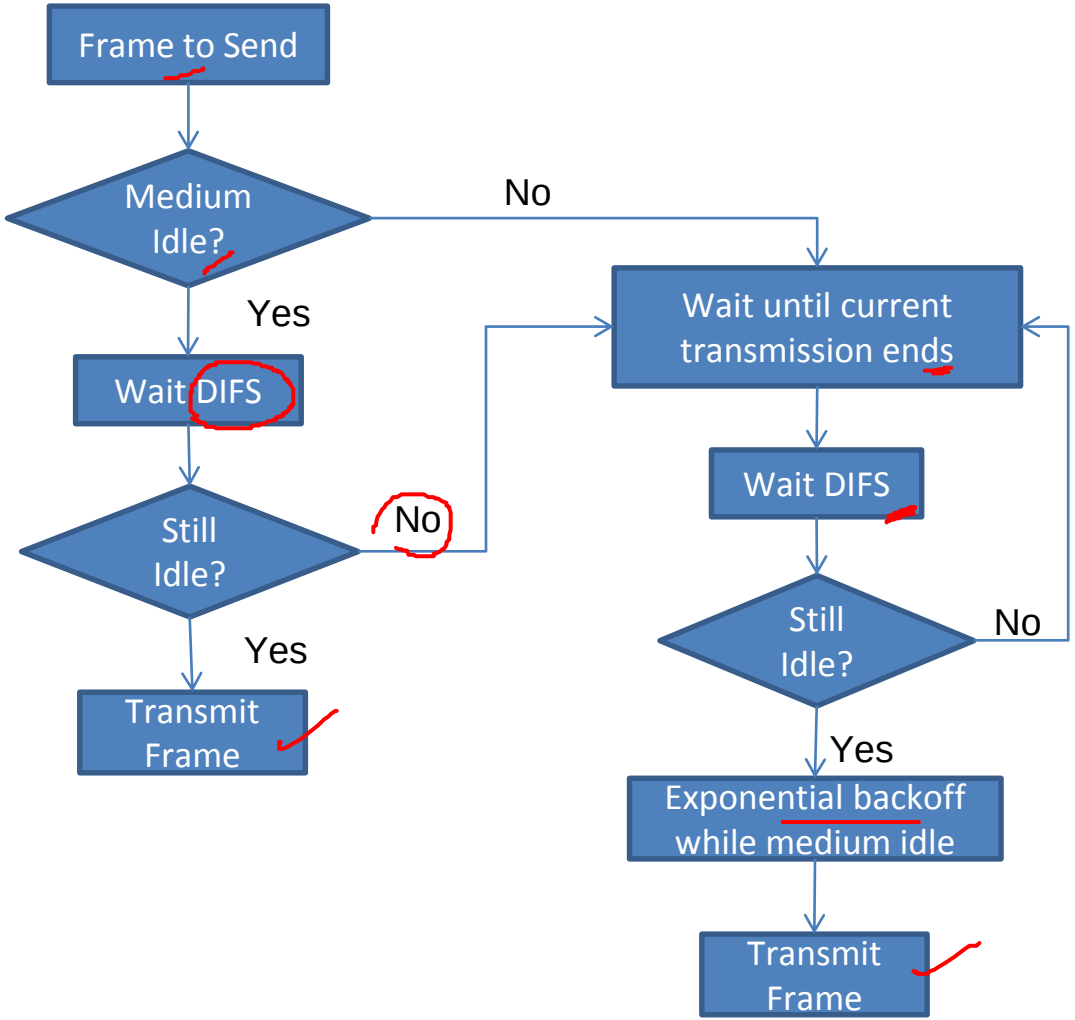
Solution Approach



- Collision Avoidance: Backoff before transmission (in contrast to 1-persistent approach of Ethernet)
  - Achieved via Contention Window (CW) in terms of number of slots
- But collisions still inevitable
  - How to detect collision then?
  - Answer: Immediate ACK (No ACK → Collision)

