Chapter 2:
Power Saving in IEEE 802.11

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Motivation

- Since mobile hosts are supported by battery power, saving battery as much as possible is very important.

- Power management in 802.11
  - in infrastructure network vs. ad hoc network
  - PCF vs. DCF

Introduction

- Power management modes
  - Active mode (AM)
  - Power Save mode (PS)

- Power consumption of ORiNOCO WLAN Card

Transmit mode	Receive mode	Doze mode
1400mW	900mW	50mW

Basic Idea

- AP or source hosts buffer packets for hosts in PS mode.
  - AP or sources send TIM periodically.
    - TIM = traffic indication map (a partial virtual bitmap associated with station id)
    - TIM is associated with beacon.
- Hosts in PS mode only turn on antenna when necessary.
  - Hosts in PS mode only “wake up” to monitor TIM.

TIM (Traffic Indication Map)

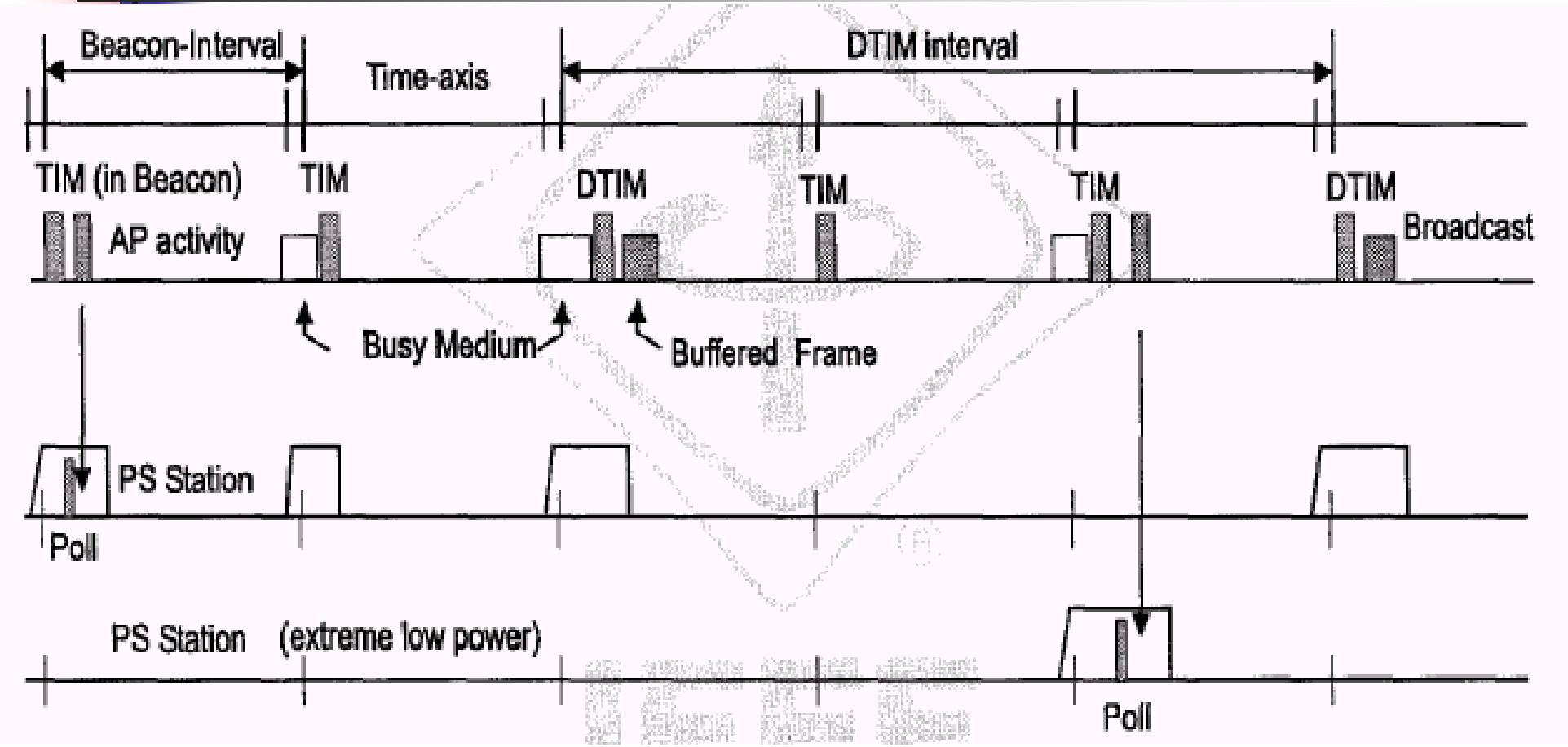
- 協調者有訊框要送給省電模式工作站時，不可以隨時傳送，必須先將這些訊框儲存起來而自特定的時間傳送
- 有那些工作站有訊框儲存在協調者中待送，則是紀錄在 TIM 中
- 協調者每次傳送 beacon 訊框時會將此對照表放入其中

