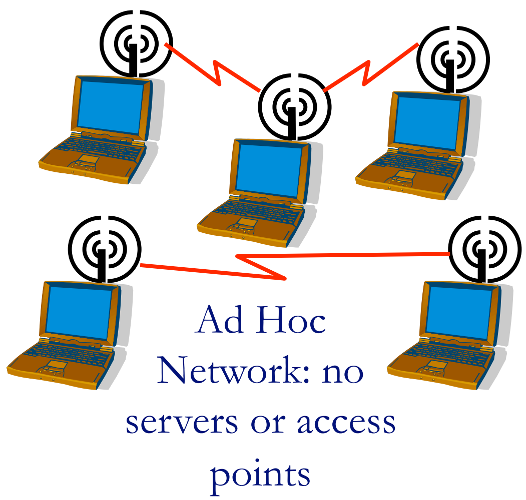
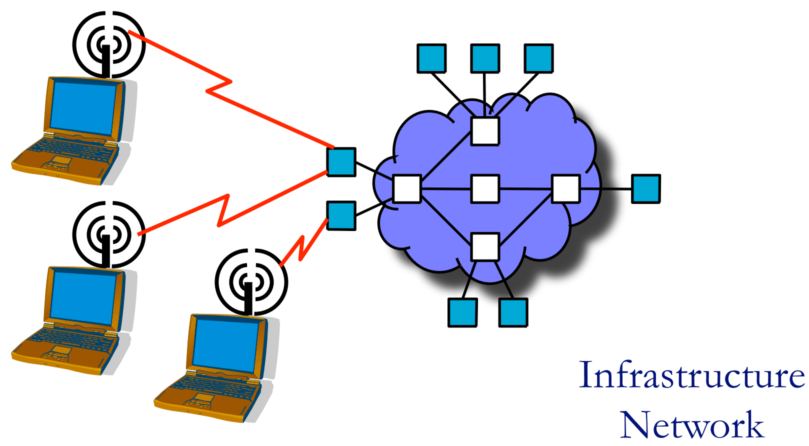
CSE 461: Wireless Networks

Wireless

- IEEE 802.11
  - A physical and multiple access layer standard for wireless local area networks (WLAN)





802.11 Protocol Stages

- Discovery
  - Ben's laptop: "Is network UniversityOfWashingtonCSE out there?"
    - This is the SSID, or network name
    - Sent in a probe request – ACTIVE SCANNING
  - Network: "Yep, I'm UniversityOfWashingtonCSE!"
    - Probe reply
    - Alternatively, network could announce – PASSIVE SCANNING
- Authentication
  - Ben's laptop: "Hey, this is Ben. Let me use your network"
  - Network: "OK. Your credentials check."

802.11 Protocol Stages (cont.)

- Association
  - Ben's laptop: "Alright, I'm binding to you. Here are my capabilities."
  - Network: "OK, I've got you in my table. Here are my capabilities."
- Data communication
  - Ben's laptop: "Give me an IP address"
  - Ben's laptop: "Stream the Daily Show…"

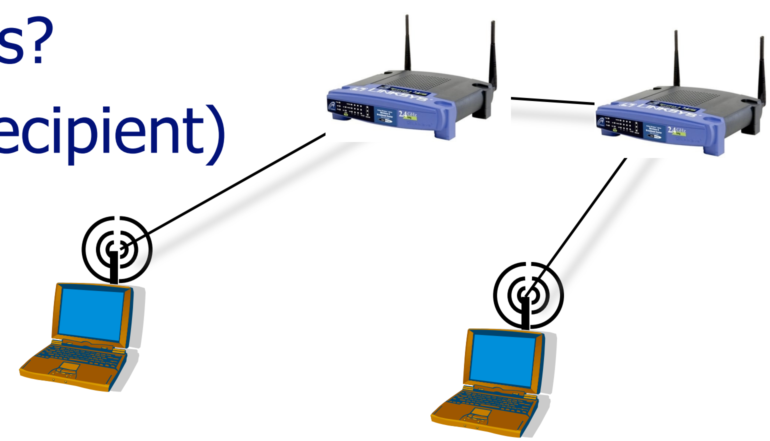
802.11 Frame Format

Octets: 2	2	6	6	6	2	6	0 - 2312	4
Frame Control	Duration/ ID	Address 1	Address 2	Address 3	Sequence Control	Address 4	Frame Body	FCS

MAC Header

Type is in here (e.g., probe request)

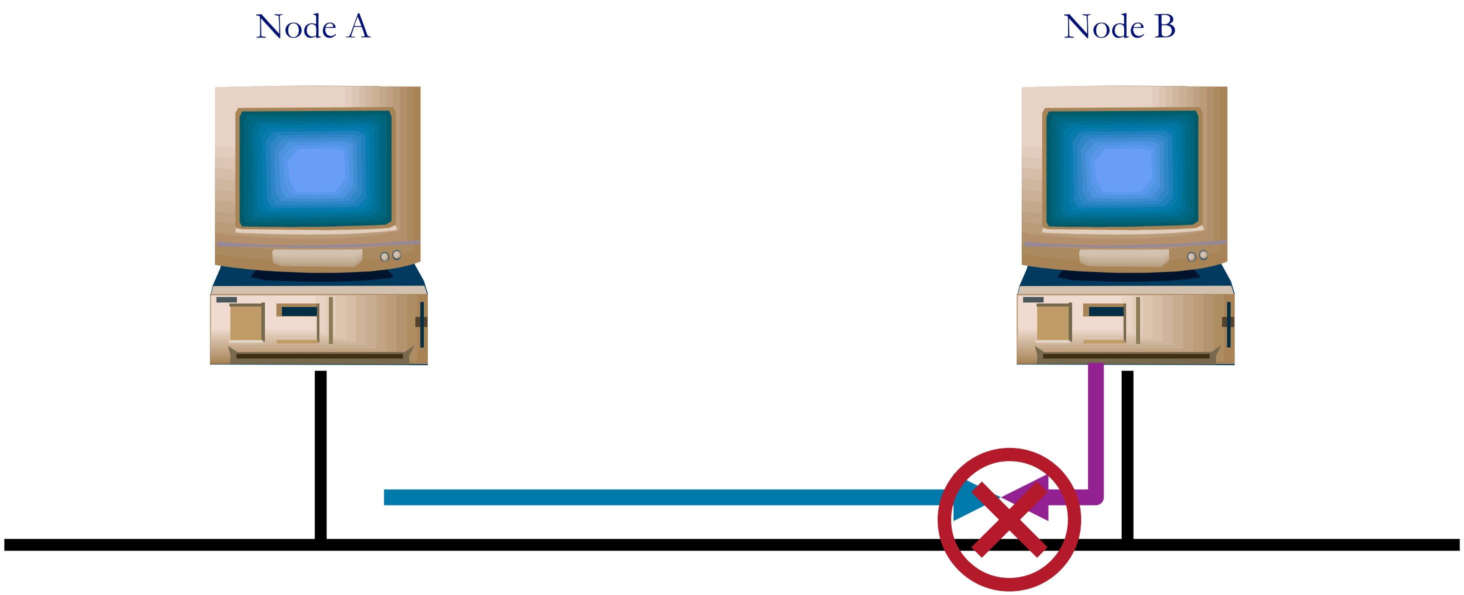
- Why are there FOUR addresses?
  - Destination address (final recipient)
  - Source address
  - Receiver address
  - Transmitter address



Medium Access Control

- Wireless channel is a shared medium
- Need access control mechanism to avoid interference
- Why not CSMA/CD?

