Wireless Local Area Networks (WLANs) Part I

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Audio/Video recordings of this lecture are available at:
http://www.cse.wustl.edu/~jain/cse574-10/

IEEE 802.11

1. Features
2. MAC
3. Physical Layers

WiFi

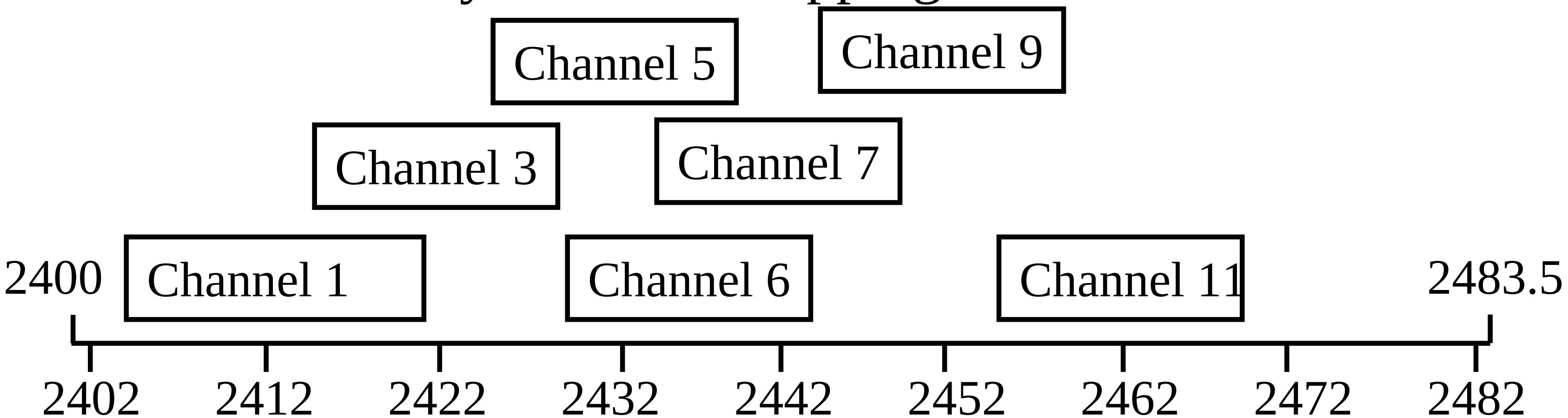
- Almost all wireless LANs now are IEEE 802.11 based
- Competing technologies, e.g., HiperLAN can't compete on volume and cost
- 802.11 is also known as WiFi = "Wireless Fidelity"
- Fidelity = Compatibility between wireless equipment from different manufacturers
- WiFi Alliance is a non-profit organization that does the compatibility testing (WiFi.org)

IEEE 802.11 Features

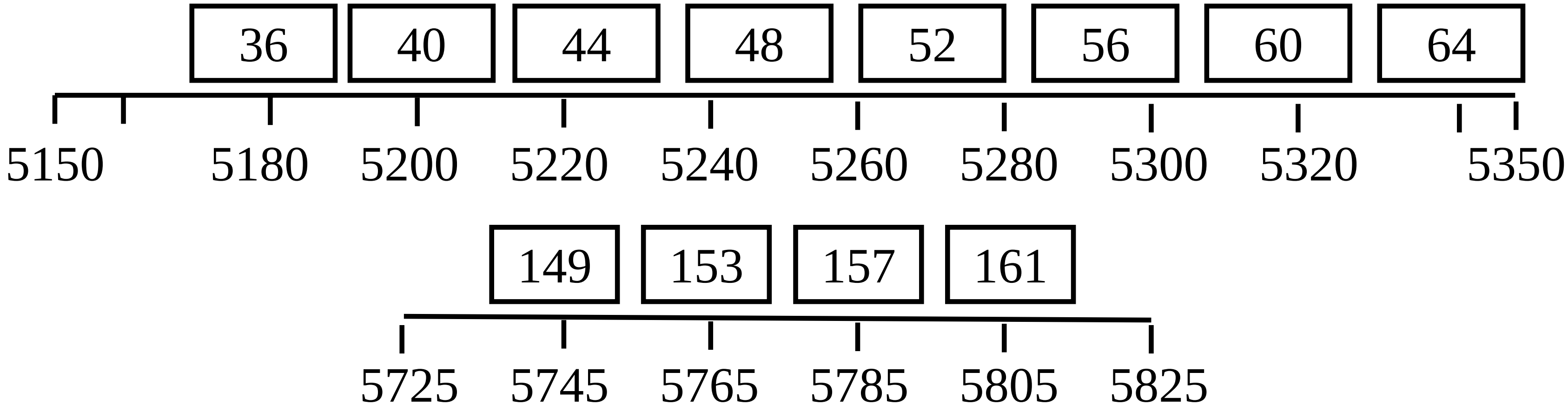
- Original 802.11 was at 1 and 2 Mbps.
  Newer versions at 11 Mbps, 54 Mbps, 108 Mbps, 200 Mbps
- Supports both Ad-hoc and base-stations
- Spread Spectrum $\Rightarrow$ No licensing required.
  Three Phys: Direct Sequence, Frequency Hopping, 915-MHz, **2.4 GHz** (Worldwide ISM), 5 GHz, and Diffused Infrared (850-900 nm) bands.
- Supports multiple priorities
- Supports time-critical and data traffic
- Power management allows a node to doze off