Power-saving operation

- 處於省電模式的工作站應定時的起來 (wake up) 接收 beacon 訊框
  - Time interval 是由工作站內部的 aListenInterval 參數定義
- 工作站取得 TIM 後可自行研判其是否友訊框儲存在協調者中

TIM Types

- TIM :
  - transmitted with every beacon (for Unicast)
- Delivery TIM (DTIM):
  - transmitted less frequently (every DTIM_interval)
  - for sending buffered broadcast packets
- Ad hoc TIM (ATIM):
  - transmitted in ATIM-Window by stations who want to send buffered packets
  - structured the same as TIM


Beacon-Interval
Time-axis
DTIM interval
TIM (in Beacon)
TIM
DTIM
TIM
TIM
DTIM
AP activity
Broadcast
Busy Medium
Buffered Frame
PS Station
Poll
PS Station (extreme low power)
Poll

PS in Infrastructure Network

PS in Infrastructure Network

- Assumptions:
  - TIM interval (beacon interval) and DTIM interval are known by all hosts
    - requires time synchronization
  - Stations in PS mode are known or can be predicted.
- Two Operational Models:
  - under DCF (contention-based)
  - under PCF (contention-free)

Synchronized in 802.11

- 讓每一個工作站都配置一個 (Timing Synchronization Function Timer, TSF Timer)
  - 希望每部工作站內的 TSF Timer 值都能相同
  - 由於 BSSs 所涵蓋的範圍可以部分或全部重疊，因此各個 BSS的 AP (Access Point)彼此之間應該不要同步
    - 以免所管轄的 host 在接收 beacon 訊框 發生conflict

Under DCF (Infrastructure Mode)

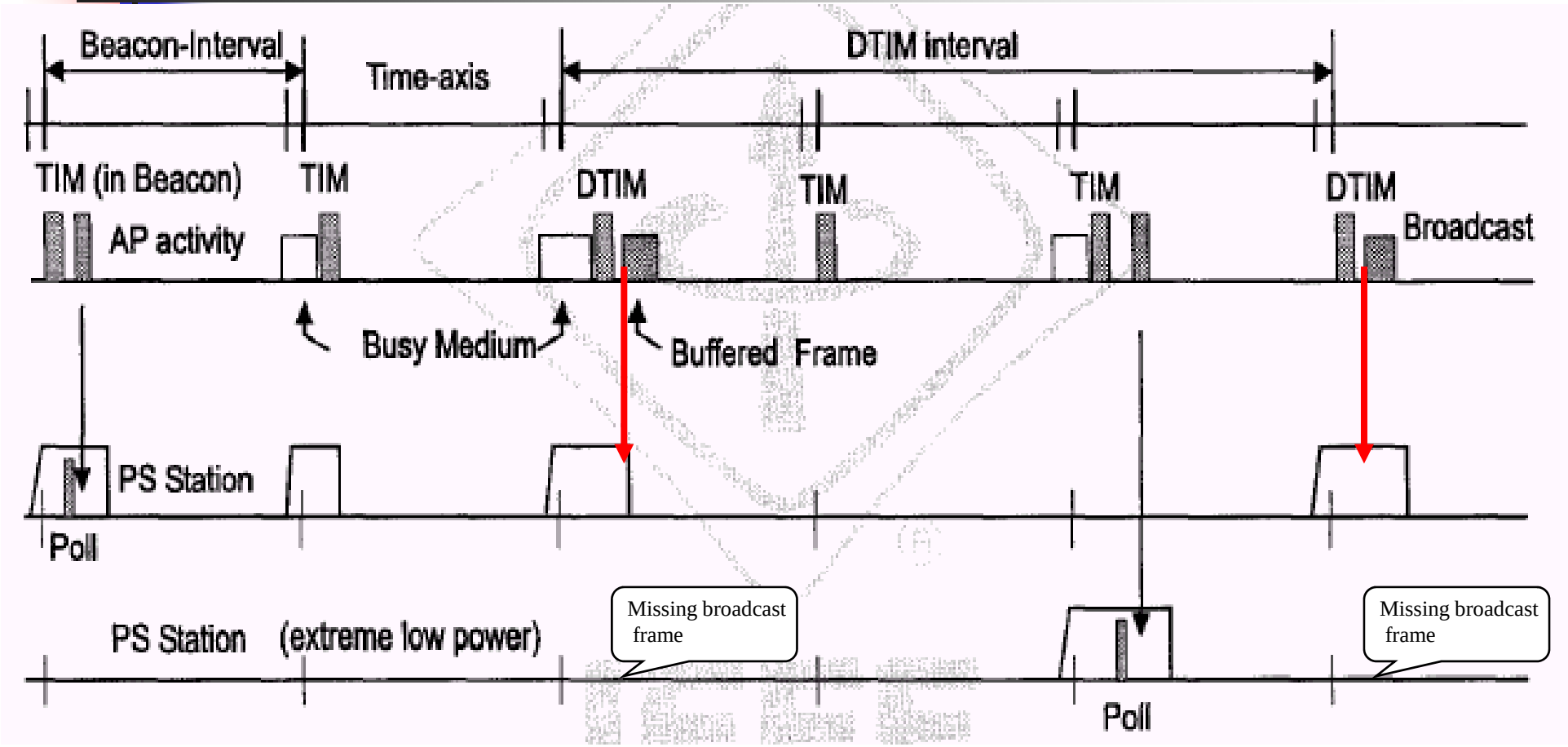
- Basic assumption:
  - use CSMA/CA to access the channel
  - RTS, CTS, ACK, PS-Poll are used to overcome the hidden-terminal problem