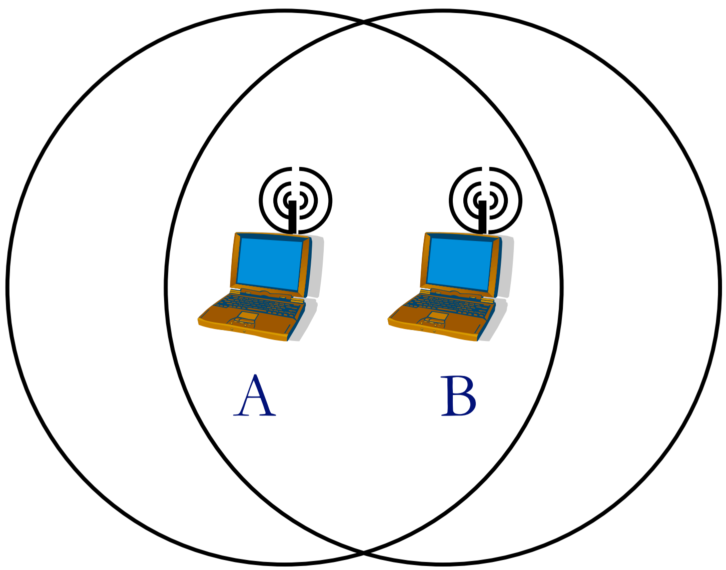
Ethernet MAC Algorithm



- Listen for carrier sense before transmitting
- Collision: What you hear is not what you sent!

CSMA/CD in WLANs?

- Most (if not all) radios are half-duplex
  - Listening while transmitting is not possible
- Collision might not occur at sender
  - Collision at receiver might not be detected by sender!

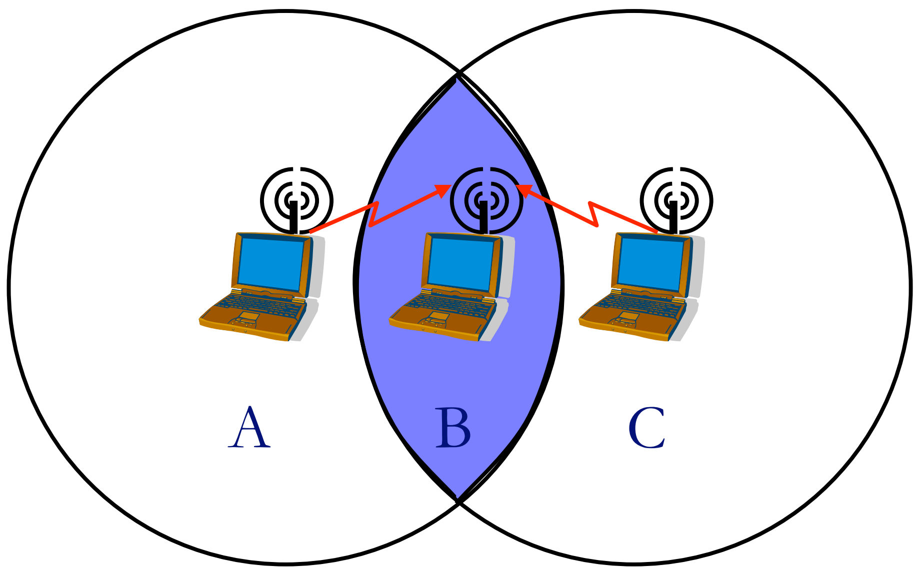


Wireless Ethernet - CSMA/CA

- CS – Carrier Sense
  - Nodes can distinguish between an idle and a busy link
- MA - Multiple Access
  - A set of nodes send and receive frames over a shared link
- CA – Collision Avoidance
  - Nodes use protocol to prevent collisions from occurring

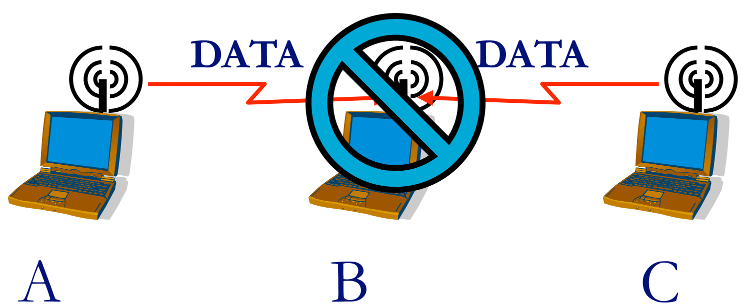
IEEE 802.11 MAC Layer Standard

- Similar to Ethernet
- But consider the following:



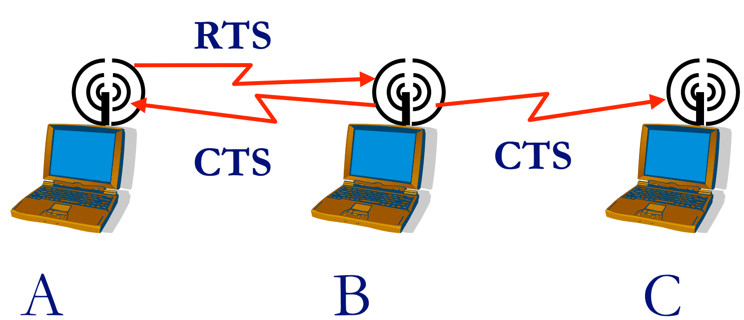
Hidden Terminal Problem

- Node B can communicate with both A and C
- A and C cannot hear each other
- When A transmits to B, C cannot detect the transmission using the carrier sense mechanism
- If C transmits, collision will occur at node B



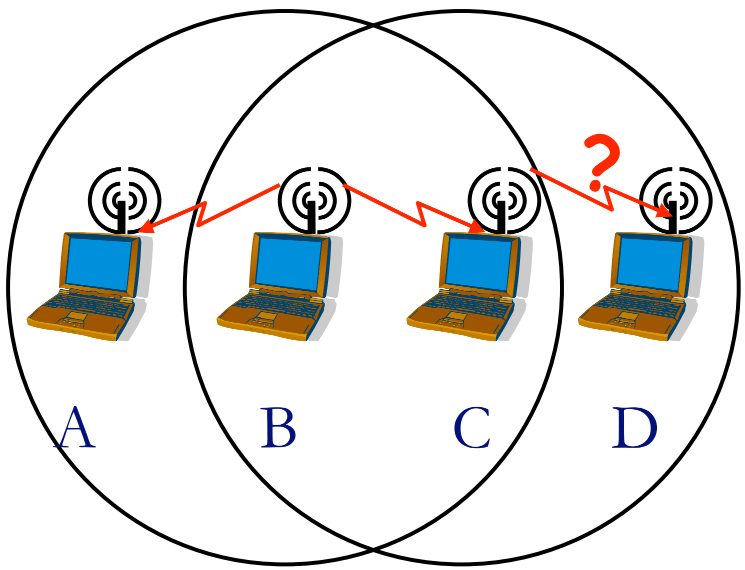
MACA Solution for Hidden Terminal Problem

- When node A wants to send a packet to node B
  - Node A first sends a Request-to-Send (RTS) to A
- On receiving RTS
  - Node A responds by sending Clear-to-Send (CTS)
  - provided node A is able to receive the packet
- When a node C overhears a CTS, it keeps quiet for the duration of the transfer



