ITCE 720A Autonomic Wireless Networking (Fall 2009)

IEEE 802.11: MAC Management

Prof. Chansu Yu

chansuyu@postech.ac.kr

802.11: MAC Management

- Synchronization
  - Finding and staying with a WLAN
  - Synchronization function – TSF timer, beacon generation
- Power management
  - Sleeping without missing a message
  - periodic sleep, frame buffering, TIM (traffic indication map)
- Association/Reassociation
  - Joining a LAN
  - roaming, i.e. moving from one AP to another
  - scanning, i.e. active search for a network
- MIB - Management Information Base
  - managing, read, write

(1) 802.11 MAC Management: Synchronization

Timing synchronization function (TSF) is used for

- Power management
  - Wakeup/sleep management
- Point coordination timing
  - TSF timer used to predict start of CF burst
- Hop timing for FH PHY
  - TSF timer used to time dwell interval
  - All stations are synchronized, so they hop at the same time

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FHSS : Frequency Hopping Spread Spectrum

- Discrete changes of carrier frequency
  - sequence of frequency changes determined via pseudo random number sequence
- Two variations:
  - Fast Hopping: several frequencies per user bit
  - Slow Hopping: several user bits per frequency

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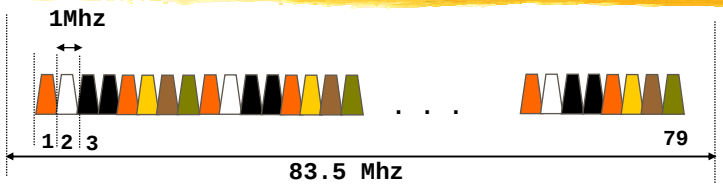
Bluetooth/802.11 uses FHSS



- Bluetooth
  - Channels: 2.402 GHz + k MHz, k=0, …, 78
  - Hopping rate: 1,600 hops per second
  - Dwell time in each carrier frequency: 625-μs
  - During each 625-μs time slot, it transmits one packet
- IEEE 802.11 standard
  - IR / DSSS / FHSS are defined as its physical layers
  - FHSS: 2.5 hops per second

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Synchronization: TSF

- Timing synchronization function (TSF) is used for
  - Power management
    - Wakeup/sleep management
  - Point coordination timing
    - TSF timer used to predict start of CF burst
  - Hop timing for FH PHY
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Synchronization: Beacons

- Beacons
  - Beacons are sent at well known intervals (beacon interval)
    - Beacons contain timestamp for the entire BSS
    - All station timers in BSS are synchronized
    - Transmission may be delayed by CSMA deferral (not relative to the last beacon transmission)
  - Who sends beacons?
    - AP controls in infrastructure networks
    - Distributed function for IBSS

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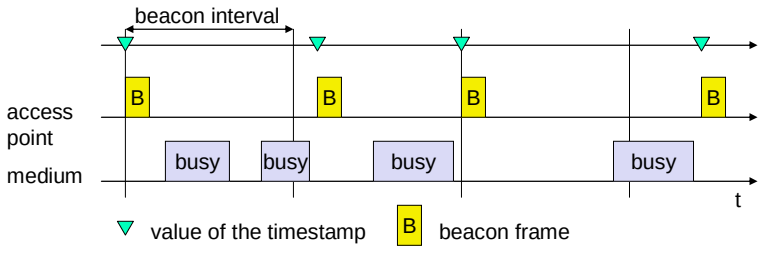
Synchronization using a Beacon in infrastructure network



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Synchronization using a Beacon in Ad-hoc network

- TSF is complicated for ad hoc networks
- Master Election steps
  - Every station is responsible for generating a beacon
  - All stations compete for transmission of the beacon using the standard backoff algorithm
  - The first wins the race and all others cancel their beacon transmission and adjust their local timers to the timestamp of the winning beacon

