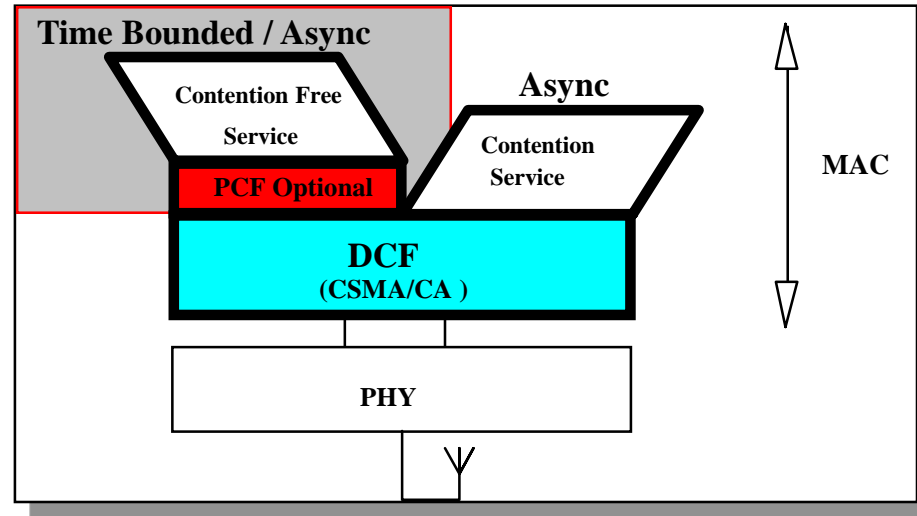


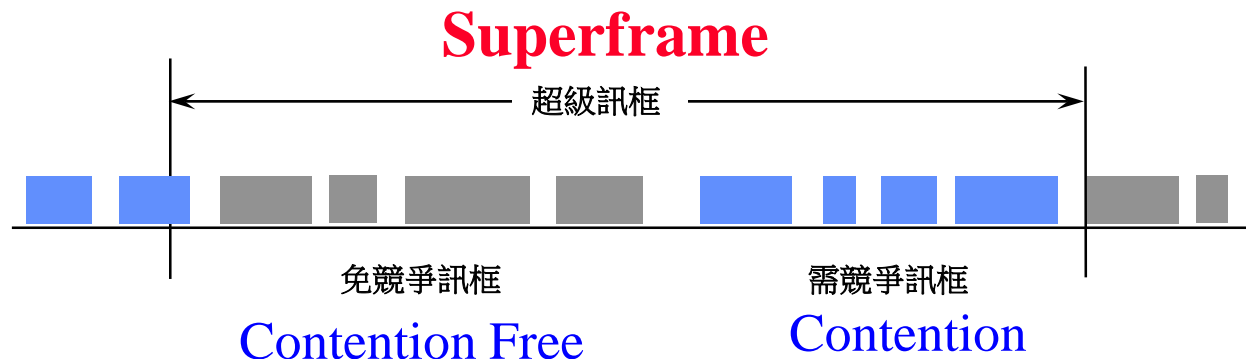
# Optional Point Coordination Function (PCF)



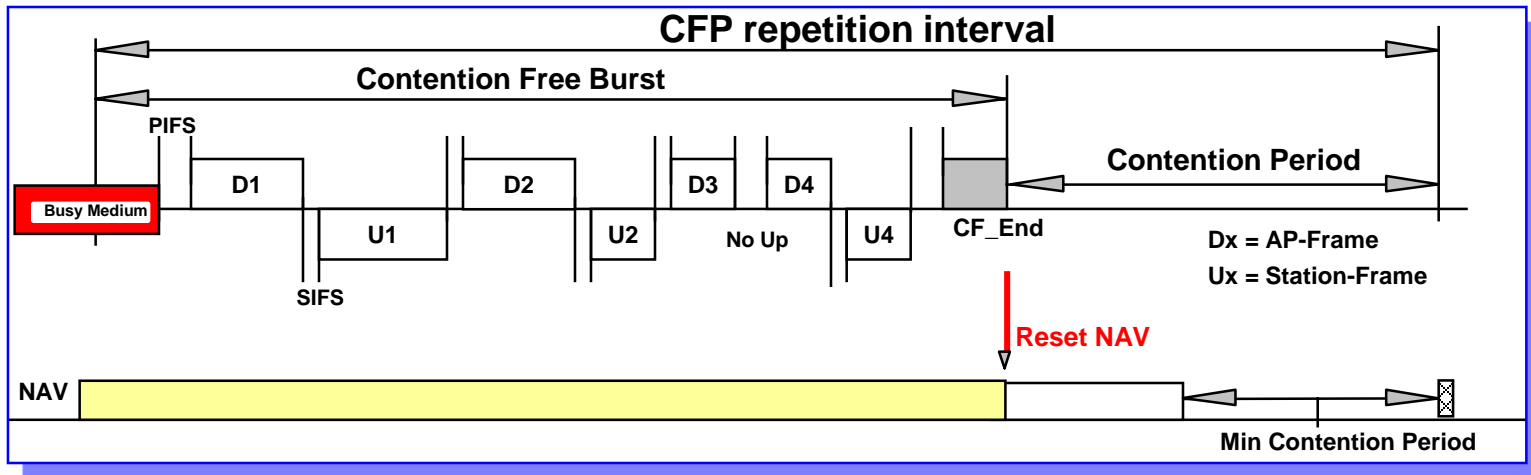
- **Contention Free Service uses Point Coordination Function (PCF) on a DCF Foundation.**
  - PCF can provide **lower transfer delay** variations to support **Time Bounded Services**.
  - Async Data, Voice or mixed implementations possible.
  - Point Coordinator **resides in AP**.
- **Coexistence between 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.