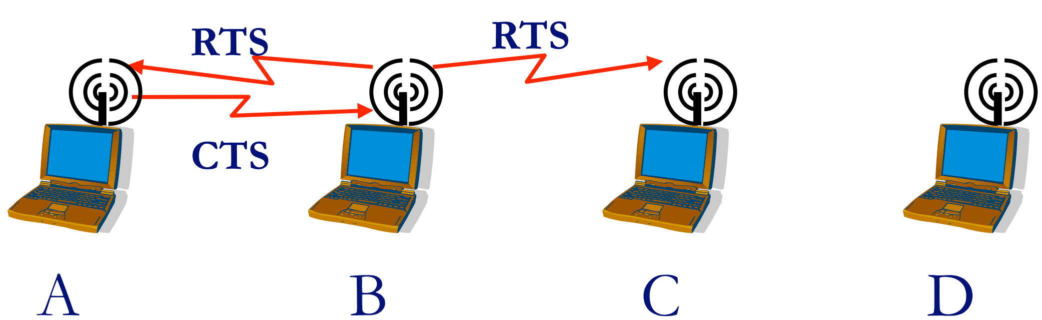
IEEE 802.11 MAC Layer Standard

- But we still have a problem



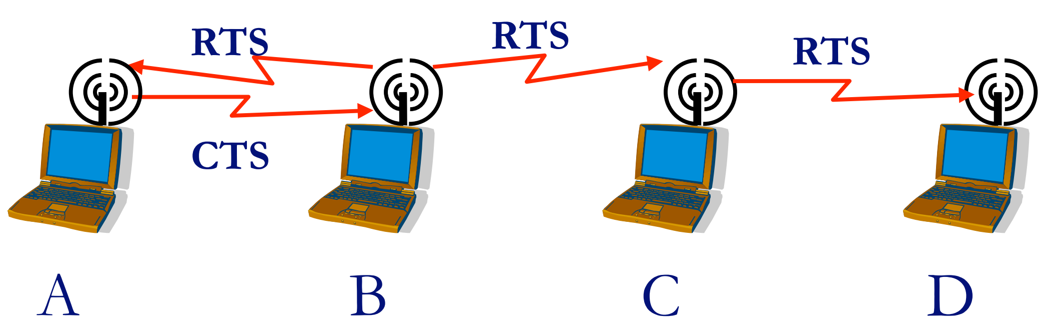
Exposed Terminal Problem

- B talks to A
- C wants to talk to D
- C senses channel and finds it to be busy
- C stays quiet (when it could have ideally transmitted)



MACA Solution for Exposed Terminal Problem

- Sender transmits Request to Send (RTS)
- Receiver replies with Clear to Send (CTS)
- Neighbors
  - See CTS - Stay quiet
  - See RTS, but no CTS - OK to transmit



IEEE 802.11 MAC Layer Standard

- MACAW – Multiple Access with Collision Avoidance for Wireless
  - Sender transmits Request to Send (RTS)
  - Receiver replies with Clear to Send (CTS)
  - Neighbors
    - See CTS
      - Stay quiet
    - See RTS, but no CTS
      - OK to transmit
  - Receiver sends ACK for frame
    - Neighbors stay silent until they hear ACK

Collisions

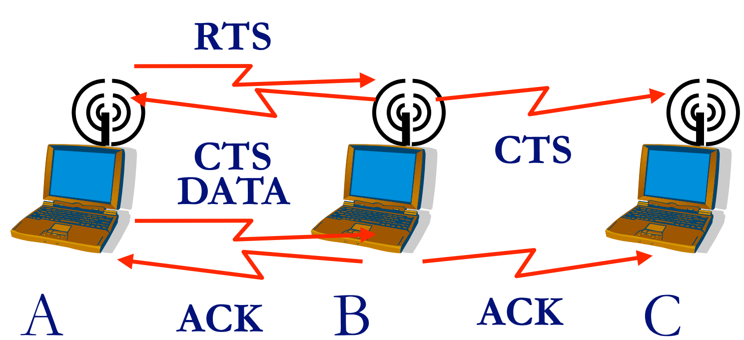
- Still possible
  - RTS packets can collide!
- Binary exponential backoff
  - Backoff counter doubles after every collision and reset to minimum value after successful transmission
  - Performed by stations that experience RTS collisions
- RTS collisions not as bad as data collisions in CSMA
  - Since RTS packets are typically much smaller than DATA packets

Reliability

- Wireless links are prone to errors
  - High packet loss rate detrimental to transport-layer performance
- Mechanisms needed to reduce packet loss rate experienced by upper layers

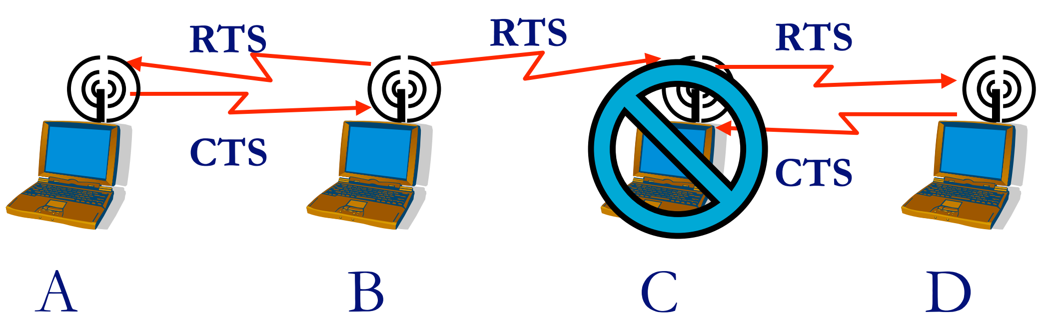
A Simple Solution to Improve Reliability - MACAW

- When node B receives a data packet from node A, node B sends an Acknowledgement (ACK)
- If node A fails to receive an ACK
  - Retransmit the packet



Revisiting the Exposed Terminal Problem

- Problem
  - Exposed terminal solution doesn't consider CTS at node C
- With RTS-CTS, C doesn't wait since it doesn't hear A's CTS
  - With B transmitting DATA, C can't hear intended receiver's CTS
  - C trying RTS while B is transmitting is useless

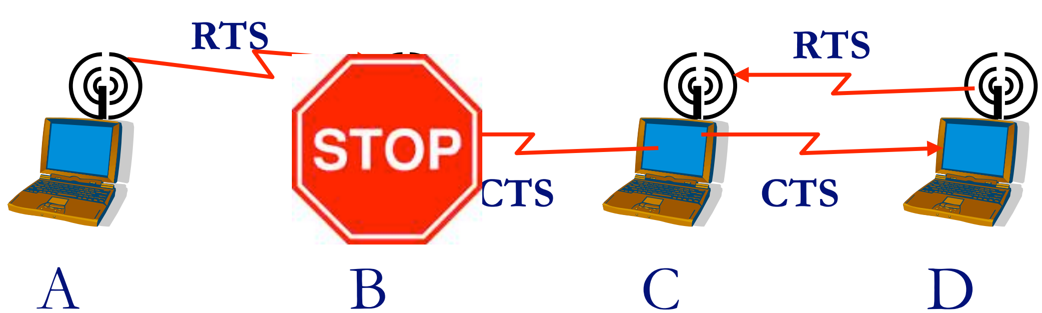


Revisiting the Exposed Terminal Problem - MACAW

- One solution
  - Have C use carrier sense before RTS
- Alternative
  - B sends DS (data sending) packet before DATA
    - Short packet lets C know that B received A's CTS
    - Includes length of B's DATA so C knows how long to wait

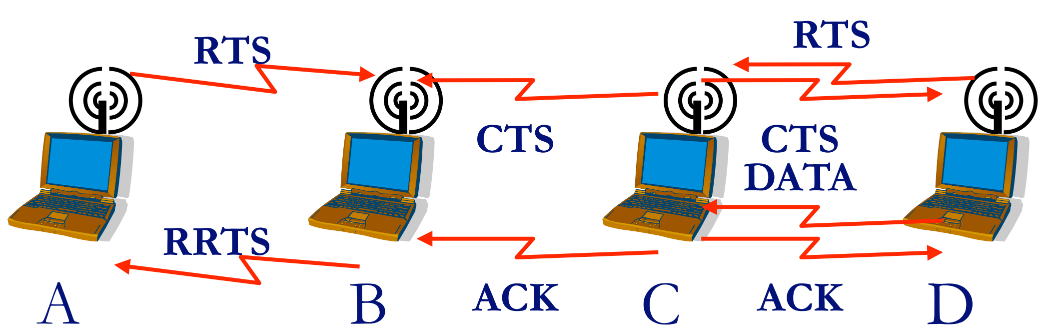
Deafness

- For the scenario below
  - Node A sends an RTS to B
    - While node C is receiving from D,
  - Node B cannot reply with a CTS
    - B knows that D is sending to C
    - A keeps retransmitting RTS and increasing its own BO timeout