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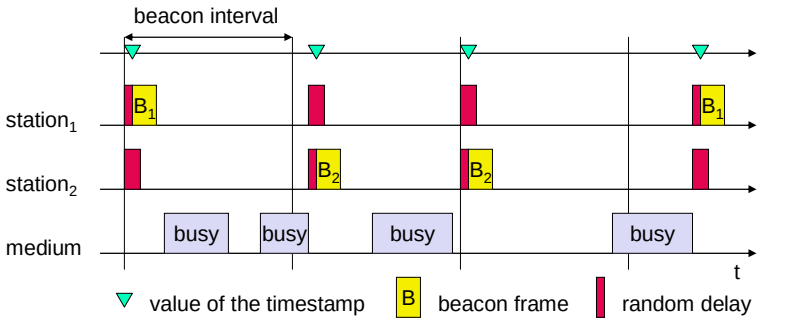
Synchronization using a Beacon in Ad-hoc network

Is this multi-hop ?



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(2) 802.11 MAC Management: Power management

- Mobile devices are battery powered
- Current LAN protocols assume stations are always ready to receive (promiscuous mode)
- Idle receive state dominates LAN adapter power consumption over time
  - Absolute value is slightly less than transmit/receive power
  - But, time duration in idle state is larger

- How can we power off during idle periods, yet maintain an active session?
- PS (Power Save) mode
  - A station sleeps most of the time
  - But wakes up periodically to receive regular beacon from AP (Access Point)
  - This is to check if there is any packet destined to it

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Power Save Mode in IEEE 802.11

<table>
<tr><th colspan="3">802.11 (WaveLAN-II)</th><th colspan="2">Bluetooth (Nokia)</th></tr>
<tr><th>Hardware State</th><th colspan="2">Mode of Operation</th><th>Mode of Operation</th><th>Hardware State</th></tr>
<tr><td rowspan="4">Awake</td><td rowspan="3">Active</td><td>Transmit (300mA)</td><td rowspan="2">Active (40-60mA)</td><td rowspan="4">Connection</td></tr>
<tr><td>Receive (250mA)</td></tr>
<tr><td>Idle(Listen) (230mA)</td><td>Sniff</td></tr>
<tr><td rowspan="3">Power Save</td><td>Hold</td></tr>
<tr><td rowspan="2">Doze</td><td>Park</td></tr>
<tr><td colspan="2">Sleep (9mA)</td><td>Standby (0.55mA)</td><td>Standby</td></tr>
</table>

2 Mbps, 250 meters

768 Kbps, 10-100 meters

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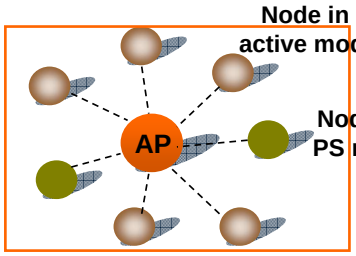
Power Save Mode in IEEE 802.11

- AP can transmit data frames to an active node at any time
- For nodes in PS mode,
  - AP buffers data frames
  - AP announces buffered traffic at a predetermined time
  - AP transmits the data frames



Requires synchronization (beacons)

Uses TIM (Traffic Indication Map)

AP maintains nodes' mode of operation

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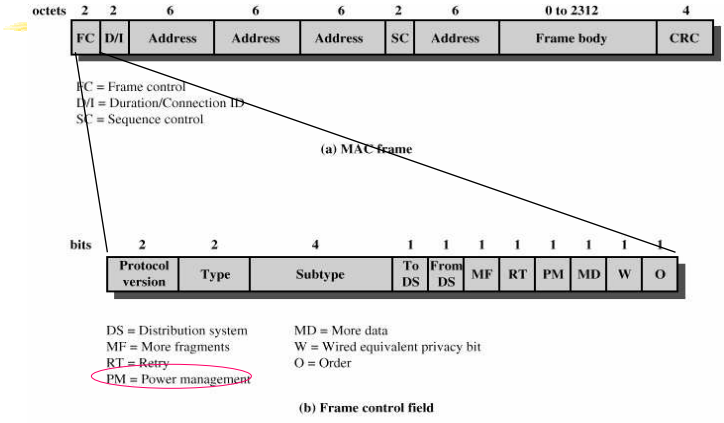
Power Save Mode in IEEE 802.11



PM field indicates the power management mode of a station in which it will be after the successful completion of the current frame.
PM=1 indicates that the station will be in PS mode.
PM=0 indicates active mode.

