802.11 Wireless Networks (MAC)

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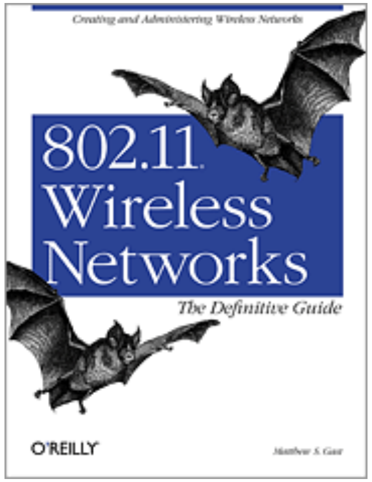
Reference

1. A Technical Tutorial on the IEEE 802.11 Protocol
   By Pablo Brenner
   online: http://www.sss-mag.com/pdf/802_11tut.pdf

2. IEEE 802.11 Tutorial
   By Mustafa Ergen
   online: http://wow.eecs.berkeley.edu/ergen/docs/ieee.pdf

3. 802.11 Wireless Networks: The Definitive Guide
   By Matthew S Gast



We will cover …

- Medium Access Control
  - Infrastructure mode vs. Ad Hoc mode
  - DCF vs. PCF
  - CSMA/CA with exponential backoff
  - Hidden terminal
- Physical Layer Basics
  - Packet Detection
  - OFDM
  - Synchronization
  - Modulation and rate adaptation (week 5: 03/17)

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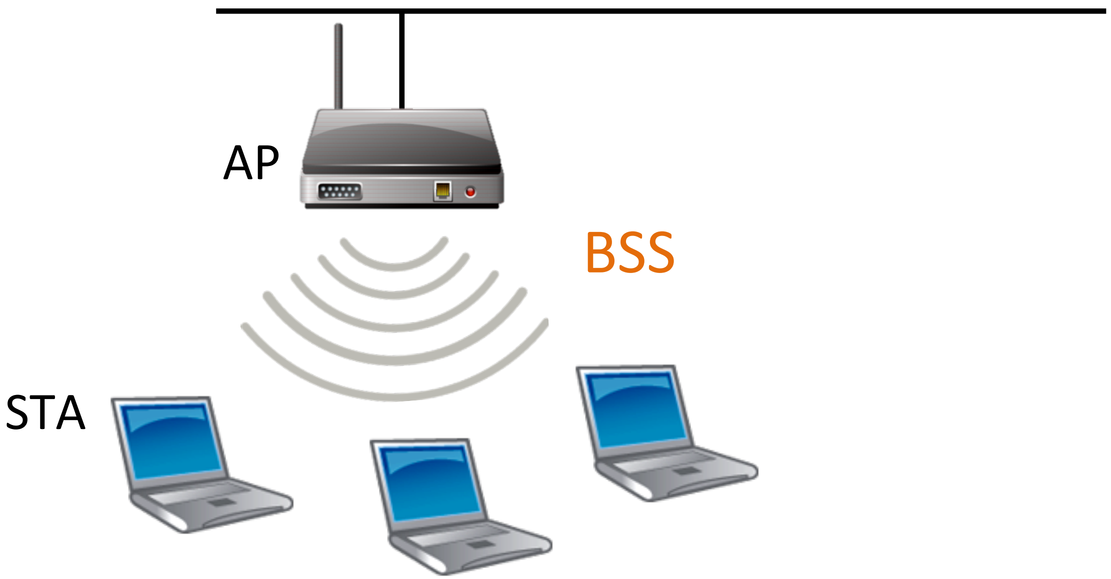
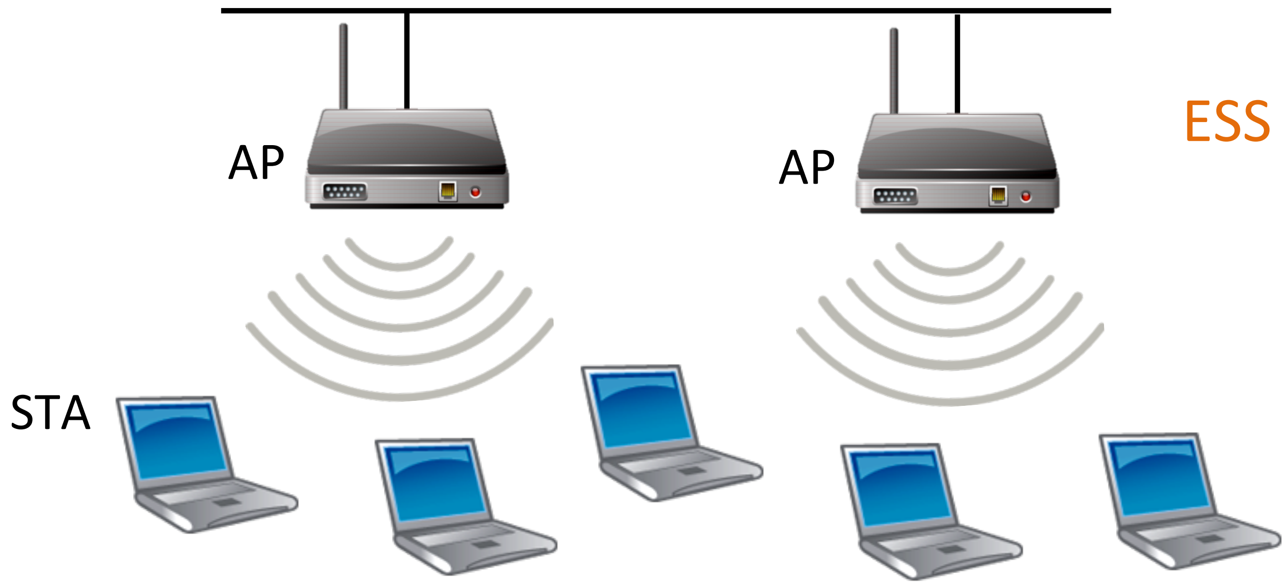
Infrastructure Mode