Operations of TIM (in DCF)

- AP periodically broadcasts beacon with TIM.
- Hosts in PS must wake up to check TIM.
  - Check for their IDs.
    - 每一個與協調者建立連結關係的host, 都會分配一個 station ID, SID
  - If found having packets buffered in AP, send PS-Poll to AP (by contention?).
    - 一個 PS-Poll 針對一筆訊框
    - Host 如果在 TIM 中發現還有其他工作站的訊框也同時儲存在協調者處，則不能立刻傳送 PS-Poll 訊框, 否則其他工作站也會做相同動作，而造成 PS-Poll 衝撞
    - 延遲一段時間再傳送 PS-Poll
  - Else, go back to PS mode.

- AP replies PS-poll with ACK.
  - The receiver must remain in active mode until it receives the packet.
- AP uses CSMA/CA to transmit to stations.

An Illustration Example



When to wake up ?

- 處於省電的工作站要不要醒來，或在何時醒來接收 TIM (DTIM) 是其本身的問題
- If each time to wake up, host can receive all frames (including broadcast and multicast frame), but it is not very power-saving.
- Otherwise, if it waits for a longer time to wake up, it is very power-saving but possibly misses broadcast/mutlicast frames.

Operations of DTIM (DCF)

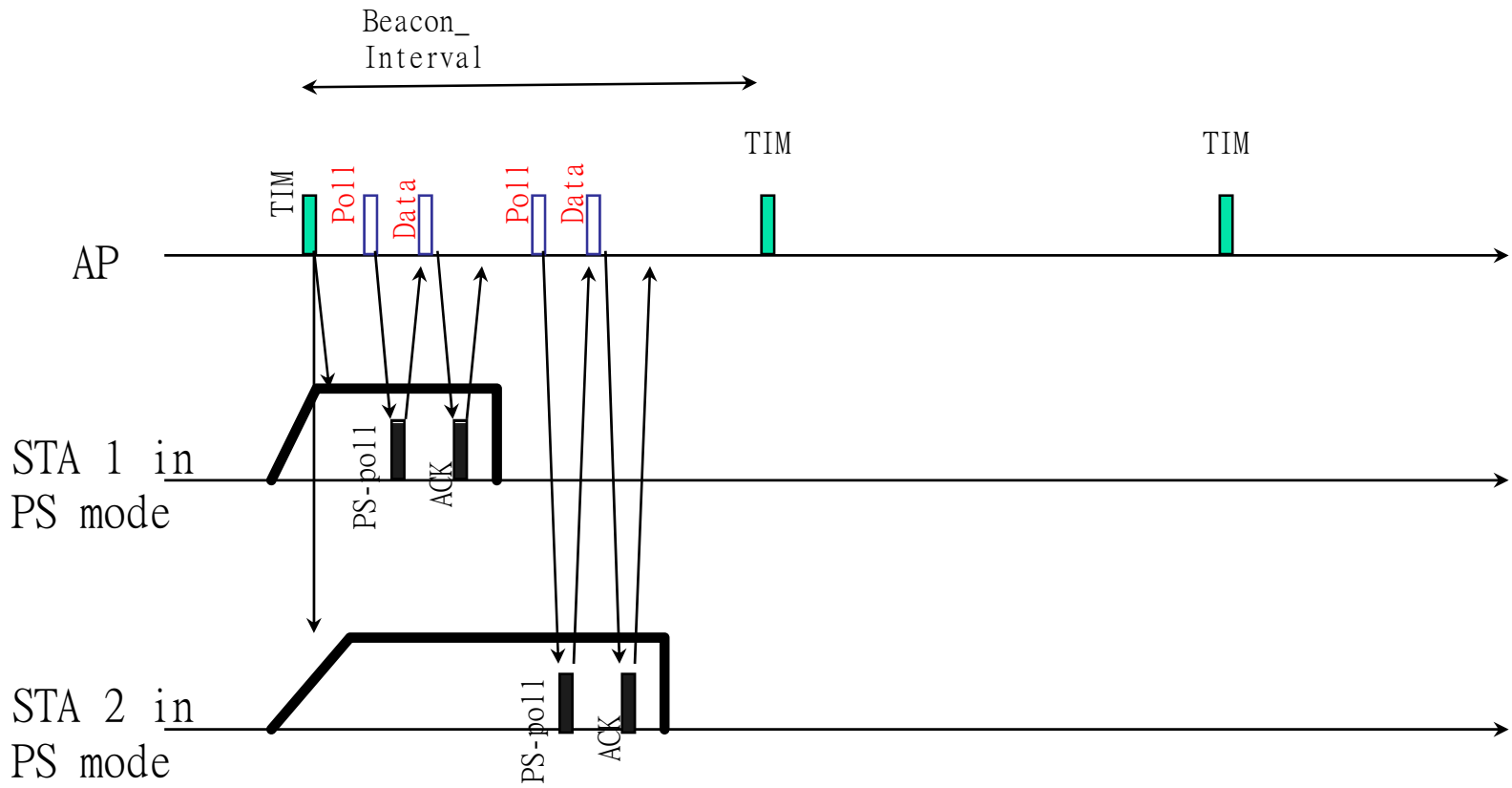
- All stations need be in active mode when AP broadcasts DTIM.
- Immediately after DTIM, AP sends out the broadcast/multicast packets to all hosts.
  - Broadcast/multicast packets will not be ACKed by the receivers.
- In DTIM, the broadcast packets are unreliable.

Under PCF (Infrastructure Mode)

- Basic Assumption:
  - Point coordinator uses CF-Polling to access the channel.
  - AP only maintains the CF-Pollable stations.

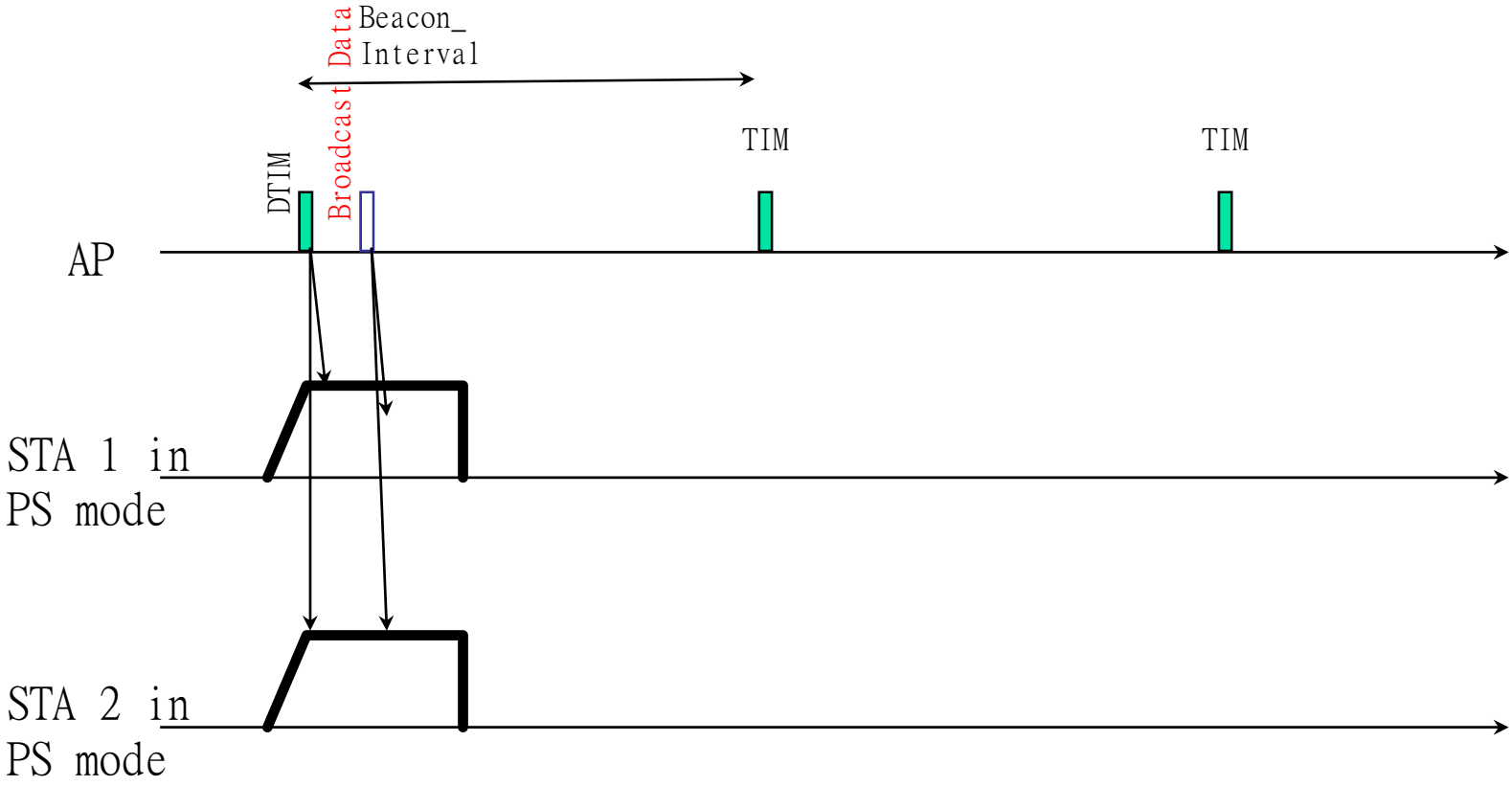
Operations of TIM (PCF)