Request for RTS - MACAW

- Have B do contention on behalf of A
  - If B receives RTS for which it must defer CTS reply
  - Then B later sends RRTS to A when it can send
  - A responds by starting normal RTS-CTS
  - Others hearing RRTS defer long enough for RTS-CTS

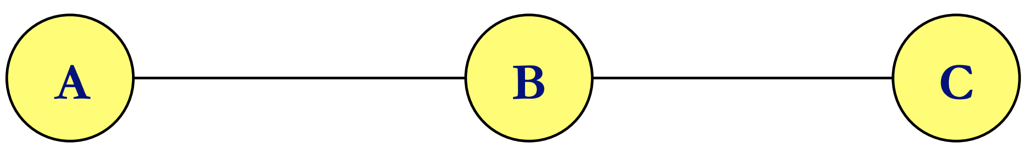


IEEE 802.11 Wireless MAC

- Distributed and centralized MAC components
  - Distributed Coordination Function (DCF)
  - Point Coordination Function (PCF)
- DCF suitable for multi-hop ad hoc networking
- DCF is a Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) protocol

IEEE 802.11 DCF

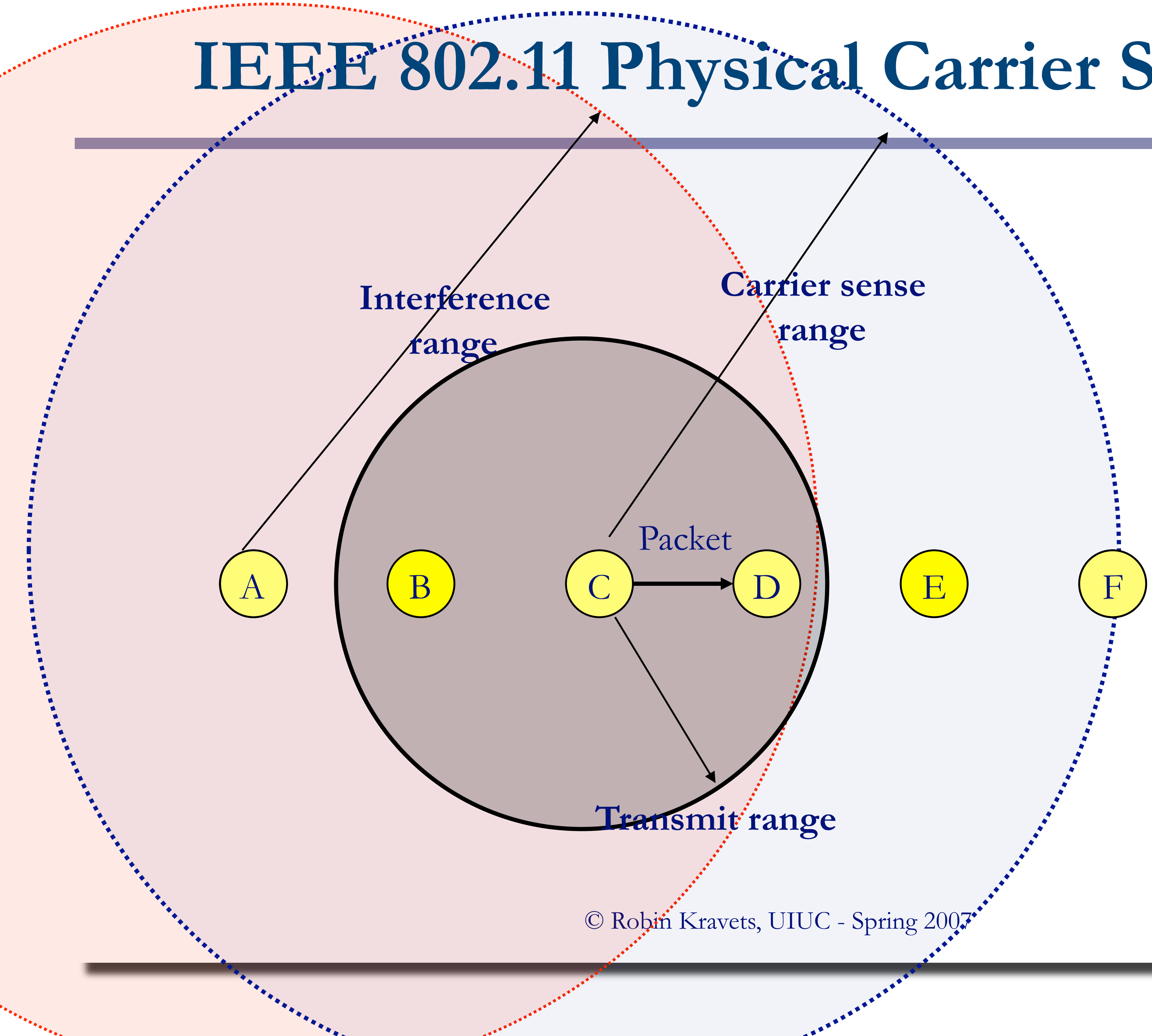
- Uses RTS-CTS exchange to avoid hidden terminal problem
  - Any node overhearing a CTS cannot transmit for the duration of the transfer
- Uses ACK to achieve reliability
- Any node receiving the RTS cannot transmit for the duration of the transfer
  - To prevent collision with ACK when it arrives at the sender
  - When B is sending data to C, node A keeps quite



IEEE 802.11 CSMA/CA

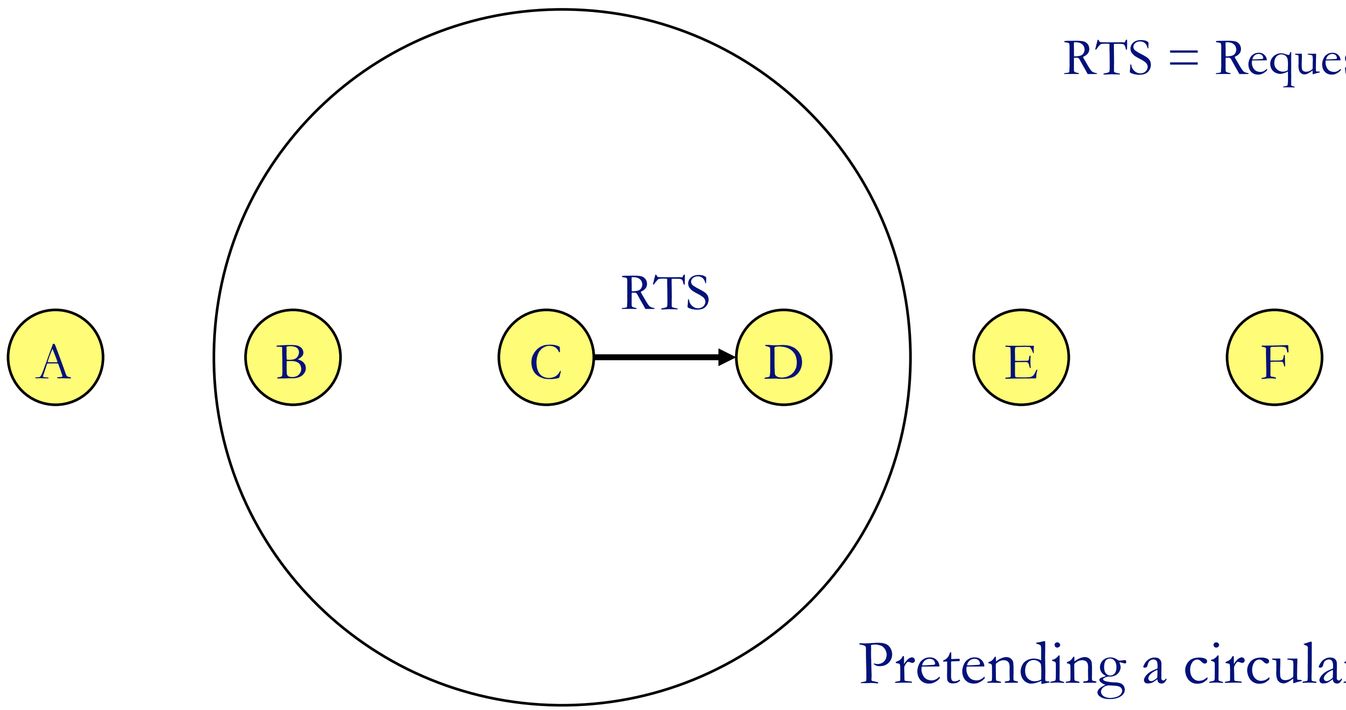
- Nodes stay silent when carrier sensed
  - Physical carrier sense
  - Virtual carrier sense
    - Network Allocation Vector (NAV)
    - NAV is updated based on overheard RTS/CTS/DATA/ACK packets, each of which specified duration of a pending transmission
- Backoff intervals used to reduce collision probability