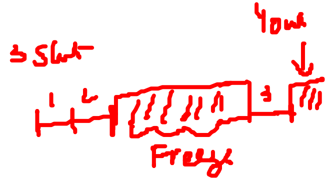


802.11 MAC Logic

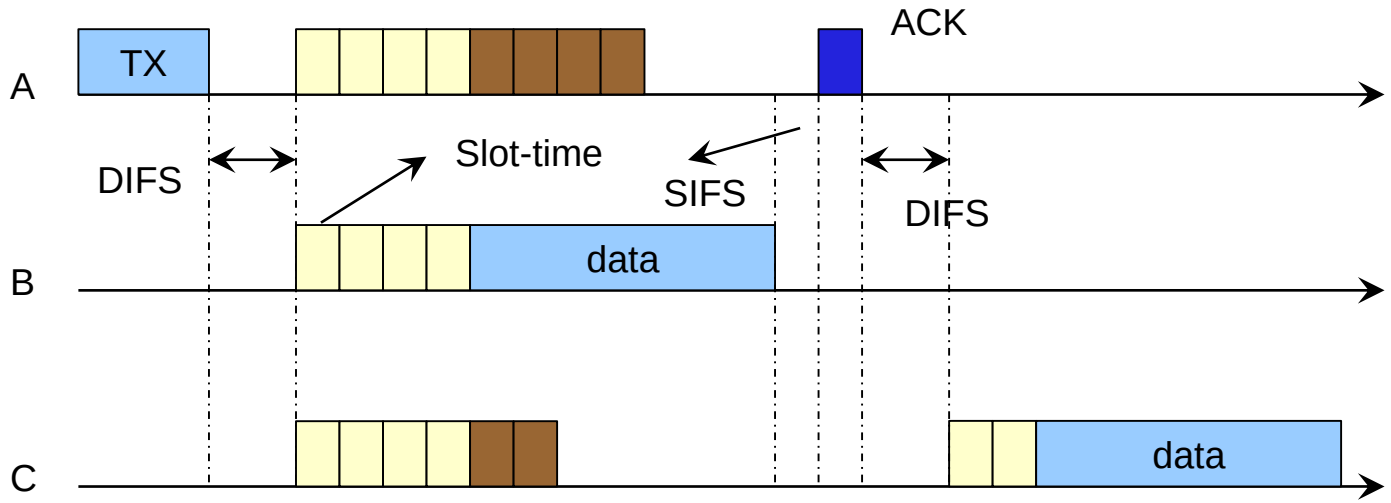


Exponential Backoff

- Contention Window (CW): Choose number of slots within window to backoff (view as Backoff counter)
- Decrement backoff counter over time if channel idle
  - Freeze counter when channel busy
- Backoff counter hits zero, (re)transmit frame
  - Two stations hit zero same time will collide
- Each failed transmission, double CW
  - Start at CW_{min} and go till CW_{max}
  - Give up after retry limit of retransmission reached



CSMA/CA + ACK

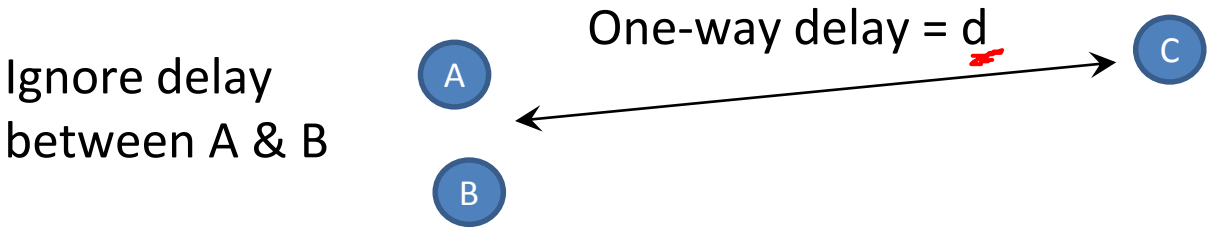


- ACK missing ➔ deduce collision, retransmit
  - Have to contend anew
- SIFS should be < DIFS
  - ACK gets higher priority over next frame

Interframe Spacing

- Short Interframe Space (SIFS): Permits transmitting station to switch back to receiving
  - Depends on PHY hardware capabilities
  - Standards in 2.4Ghz use10 us while 5 Ghz use 16 us
- DCF Interframe Spacing (DIFS) = SIFS + 2*slot-time
  - Slot-time is 20us for 802.11b, 802.11g, 802.11n
  - Slot-time is 9us for 802.11a, 802.11g, 802.11n, 802.11ac
- PCF Interframe Spacing (PIFS) = SIFS + slot-time

What Determines Slot Time?