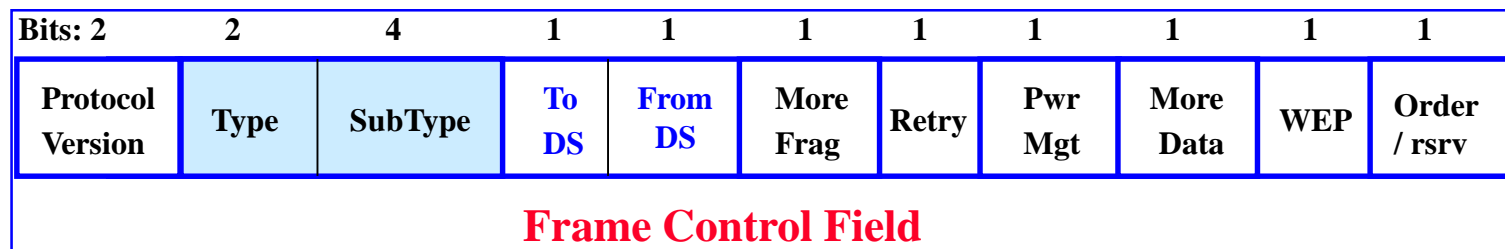
# PCF Burst



- **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<br>b3 b2 | Type description | Subtype Value<br>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<br>indication message (ATIM) |
| 00                  | Management       | 1010                         | Disassociation                                    |
| 00                  | Management       | 1011                         | Authentication                                    |
| 00                  | Management       | 1100                         | Deauthentication                                  |
| 00                  | Management       | 1101-1111                    | Reserved  |



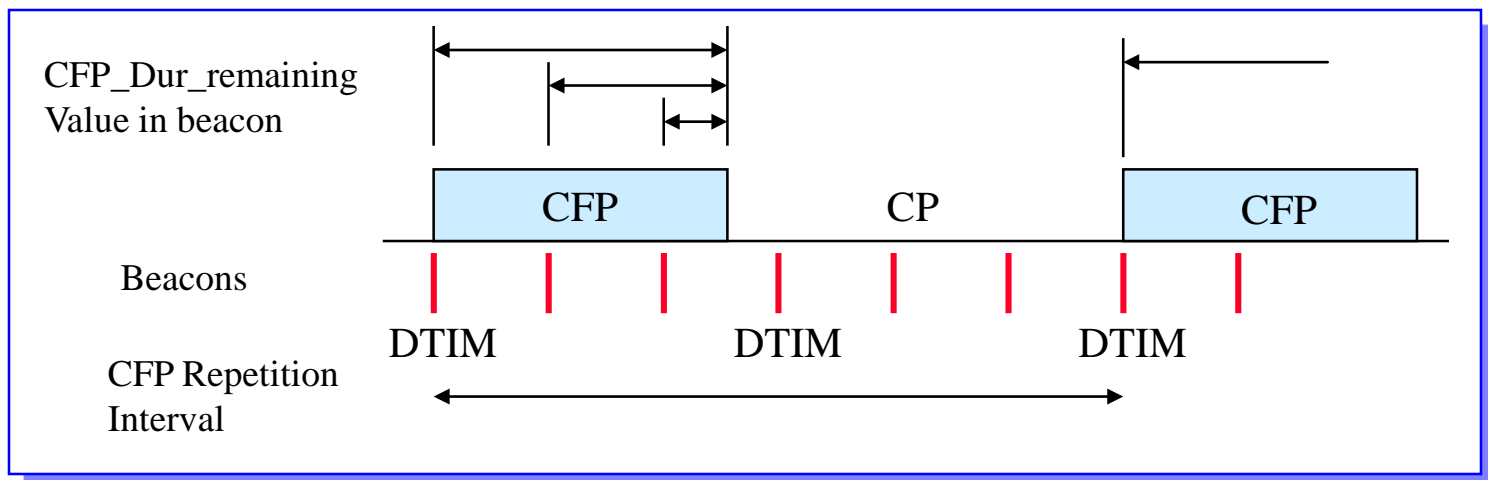
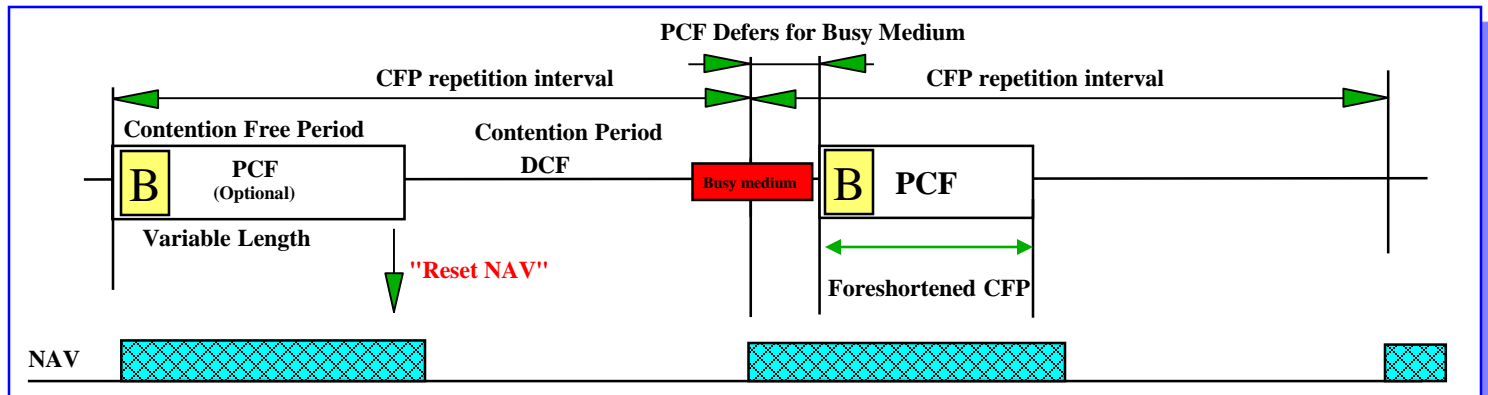
# Valid Type/Subtype combinations 2/2

| Type value<br>b3 b2 | Type description | Subtype Value<br>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                   |