North American Channels

2.4 GHz Band: 14 5-MHz Channels. Only 12 in USA.
20 MHz => Only 3 non-overlapping channels



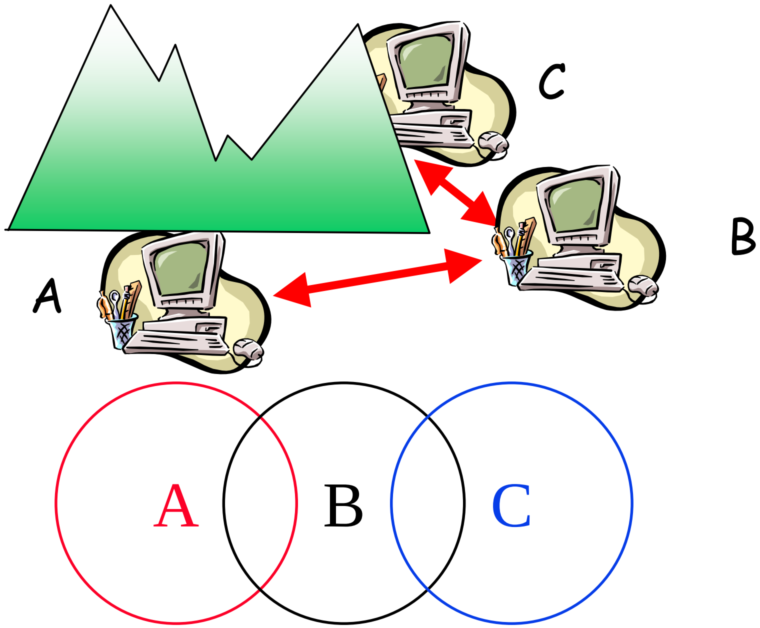
5 GHz Band: 12 non-overlapping channels



IEEE 802.11 Physical Layers

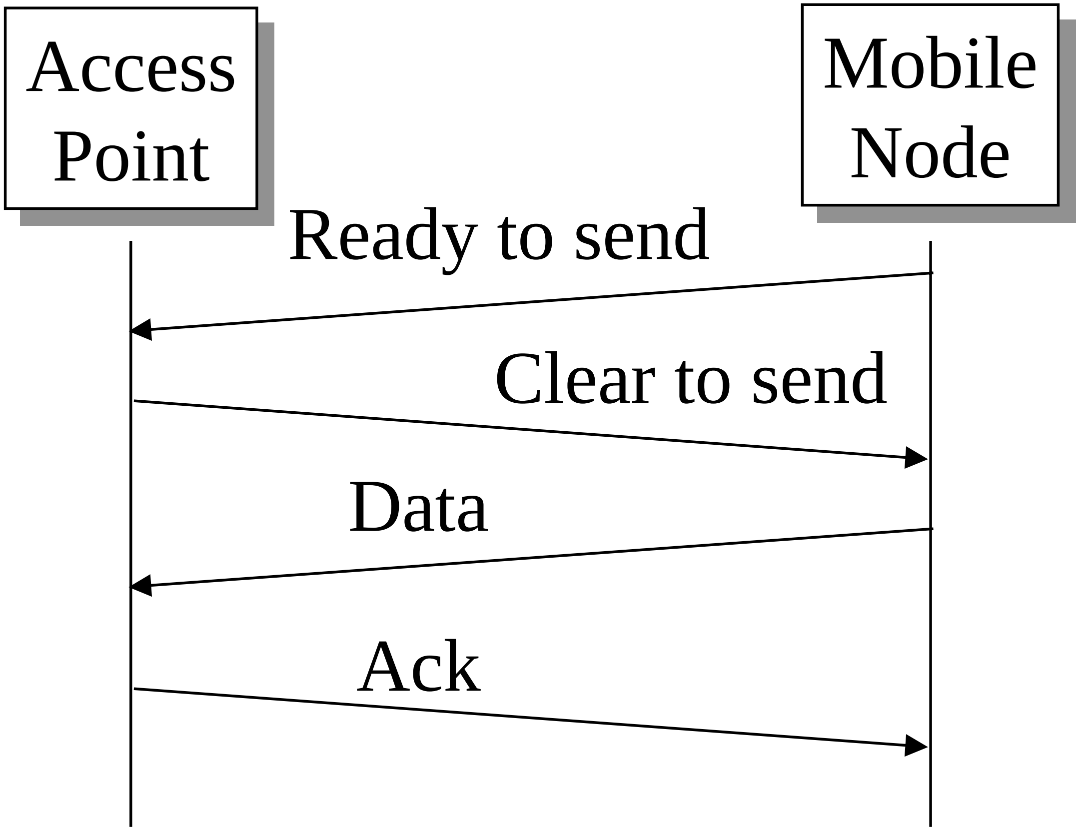
- Issued in four stages
- First part in 1997: IEEE 802.11
  - Includes MAC layer and three physical layer specifications
  - Two in 2.4-GHz band and one infrared
  - All operating at 1 and 2 Mbps
- Two additional parts in 1999:
  - IEEE 802.11a-1999: 5-GHz band, 54 Mbps/20 MHz, OFDM
  - IEEE 802.11b-1999: 2.4 GHz band, 11 Mbps/20 MHz
- Fourth part:
  - IEEE 802.11g-2003 : 2.4 GHz band, 54 Mbps/20 MHz, OFDM

Hidden Node Problem



- A can hear B, B can hear C, but C cannot hear A.
- C may start transmitting while A is also transmitting $\Rightarrow$ A and C can't detect collision.
- Only the receiver can help avoid collisions