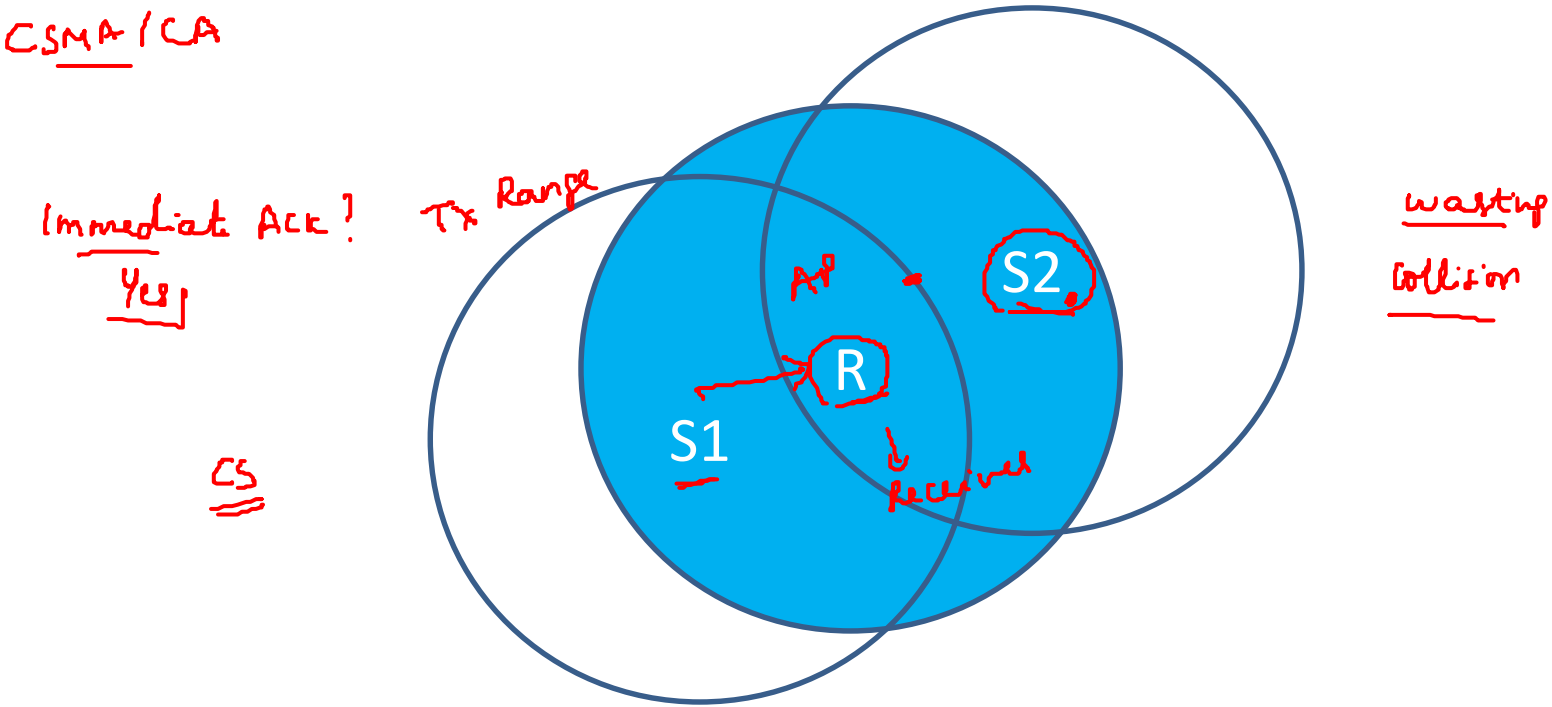


1. A finishes tx at time t
2. B senses channel as free at t, C senses channel as free at t+d
3. C starts sending at t+d+DIFS, this reaches B at t+d+DIFS+d
4. For B to detect the slot is idle/busy ➔ slot-time should be > 2d

