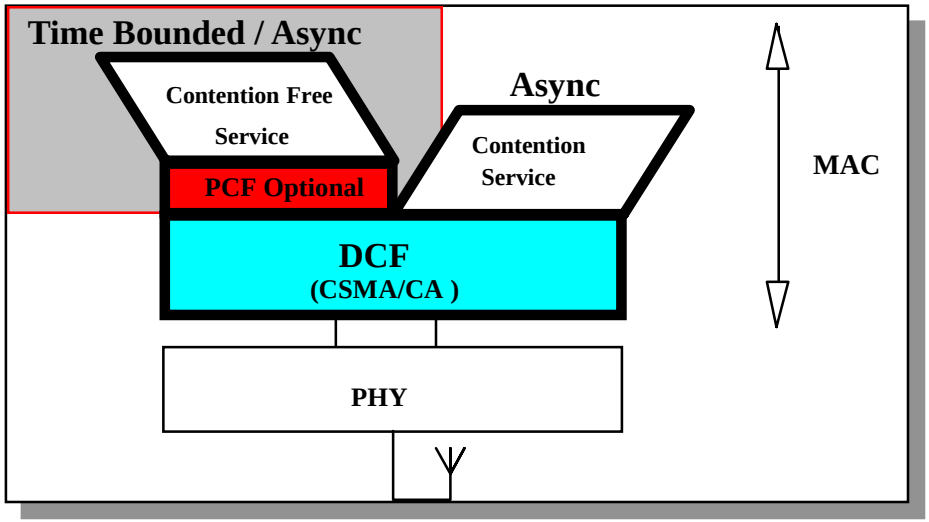
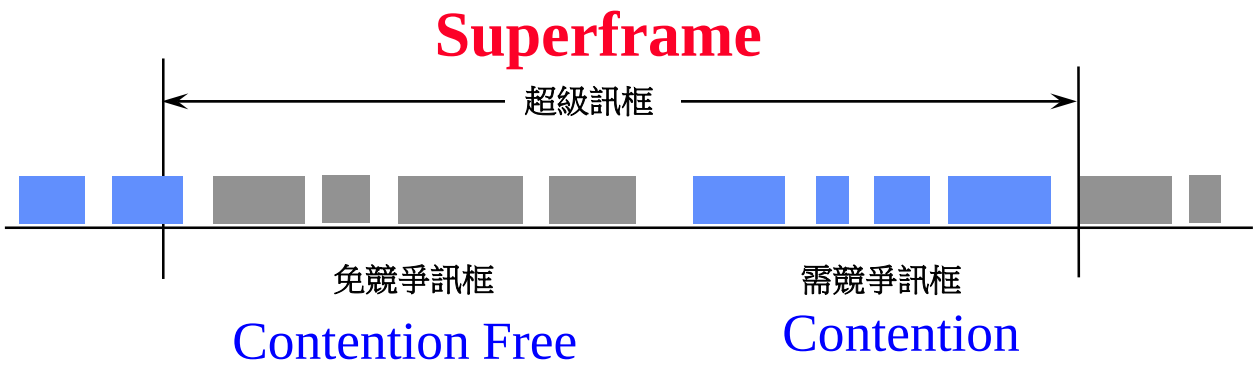
Optional Point Coordination Function (PCF)



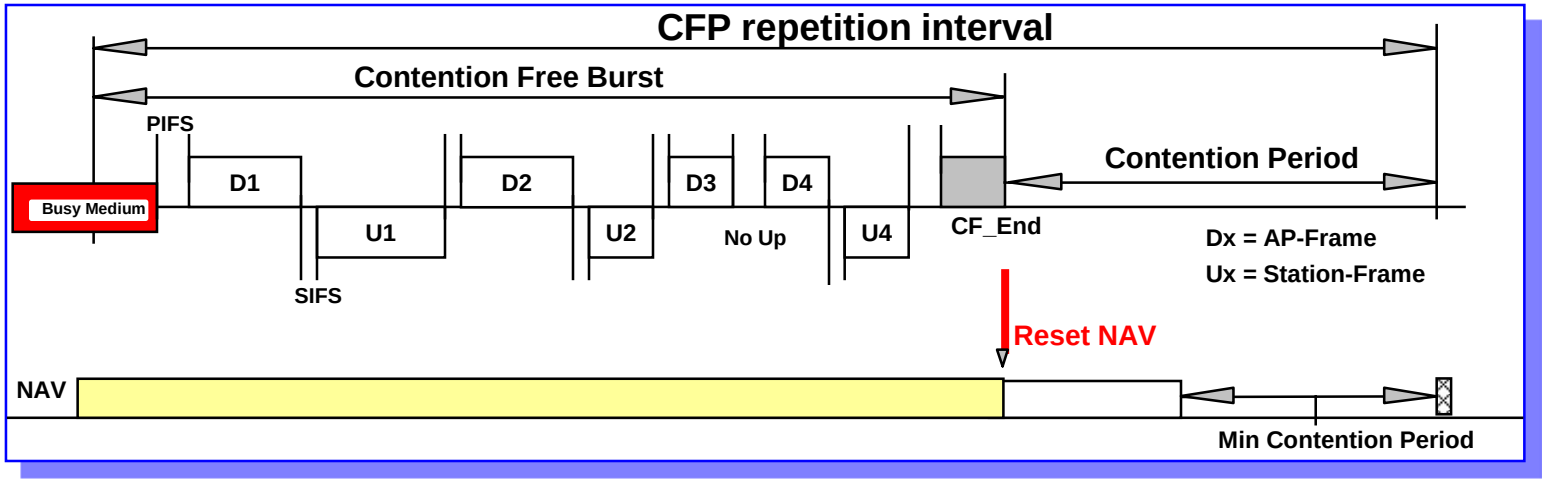
- **Contention Free Service uses Point Coordination Function (PCF) on a DCF Foundation.**
  - **PCF can provide *lower transfer delay* variations to support *Time Bounded Services*.**
  - **Async Data, Voice or mixed implementations possible.**
  - **Point Coordinator resides in AP.**
- **Coexistence between Contention and optional Contention Free does not burden the implementation.**

Point Coordination Function(PCF)

- The PCF provides contention free services.
- It is an option for a station to become the Point Coordinator(PC), which generates the Superframe (SF).
- The SF consists of a Contention Free (CF) period and a Contention Period.
- The length of a SF is a manageable parameter and that of the CF period may be variable on a per SF basis.