IEEE 802.11 Physical Carrier Sense



IEEE 802.11 Virtual Carrier Sense

RTS = Request-to-Send

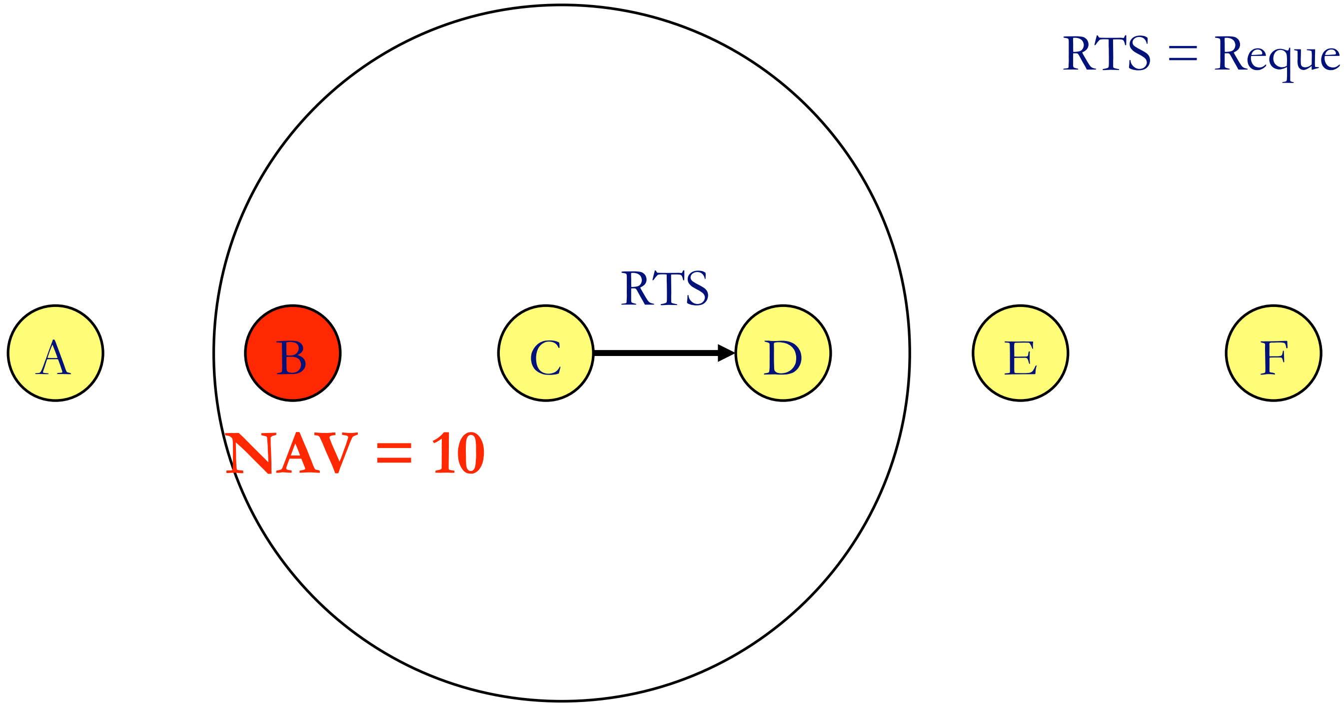


Pretending a circular range

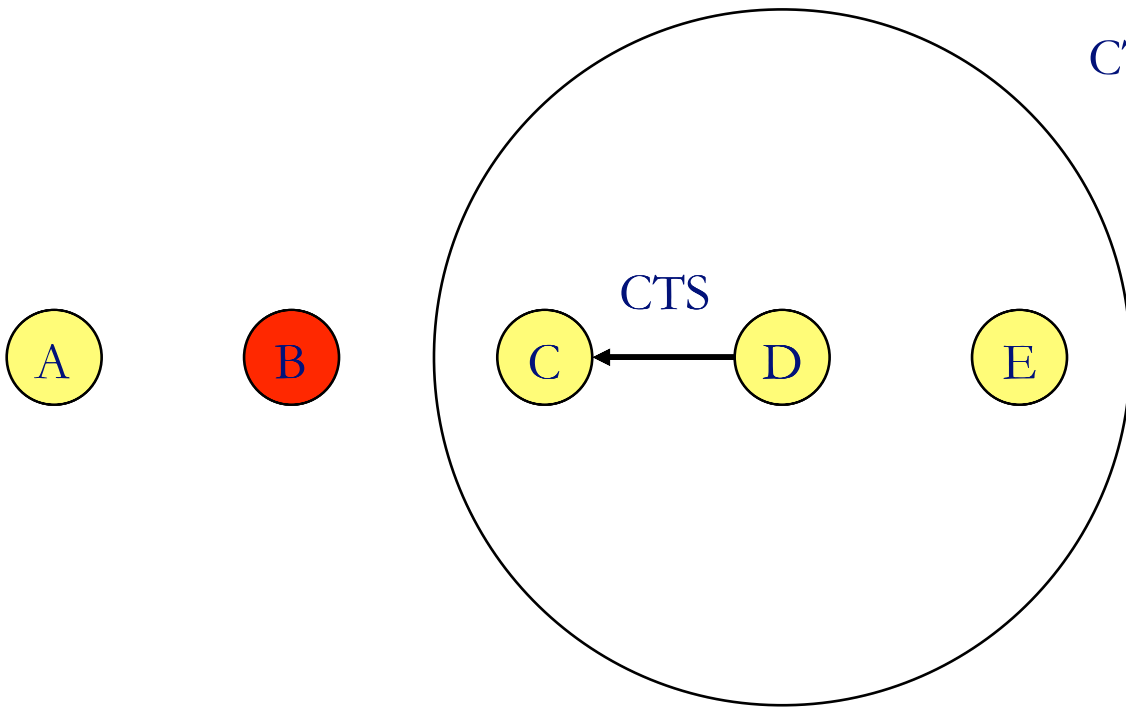
IEEE 802.11 Virtual Carrier Sense

NAV = remaining duration to keep quiet

RTS = Request-to-Send



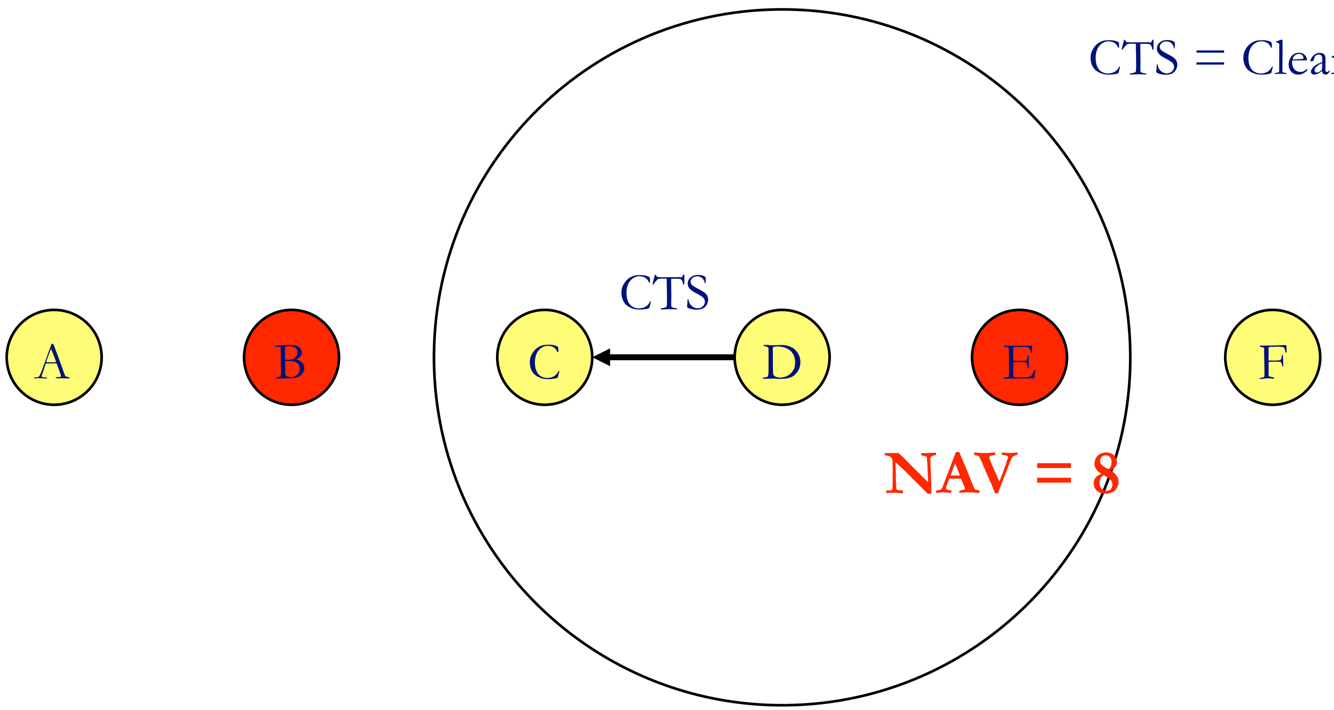