- Slot-time has other dependences as well

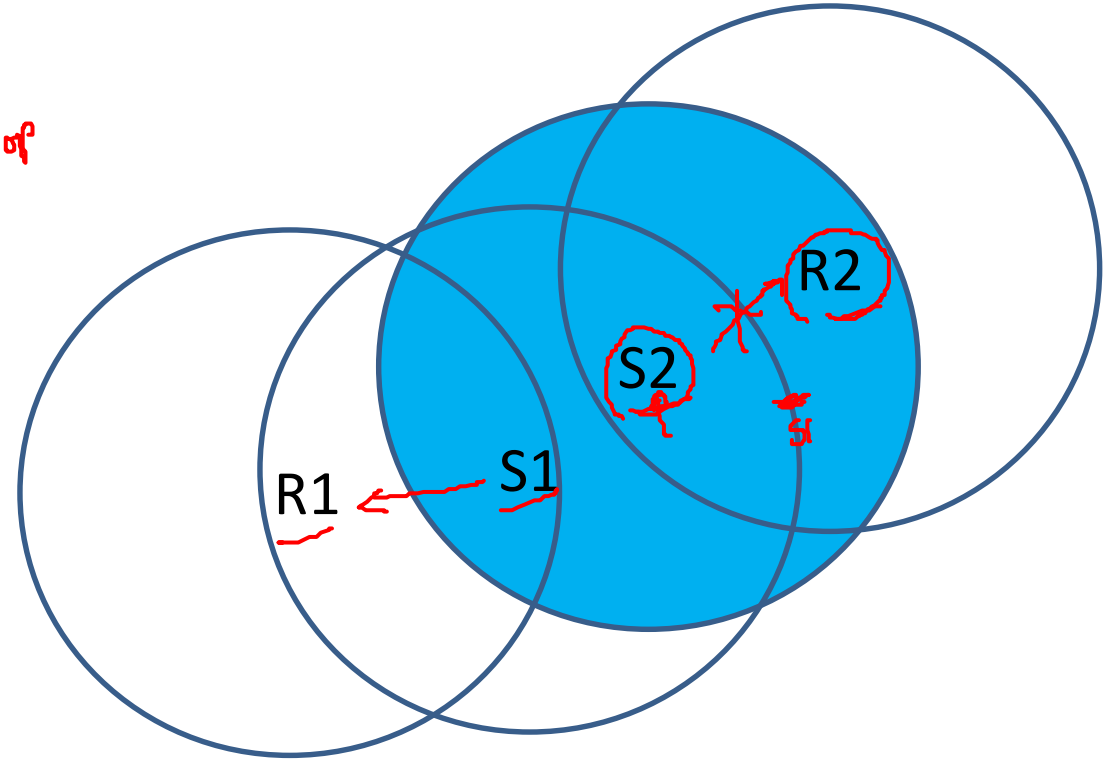
Break

The Hidden Node Problem



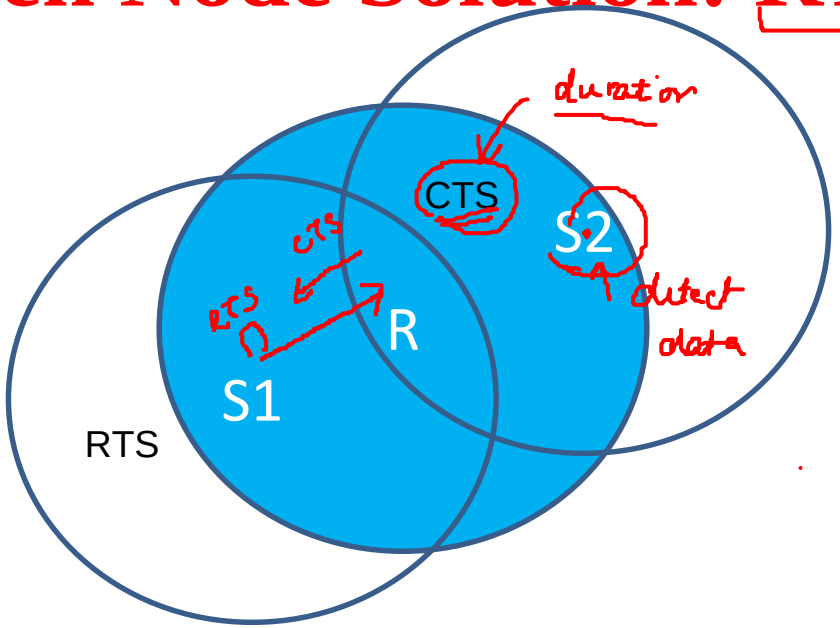
Medium is free DOES NOT IMPLY ok to transmit

