# Wireless Local Area Networks (WLANs)

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IEEE 802.11

1. Features
2. MAC
3. Physical Layers
4. Current Activities
5. Next Generation: 802.11n
6. Enhanced Quality of Service: 802.11e

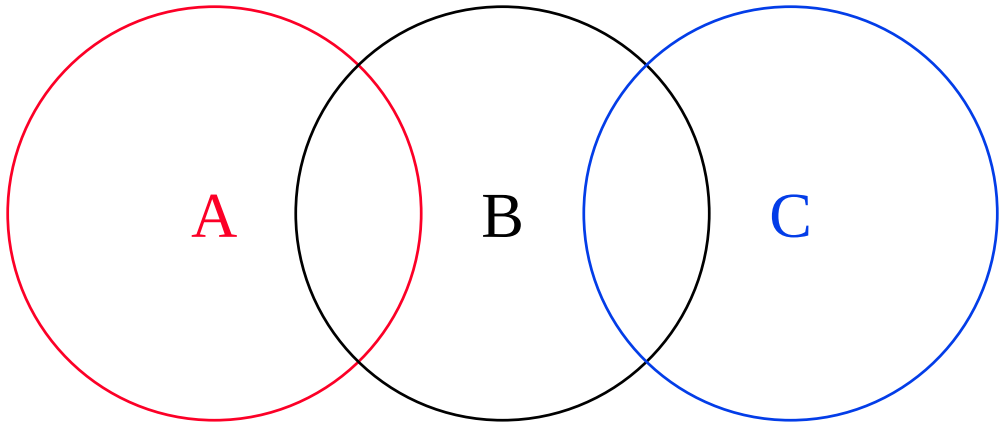
# WiFi

- 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

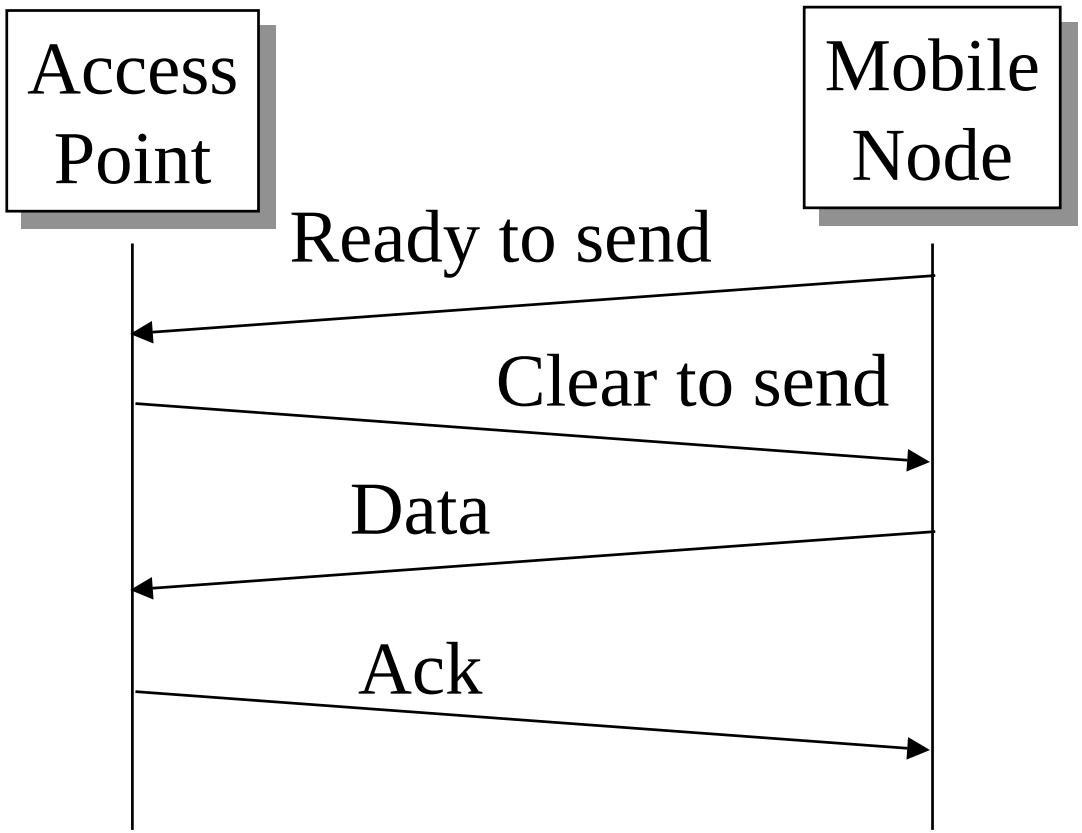
- Original 802.11 at 1 and 2 Mbps
- Supports both Ad-hoc and base-stations
- Spread Spectrum ⇒ No licensing required.
  Three Phys: Direct Sequence, Frequency Hopping, 915-MHz, **2.4 GHz** (Worldwide ISM), 5.2 GHz, and Diffused Infrared (850-900 nm) bands.
- Supports multiple priorities
- Supports time-critical and data traffic
- Power management allows a node to doze off