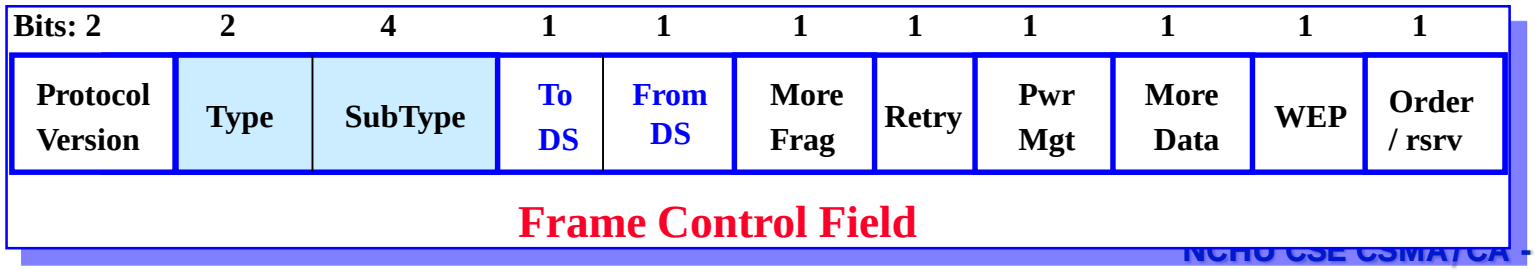
PCF Burst



- CF-Burst by Polling bit in CF-Down frame.
- Immediate response by Station on a CF_Poll.
- Stations to maintain NAV to protect CF-traffic
- Responses can be variable length.
- Reset NAV by last (CF_End) frame from AP.
- "ACK Previous Frame" bit in Header. (piggyback)

Valid Type/Subtype combinations 1/2

Type value b3 b2	Type description	Subtype Value b7 b6 b5 b4	Subtype description
00	Management	0000	Association request
00	Management	0001	Association response
00	Management	0010	Reassociation request
00	Management	0011	Reassociation response
00	Management	0100	Probe request
00	Management	0101	Probe response
00	Management	0110-0111	Reserved
00	Management	1000	Beacon
00	Management	1001	Announcement traffic indication message (ATIM)
00	Management	1010	Disassociation
00	Management	1011	Authentication
00	Management	1100	Deauthentication
00	Management	1101-1111	Reserved

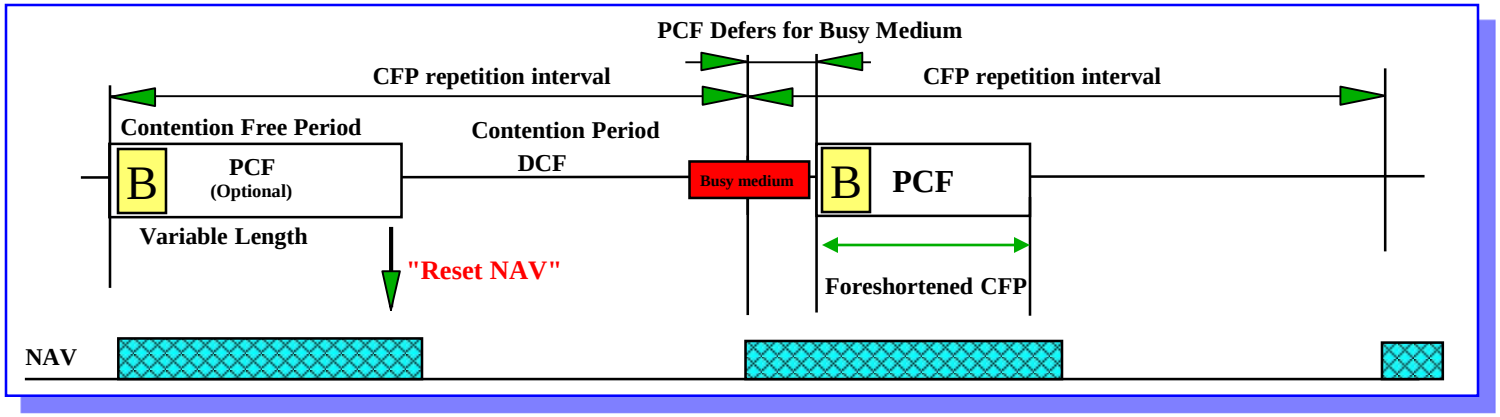


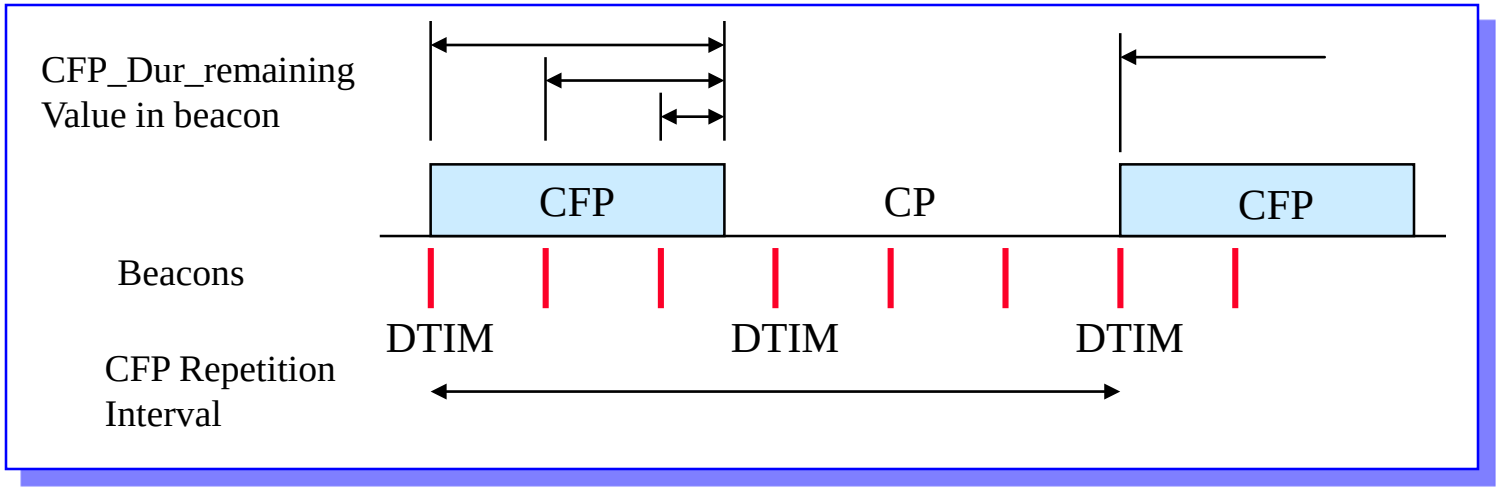
Valid Type/Subtype combinations 2/2

Type value b3 b2	Type description	Subtype Value b7 b6 b5 b4	Subtype description
01	Control	000-1001	Reserved
01	Control	1010	Power Save (PS-Poll)
01	Control	1011	RTS
01	Control	1100	CTS
01	Control	1101	ACK
01	Control	1110	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)
10	Data	1000-1111	Reserved
11	Reserved	0000-1111	Reserved