The Exposed Node Problem

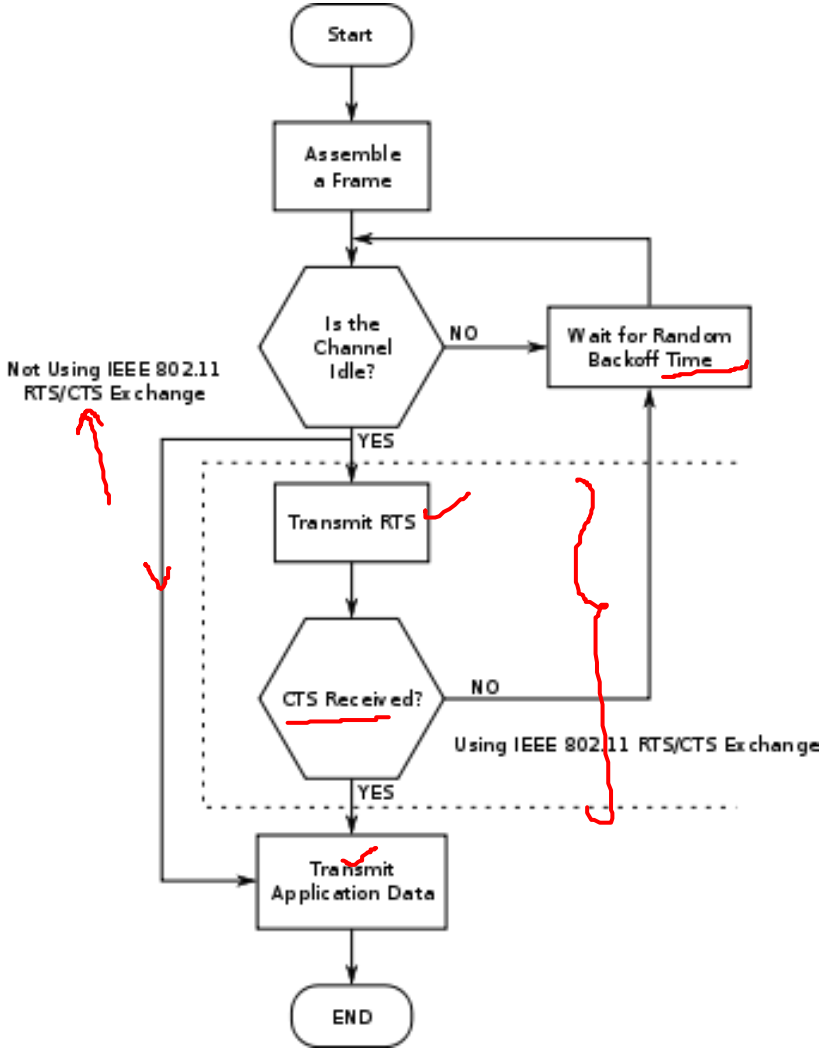


Medium is busy DOES NOT IMPLY not-ok to transmit

Hidden Node Solution: RTS/CTS



1. S1 says “can I send for X duration?” (RTS)
2. R says “yes, send for Y duration” (CTS)
3. S2 knows to be silent for Y duration