- AP broadcasts beacon with TIM.
- Hosts in PS mode checks TIM for their IDs.
  - If there are buffered packets in AP, the host must remain in Active Mode until being polled.
  - O/w, the station goes back to PS mode.
- Then AP polls those PS stations.
- When being polled, the station (in PS mode) sends PS-Poll to AP.
  - Then AP sends buffered packets to the station.
  - (See next page.)
- AP must poll stations in PS mode first.

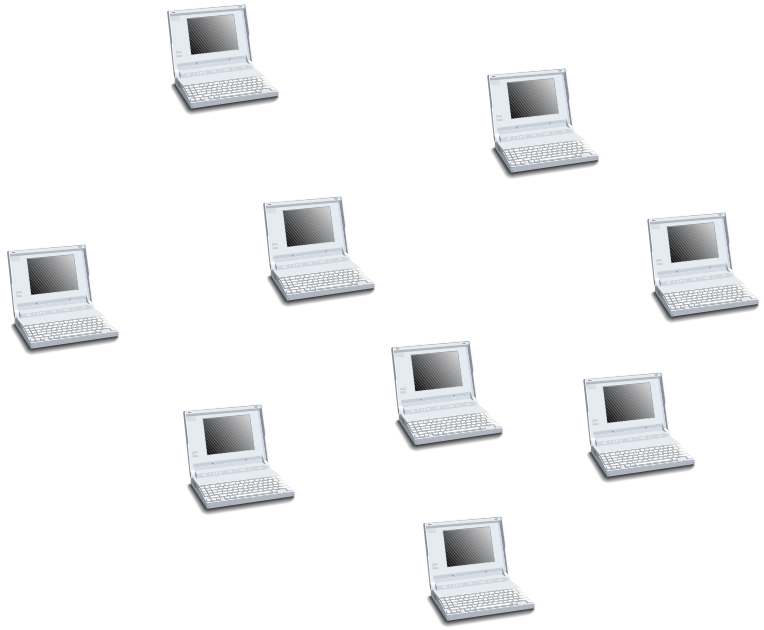

Beacon_
Interval
TIM
TIM
TIM
Poll
Data
Poll
Data
AP
STA 1 in
PS mode
PS-poll
ACK
STA 2 in
PS mode
PS-poll
ACK

Operations of DTIM (PCF)

- All CF-pollable stations need be in Active Mode when AP broadcasts DTIM.
- Immediately after DTIM, AP sends out the buffered broadcast/multicast packets.