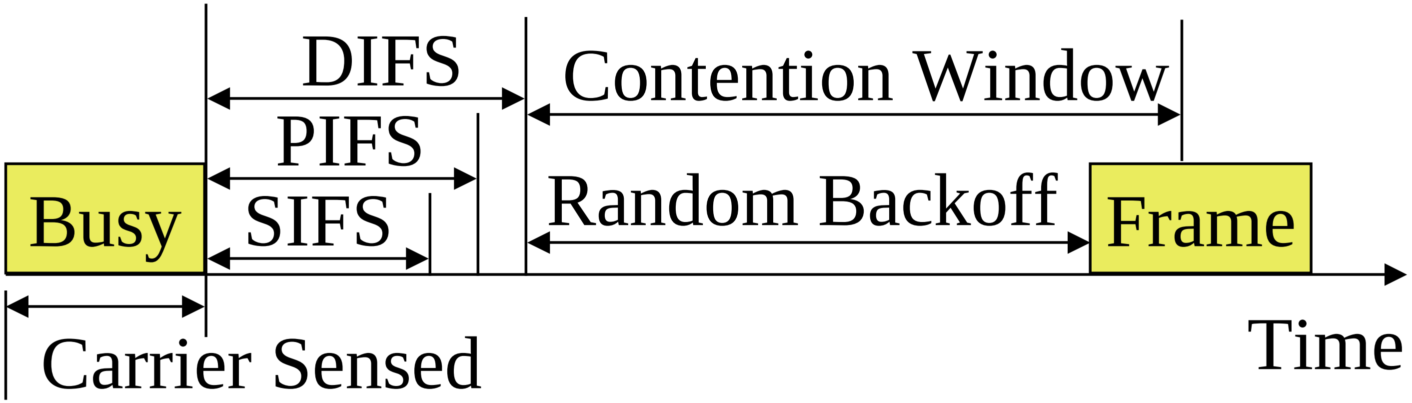
4-Way Handshake



IEEE 802.11 MAC

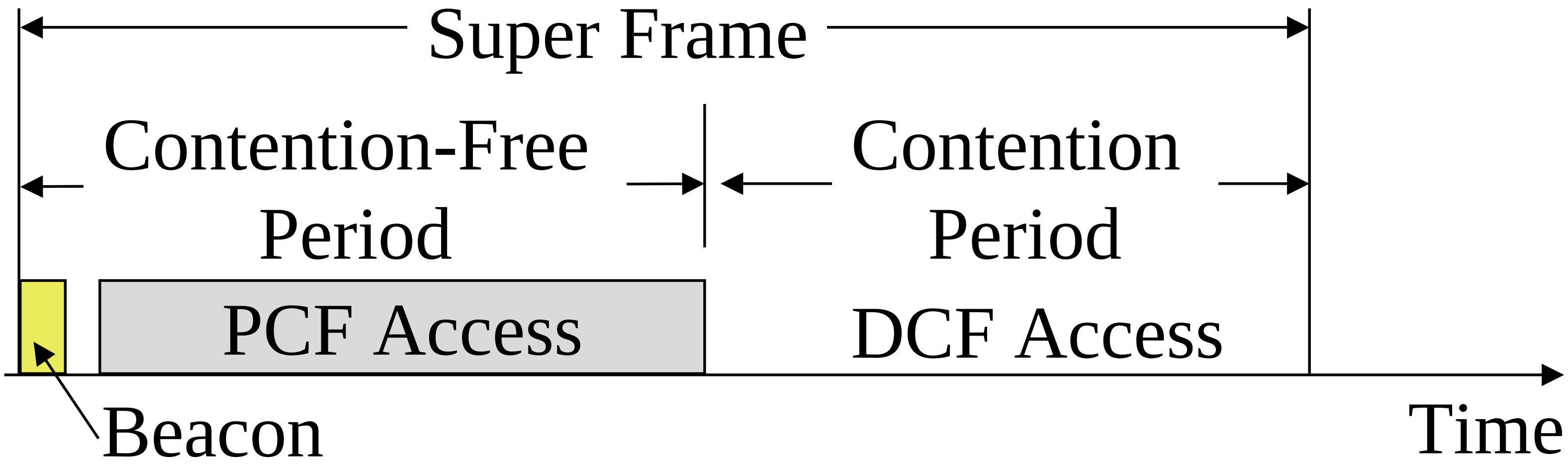
- Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
- Listen before you talk. If the medium is busy, the transmitter backs off for a random period.
- Avoids collision by sending a short message:
  Ready to send (RTS)
  RTS contains dest. address and <u>duration</u> of message.
  Tells everyone to backoff for the duration.
- Destination sends: Clear to send (CTS)
  Other stations set their network allocation vector (NAV) and wait for that duration
- Can not detect collision $\Rightarrow$ Each packet is acked.
- MAC level retransmission if not acked.

IEEE 802.11 Priorities



- Initial interframe space (IFS)
- Highest priority frames, e.g., Acks, use short IFS (SIFS)
- Medium priority time-critical frames use "Point Coordination Function IFS" (PIFS)
- Asynchronous data frames use "Distributed coordination function IFS" (DIFS)

Time Critical Services



- Timer critical services use Point Coordination Function
- The point coordinator allows only one station to access
- Coordinator sends a beacon frame to all stations. Then uses a polling frame to allow a particular station to have contention-free access
- Contention Free Period (CFP) varies with the load.