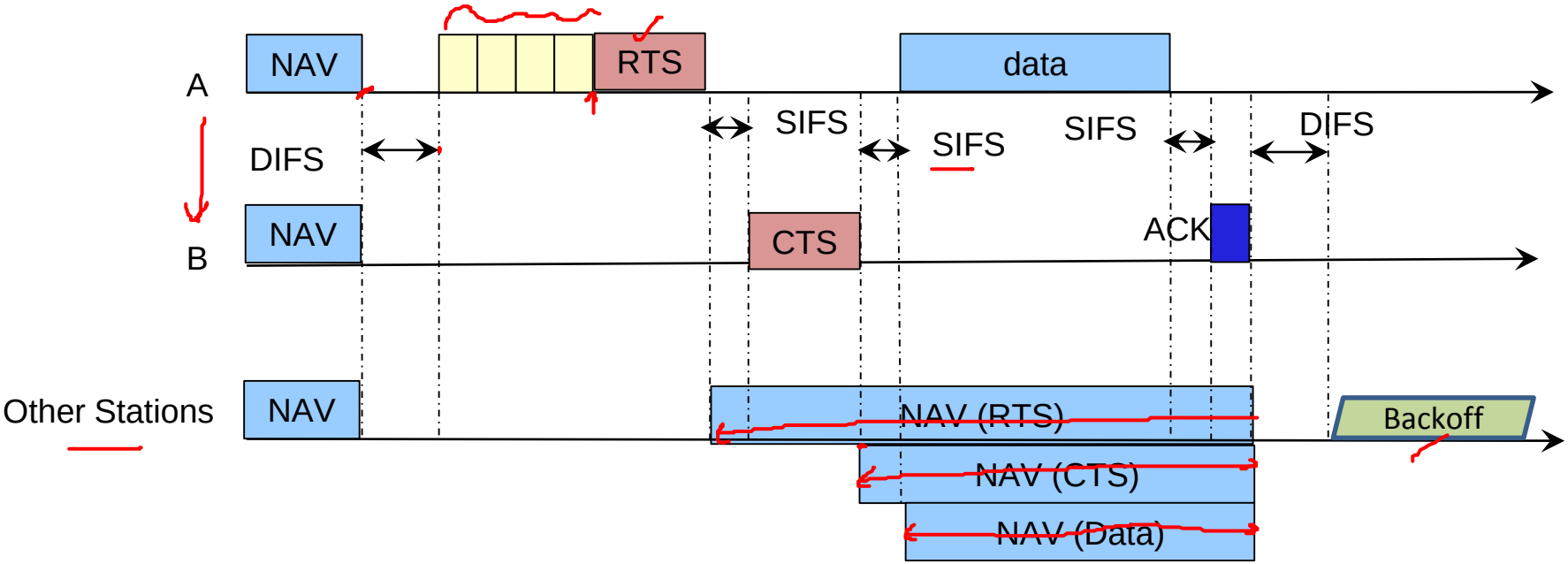

Start
Assemble a Frame
Is the Channel Idle?
NO
Wait for Random Backoff Time
Not Using IEEE 802.11 RTS/CTS Exchange
YES
Transmit RTS
CTS Received?
NO
Using IEEE 802.11 RTS/CTS Exchange
YES
Transmit Application Data
END

Virtual Carrier Sensing

- Duration is specified in the duration id field in RTS/CTS
  - Important to specify since some nodes may not hear the data packet
- Network Allocation Vector (NAV): counter that implements virtual carrier sensing
  - Assumes channel is busy for this duration (doesn't have to sense channel)
  - Captures the time that must elapse before checking status of the channel

RTS/CTS Questions

1. Access mechanism before sending RTS?
2. Gap between RTS & CTS?
3. Gap between CTS & DATA?
4. Can there be collision of two RTS frames?
5. What are the disadvantages of using RTS/CTS? When should it not be used?


A
B
NAV
RTS
data
DIFS
SIFS
SIFS
SIFS
DIFS
NAV
CTS
ACK
Other Stations
NAV
NAV (RTS)
Backoff
NAV (CTS)
NAV (Data)

Points to Note

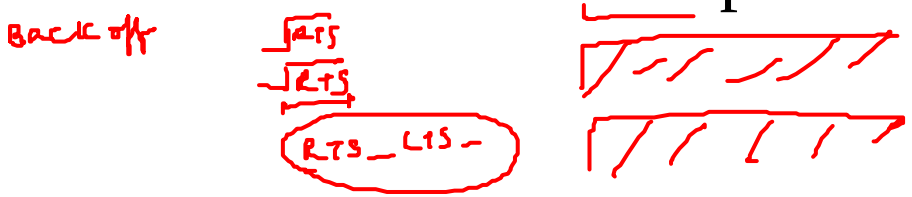
- Access mechanism before sending RTS?
  - RTS precedes data transmission
- Gap between RTS & CTS?
- Gap between CTS & DATA?

DIFS

  - Use of SIFS to gain access to the media

Points to Note

- Can there be collision of two RTS frames?
  - RTS can experience collision. Its ok since RTS packets are small



- What are the disadvantages of using RTS/CTS? When should it not be used?
  - Drawback: High Overhead especially for short data packets
  - Use RTS threshold: RTS/CTS used only if data packet exceeds the threshold

Summary

- 802.11 MAC based on a random access protocol CSMA/CA
- Understood the various aspects of the MAC
  - Why CA and not CD? How to detect collisions? Why IFS? What dictates slot times? etc
- Problems with basic MAC: hidden terminal problem
  - Solution in the form of RTS/CTS and virtual carrier sensing
- MAC design can be challenging: lot of subtleties