Power Management in infrastructure network

- The AP is responsible for generating beacons, which contains time information
- Beacon also contains a traffic indication map (TIM)
  - All unicast packets for stations in doze mode are announced in the TIM
  - Broadcast/multicast frames are announced in TIM and are sent immediately after
- Devices in PS mode
  - have to be synchronized to wake up at one particular time, in which the AP announces buffered frames for receivers with TIM
  - A station that receives such an announcement stays awake until the frame is delivered

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Power Management in infrastructure network

- TSF assures AP and stations are synchronized
- TIM: Infrastructure network
  - TIM: list of unicast receivers transmitted by AP
- DTIM (Delivery TIM): Broadcast/multicasts
  - Broadcast frames are also buffered in AP
  - DTIM: list of broadcast/multicast receivers transmitted by AP
  - All broadcast/multicasts are buffered
  - Broadcast/multicasts are only sent after DTIM
  - DTIM interval is a multiple of TIM interval
- ATIM (Ad-hoc TIM): Ad-hoc network
  - IBSS also have power management
  - Similar in concept, distributed approach
    - announcement of receivers by stations buffering frames
    - more complicated, collision of ATIMs possible - no central AP

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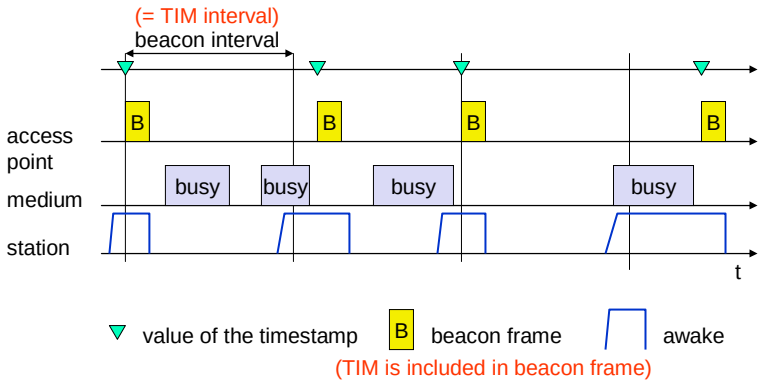
Power Management in infrastructure network



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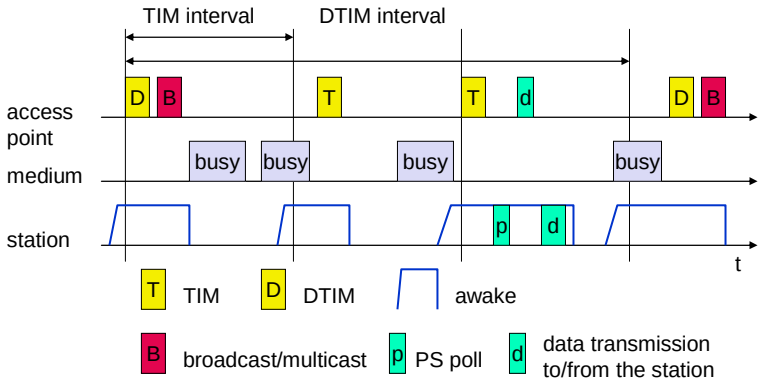
Power Management in infrastructure network



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Power Management in Ad-hoc network

- Beacon is followed by ATIMs announced during ATIM window
- ATIM (Ad-hoc TIM): Ad-hoc network
  - Announcement of receivers by stations buffering frames
  - More complicated, collision of ATIMs possible - no central AP
- Data transmission
  - Data is announced by ad hoc TIMs (ATIMs) in special time interval called "ATIM Window" after a beacon
  - Packets for a station in doze state have to be buffered by the sender (not the master) until the end of the beacon interval