Beacon_
Interval
Data
Broadcast
DTIM
TIM
TIM
AP
STA 1 in
PS mode
STA 2 in
PS mode

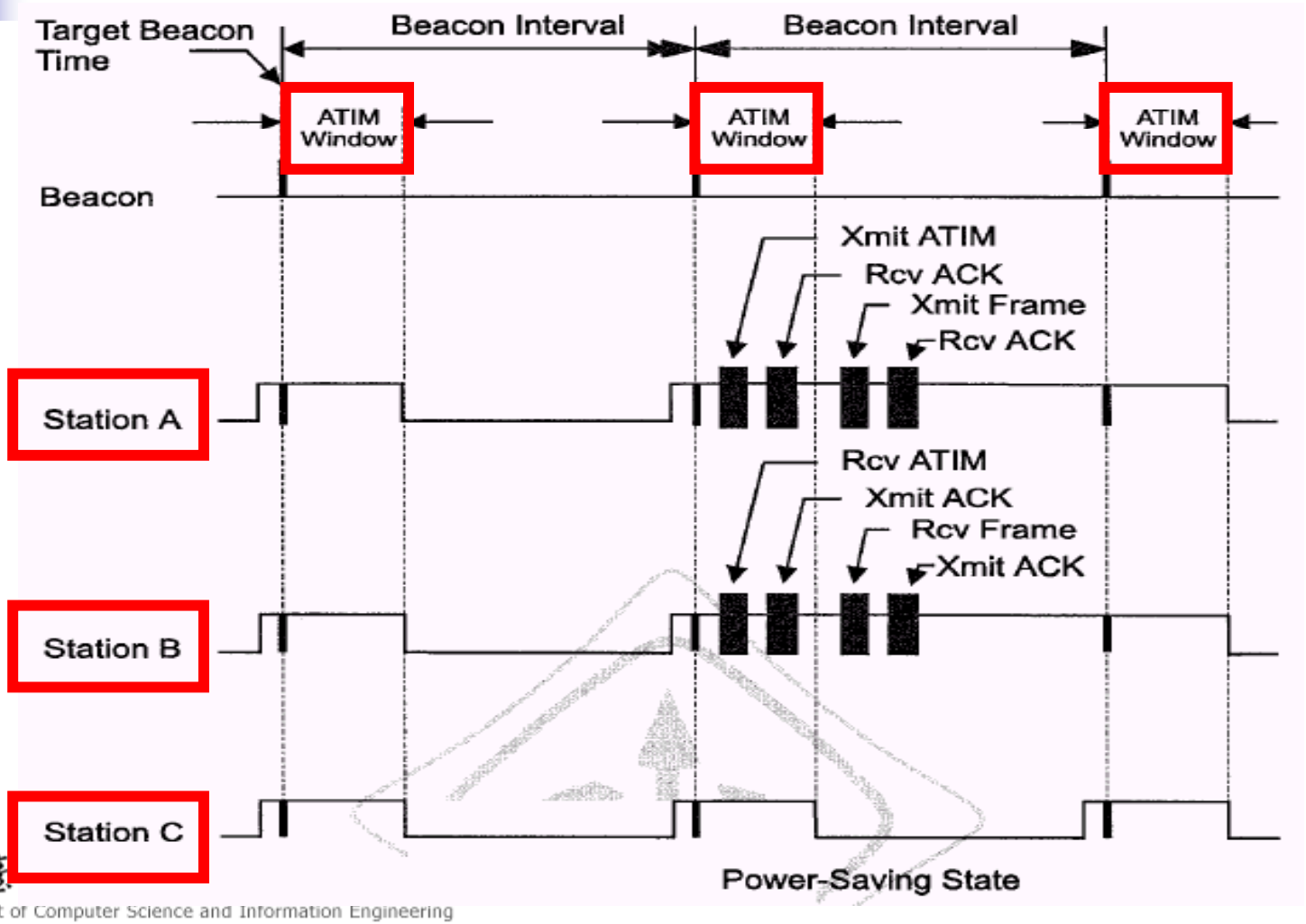
PS in Ad Hoc Mode (without base station)

