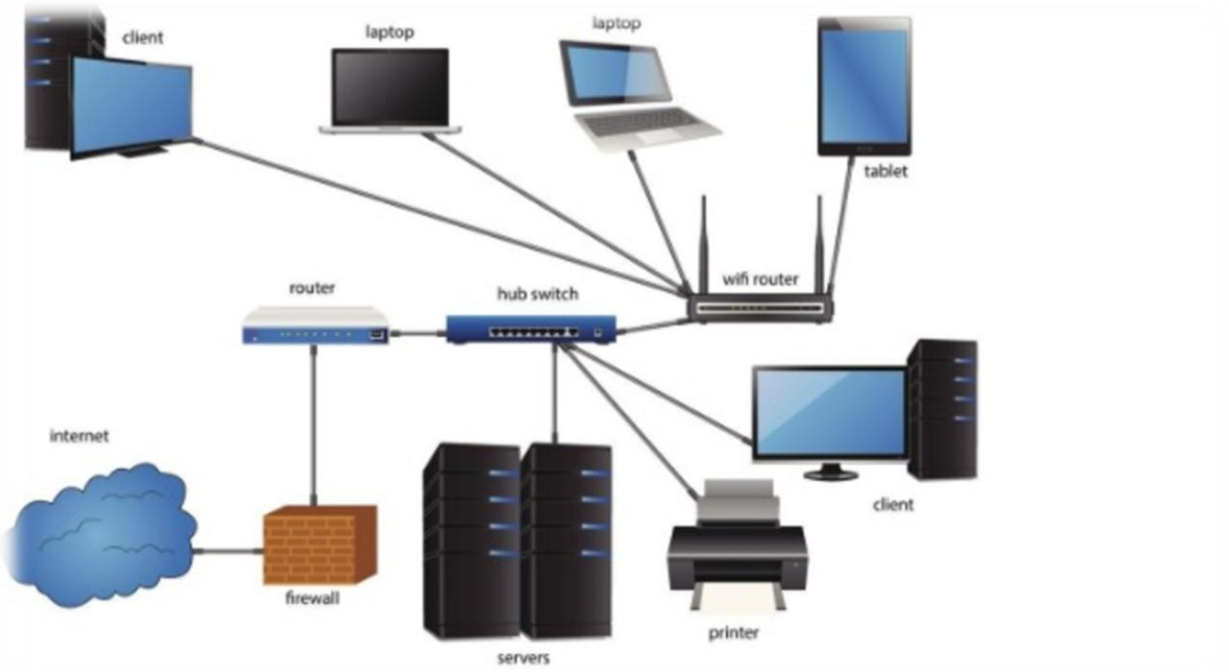
# COMPUTER NETWORKS




**Instructor:** Mr. B. V. Sathish Kumar, Assistant Professor

**Department of Electronics and Communication Engineering**

# UNIT – IV

- The Medium Access Control Sublayer-The Channel Allocation Problem-Static Channel Allocation-Assumptions for Dynamic Channel Allocation, Multiple Access Protocols-Aloha-Carrier Sense Multiple Access Protocols-Collision-Free Protocols-Limited Contention Protocols

- Wired LAN Protocols, Ethernet-Classic Ethernet Physical Layer-Classic Ethernet MAC Sub layer Protocol-Ethernet Performance-Fast Ethernet Gigabit Ethernet-10-Gigabit Ethernet-Retrospective on Ethernet

- Wireless LAN-The 802.11 Architecture and Protocol Stack-The 802.11 Physical Layer-The802.11 MAC Sublayer Protocol-The 802.11 Frame Structure-Services

# IEEE 802 Standards

| Number | Topic |
|---|---|
| 802.1 | Overview and architecture of LANs |
| 802.2 ↓ | Logical link control |
| 802.3 * | Ethernet |
| 802.4 ↓ | Token bus (was briefly used in manufacturing plants) |
| 802.5 | Token ring (IBM's entry into the LAN world) |
| 802.6 ↓ | Dual queue dual bus (early metropolitan area network) |
| 802.7 ↓ | Technical advisory group on broadband technologies |
| 802.8 † | Technical advisory group on fiber optic technologies |
| 802.9 ↓ | Isochronous LANs (for real-time applications) |
| 802.10 ↓ | Virtual LANs and security |
| 802.11 * | Wireless LANs |
| 802.12 ↓ | Demand priority (Hewlett-Packard's AnyLAN) |
| 802.13 | Unlucky number. Nobody wanted it |
| 802.14 ↓ | Cable modems (defunct: an industry consortium got there first) |
| 802.15 * | Personal area networks (Bluetooth) |
| 802.16 * | Broadband wireless |
| 802.17 | Resilient packet ring |

The important are marked with *. The ones marked with ↓ are hibernating. The ones marked with ↑ gave up.