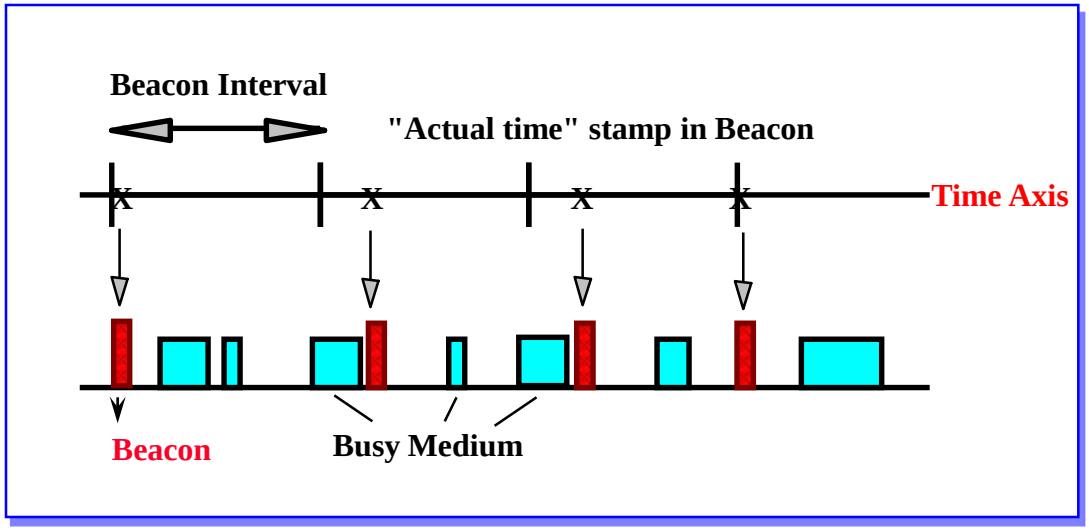
Point Coordination Function
-- CFP structure and timing (1/2)

- **The PC generates CFPs at the contention-free repetition rate (CFPRate), which is defined as a number of DTIM intervals.**





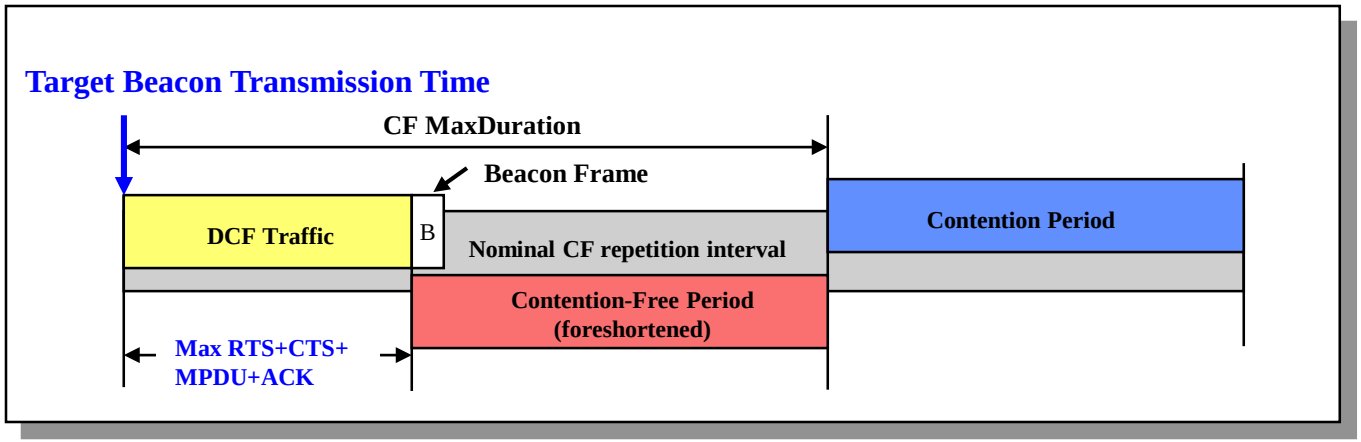
Infrastructure Beacon Generation



- APs send Beacons in infrastructure networks.
- Beacons scheduled at Beacon Interval .
- Transmission may be delayed by CSMA deferral.
  - subsequent transmissions at expected Beacon Interval
  - next Beacon sent at Target Beacon Transmission Time (TBTT)
  - not relative to last Beacon transmission
- Timestamp contains timer value at transmit time.

Point Coordination Function
-- CFP structure and timing (2/2)

- The length of the CFP is controlled by the PC, with maximum duration specified by the value of the **CFP-MaxDuration Parameter Set** at the PC. (broadcast by Beacon & probe response)
- Because the transmission of any beacon may be delayed due to a medium busy, **a CFP may be foreshortened** by the amount of the delay.
- The **CFPDurRemaining** value in the beacon shall let the CFP end time no later than **TBTT** plus the value of **CF MaxDuration**.



PCF Access Procedure (1/2)

- The PCF protocol is based on a polling scheme controlled by one special STA per BSS called the Point Coordinator (PC).
- The PC gains control of the medium at the beginning of the CF and maintains control for the entire CF period by waiting a shorter time between transmissions.
- At the beginning of the CF, the PCF shall sense the medium.
- If it is free the PCF shall wait a PIFS time and transmit
  - a Data frame with the CF-Poll Subtype bit set, to the next station on the polling list, or
  - a CF-End frame, if a null CF period is desired.

PCF Access Procedure (2/2)