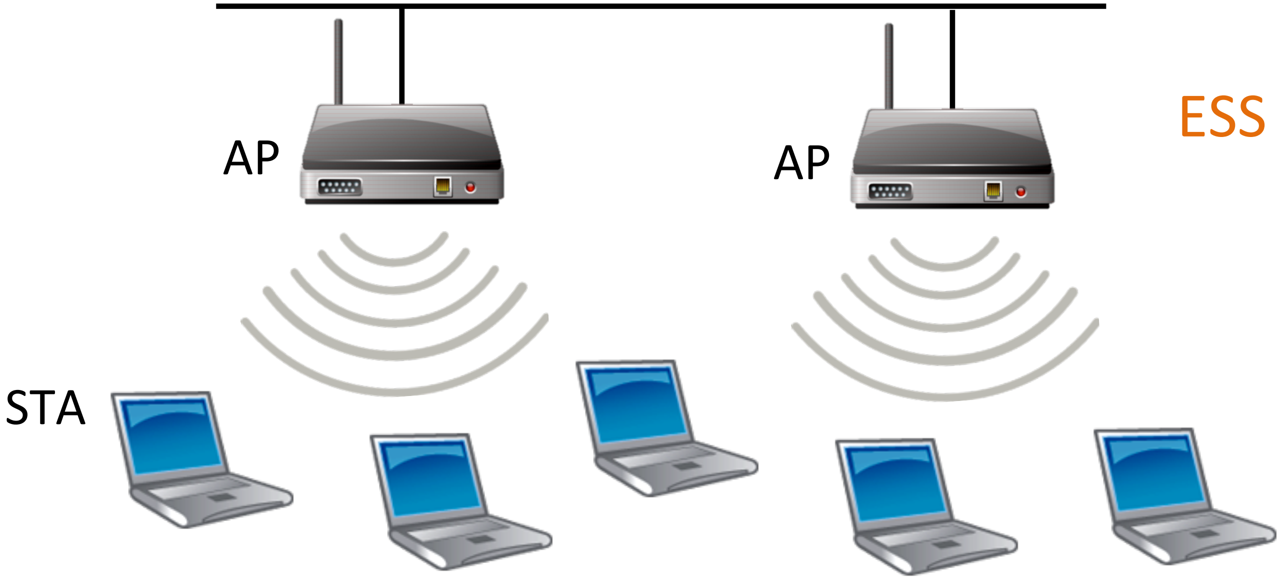
- Access point (AP) announces beacons periodically
- Each station (STA) connects to an AP
- An AP and its stations form a basic service set (BSS)

Infrastructure Mode



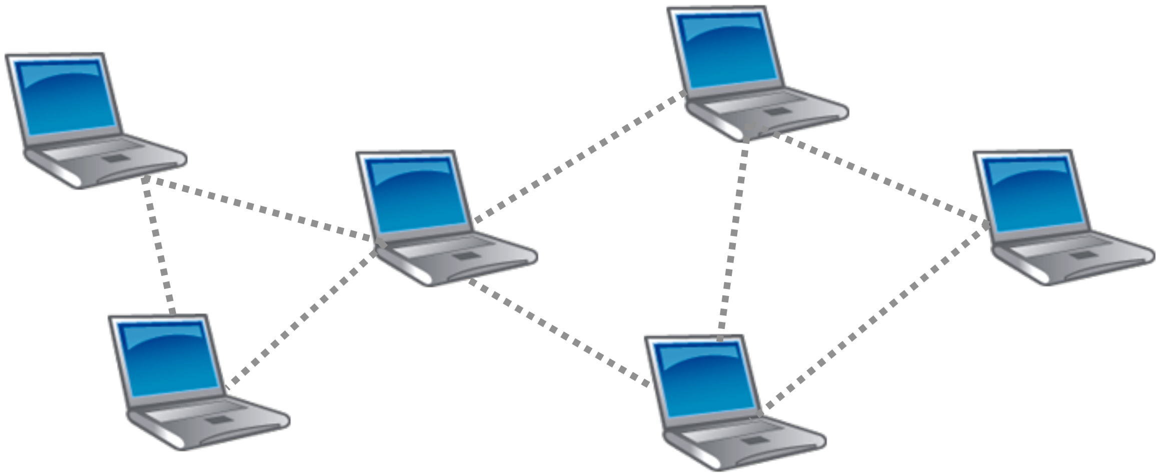
- Several APs (BSSs) could form an extended service set (ESS)
- A roaming user can move from one BSS to another within the ESS

Infrastructure Mode



- Issues
  - Inter-BSS interference: channel assignment
  - Load balancing: user association

Ad Hoc Mode



- Clients form a peer-to-peer network without a centralized coordinator
- Clients communicate with each other via multi-hop routing