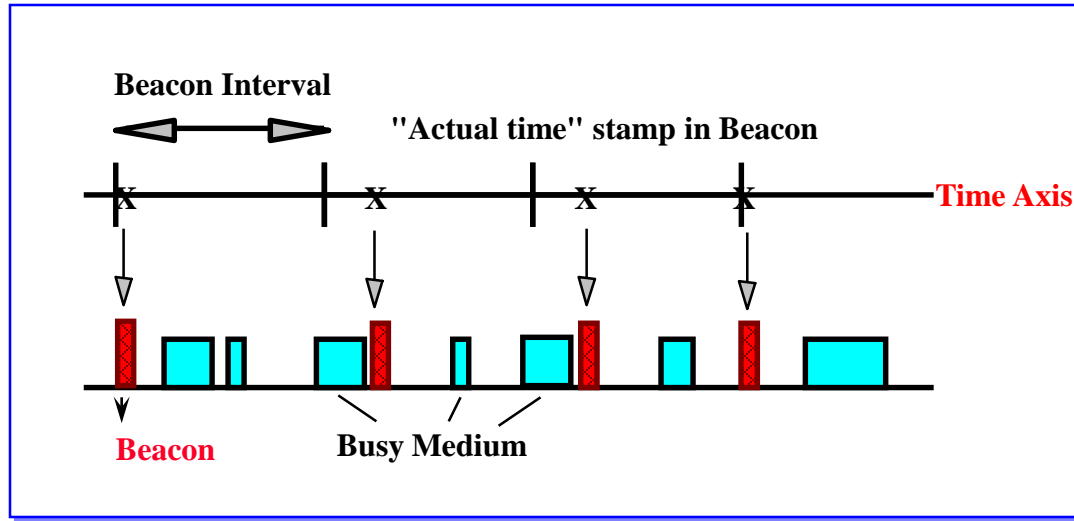
# Point Coordination Function

## -- 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

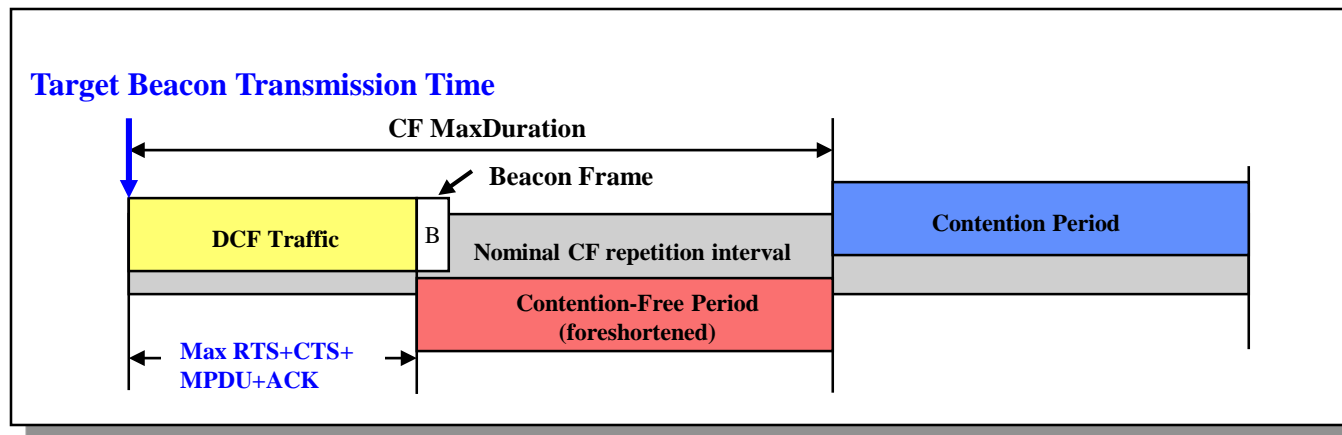


- **APs send Beacons** in infrastructure networks.
- Beacons scheduled at **Beacon Interval** .
- Transmission **may be delayed** by CSMA deferral.
  - subsequent transmissions at expected Beacon Interval
  - next Beacon sent at **Target Beacon Transmission Time (TBTT)**
  - not relative to last Beacon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





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## PCF Access Procedure (1/2)

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- 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.