# Hidden Node Problem




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

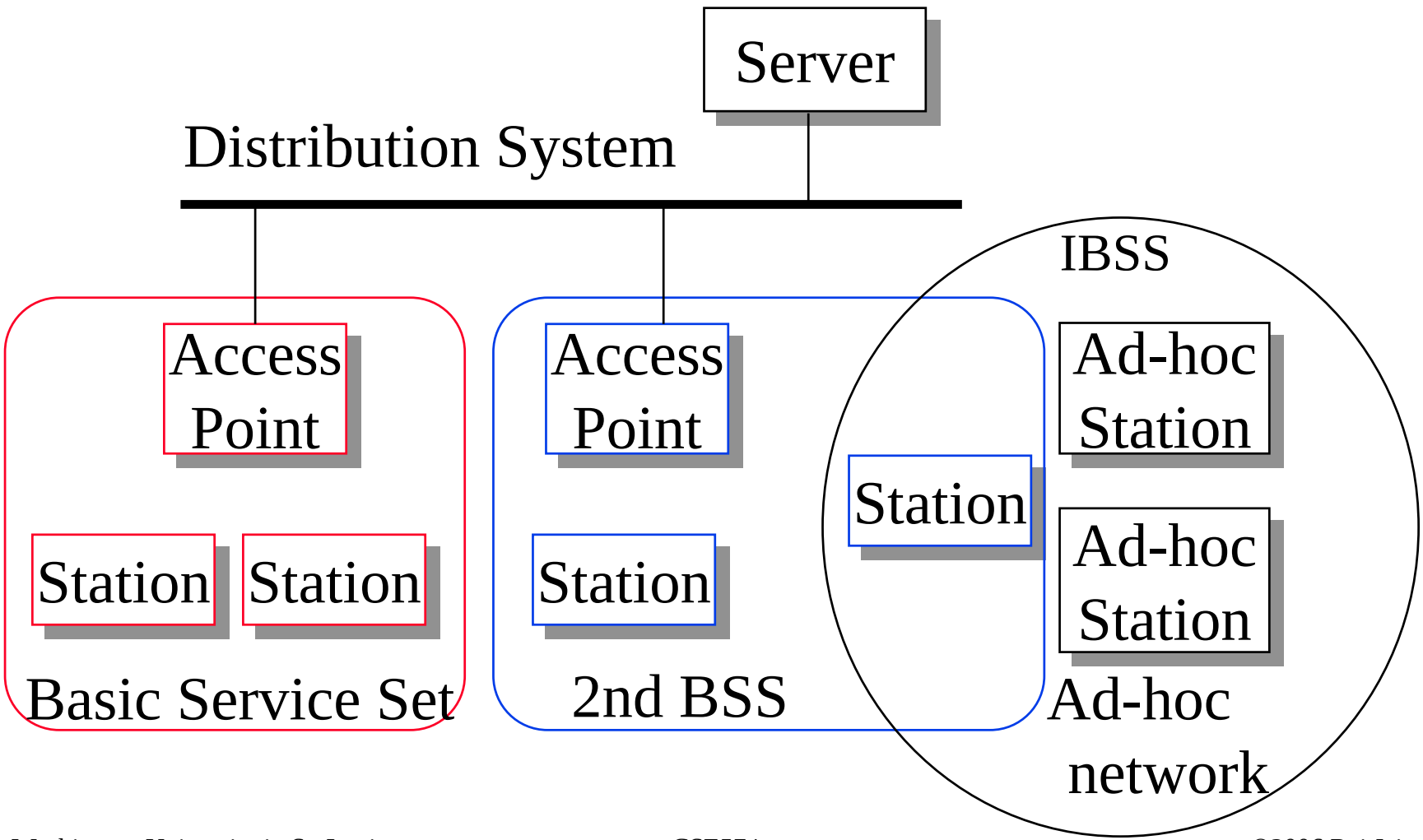
# 4-Way Handshake



# 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 duration of message.
  Tells everyone to backoff for the duration.
- Destination sends: Clear to send (CTS)
  Other stations set their network allocation vector (NAV) and do not transmit for that duration
- Can not detect collision ⇒ Each packet is acked.
- MAC level retransmission if not acked.