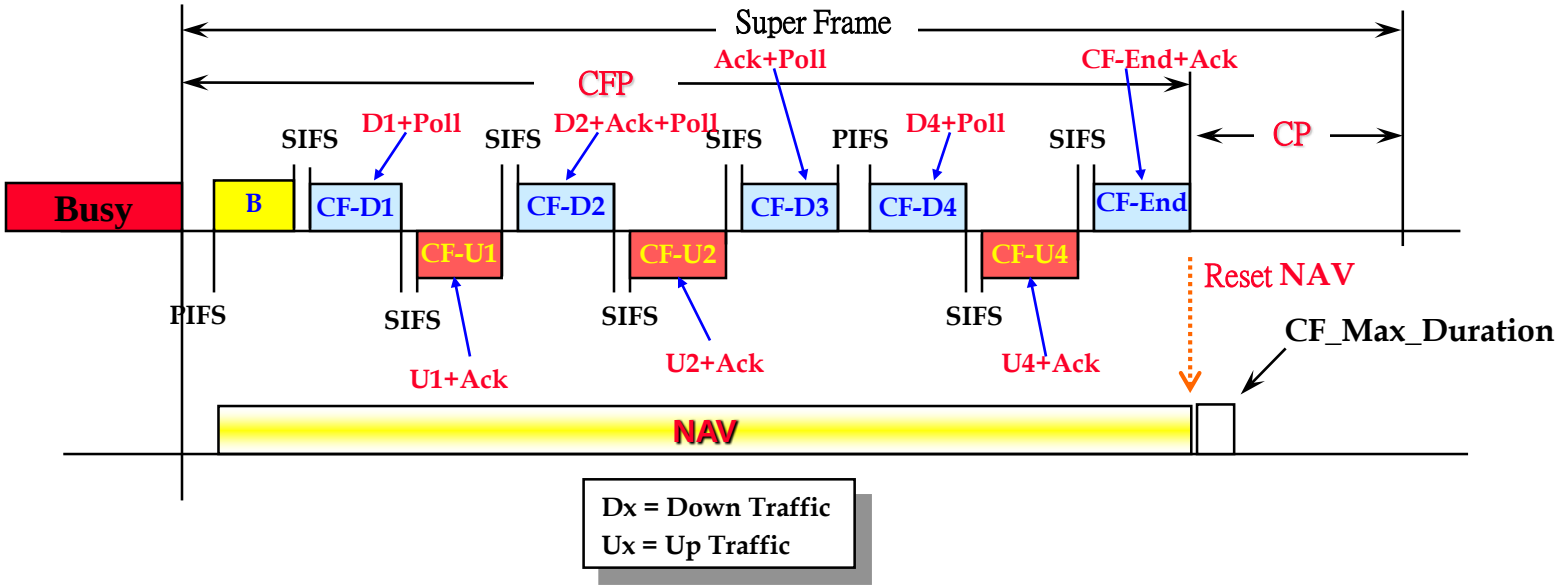
- **The PCF uses the PCF priority level protocol. The shorter PIFS gap causes a burst traffic with inter-frame gaps that are shorter than the DIFS gap needed by stations using the Contention Period.**

- **Each station, except the station with the PCF, shall preset it's NAV to the maximum CF-Period length at the beginning of every SF.**

- **The PCF shall transmit a CF-End or CF-End+ACK frame, at the end of the CF-Period, to reset the NAV of all stations in the BSS.**

PCF Transfer Procedure

- **PCF Transfers When the PCF Station is Transmitter or Recipient**
  - **Stations shall respond to the CF-Poll immediately when a frame is queued, by sending this frame after an SIFS gap.**
  - **This results in a burst of Contention Free traffic (CF-Burst).**
  - **For services that require MAC level ack, the ack is preferably done through the CF-Ack bit in the Subtype field of the responding CF-Up frame.**



MAC Management Layer

- **Synchronization**
  - Finding and staying with a WLAN
  - Synchronization functions
    - » TSF Timer, Beacon Generation
- **Power Management**
  - Sleeping without missing any messages
  - Power Management functions
    - » periodic sleep, frame buffering, Traffic Indication Map
- **Association and Reassociation**
  - Joining a network
  - Roaming, moving from one AP to another
  - Scanning
- **Management Information Base**

Timing Synchronization Function (TSF)

Synchronization in 802.11

- **Timing Synchronization Function (TSF)**
  - **Used for Power Management**
    - » **Beacons sent at well known intervals**
    - » **All station timers in BSS are synchronized**
  - **Used for Point Coordination Timing**
    - » **TSF Timer used to predict start of Contention Free burst**
  - **Used for Hop Timing for FH PHY**
    - » **TSF Timer used to time Dwell Interval**
    - » **All Stations are synchronized, so they hop at same time.**

Synchronization Approach

- All stations maintain a local timer.
- Timing Synchronization Function
  - Keeps timers from all stations in synch
  - AP controls timing in infrastructure networks
  - Distributed function for Independent BSS
- Timing conveyed by periodic Beacon transmissions
  - Beacons contain Timestamp for the entire BSS
  - Timestamp from Beacons used to calibrate local clocks
  - Not required to hear every Beacon to stay in sync
  - Beacons contain other management information
    - » also used for Power Management, Roaming

Beacon Generation (*)

- In Infrastructure
  - AP defines the *aBeaconPeriod* for transmitting beacons
  - *aBeaconPeriod* is broadcast by beacon and probe response
  - May delayed by using CSMA/CA for transmitting data of others
- In IBSS
  - all members participate in beacon generation
  - The IBSS initiator defines the *aBeaconPeriod*
  - At each TBTT, STA shall
    - » suspend the decrementing backoff timer for any non-beacon or non-ATIM transmission
    - » calculate a random delay from [0, 2*(CWmin*Slot_time)]
    - » backoff the selected random delay
    - » If a beacon is detected, give up sending beacon and decrementing backoff timer
    - » otherwise, transmit beacon

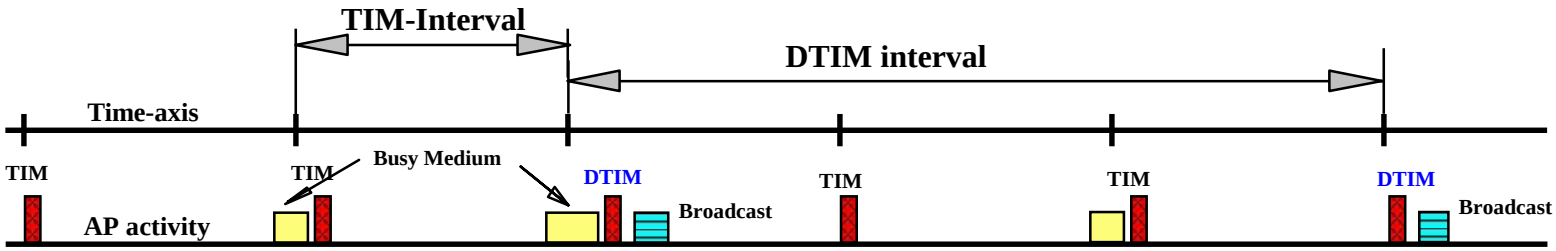
Power Management

- **Mobile devices are battery powered.**
  - ***Power Management* is important for mobility.**
- **Current LAN protocols assume stations are always ready to receive.**
  - **Idle receive state dominates LAN adapter power consumption over time.**
- **How can we power off during idle periods, yet maintain an active session?**
- **802.11 Power Management Protocol:**
  - **allows transceiver to *be off as much as possible***
  - **is transparent to existing protocols**
  - **is flexible to support different applications**
    - » **possible to trade off throughput and battery life**