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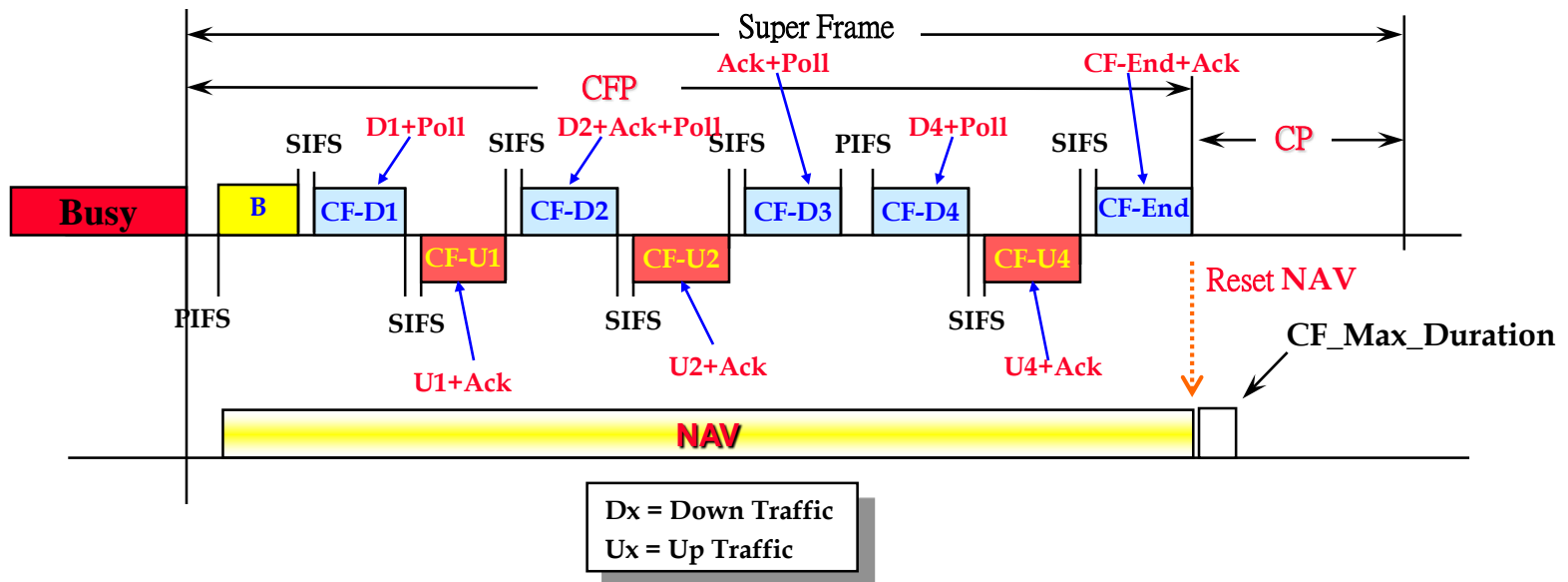
## PCF Access Procedure (2/2)

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- 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 its 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.



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# MAC Management Layer

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- **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**

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# Synchronization in 802.11

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- **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.

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# Synchronization Approach

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- 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

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## Beacon Generation (\*)

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- In Infrastructure
  - AP defines the ***aBeaconPeriod*** for transmitting beacons
  - ***aBeaconPeriod*** is broadcast by beacon and probe response
  - May be 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  $[0, 2 * (CW_{min} * Slot\_time)]$
    - » **backoff** the selected random delay
    - » If a beacon is detected, give up sending beacon and decrementing backoff timer
    - » otherwise, transmit beacon

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# Power Management

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- **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**



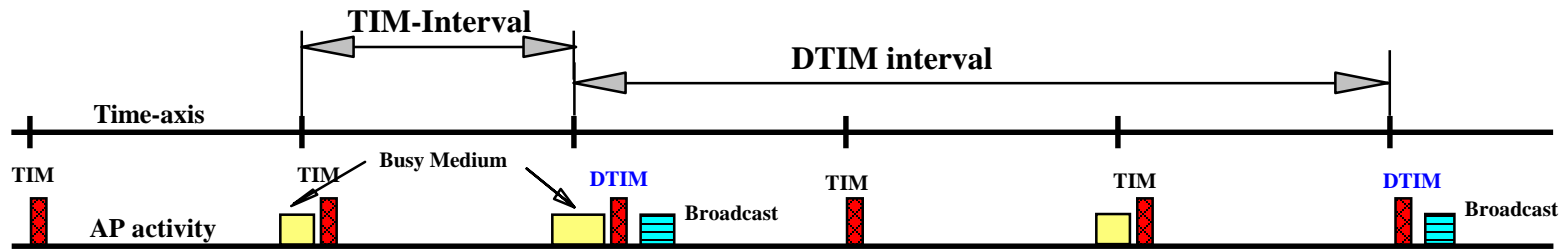
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# Power Management Approach

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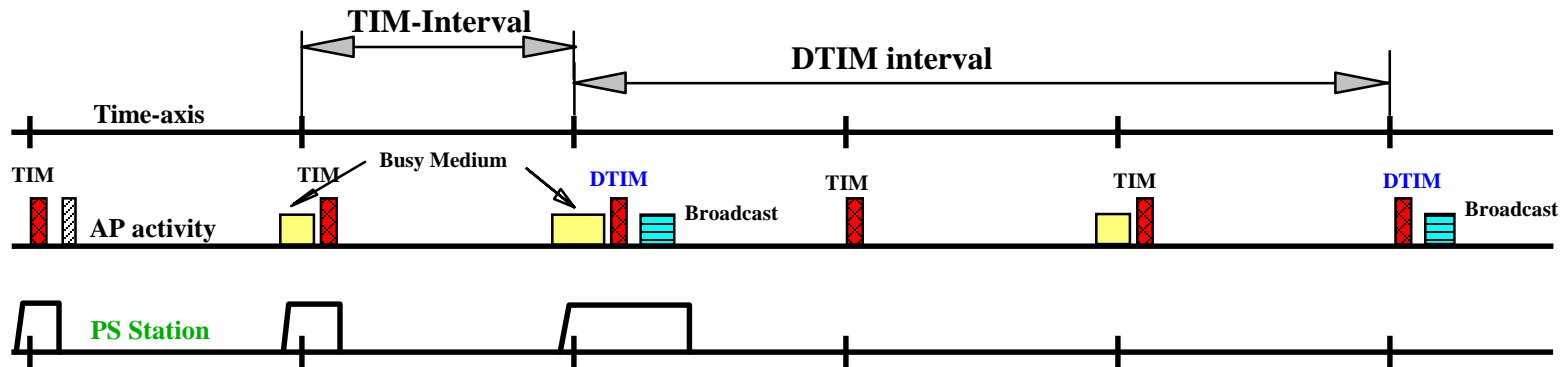
- **Allow idle stations to go to sleep**
  - station power save mode stored in AP
- **APs buffer packets for sleeping stations.**
  - AP announces which stations have frames buffered
  - **Traffic Indication Map (TIM) sent with every Beacon**
- **Power Saving stations wake up periodically**
  - listen 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