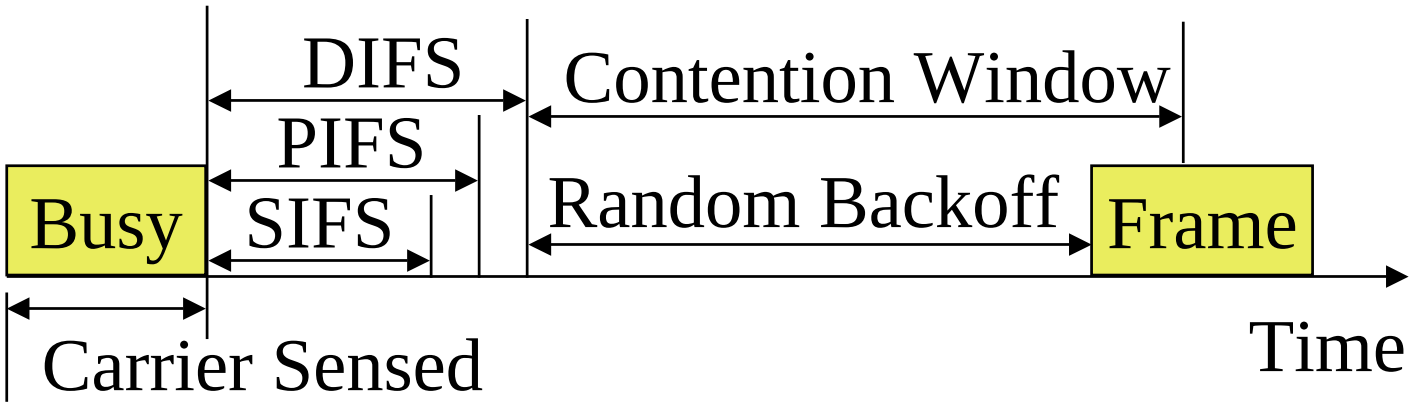
# IEEE 802.11 Architecture



# IEEE 802.11 Architecture (Cont)

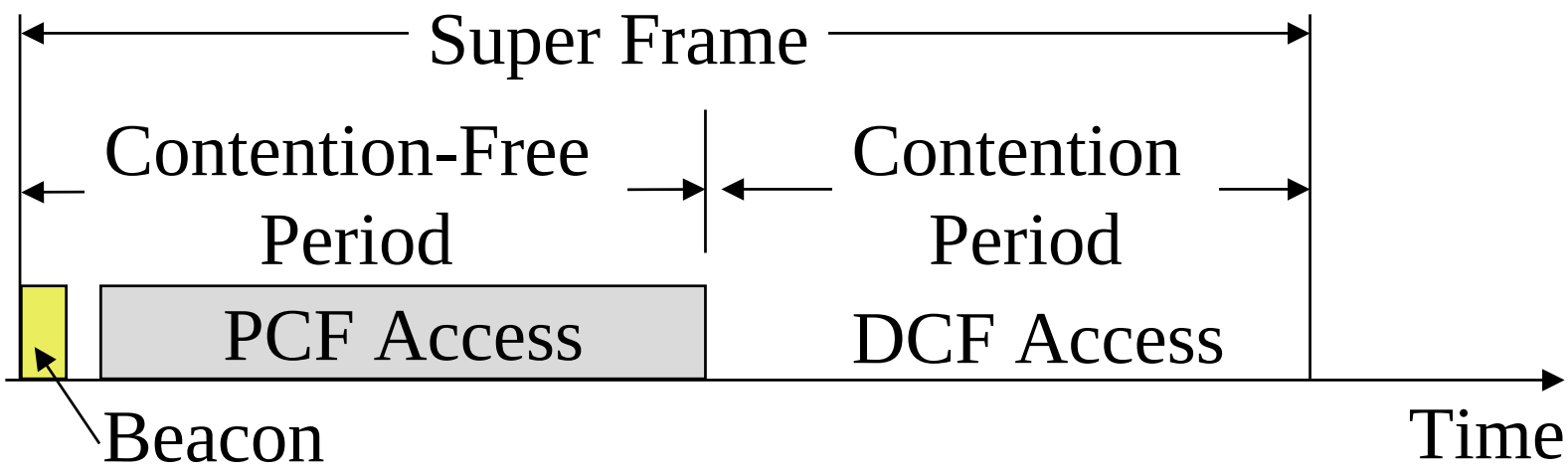
- Basic Service Area (BSA) = Cell
- Each BSA may have several wireless LANs
- Distribution System (DS) - wired backbone
- Extended Service Area (ESA) = Multiple BSAs interconnected via Access Points (AP)
- Basic Service Set (BSS)
  = Set of stations associated with an AP
- Extended Service Set (ESS)
  = Set of stations in an ESA
- Independent Basic Service Set (IBSS): Set of computers in ad-hoc mode. May not be connected to wired backbone.
- Ad-hoc networks coexist and interoperate with infrastructure-based networks