IEEE 802.11 Virtual Carrier Sense



CTS = Clear-to-Send

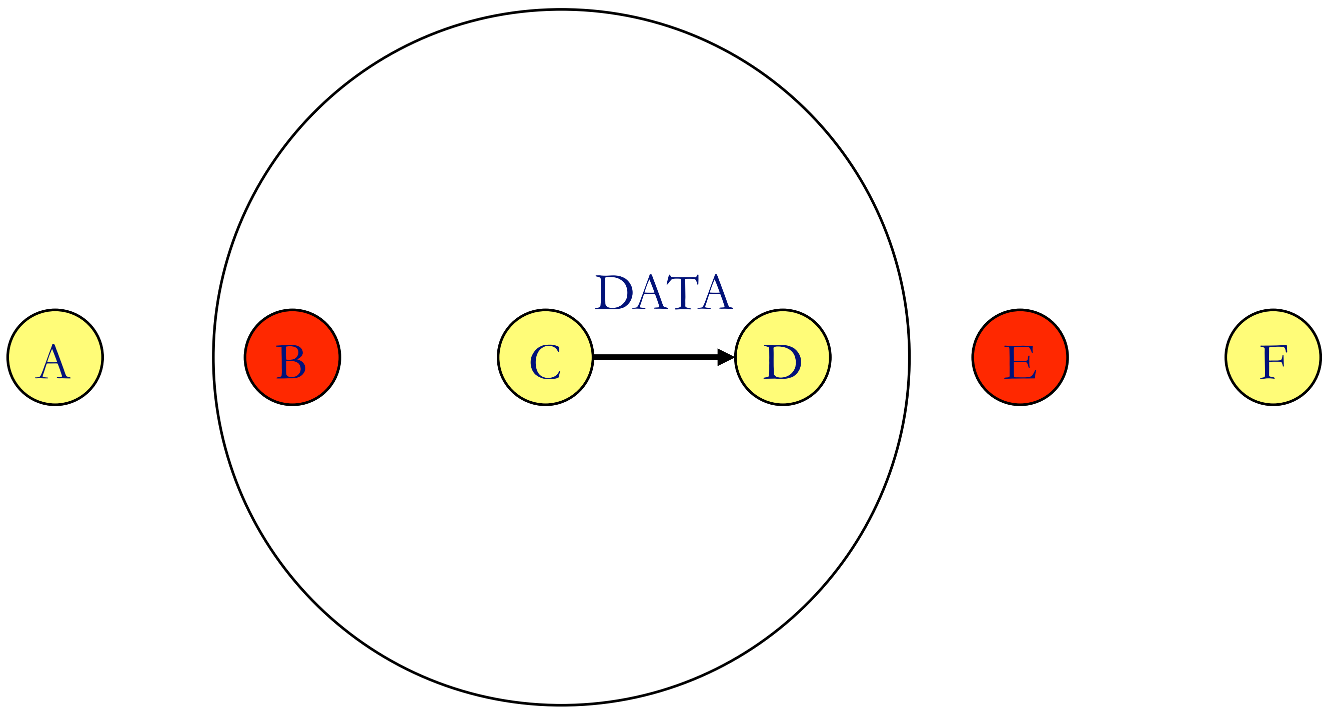
IEEE 802.11 Virtual Carrier Sense

CTS = Clear-to-Send



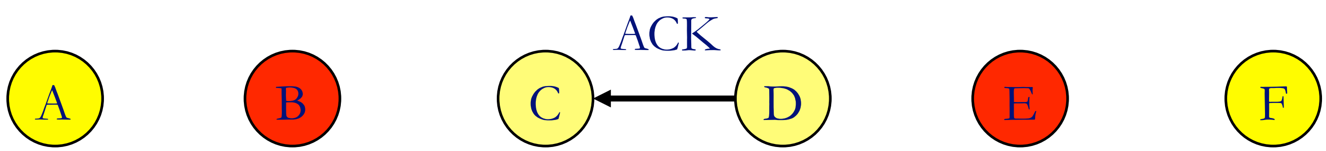
IEEE 802.11 Virtual Carrier Sense

- DATA packet follows CTS

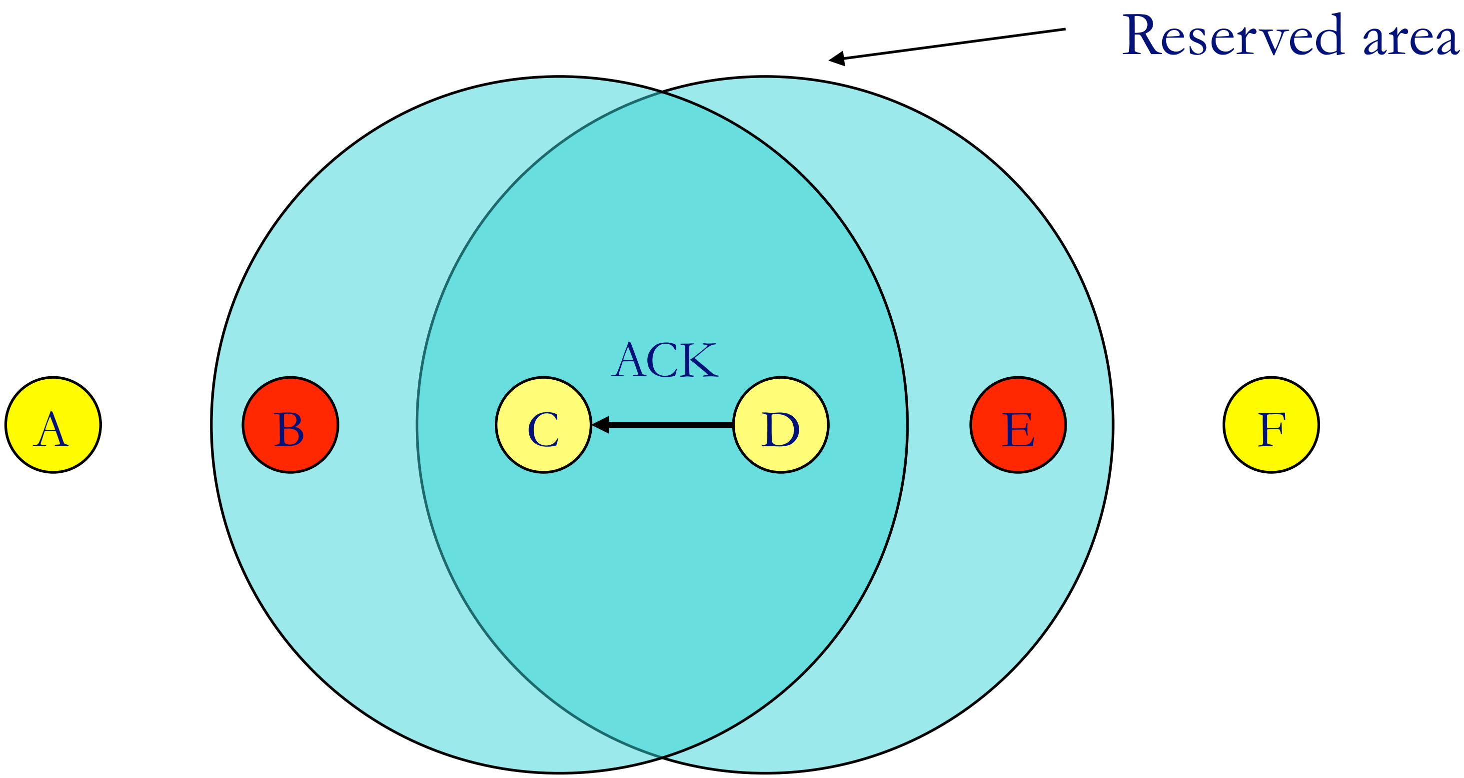


IEEE 802.11 Virtual Carrier Sense

- Successful data reception acknowledged using ACK