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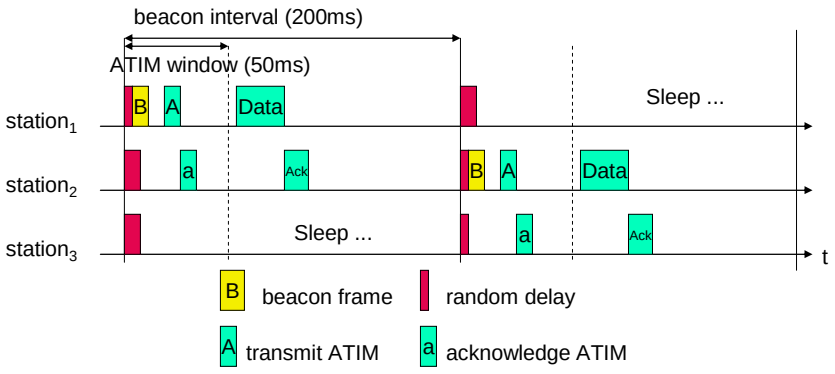
Power Management in Ad-hoc network



Nodes that are not addressed during the ATIM window can sleep during the rest of the beacon interval.

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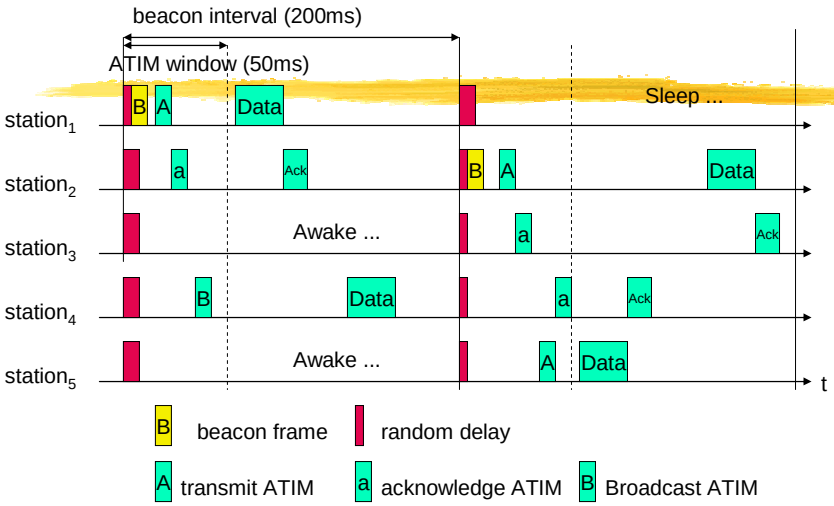
ATIM and Data transmissions follow the general CSMA principle



Large ATIM window: less power saving, less throughput
Small ATIM window: not enough time to announce traffic, but it may be OK when traffic is light

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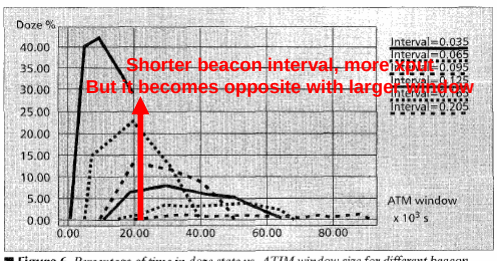
Power consumption depends on

- Beacon interval
- ATIM window size
- Offered load

Issues are

- Clock synchronization
- Leader election
- Transition time

■ **Figure 5.** *Throughput vs. ATM window for different beacon intervals, load = 60.76 percent eight stations in PS mode.*



■ **Figure 6.** *Percentage of time in doze state vs. ATIM window size for different beacon intervals, load = 30.72 percent, eight stations in PS mode.*

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Dynamic ATIM Window

- Power-Saving Mechanisms in Emerging Standards for Wireless LANs: The MAC Level Perspective
  - Hagen Woesner, Jean-Pierre Ebert, Morten Schlager, and Adam Wolisz
  - *IEEE Personal Communications*, Vol. 5, Issue 3, pp. 40-48, Jun. 1998.
- Minimizing Energy for Wireless Web Access Using Bounded Slowdown
  - Ronny Krashinsky and Hari Balakrishnan
  - *MobiCom*, 2002.
- An Energy Efficient MAC Protocol for Wireless LANs
  - E. Jung and N. Vaidya
  - *IEEE Infocom*, 2002.