# 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)

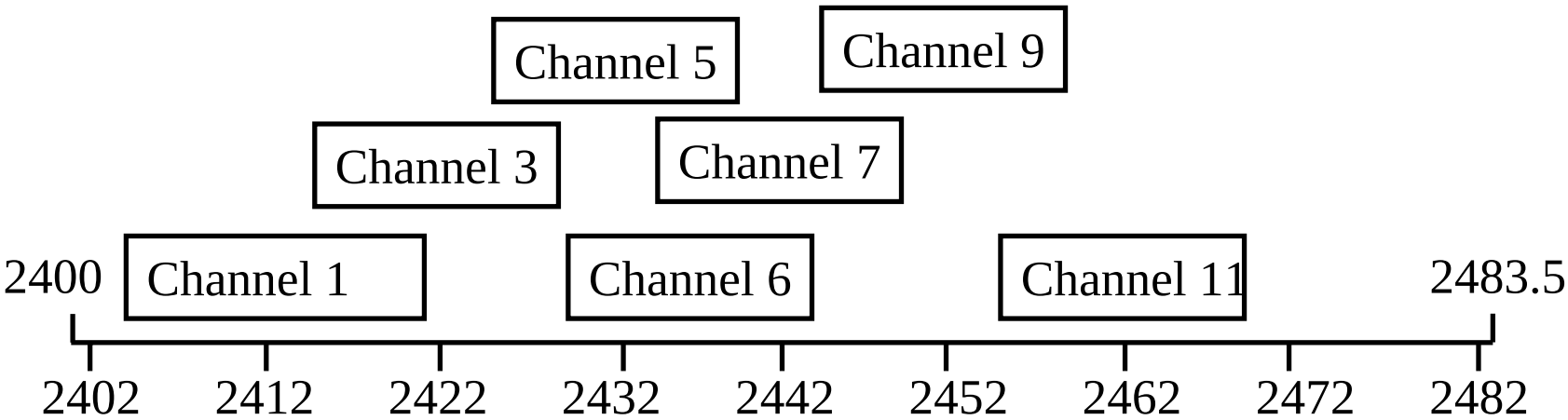
# Time Critical Services



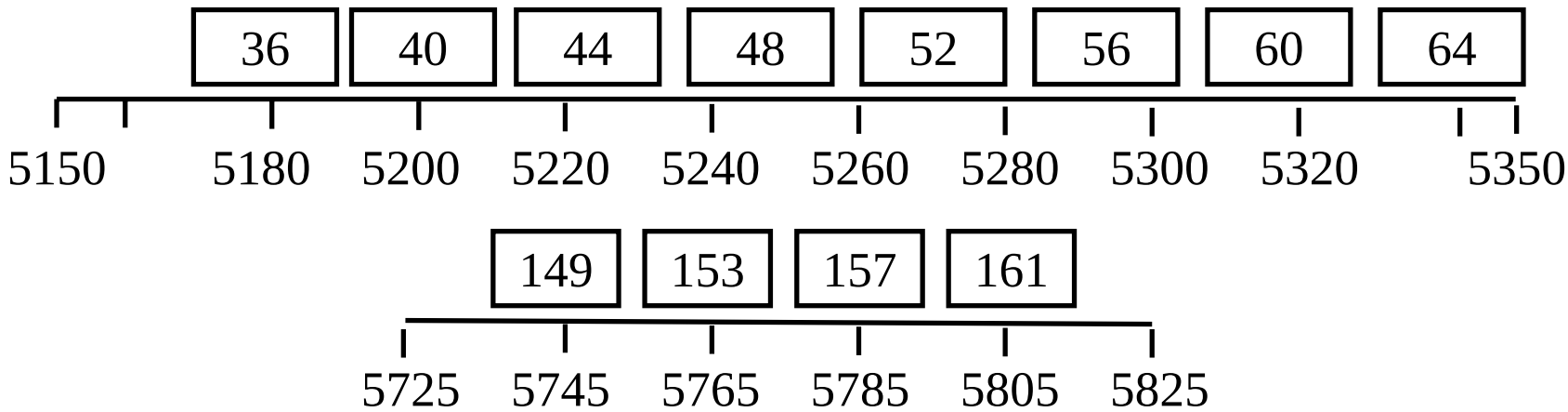

- Timer critical services use Point Coordination Function
- The point coordinator allows only one station to access
- Coordinator sends a beacon frame to all stations. Then uses a polling frame to allow a particular station to have contention-free access
- Contention Free Period (CFP) varies with the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

# North American Channels

**2.4 GHz Band**: 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

# IEEE 802.11 Activities

- **802.11c**: Bridge Operation (Completed. Added to IEEE 802.1D)
- **802.11d**: Global Harmonization (PHYs for other countries. Published as IEEE Std 802.11d-2001)
- **802.11e**: Quality of Service. IEEE Std 802.11e-2005
- **802.11f**: Inter-Access Point Protocol (Published as IEEE Std Std 802.11F-2003)
- **802.11h**: Dynamic Frequency Selection and transmit power control to satisfy 5GHz band operation in Europe. Published as IEEE Std 802.11h-2003
- **802.11i**: MAC Enhancements for Enhanced Security. Published as IEEE Std 802.11i-2004
- **802.11j**: 4.9-5 GHz operation in Japan. IEEE Std 802.11j-2004
- **802.11k**: Radio Resource Measurement interface to higher layers. Active.

# IEEE 802.11 Activities (Cont)

- **802.11m**: Maintenance. Correct editorial and technical issues in 802.11a/b/d/g/h. Active.
- **802.11n**: Enhancements for higher throughput (100+ Mbps). Active.
- **802.11p**: Inter-vehicle and vehicle-road side communication at 5.8GHz. Active.
- **802.11r**: Fast Roaming. Started July 2003. Active.
- **802.11s**: ESS Mesh Networks. Active.
- **802.11T**: Wireless Performance Metrics. Active.
- **802.11u**: Inter-working with External Networks. Active.
- **802.11v**: Wireless Network Management enhancements for interface to upper layers. Extension to 80211.k. Active.
- **Study Group ADS**: Management frame security. Active
- **Standing Committee Wireless Next Generation WNG**: Globalization jointly w ETSI-BRAN and MMAC. Active.