Power Management Approach

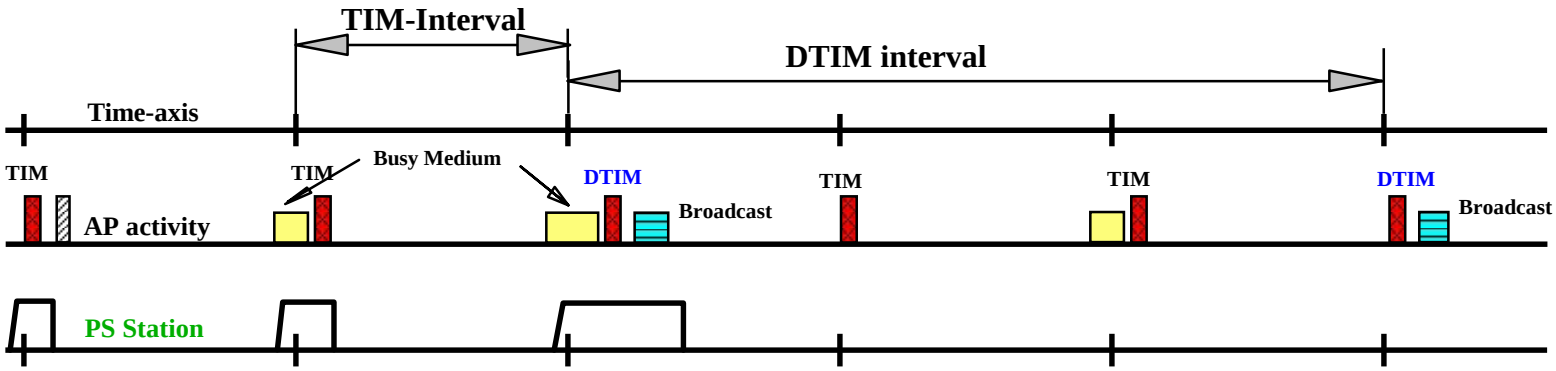
- Allow idle stations to go to sleep
  - station power save mode stored in AP
- APs buffer packets for sleeping stations.
  - AP announces which stations have frames buffered
  - Traffic Indication Map (TIM) sent with every Beacon
- Power Saving stations wake up periodically
  - listen for Beacons
- TSF assures AP and Power Save stations are synchronized
  - stations will wake up to hear a Beacon
  - TSF timer keeps running when stations are sleeping
  - synchronization allows extreme low power operation
- Independent BSS also have Power Management
  - similar in concept, distributed approach

Infrastructure Power Management



- **Broadcast frames are also buffered in AP.**
  - **all broadcasts/multicasts are buffered**
  - **broadcasts/multicasts are only sent after DTIM**
    - » **DTIM : Delivery Traffic Indication Message**
  - **DTIM interval is a multiple of TIM interval**

Infrastructure Power Management



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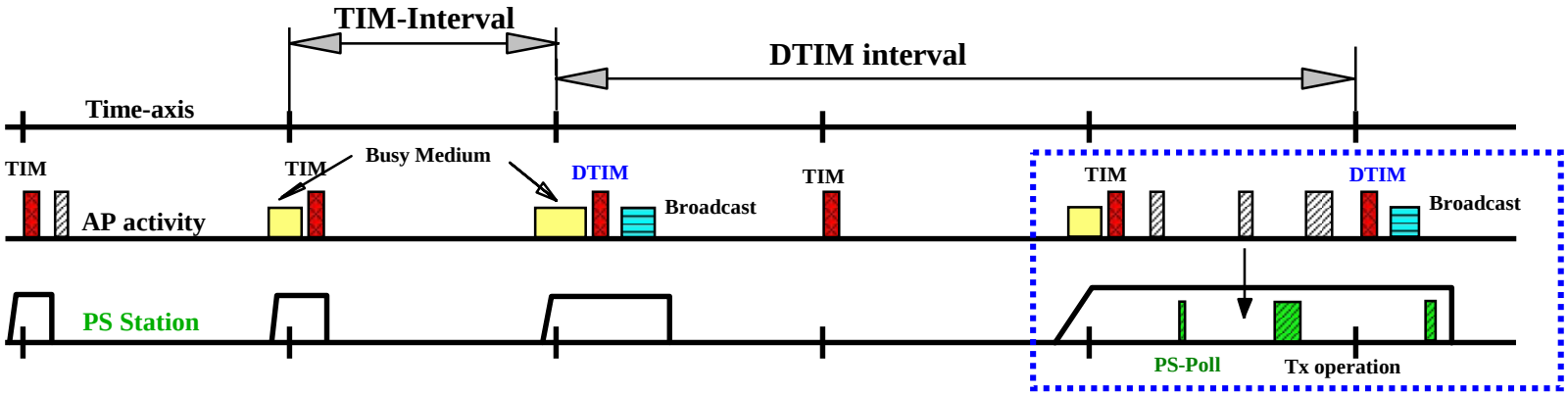
  - **DTIM interval is a multiple of TIM interval**
- **Stations wake up prior to an expected (D)TIM.**