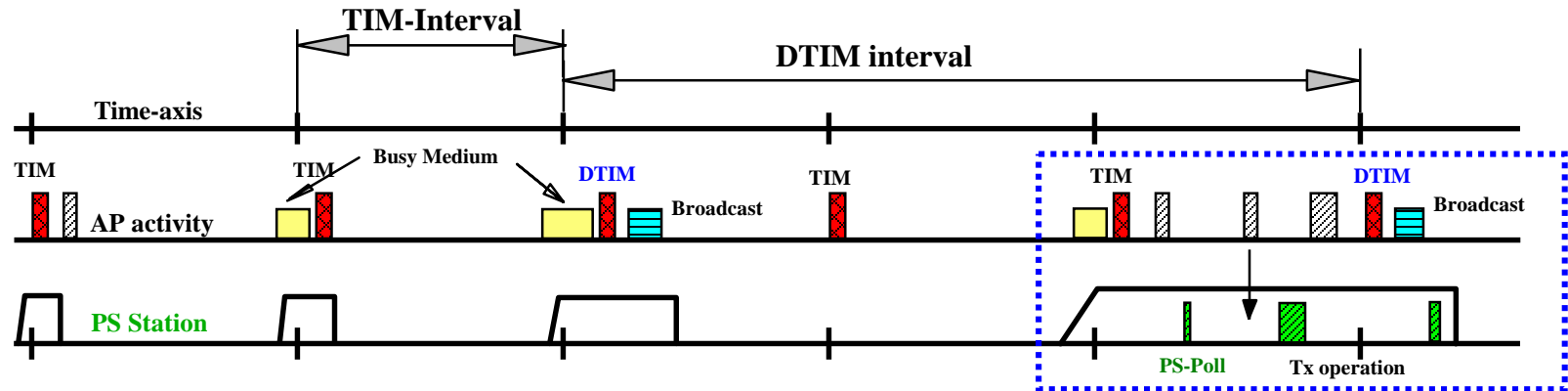
- **Broadcast** frames are also buffered in AP.
  - all broadcasts/multicasts are buffered
  - **broadcasts/multicasts are only sent after DTIM**
    - » **DTIM : Delivery Traffic Indication Message**
  - **DTIM interval is a multiple of TIM interval**

# Infrastructure Power Management



- **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.**

# 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**

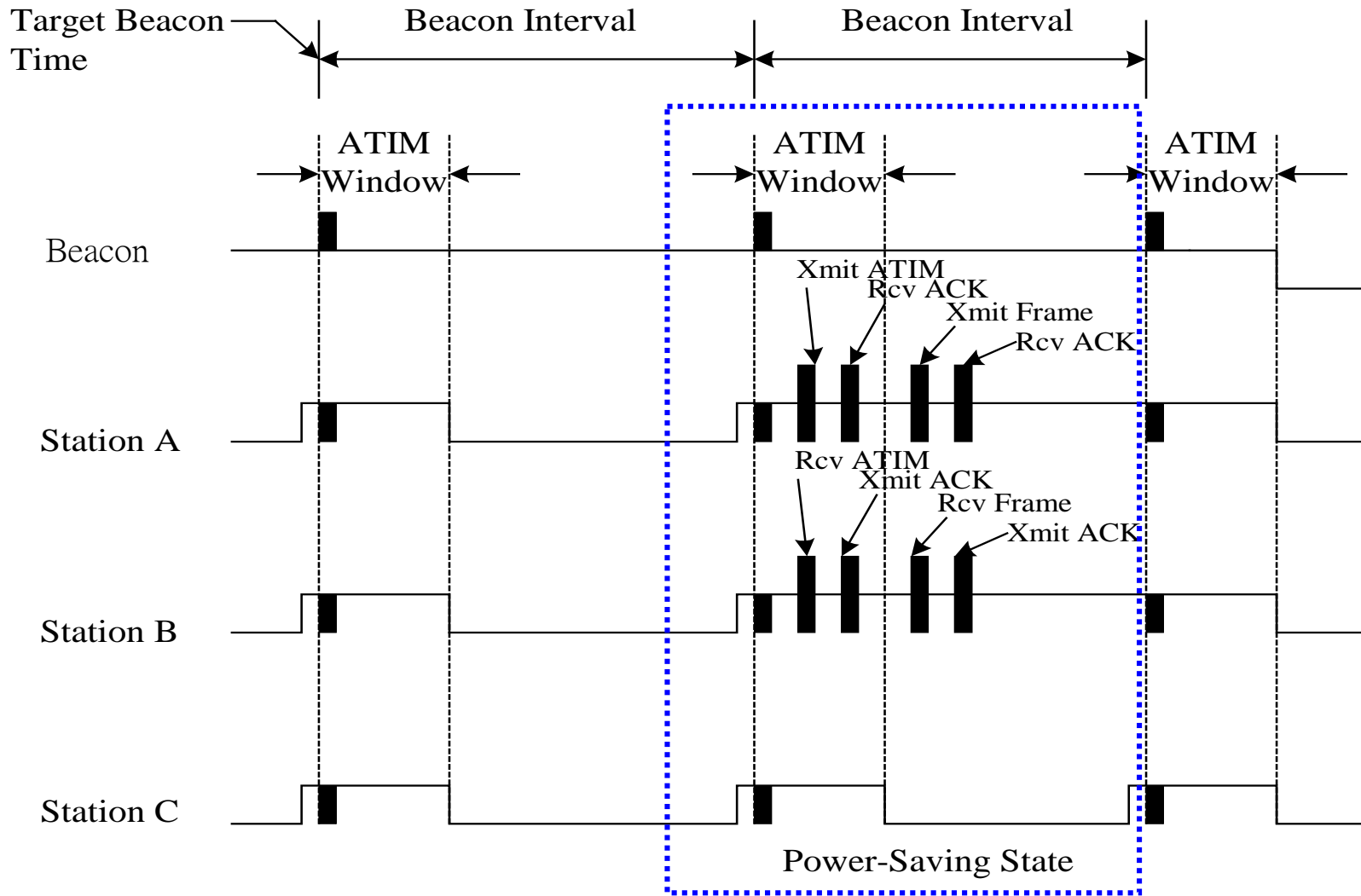
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# IBSS Power Management