# 802.11n

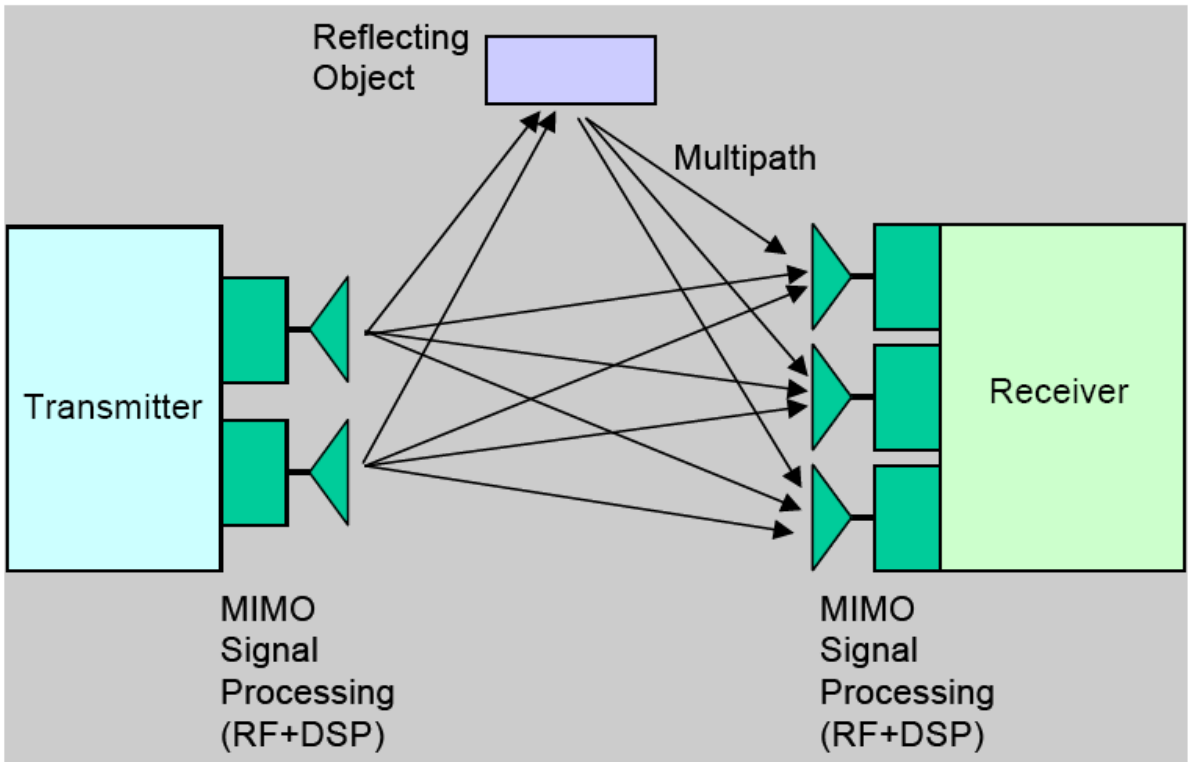
- Trend: HDTV and flat screens are taking off
  Media Center Extenders from Linksys and other vendors
- Application: HDTV and streaming video (over longer distances than permitted by 802.15.3 WPANs)
- 11n = Next Generation of 802.11
- At least 100 Mbps at MAC user layer
  $\Rightarrow$ 200+ Mbps at PHY $\Rightarrow$ 4x to 5x faster than 11a/g
  (802.11a/g have 54 Mbps over the air and 25 Mbps to user)
- Pre-11n products already available
- Task Group n (TGn) setup: Sept 2003
- Expected Completion: March 2007

# 802.11n

- Uses multiple input multiple output antenna (MIMO)
- Data rate and range are enhanced by using spatial multiplexing (N antenna pairs) plus antenna diversity
- Occupies one WLAN channel, and in compliance with 802.11
- Backwards compatible with 802.11 a,b,g
- One access point supports both standard WLAN and MIMO devices