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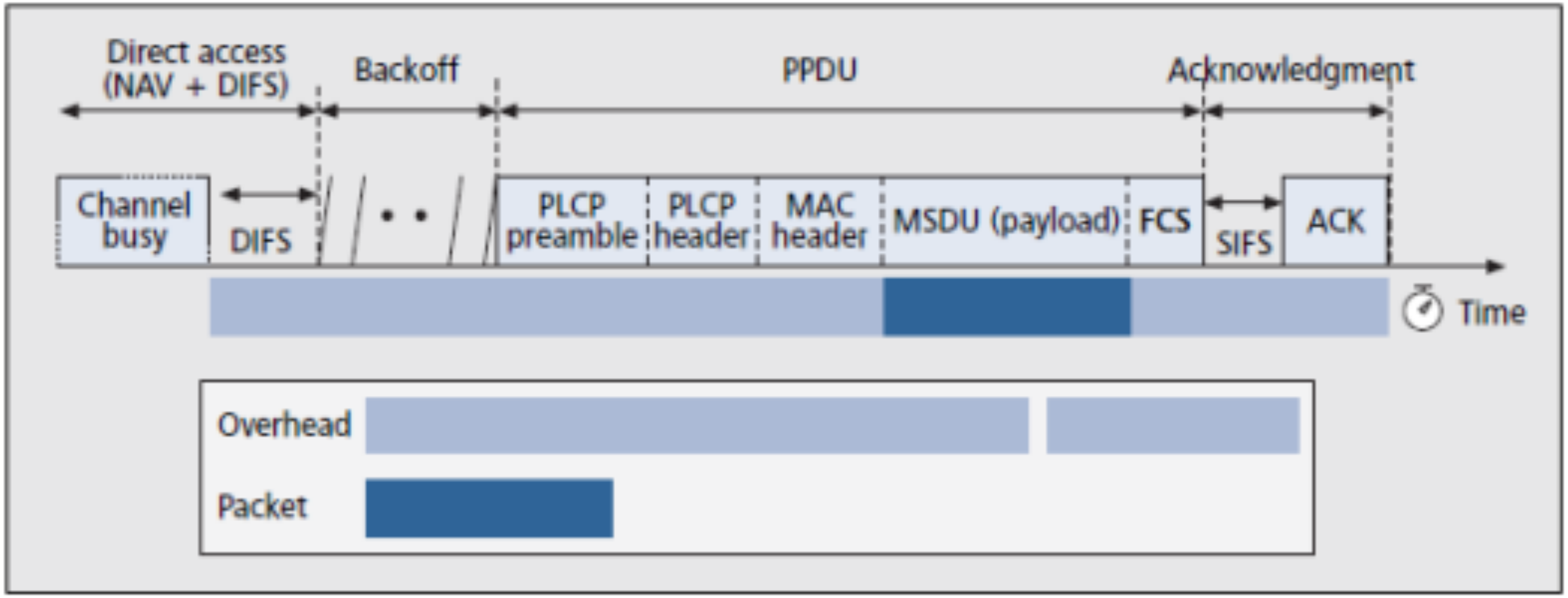
Two Operational Modes

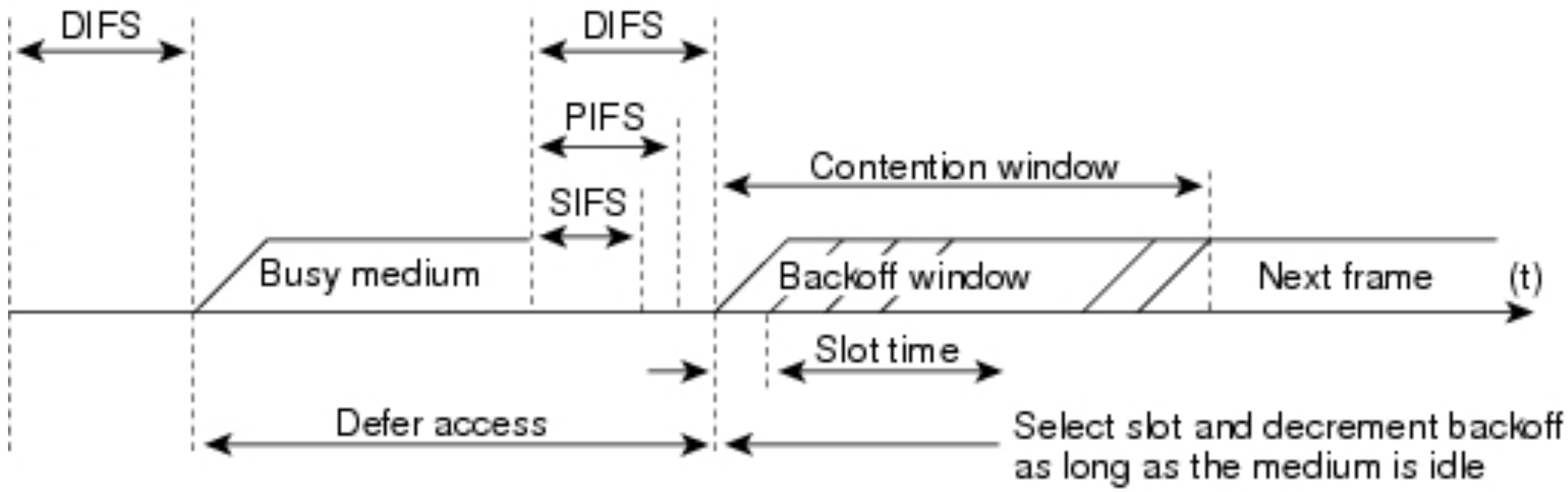
- Distributed coordination function (DCF)
  - Stations contend for transmission opportunities in a distributed way
- Point coordination function (PCF)
  - AP sends poll frames to trigger transmissions