Infrastructure Power Management

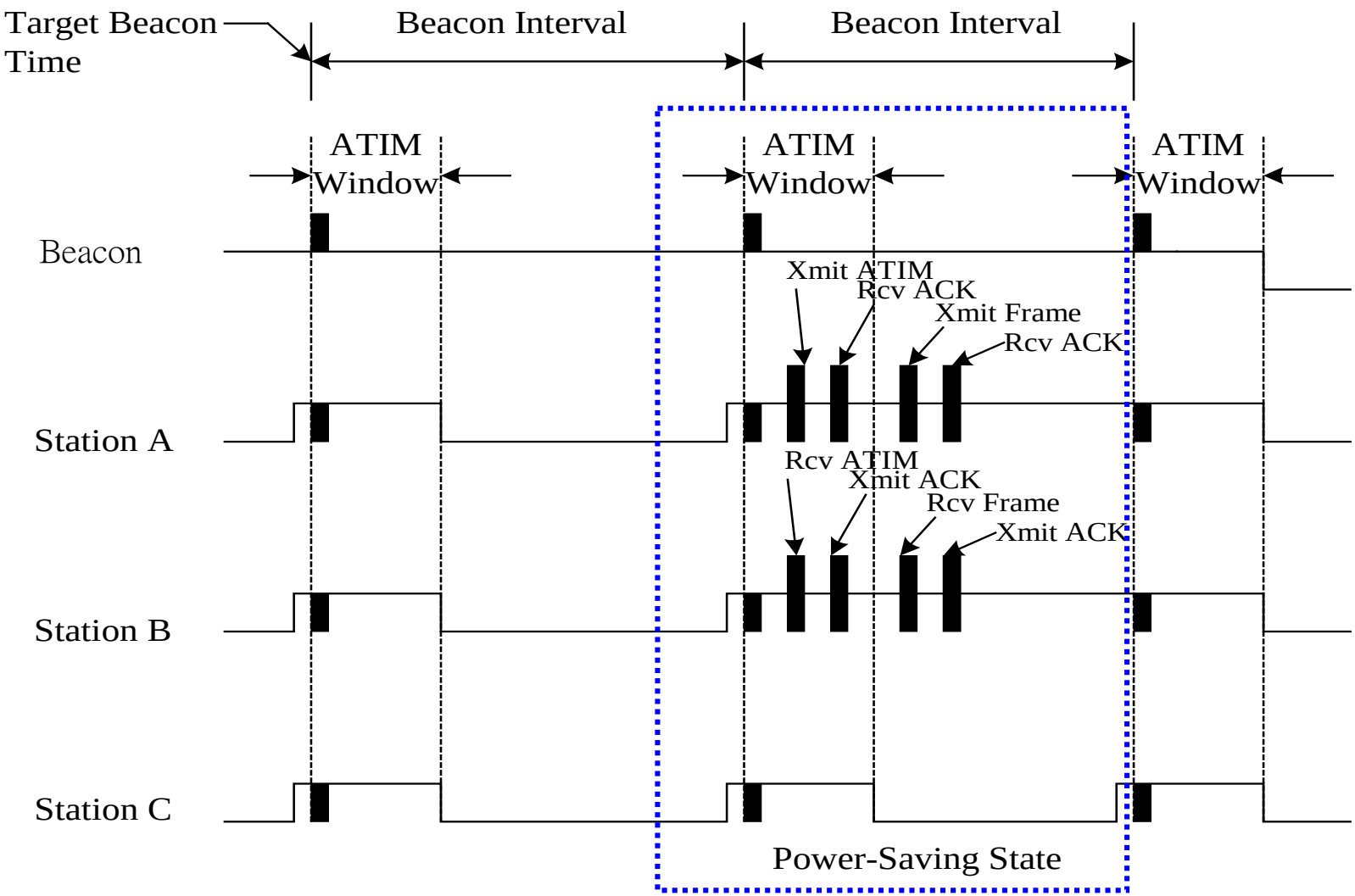


- **Broadcast frames are also buffered in AP.**
  - **all broadcasts/multicasts are buffered**
  - **broadcasts/multicasts are only sent after DTIM**
  - **DTIM interval is a multiple of TIM interval**
- **Stations wake up prior to an expected (D)TIM.**
- **If TIM indicates frame buffered**
  - **station sends PS-Poll (with AID) and stays awake to receive data**
- **else station sleeps again**

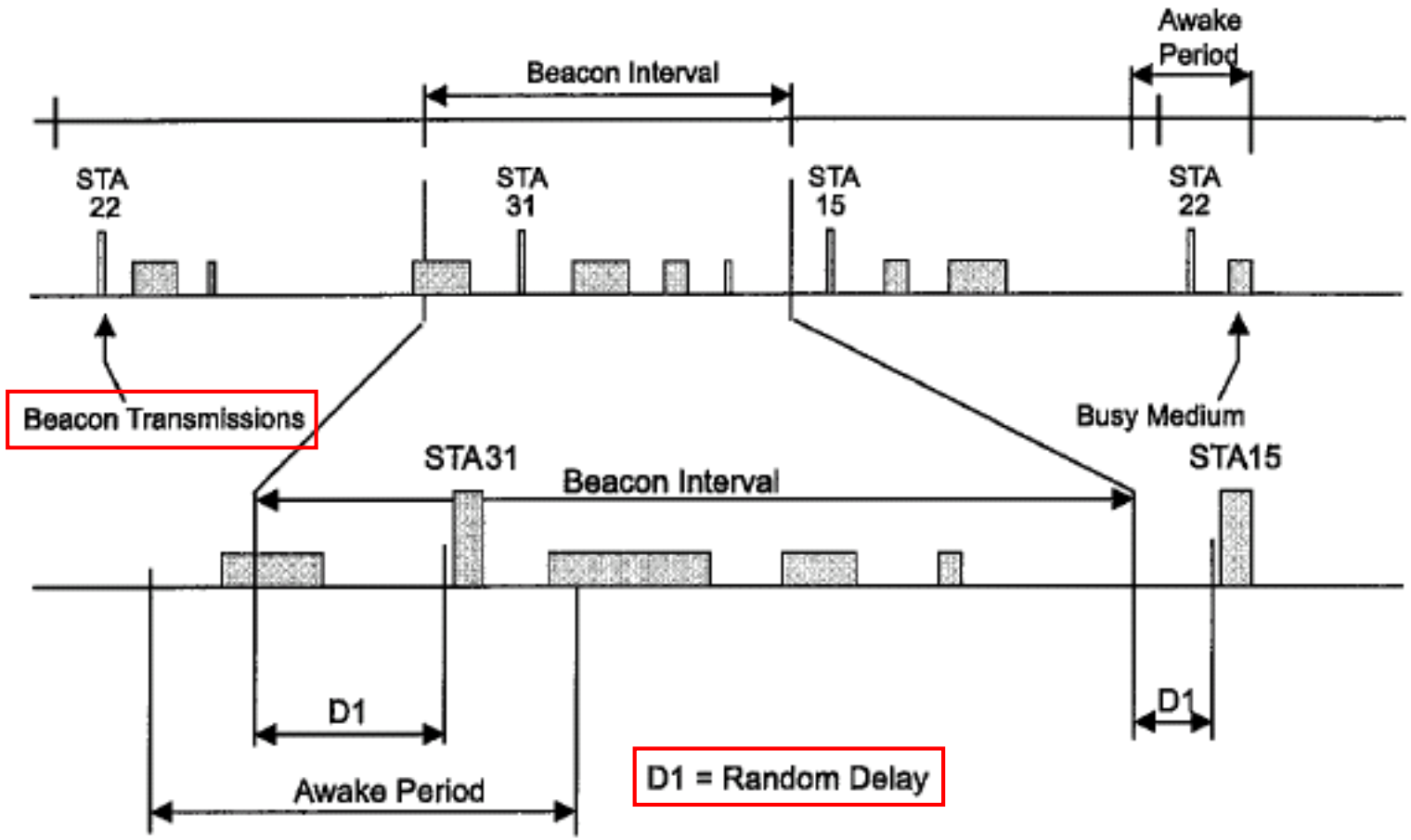
IBSS Power Management

- **ATIM: Ad Hoc (Announced) Traffic Indication Message.**
- **If a STA is PS, it shall enter the Awake state prior to each TBTT.**
- **If received a ATIM, a STA shall remain in the Awake state until the end of the next ATIM window.**
- **If a STA transmits a Beacon or an ATIM management frame, it shall remain in the Awake state until the end of the next ATIM window.**
- **Use RTS/CTS to detect if a STA is in PS-mode.**
- **A STA shall transmit no frame types other than RTS, CTS, and ACK Control frames, and Beacon, ATIM management frames in ATIM window.**
- **Transmission is begin following the ATIM window, backoff, DCF is used.**