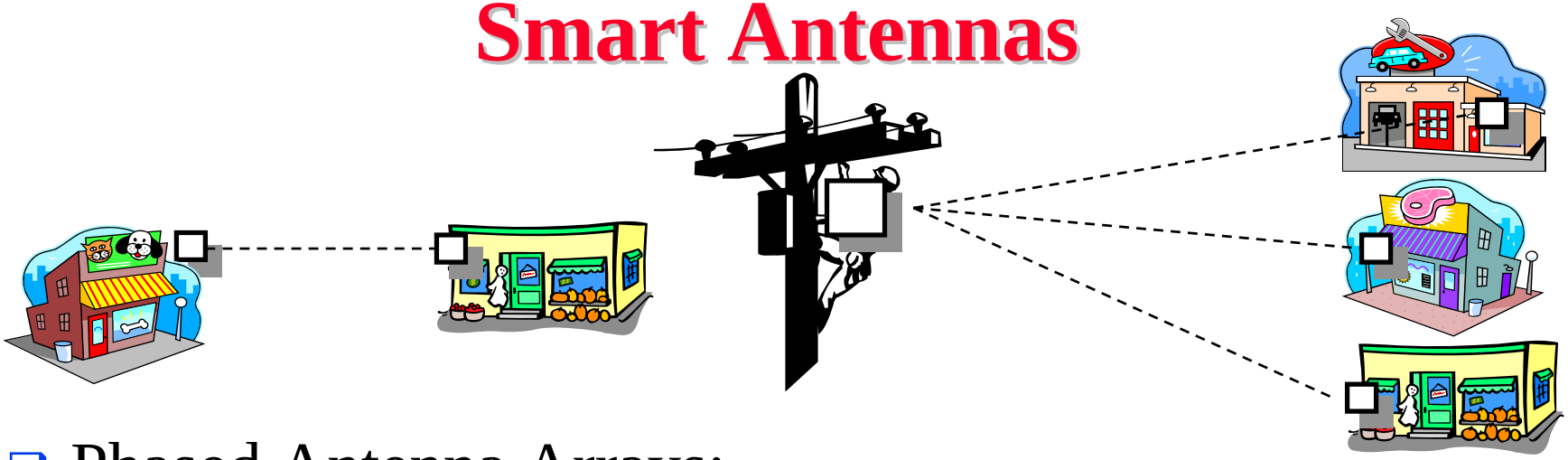
# MIMO

- Multiple Input Multiple Output
- 54 Mbps/20 MHz = 2.7 bps/Hz,
  MIMO ⇒ 108 Mbps or 5.4 bps/Hz




2x3

# Smart Antennas



- Phased Antenna Arrays:
  Receive the same signal using multiple antennas
- By phase-shifting various received signals and then summing ⇒ Focus on a narrow directional beam
- Digital Signal Processing (DSP) is used for signal processing
- Self-aligning

# IEEE 802.11n Status

- Two Competing Groups:
  - Task Group n Synchronization (TGn Sync): Cisco, Intel, Nortel, Sony, Toshiba (tgnsync.org)
  - World Wide Spectrum Efficiency (WWiSE): Nokia, Motorola, TI, NTT, Broadcom (wwise.org)
- Both agree on MIMO

# TGnSync vs WWise

| | TGnSync | WWiSE |
|---|---|---|
| Band | 5 GHz | 2.4 GHz |
| Channel Size | Initially 40 MHz<br>Now 20 MHz | 20 MHz (40 MHz not permitted in Japan and some parts of Europe) |
| Throughput | • Mandatory 144 Mbps with 2x2 20 MHz<br>• 250 Mbps with 2x2 MIMO<br>• Optional 600 Mbps with 4x4 transmitters. | • Mandotory 135 Mbps with 2x2 20 MHz<br>• Optional 540 Mbs with 4x4 and 40 MHz channel |

- Latest Status: A proposal which combines the best of both and a third one from "Enhance Wireless Consortium" was selected.

# IEEE 802.11 DCF Backoff

- MAC works with a single FIFO Queue
- Two variables:
  - Contention Window (CW)
  - Backoff count (BO)
- BO is a pseudorandom integer in [0, CW]
- Initially and after each successful transmission:

$$CW = CW_{min}$$

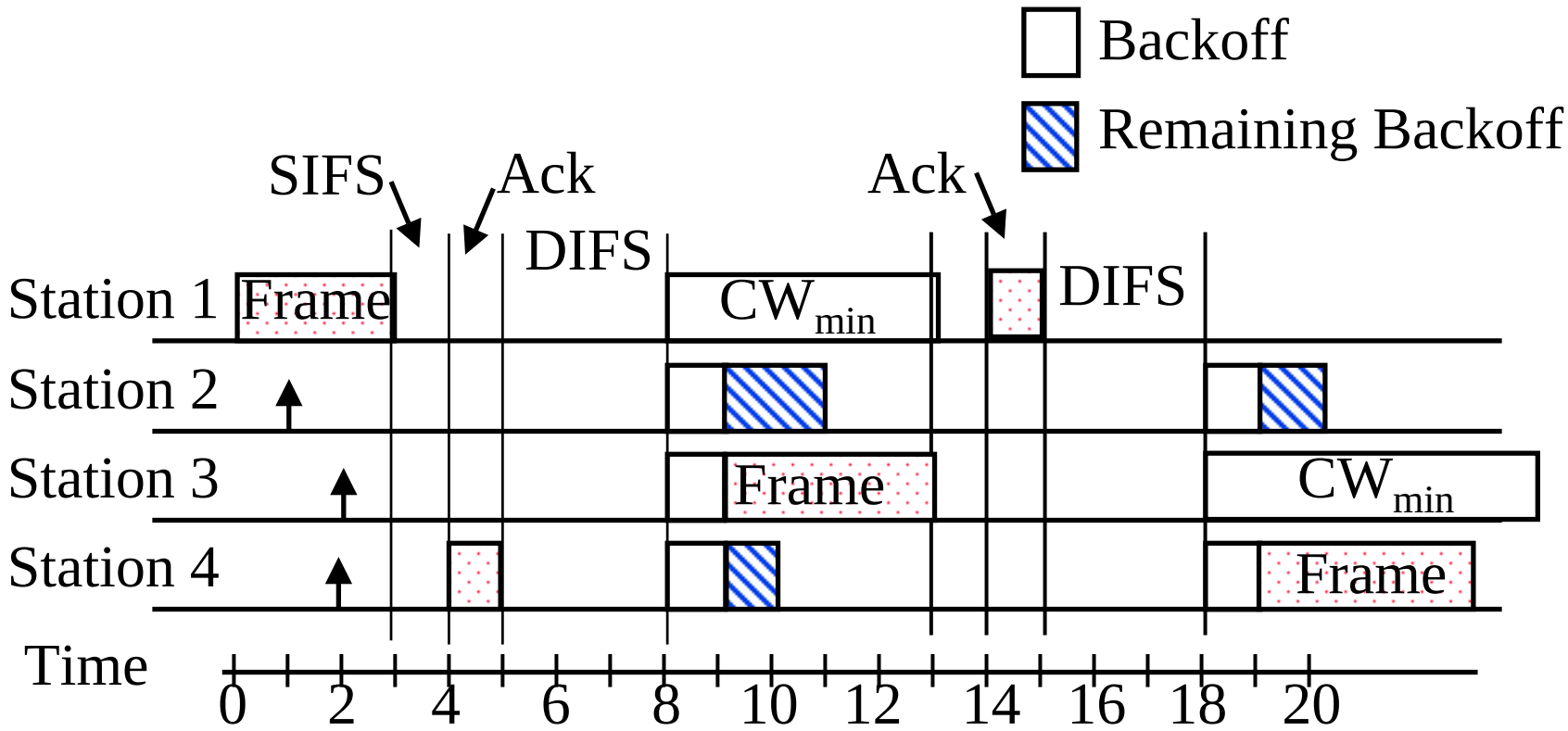
- After each unsuccessful attempt

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

- The stations wait for BO. If another station starts transmitting, the waiting stations pause their backoff counter and restart it DIFS after the end of frame again.

# DFS

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

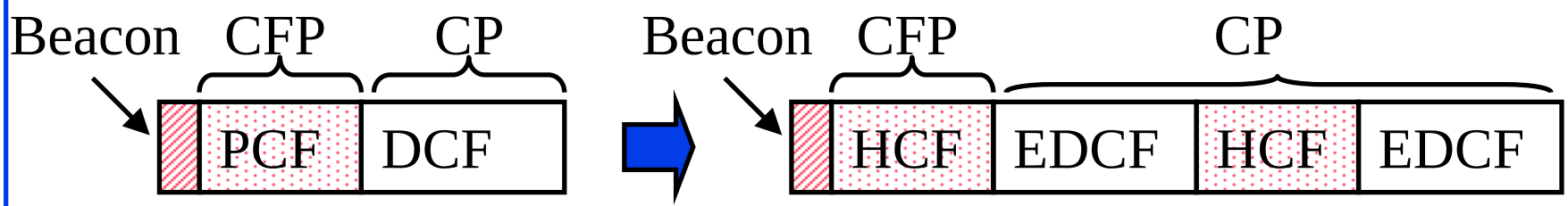


# DFS: Example (Cont)

- 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)
- 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.
  Station 2 and 4 pause backoff counter at 2 and 1 resp.
- T=13 Station 3 finishes transmission
- T=14 Station 3 receives Ack.
- T=15 Medium becomes free
- T=18 DIFS expires
  Stations 2 and 4 start their backoff counter
- T=19 Station 4 starts transmitting