DCF



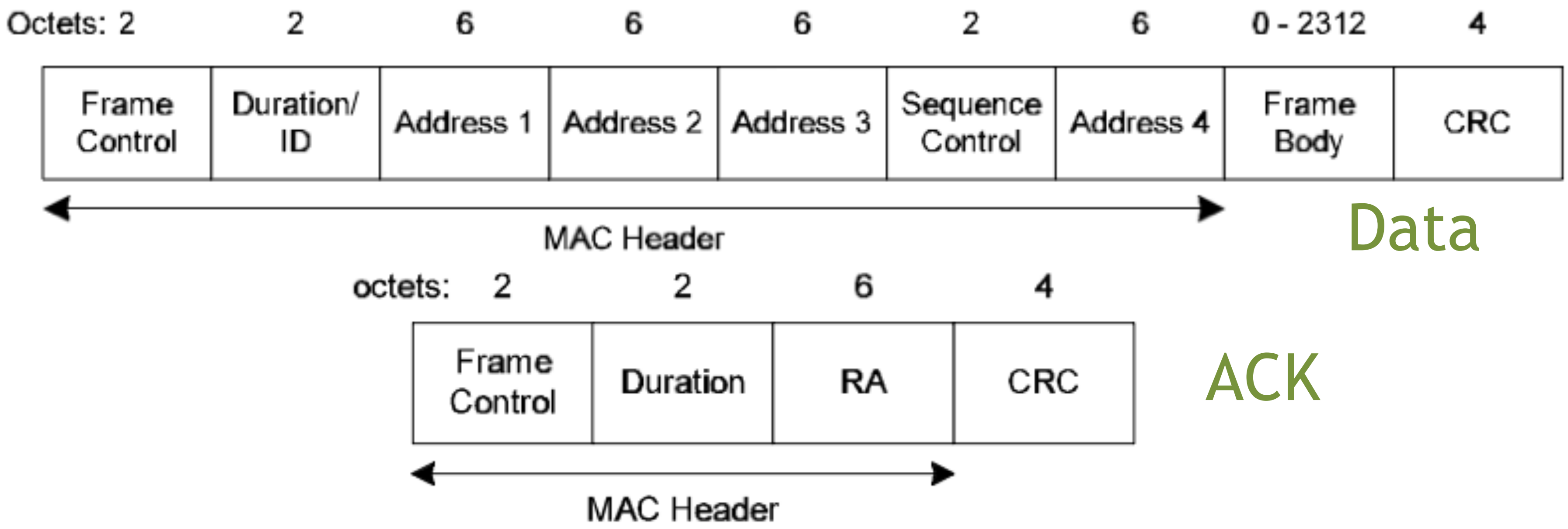
- Start contention after the channel keeps idle for DIFS
- AP responds ACK if the frame passes the CRC check
- Retransmit the frame until the retry limit is reached

Prioritized Interframe Spacing



- SIFS > PIFS > DIFS
- SIFS (Short interframe space): ACK, CTS
- PIFS (PCF interframe space): CF-Poll
- DIFS (DCF interframe space): data frame

Frame Format



- Overhead of a 1500 byte packet
  (ignore contention, assume all bits sent at 1Mbps)
  $= 1 - T_{Data} \,/\, (T_{DIFS} + T_{PLCP} + T_{MAC} + T_{Data} + T_{SIFS} + T_{ACK})$
  $= 1 - (1500*8)/(50[DIFS] + 34*8 + 1500*8 + 10[SIFS] + 14*8)$

Fragmentation and Aggregation

- Large frame
  - Reduced overhead, but less reliable
  - Packet delivery ratio of an N-bit packet = $(1\text{-}BER)^N$
- Fragmentation
  - Break a frame into into small pieces so that interference only affects small fragments
- Aggregation
  - Aggregate multiple small frames in order to reduce the overhead

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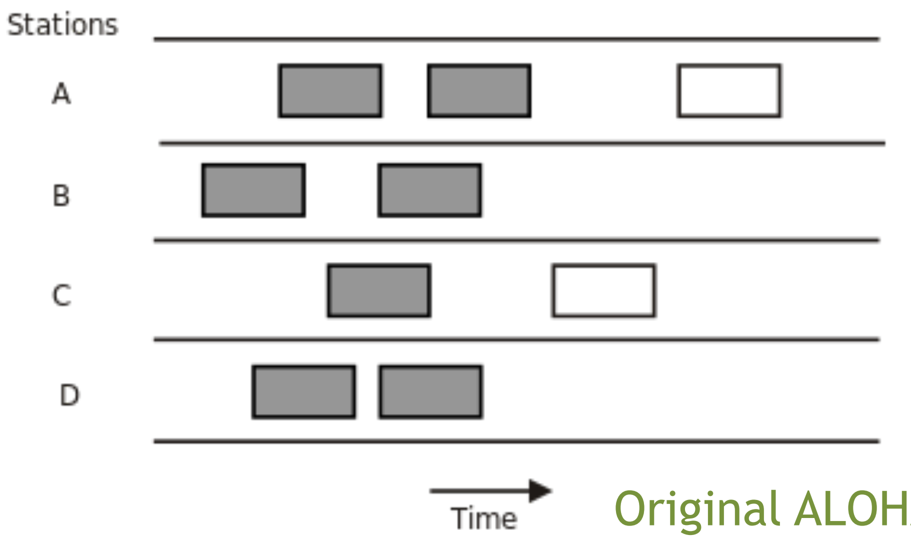
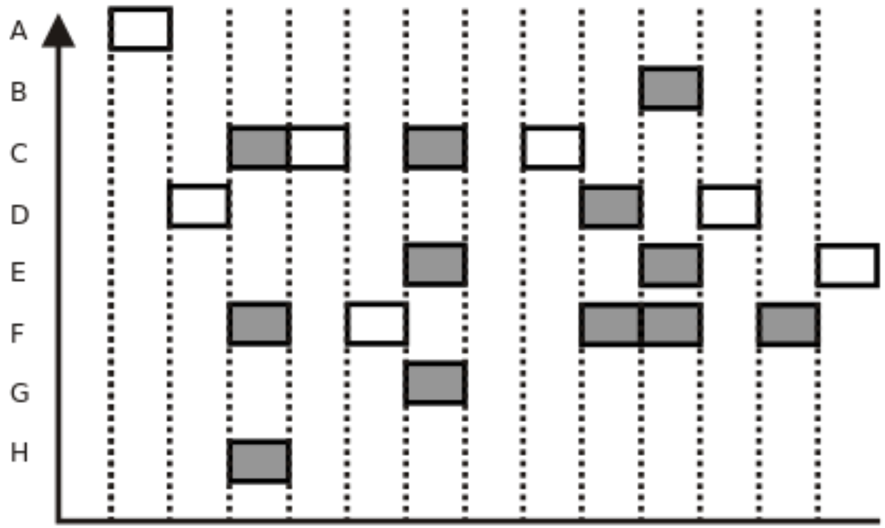
ALOHA