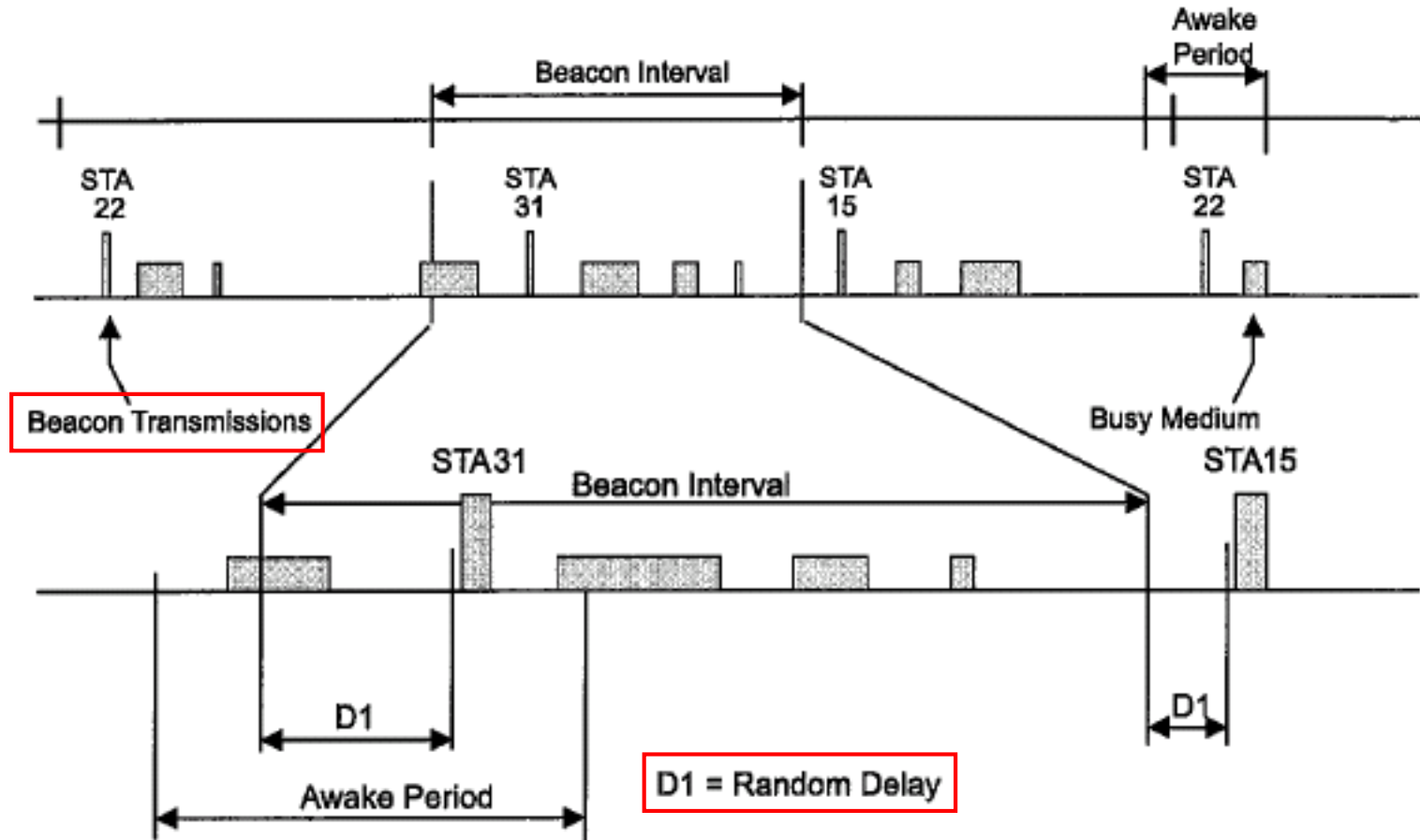
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- **ATIM: Ad Hoc (Announced) Traffic Indication Message.**
- If a STA is PS, it shall enter the Awake state prior to each TBTT.
- If **received** a ATIM, a STA shall remain in the Awake state until the end of the next ATIM window.
- If a STA **transmits** 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



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# Scanning

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- **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.**