IEEE 802.11 DCF Backoff

- MAC works with a single FIFO Queue
- Three variables:
  - Contention Window (CW)
  - Backoff count (BO)
  - Network Allocation Vector (NAV)
- If a frame (RTS, CTS, Data, Ack) is heard, NAV is set to the duration in that frame. Stations sense the media after NAV expires.
- If the medium is idle for DIFS, and backoff is not already active, the station draws a random BO in [0, CW] and sets the backoff timer.
- If the medium becomes busy during backoff, the timer is stopped and a new NAV is set. After NAV, back off continues.

IEEE 802.11 DCF Backoff

- Initially and after each successful transmission:

$$CW = CW_{min}$$

- After each unsuccessful attempt

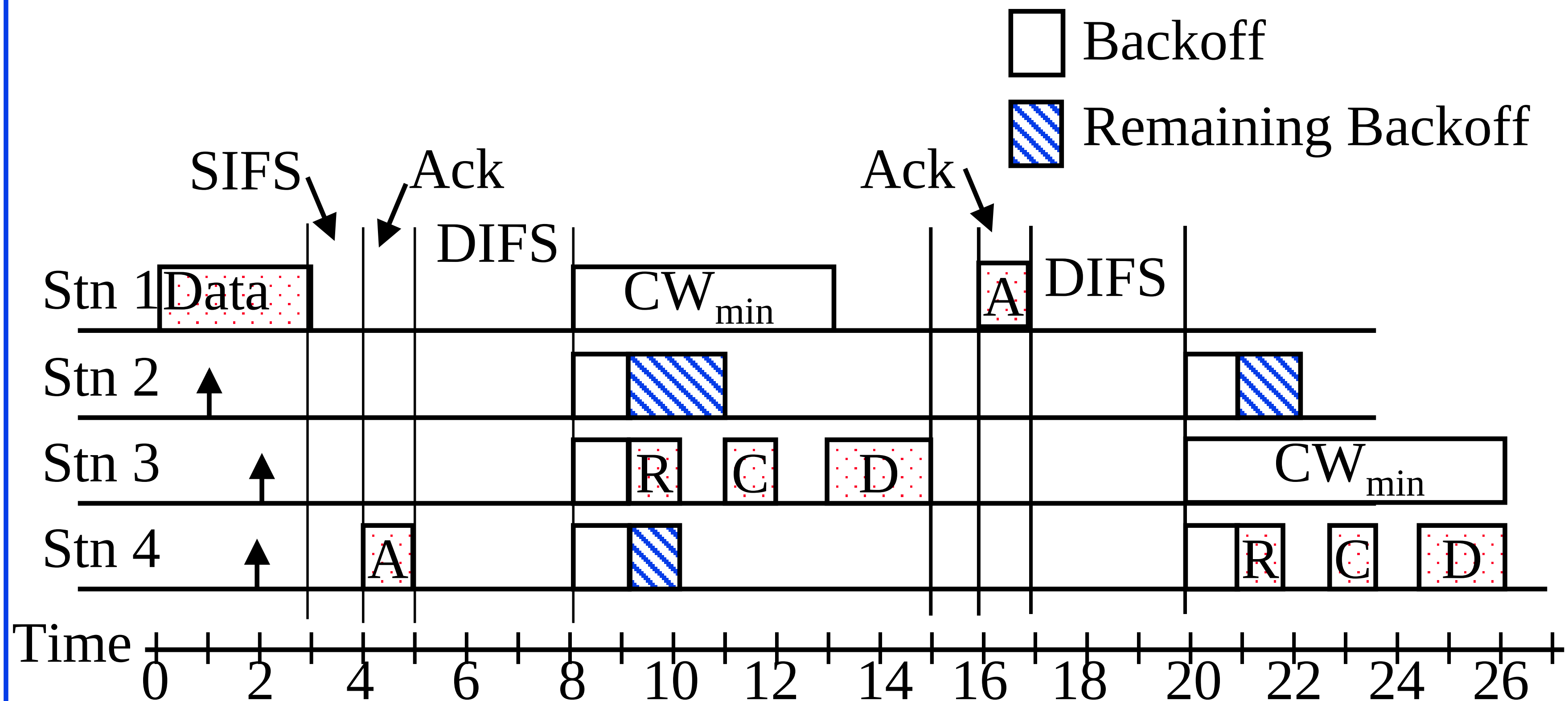
$$CW = \min\{2CW+1, CW_{max}\}$$

Typical Parameter Values

- For DS PHY: Slot time = 20 us, SIFS = 10 us, CWmin = 31, CWmax = 1023
- For FH PHY: Slot time = 50 us, SIFS = 28 us, CWmin = 15, CWmax = 1023
- 11a: Slot time = 9 us, SIFS= 16 us, CWmin= 15, CWmax=1023
- 11b: Slot time = 20 us, SIFS = 10 us, Cwmin= 31, Cwmax=1023
- 11g: Slot time = 20 us or 9 us, SIFS = 10 us, Cwmin= 15 or 31, Cwmax=1023
- PIFS = SIFS + 1 slot time
- DIFS = SIFS + 2 slot times

DFS

- Example: Slot Time = 1, CWmin = 5, DIFS=3, PIFS=2, SIFS=1,



DFS: Example (Cont)

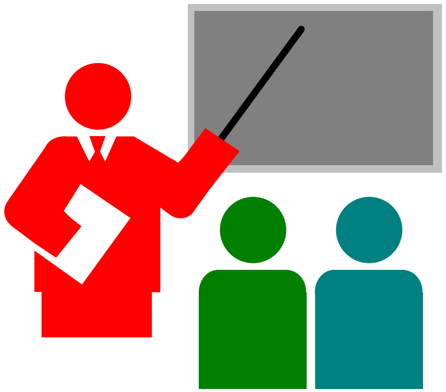
- T=1 Station 2 wants to transmit but the media is busy
- T=2 Stations 3 and 4 want to transmit but the media is busy
- T=3 Station 1 finishes transmission.
- T=4 Station 1 receives ack for its transmission (SIFS=1)
  Stations 2, 3, 4 set their NAV to 1.
- T=5 Medium becomes free
- T=8 DIFS expires.
  Stations 2, 3, 4 draw backoff count between 0 and 5.
  The counts are 3, 1, 2