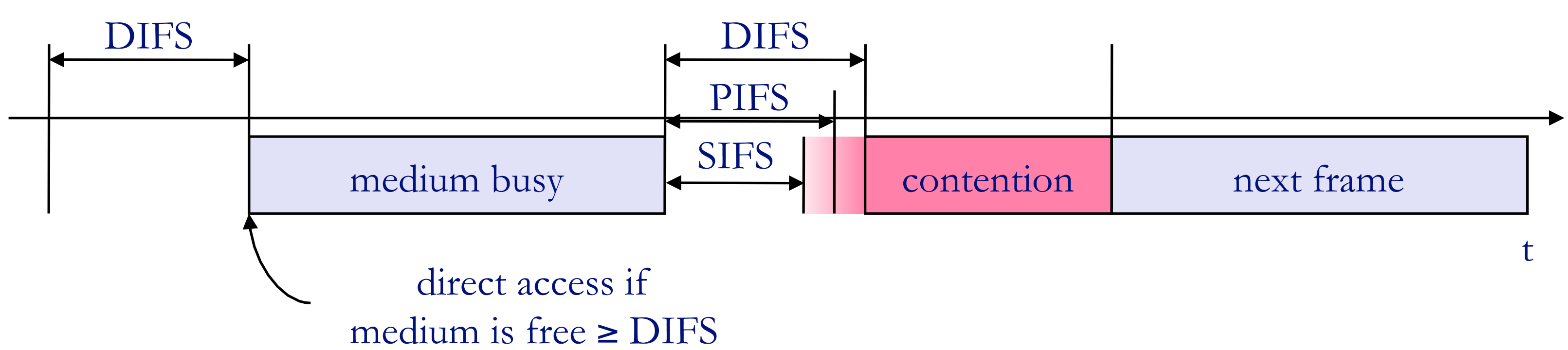


IEEE 802.11



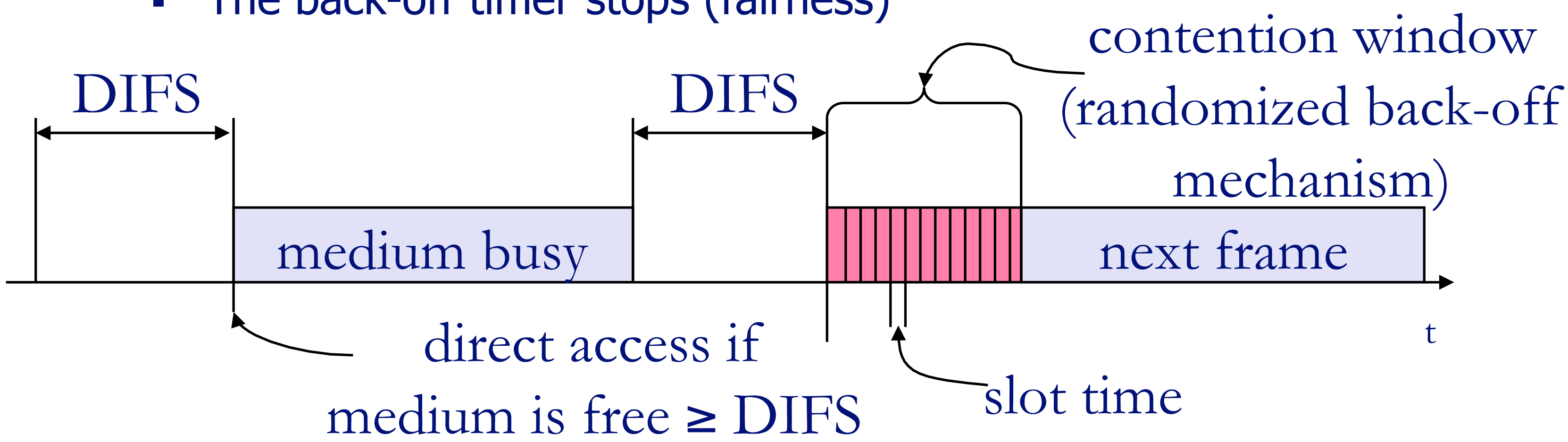
Interframe Spacing

- Interframe spacing
  - Plays a large role in coordinating access to the transmission medium
- Varying interframe spacings
  - Creates different priority levels for different types of traffic!
- 802.11 uses 4 different interframe spacings