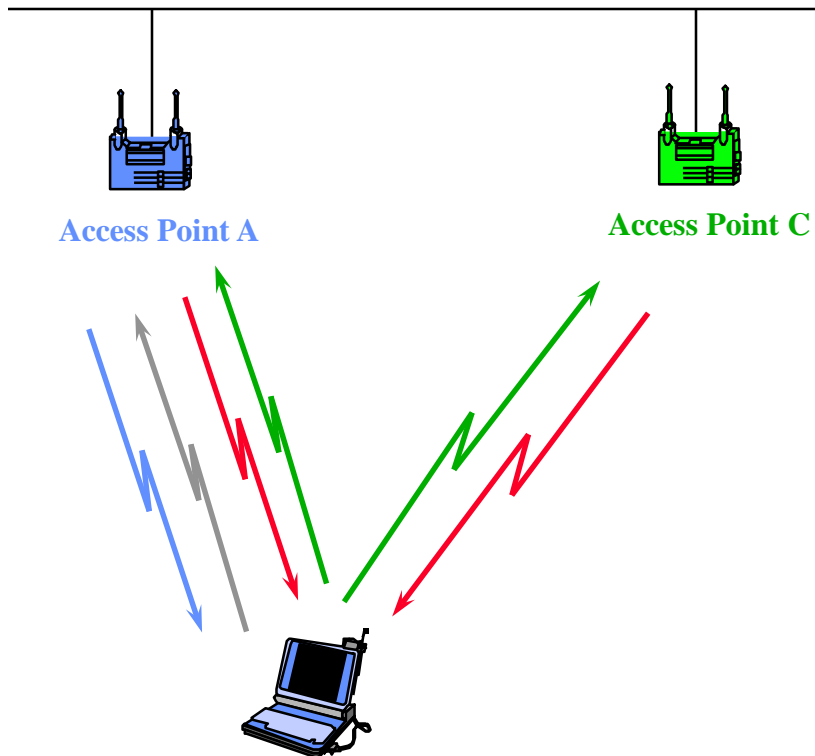
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# Channel Scanning

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- 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



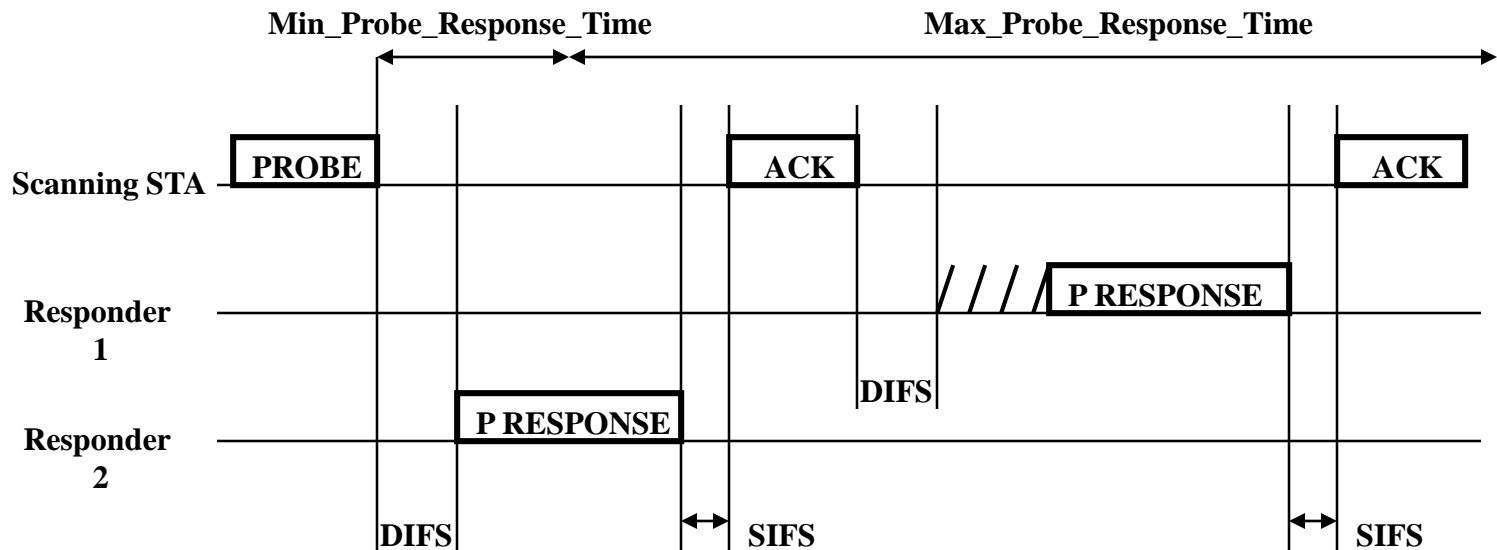
## Steps to Association:

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

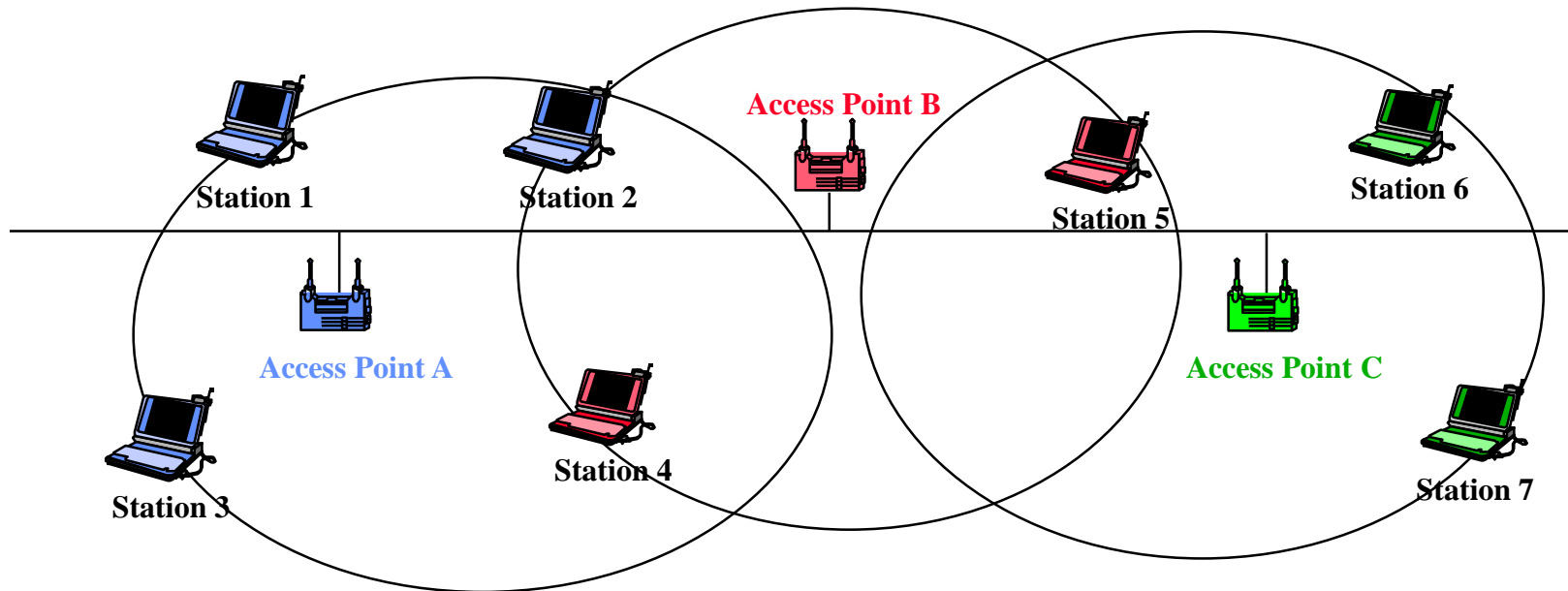
**Initial connection to an Access Point**  
- Reassociation follows a similar process

# 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.

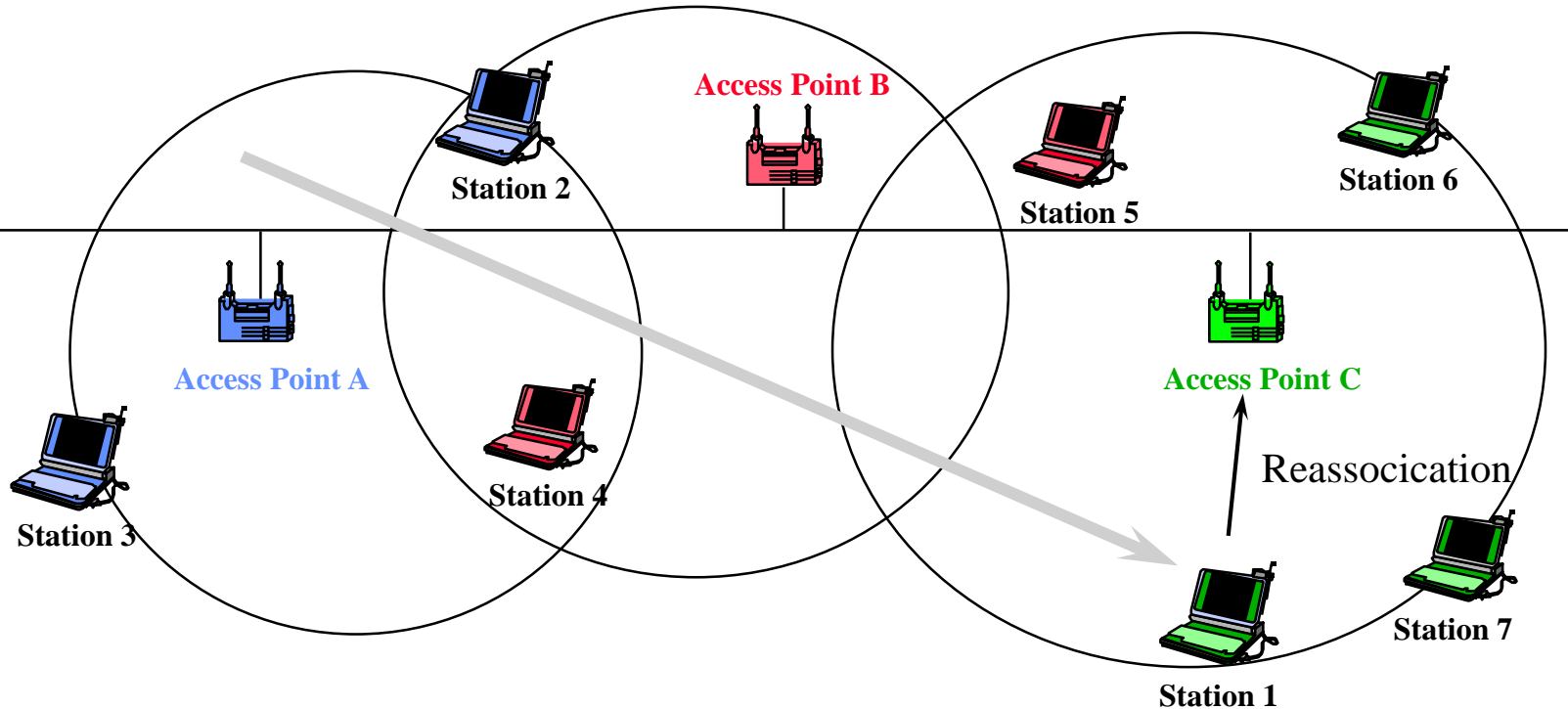


# Wireless LAN Infrastructure Network



- **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**

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# Roaming Approach

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- **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