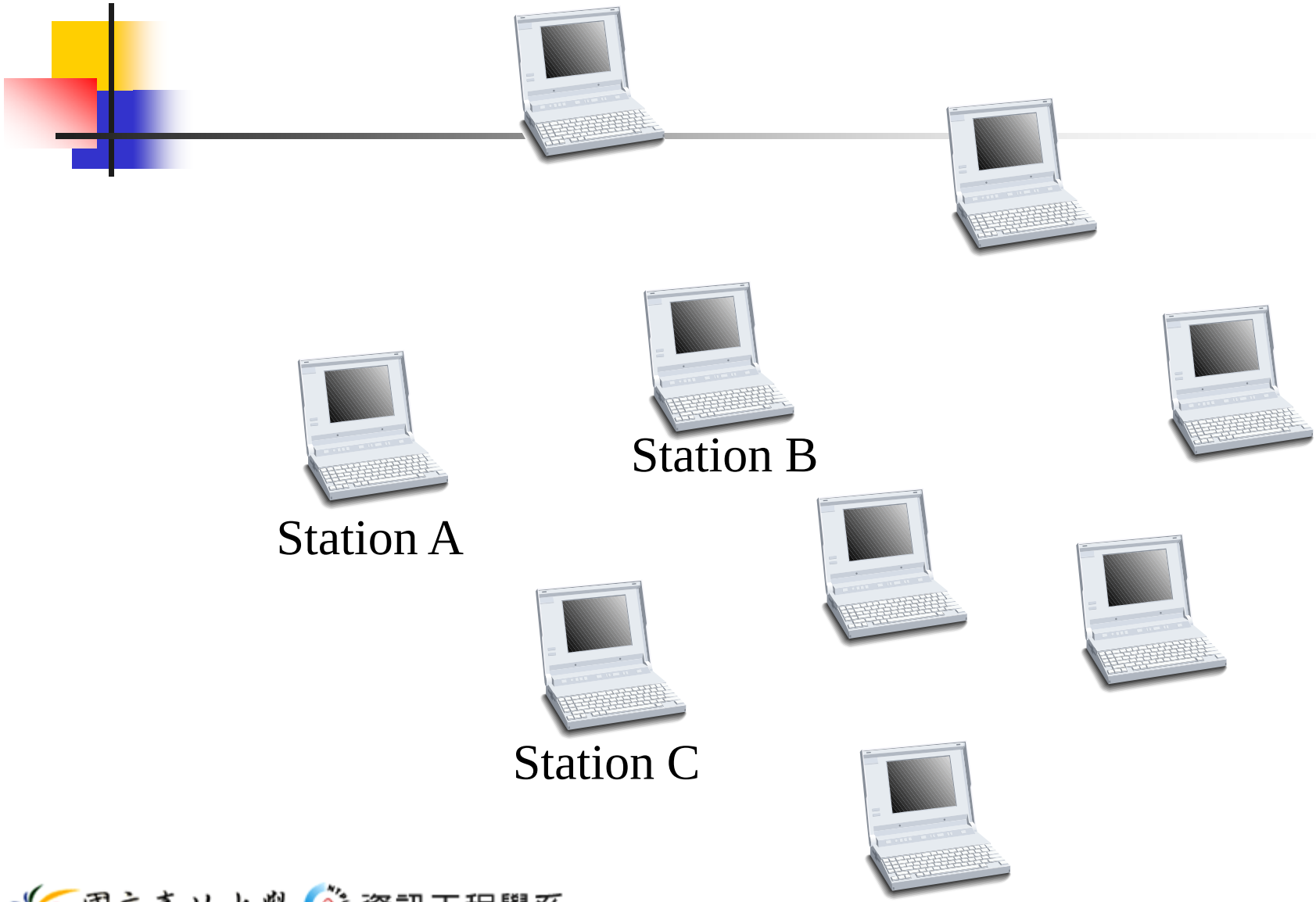


PS in Ad Hoc Mode

- Ad hoc TIM (ATIM):
  - transmitted in ATIM-Window by stations who want to send buffered packets
  - structured the same as TIM
- Assumptions:
  - ATIM interval (beacon interval) & ATIM window are known by all hosts
  - Each station predicts which stations are in PS mode.
  - The network is fully connected, (single-hop network ?)
- Basic Method:
  - CSMA/CA is used to access the channel.
  - RTS, CTS, ACK, PS-Poll are used to overcome hidden terminal.

Example


Target Beacon Time
Beacon Interval
Beacon Interval
ATIM Window
ATIM Window
ATIM Window
Beacon
Xmit ATIM
Rcv ACK
Xmit Frame
Rcv ACK
Station A
Rcv ATIM
Xmit ACK
Rcv Frame
Xmit ACK
Station B
Station C
Power-Saving State