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(3) 802.11 MAC Management: Association/ Reassociation (Roaming/Scanning)

- Each station is associated with a particular AP
  - Association: Establishes initial association between station and AP
- Mobile stations may move...
  - Beyond the coverage area of their AP
  - But within range of another AP
- Reassociation allows station to continue operation
  - Reassociation: Enables transfer of association from one AP to another, allowing station to move from one BSS to another
- Disassociation
  - Association termination notice from station or AP

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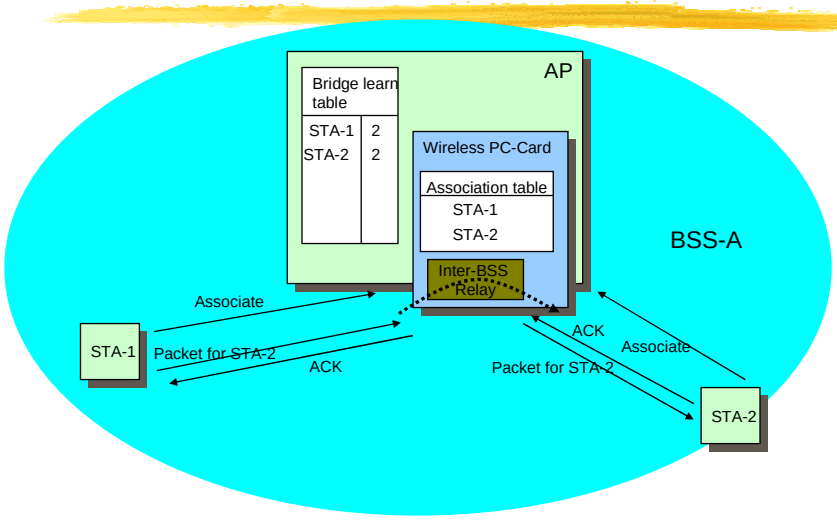
Operational processes
Traffic flow in a BSS



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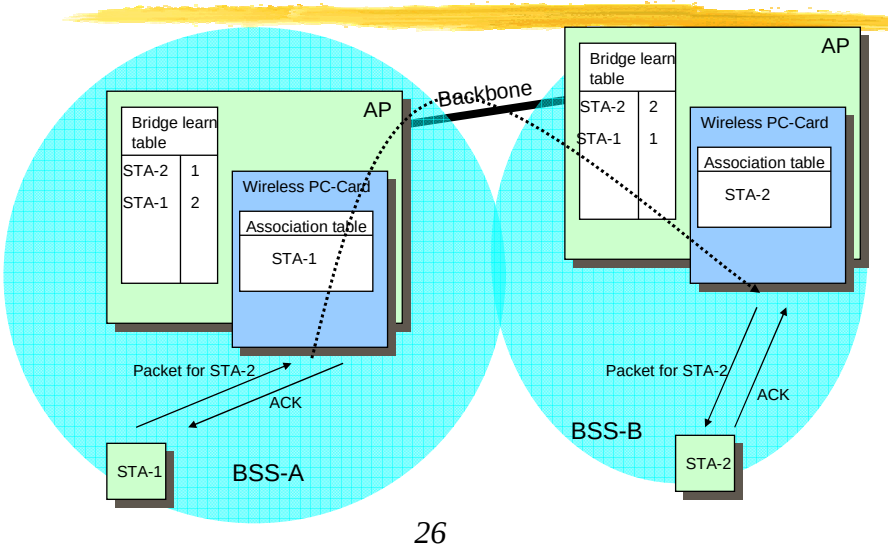
Operational processes
Traffic flow in an ESS



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Association/ Reassociation

- How does a station associate with an AP?
  - AP periodically (typically, 100ms) transmits beacon.
  - Beacon contains information such as BSSID, timestamp, TIM, power management, and roaming.
  - When a station receives a beacon with a reasonable signal strength, it "associates" with the AP.
  - AP grants permission to the station via an "association response" frame.