IEEE 802.11 - CSMA/CA

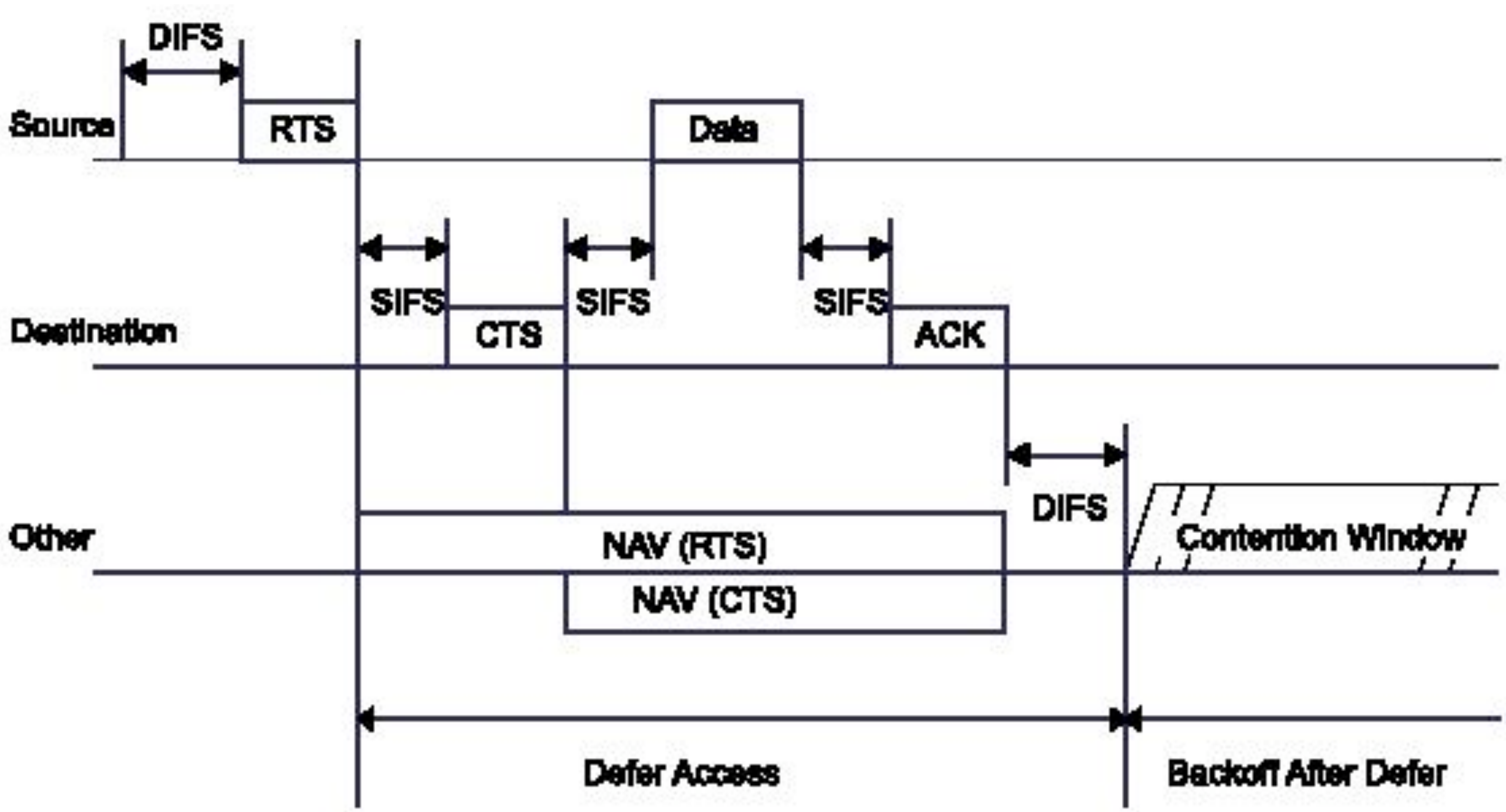
- Sensing the medium
- If free for an Inter-Frame Space (IFS)
  - Station can start sending (IFS depends on service type)
- If busy
  - Station waits for a free IFS, then waits a random back-off time (collision avoidance, multiple of slot-time)
- If another station transmits during back-off time
  - The back-off timer stops (fairness)



Types of IFS

- SIFS
  - Short interframe space
  - Used for highest priority transmissions
  - RTS/CTS frames and ACKs
- DIFS
  - DCF interframe space
  - Minimum idle time for contention-based services (> SIFS)
- PIFS
- EIFS

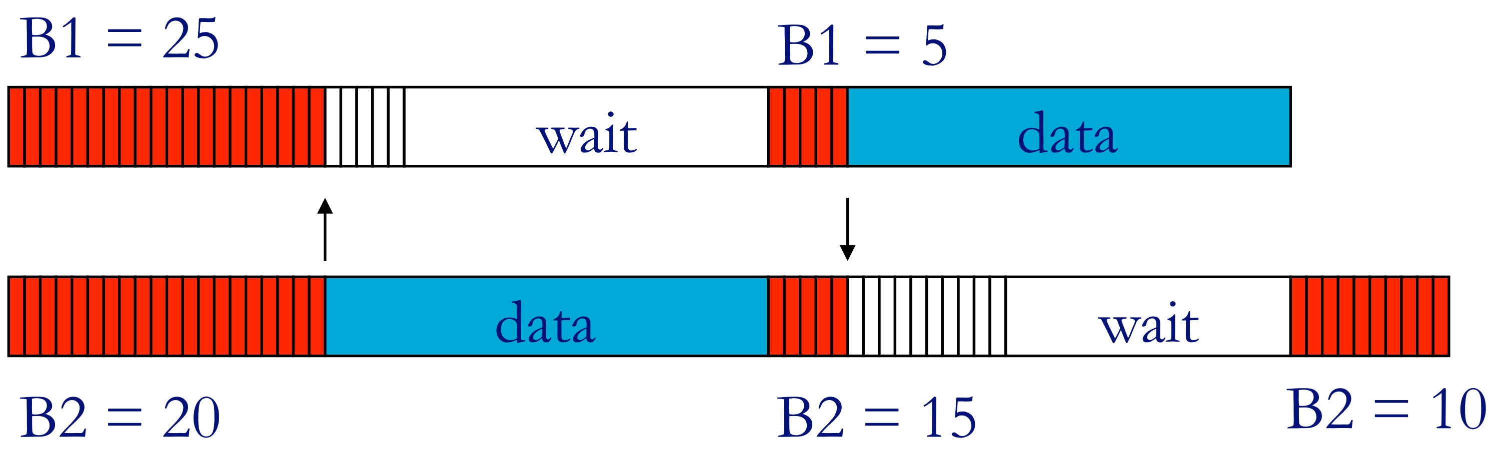
Competing Stations



Backoff Interval

- When transmitting a packet, choose a backoff interval in the range [0,CW]
  - CW is contention window
- Count down the backoff interval when medium is idle
  - Count-down is suspended if medium becomes busy
- When backoff interval reaches 0, transmit RTS

DCF Example



CW = 31

B1 and B2 are backoff intervals at nodes 1 and 2

Backoff Interval

- The time spent counting down backoff intervals is a part of MAC overhead
- Large CW
  - Large backoff intervals
  - Can result in larger overhead
- Small CW
  - Larger number of collisions (when two nodes count down to 0 simultaneously)

Backoff Interval

- The number of nodes attempting to transmit simultaneously may change with time
  - Some mechanism to manage contention is needed
- IEEE 802.11 DCF
  - Contention window CW is chosen dynamically depending on collision occurrence

Binary Exponential Backoff in DCF

- When a node fails to receive CTS in response to its RTS, it increases the contention window
  - cw is doubled (up to an upper bound)
- When a node successfully completes a data transfer, it restores cw to CW_{min}
  - cw follows a sawtooth curve

Punchline: RTS/CTS rarely used

- Why?
  - Doesn't always work
  - Inefficient
    - 20byte RTS + IFS + 14btye CTS + IFS = lots of overhead
    - On most networks, more efficient to do CS and cross fingers