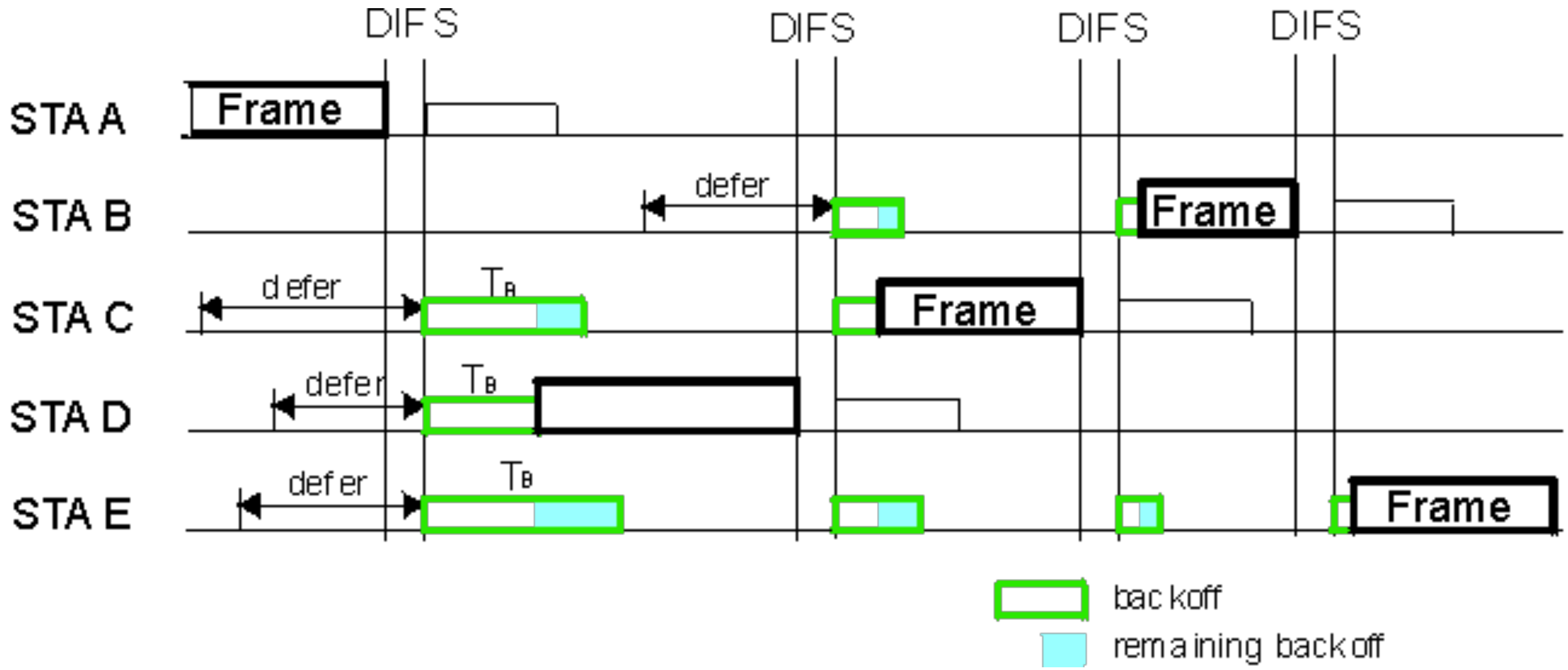
Original ALOHA



Slotted ALOHA

- First distributed access control (about 1970)
- Transmit immediately whenever a node has data to send
- Do not sense the medium before transmission