IBSS Power Management



IBSS Beacon Transmission



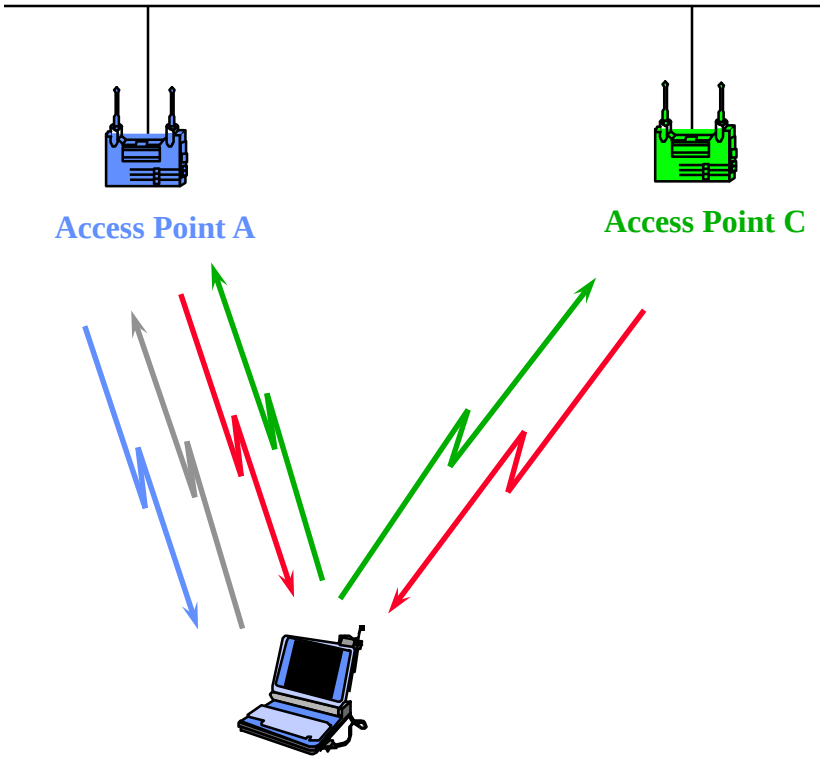
Scanning

- Scanning required for many functions.
  - finding and joining a network
  - finding a new AP while roaming
  - initializing an Independent BSS (ad hoc) network
- 802.11 MAC uses a common mechanism for all PHY.
  - single or multi channel
  - passive or active scanning
- Passive Scanning
  - Find networks simply by listening for Beacons
- Active Scanning
  - On each channel
    - » Send a Probe and wait for a Probe Response
- Beacon or Probe Response contains information necessary to join new network.

Channel Scanning

- A STA shall operate in either a Passive Scanning mode or an Active Scanning mode.
- Passive Scanning:
  - the STA shall scan for Beacon frames containing the desired SSID (or broadcast SSID).
  - The STA shall listen to each channel scanned for no longer than a maximum duration defined by the ChannelTime parameter.
- Active Scanning:
  - the STA shall transmit Probe request containing the desired SSID (also can use broadcast SSID).
  - If a STA's scanning does not result in finding a BSS with the desired SSID, or does not result in finding any BSS, the STA may start an IBSS .
  - A STA may start its own BSS without first scanning for a BSS to join.

Active Scanning Example



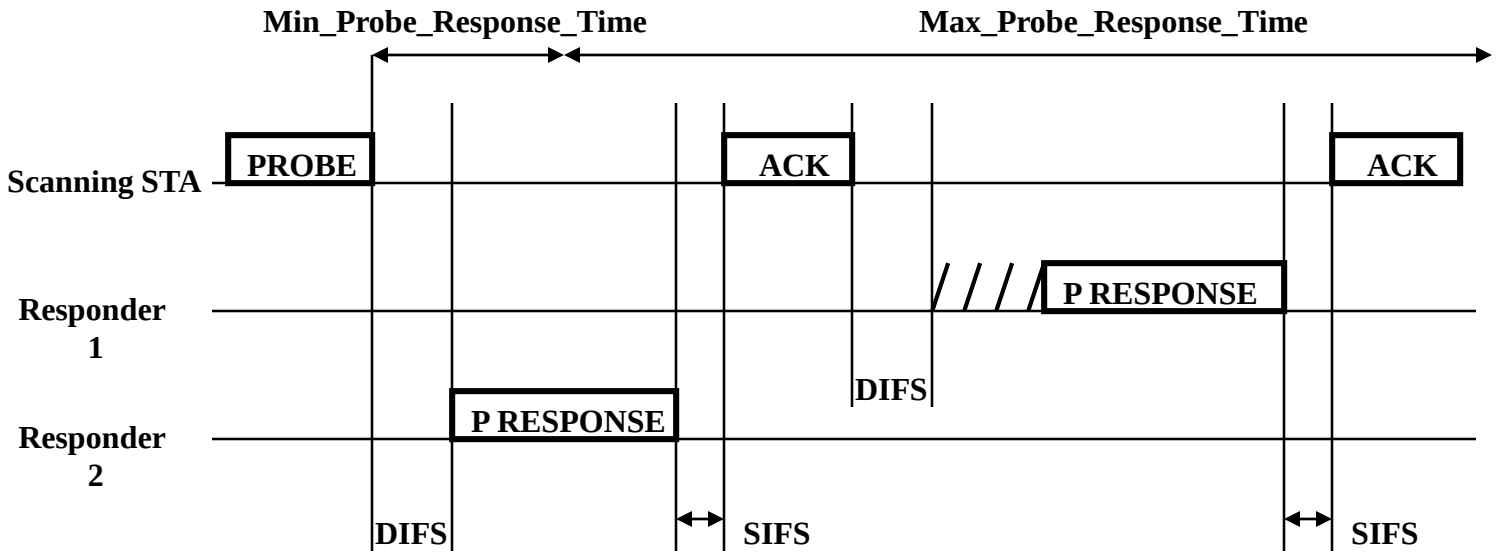
Steps to Association:

- Station sends Probe Request.
- APs send Probe Response.
- Station selects best AP.
- Station sends Association Request to selected AP.
- AP sends Association Response.