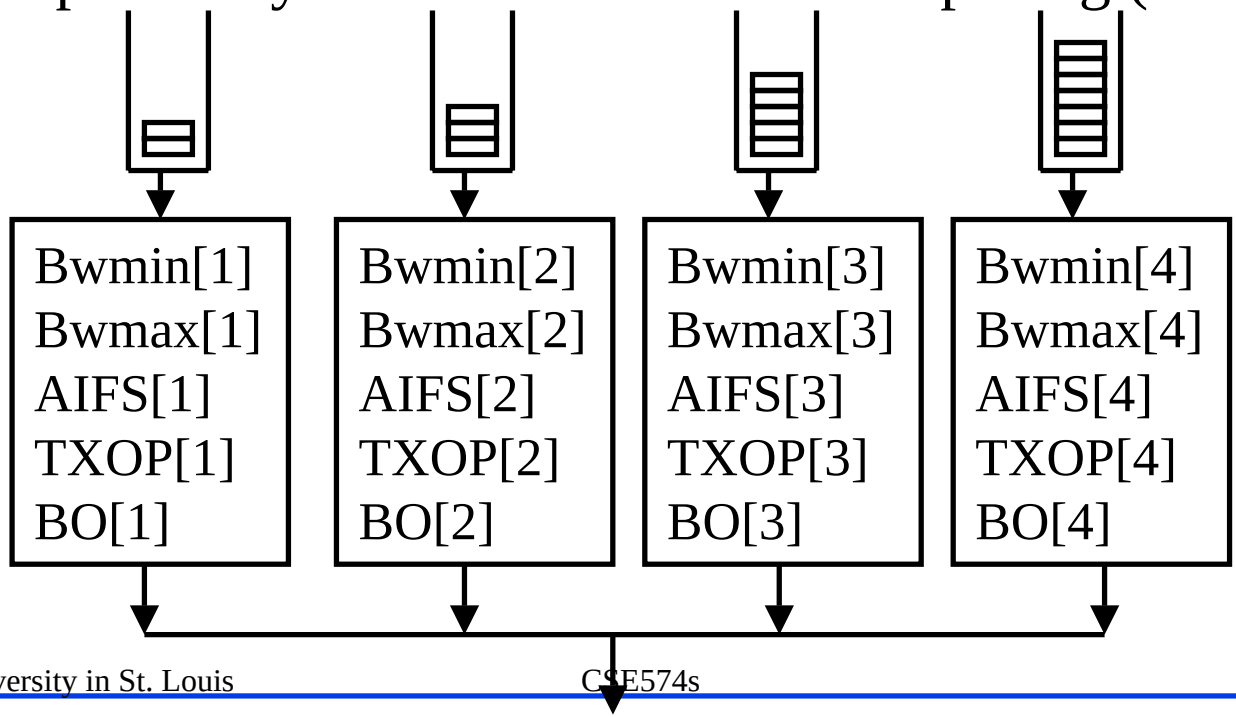
# IEEE 802.11e QoS

- Backward compatible:
  $\Rightarrow$ Non-802.11e terminals can receive QoS enabled streams
- New Features:
  1. Hybrid Coordination Function (HCF) w two components
     a. Contention Free Access: Hybrid Polling
     b. Contention-based Access: Enhanced DCF (EDCF)
  2. Direct Link: Traffc sent directly between two stations
  3. Frame bursting and Group Acknowledge
  4. Multiple Priority levels



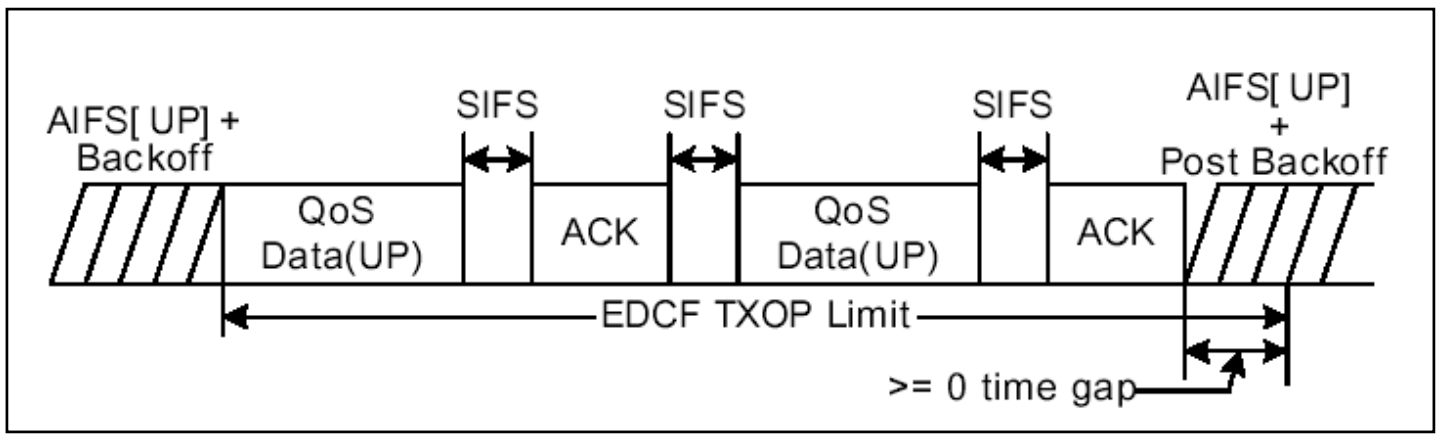
# Enhanced DCF

- Up to 8 queues. Each Q gets a different set of four Parameters:
  - $CW_{min}/CW_{max}$
  - Arbitrated Inter-Frame Spacing (AIFS)
  - Transmit Opportunity (TXOP) duration
- DIFS replaced by Arbitrated Inter-frame Spacing (AIFS)

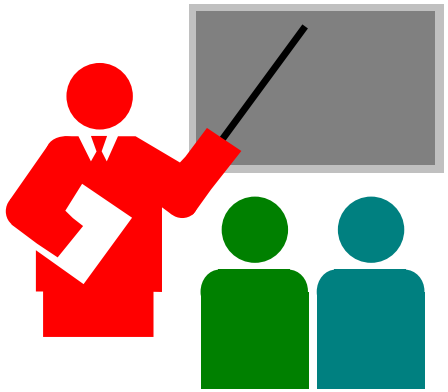


# ECDF Bursting

- EDCF parameters announced by access point in beacon frames
- Can not overbook higher priorities ⇒ Need admission control
- EDCF allows multiple frame transmission
- Max time = Transmission Opportunity (TXOP)
- Voice/gaming has high priority but small burst size
- Video/audio has lower priority but large burst size



# Summary



1. 802.11 uses both Frequency hopping and Direct Sequence CDMA
2. Allows both: Ad-Hoc vs Infrastructure-based
3. BSS, ESS, AP
4. 802.11 supports single FIFO Q. Uses SIFS, PIFS, DIFS
5. 802.11 PHYs: 802.11, 802.11a, 802.11b, 802.11g
6. 802.11n supports 100+ Mbps using MIMO
7. 802.11e supports multiple classes by multiple AIFS

# Reading Assignment

- Read sections 2.1 through 2.4 of Murthy and Manoj

# Homework 5

- 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 frame size is 3 slots. Draw a transmission diagram. How many slots before the two packets will get acknowledged assuming no new arrivals.