CSMA/CA



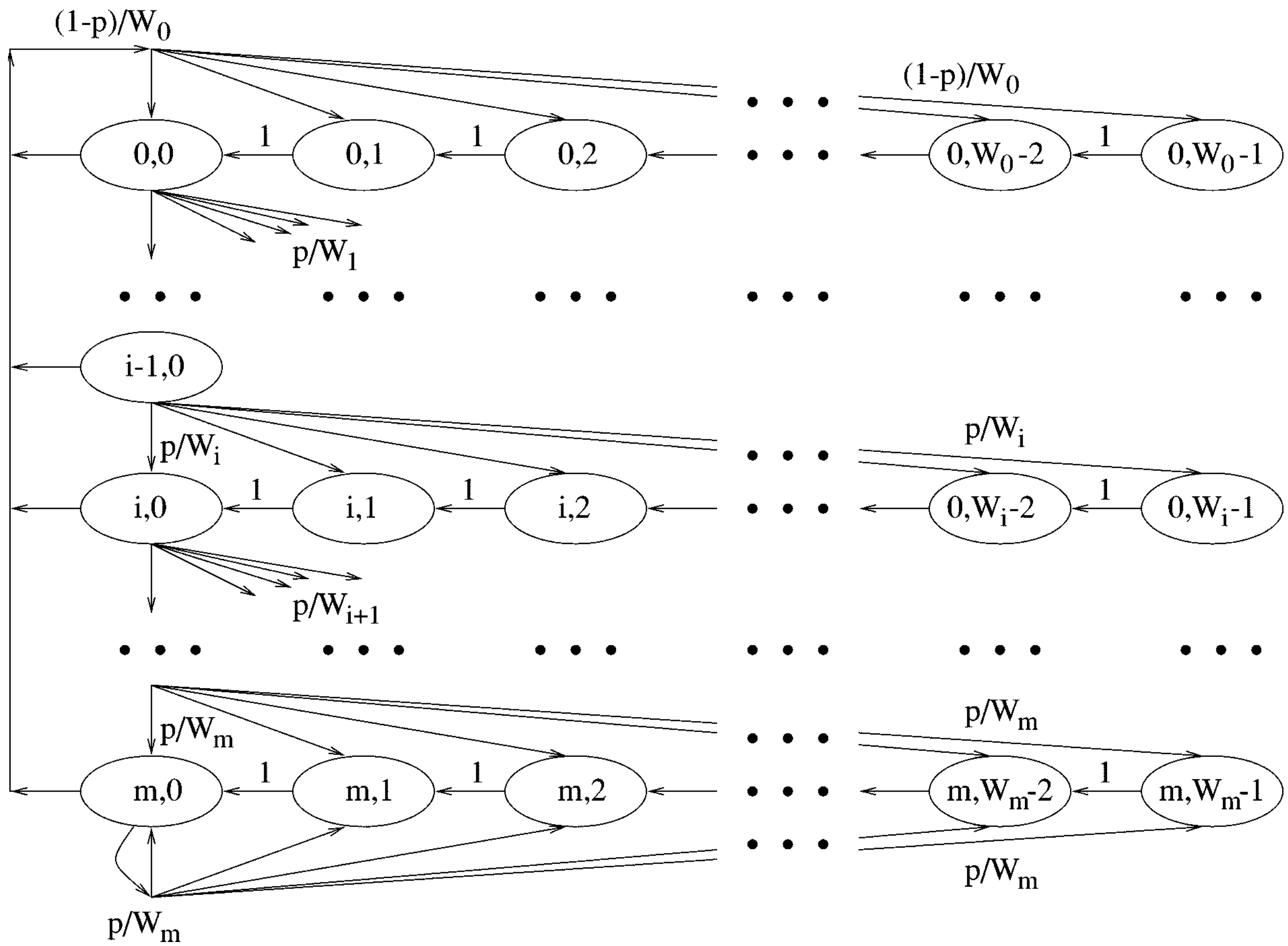
- Carrier sense multiple access with collision avoidance
- STAs listen to the channel before transmission

Exponential Backoff

1. Each STA maintains a contention window
   – Initialized to CW_{min} = 32
2. Randomly pick a number, say *k*, between [0,CW-1]
3. Count down from *k*
4. Start transmission when *k* = *0* if the channel is still idle
5. Double CW for every unsuccessful transmission, up to CW_{max}

Theoretical Performance of DCF

G. Bianchi, "Performance analysis of the IEEE 802.11 distributed coordination function," Selected Areas in Communications, IEEE Journal on 18, no. 3 (2000): 535-547