- T=9 Station 3 starts transmitting. Announces a duration of 8 (RTS+SIFS+CTS+SIFS+DATA+SIFS+ACK). Station 2 and 4 pause backoff counter at 2 and 1 resp. and wait till T=17
- T=15 Station 3 finishes data transmission
- T=16 Station 3 receives Ack.
- T=17 Medium becomes free

DFS: Example (Cont)

- T=20 DIFS expires

  Stations 2 and 4 start their backoff counter
- T=21 Station 4 starts transmitting RTS

Summary



1. 802.11 uses Frequency hopping, Direct Sequence CDMA, OFDM
2. 802.11 PHYs: 802.11, 802.11a, 802.11b, 802.11g
3. Allows both: Ad-Hoc vs Infrastructure-based
4. 802.11 supports single FIFO Q. Uses SIFS, PIFS, DIFS

Homework 6

- Two 802.11 stations get frames to transmit at time t=0. The 3rd station has just finished transmitting a long packet at t=0. The transmission parameters are: Slot time=1, SIFS=1, DIFS=3, CWmin=5, CWmax=7. Assume that the pseudo-random number generated are 1, 3. The data size is 3 slots. Draw a transmission diagram. How many slots before the two packets will get acknowledged assuming no new arrivals.

Reading List

- IEEE 802.11 Tutorial, http://www.eecs.berkeley.edu/~ergen/docs/ieee.pdf
- A Technical Tutotial on the IEEE 802.11 Protocol, http://www.sss-mag.com/pdf/802_11tut.pdf
- Yang Xiao, "IEEE 802.11e QoS provisioning at the MAC layer", Volume: 11 Issue: 3, Pages: 72-79, IEEE Wireless Communications, 2004
- Yang Xiao, "IEEE 802.11n enhancements for higher throughput in wireless LANs", Volume: 12, Issue: 6, Pages: 82-91, IEEE Wireless Communications, 2005
- J. M. Gilbert, Won-Joon Choi and Qinfang Sun, "MIMO technology for advanced wireless local area networks", Pages: 413-415, 42nd Design Automation Conference, 2005