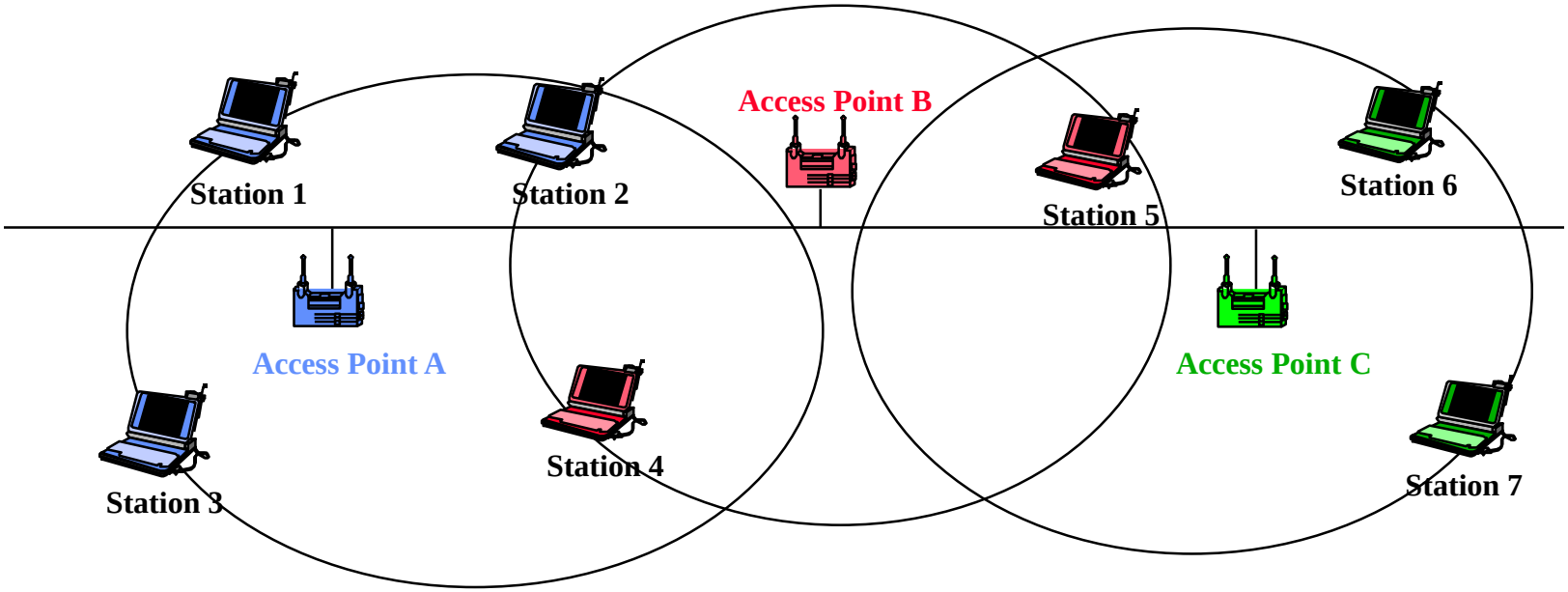
Initial connection to an Access Point
- **Reassociation follows a similar process**

Active Scanning

- For each channel to be scanned,
  - Send a Probe request with the broadcast destination, SSID, and broadcast BSSID.
  - Start a ProbeTimer.
  - If the response has not been received before the *Min_Probe_Response_time*, then clear NAV and scan the next channel, else when ProbeTimer reaches *Max_Probe_response_time*, process all received probe responses and scan the next channel.

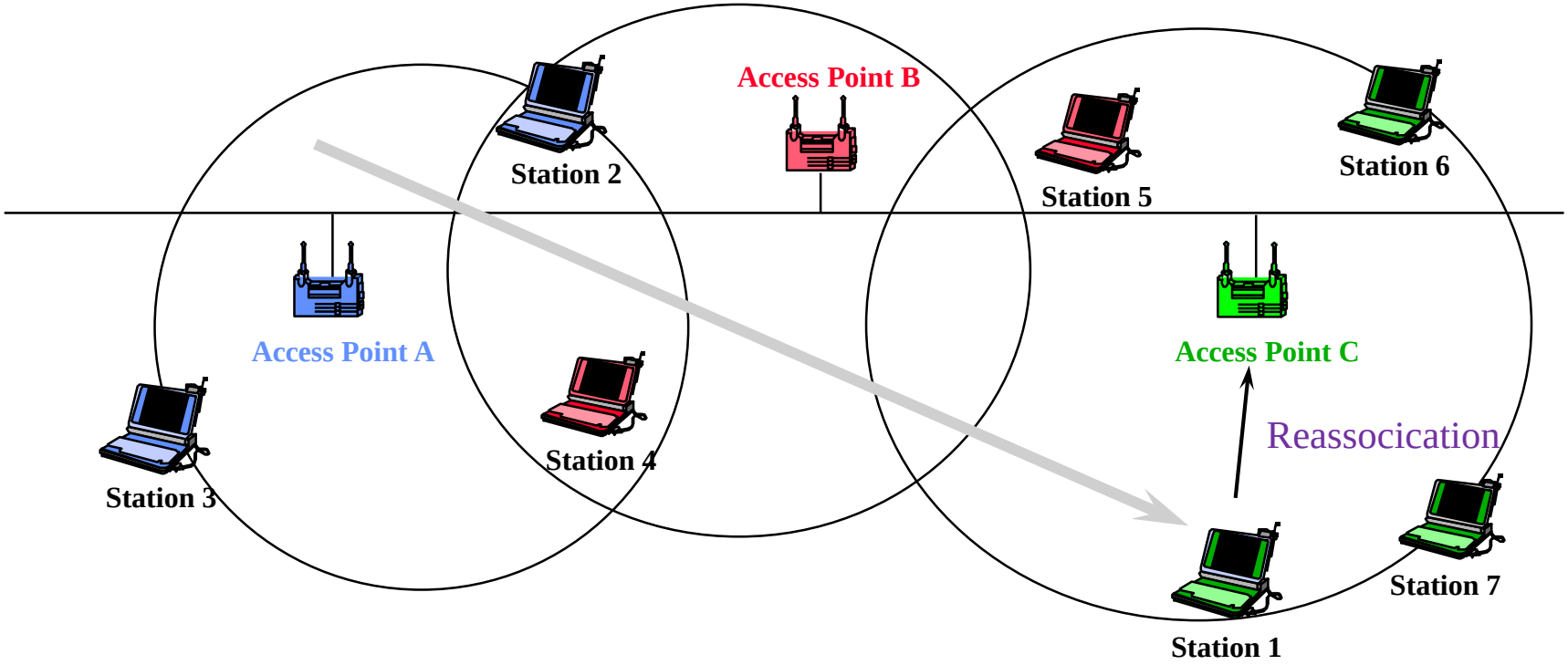


Wireless LAN Infrastructure Network



- **Each Station is Associated with a particular AP**
  - **Stations 1, 2, and 3 are associated with Access Point A**
  - **Stations 4 and 5 are associated with Access Point B**
  - **Stations 6 and 7 are associated with Access Point C**

Roaming



- **Mobile stations may move**
  - **beyond the coverage area of their Access Point**
  - **but within range of another Access Point**
- **Reassociation allows station to continue operation**

Roaming Approach

- Station decides that link to its current AP is poor
- Station uses scanning function to find another AP
  - or uses information from previous scans
- Station sends Reassociation Request to new AP
- If Reassociation Response is the successful
  - then station has roamed to the new AP

  else station scans for another AP
- If AP accepts Reassociation Request
  - AP indicates Reassociation to the Distribution System
  - Distribution System information is updated
  - Normally old AP is notified through Distribution System