Markov Chain model for the backoff window size

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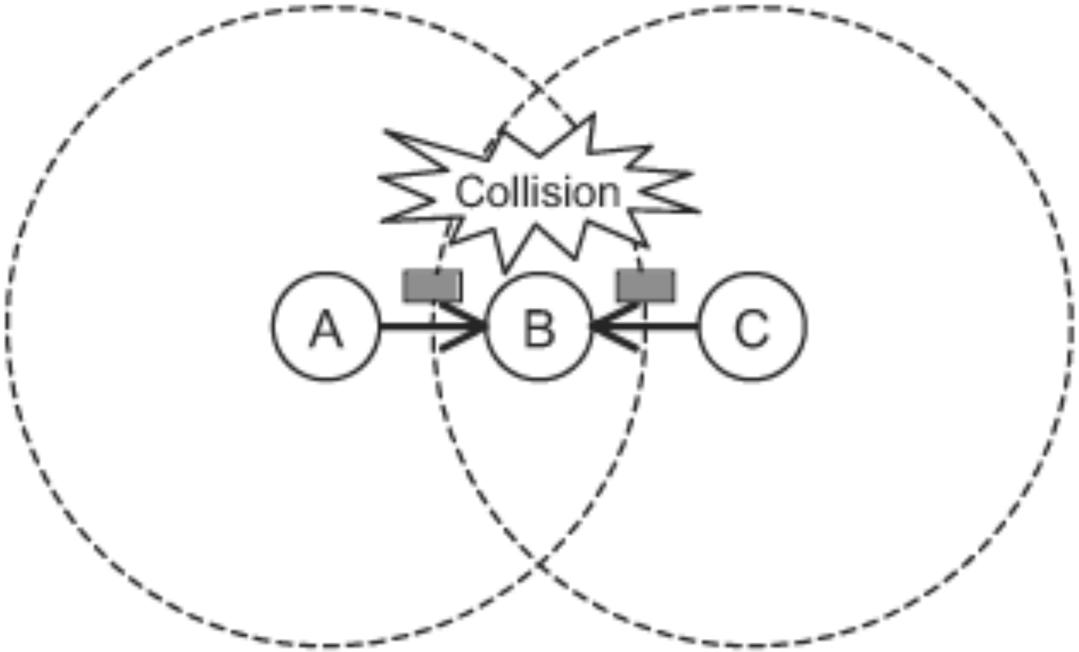
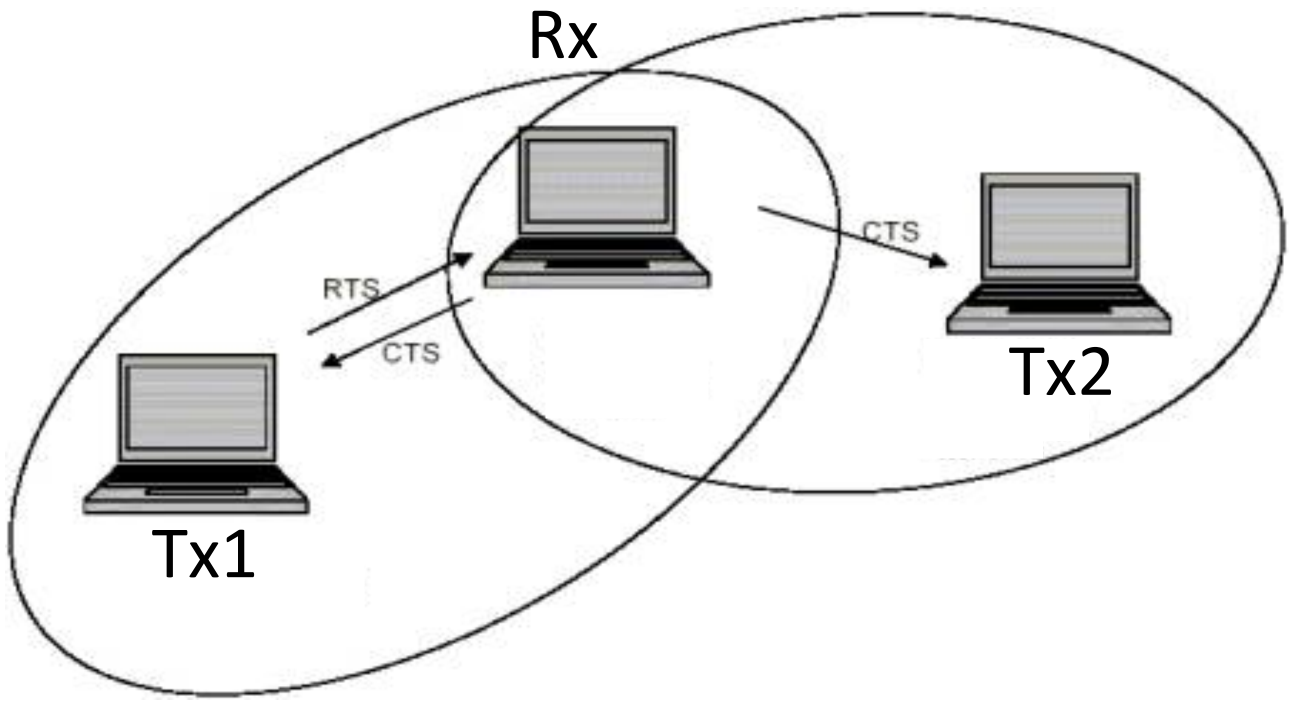
Hidden Terminal



- Two nodes hidden to each other transmit at the same time, leading to collision

802.11's Solution: RTS/CTS



- Tx1 sends RTS whenever it wins contention
- Rx broadcasts CTS
- Nodes that receive CTS defer their transmissions

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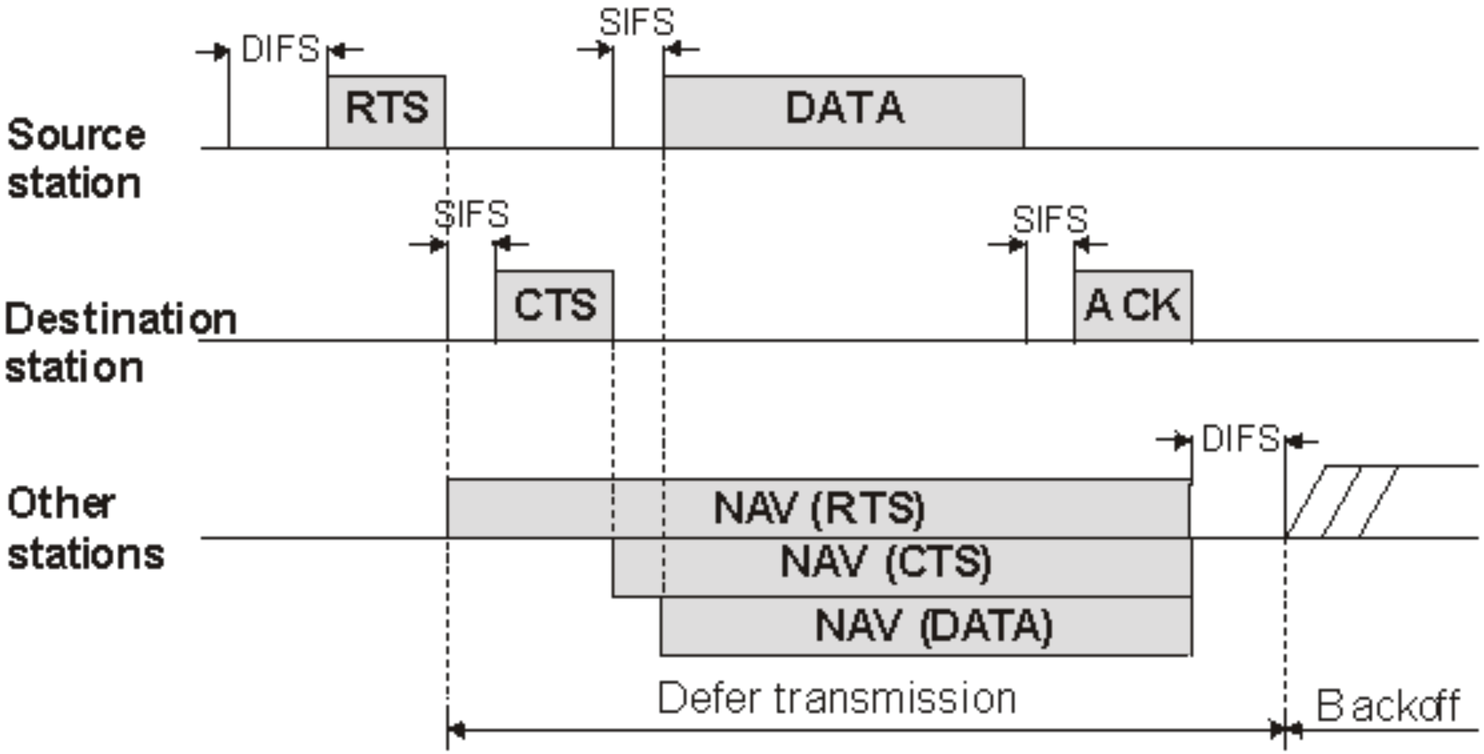