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Association/ Reassociation

- How to support mobility?
  - When a station receives a beacon from another AP in the same ESS (called BSS transition), the station "re-associates" with the new AP.
  - When a station receives a beacon from another AP in another ESS (called ESS transition), automatic handoff is not made (i.e., upper layer connection breaks. Mobile IP supports handoff of this kind.)

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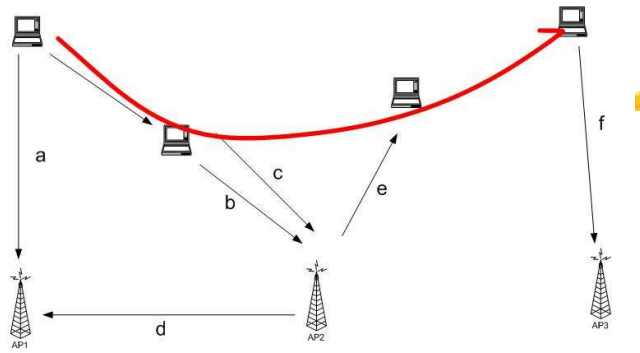
Ex.



(a) ---- The station finds AP1, it will authenticate and associate.

(b) ---- As the station moves, it may pre-authenticate with AP2.

(c) ---- When the association with AP1 is no longer desirable, it may reassociate with AP2.

(d) ---- AP2 notify AP1 of the new location of the station, terminates the previous association with AP1.

(e) ---- At some point, AP2 may be taken out of service. AP2 would disassociate the associated stations.

(f) ---- The station find another access point and authenticate and associate.

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Reassociation, Roaming/Scanning

- When is the time for a station to handoff?
  - Station measures signal strength of the current AP's beacon
  - If it becomes poor, it can simply listens to another AP's beacon (passive)
  - Or, perform scanning to find another AP (active) by sending "reassociation request" to one or several AP(s)
  - A new AP answers by sending "reassociation response"
- Reassociation request contains
  - Information about the station as well as the old AP
- Reassociation response contains
  - Information about the supported bit rates, station ID, and so on
- Question: what the old AP to do?
  - It does not know whereabout of the station : Why does it have to know?
  - No standard for communication among AP's
  - IAPP (inter-access point protocol) emerges

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Scanning & Joining

- Scanning
  - Passive Scanning : only listens for Beacon and get info of the BSS. Power is saved.
  - Active Scanning: transmit and elicit response from APs. If IBSS, last station that transmitted beacon responds. Time is saved.
- Joining a BSS
  - Synchronization in TSF and frequency : Adopt PHY parameters : The BSSID : WEP : Beacon Period : DTIM

802.11 MAC Data Type

Table 14.3 Valid Type and Subtype Combinations

Type Value	Type Description	Subtype Value	Subtype Description
00	Management	0000	Association request
00	Management	0001	Assocation response
00	Management	0010	Reassociation request
00	Management	0011	Reassociation response
00	Management	0100	Probe request
00	Management	0101	Probe response
00	Management	1000	Beacon
00	Management	1001	Announcement traffic indication message
00	Management	1010	Dissociation
00	Management	1011	Authentication
00	Management	1100	Deauthentication
01	Control	1010	Power save - poll
01	Control	1011	Request to send
01	Control	1100	Clear to send
01	Control	1101	Acknowledgment
01	Control	1110	Contention-free (CF)-end
01	Control	1111	CF-end + CF-ack
10	Data	0000	Data
10	Data	0001	Data + CF-Ack
10	Data	0010	Data + CF-Poll
10	Data	0011	Data + CF-Ack + CF-Poll
10	Data	0100	Null function (no data)
10	Data	0101	CF-Ack (no data)
10	Data	0110	CF-poll (no data)
10	Data	0111	CF-Ack + CF-poll (no data)

Homework #3

- EEE 802.11 MAC management
  - Read 11.1~3
  - Read one section, chosen from 11.4~9
- Read a paper "Mobile IP - deployment after a decade," by Kishore Ramachandran (Rutgers)
- Read a paper "Parasitic computing," http://www.nd.edu/~parasite/nature.pdf (Norte Dame)

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