Station A
Station B
Station C

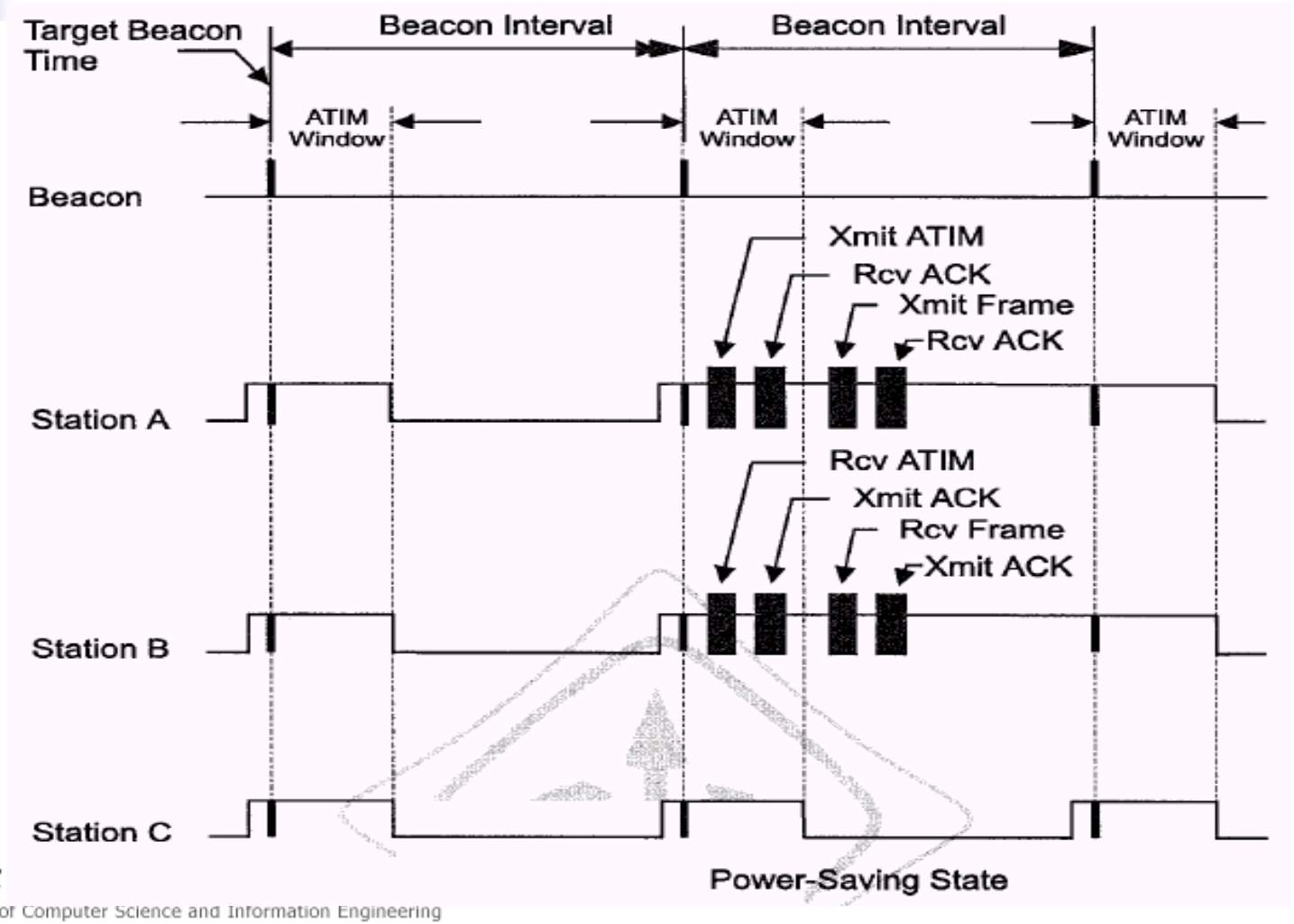
Operations of ATIM

- All stations should be in active mode during ATIM window.
- The station which completes its backoff procedure broadcasts a beacon.
  - Sending beacon is based on contention.
  - Any beacon starts the ATIM window.
  - Once a beacon is heard, the rest beacons are inhibited.

- In ATIM window, each source station having buffered packets to be sent contends to send out its ATIM.
  - If a host finds it is in the ATIM name list,
    - send an ACK to the sender.
    - remain in the ACTIVE mode throughout the beacon interval.
  - If the host is not in the name list,
    - it can go back to the PS mode.

- After ATIM window,
  - all stations use CSMA/CA to send the buffered packets
    - note: data packet >> ATIM control frames
    - So the control frames go first, followed by data frames.
  - only those hosts who have ACKed the ATIM have such opportunity.

ATIM Example



PS Summary

- PS status:
  - In infrastructure network, stations must inform the AP on entering PS mode.
  - In ad hoc network, stations tell which stations are in PS mode by guessing.
    - power management field, history, etc.
- In DTIM, the broadcast packets are unreliable.
- For stations in ad hoc network, beacon is broadcast with CSMA/CA.
  - During ATIM_window, ATIM and ACK should be given higher priority.