- Usually disabled in practice due to its expensive overhead

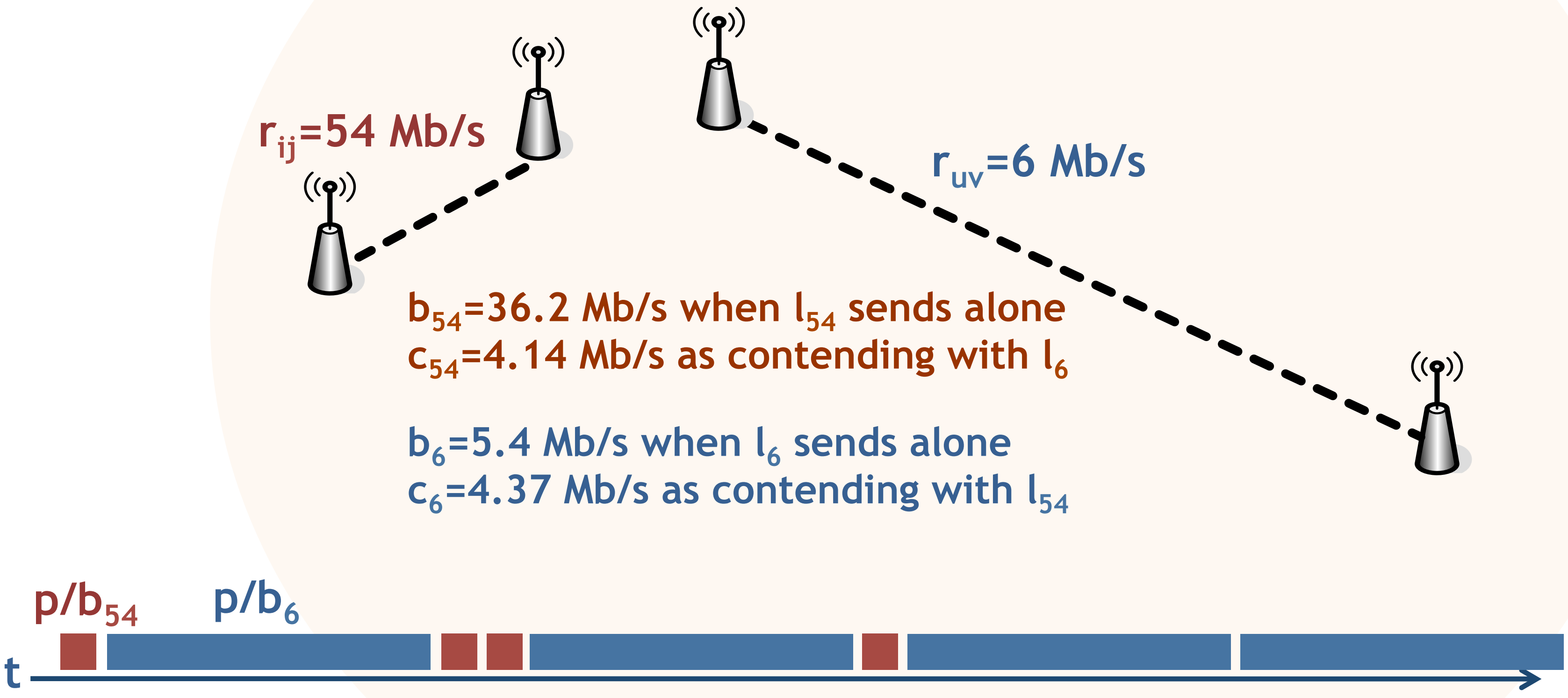
Recent Solutions to Hidden Terminals

- Embrace collisions and try to decode collisions
  - ZigZag decoding
    - S. Gollakota and D. Katabi, "ZigZag decoding: combating hidden terminals in wireless networks," ACM SIGCOMM, 2008
  - Rateless code
    - A. Gudipati and S. Katti, "Strider: automatic rate adaptation and collision handling," ACM SIGCOMM, 2011

Other Issues

- Performance anomaly
  - M. Heusse, et al., "Performance anomaly of 802.11b," IEEE INFOCOM, 2003
- Expensive overhead due to increasing data rates
  - K. Tan, et al., "Fine-grained channel access in wireless LAN," ACM SIGCOMM, 2011
  - S. Sen, et al., "No time to countdown: migrating backoff to the frequency domain," ACM MobiCom, 2011
- Flexible channelization
  - S. Rayanchu, et al., " FLUID: improving throughputs in enterprise wireless LANs through flexible channelization," ACM MOBICOM, 2012

Performance Anomaly



Channel is almost occupied by low-rate links

→ Everyone gets a similar throughput, regardless of its bit-rate