# Chapter 4

# Wireless LAN

# IEEE 802.11

In 1990, the IEEE 802 Committee formed a new working group, IEEE 802.11, specifically devoted to wireless LANs, with a charter to develop a MAC protocol and physical medium specification.

Since that time, the demand for WLANs, at different frequencies and data rates, has exploded.

Keeping pace with this demand, the IEEE 802.11 working group has issued an ever-expanding list of standards.

IEEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data link layers.

# IEEE 802.11 Terminology

| | |
|---|---|
| Access point (AP) | Any entity that has station functionality and provides access to the distribution system via the wireless medium for associated stations |
| Basic service set (BSS) | A set of stations controlled by a single coordination function |
| Coordination function | The logical function that determines when a station operating within a BSS is permitted to transmit and may be able to receive PDUs |
| Distribution system (DS) | A system used to interconnect a set of BSSs and integrated LANs to create an ESS |
| Extended service set (ESS) | A set of one or more interconnected BSSs and integrated LANs that appear as a single BSS to the LLC layer at any station associated with one of these BSSs |
| MAC protocol data unit (MPDU) | The unit of data exchanged between two peer MAC entities using the services of the physical layer |
| MAC service data unit (MSDU) | Information that is delivered as a unit between MAC users |
| Station | Any device that contains an IEEE 802.11 conformant MAC and physical layer |

# IEEE 802.11 Standards

| TABLE 1: IEEE 802.11 COMMON WIFI STANDARDS BREAKDOWN | | | | | | | |
|---|---|---|---|---|---|---|---|
| Standard | Frequency Band | Bandwidth | Modulation Scheme | Channel Arch. | Maximum Data Rate | Range | Max Transmit Power |
| 802.11 | 2.4 GHz | 20 MHz | BPSK to 256-QAM | DSSS, FHSS | 2 Mbps | 20 m | 100 mW |
| b | 2.4 GHz | 21 MHz | BPSK to 256-QAM | CCK, DSSS | 11 Mbps | 35 m | 100 mW |
| a | 5 GHz | 22 MHz | BPSK to 256-QAM | OFDM | 54 Mbps | 35 m | 100 mW |
| g | 2.4 GHz | 23 MHz | BPSK to 256-QAM | DSSS, OFDM | 54 Mbps | 70 m | 100 mW |
| n | 2.4 GHz, 5 GHz | 24 MHz and 40 MHz | BPSK to 256-QAM | OFDM | 600 Mbps | 70 m | 100 mW |
| ac | 5 GHz | 20, 40, 80, 80+80= 160 MHz | BPSK to 256-QAM | OFDM | 6.93 Gbps | 35 m | 160 mW |
| ad | 60 GHz | 2.16 GHz | BPSK to 64-QAM | SC, OFDM | 6.76 Gbps | 10 m | 10 mW |
| af | 54-790 MHz | 6, 7, and 8 MHz | BPSK to 256-QAM | SC, OFDM | 26.7 Mbps | >1km ? | 100 mW |
| ah | 900 MHz | 1, 2, 4, 8, and 16 MHz | BPSK to 256-QAM | SC, OFDM | 40 Mbps | 1 km | 100 mW |

## ***Topics discussed in this section:***

- **Architecture**
- **MAC Sublayer**
- **Physical Layer**

# 1. ARCHITECTURE

The standard defines two kinds of services:

i. Basic Service Set (BSS)

ii. Extended Service Set (ESS)

# i). Basic Service Set (BSS)

IEEE 802.11 defines the BSS as the building block of a wireless LAN.

A BSS is made of stationary or mobile wireless stations and an optional central base station, known as the access point (AP).

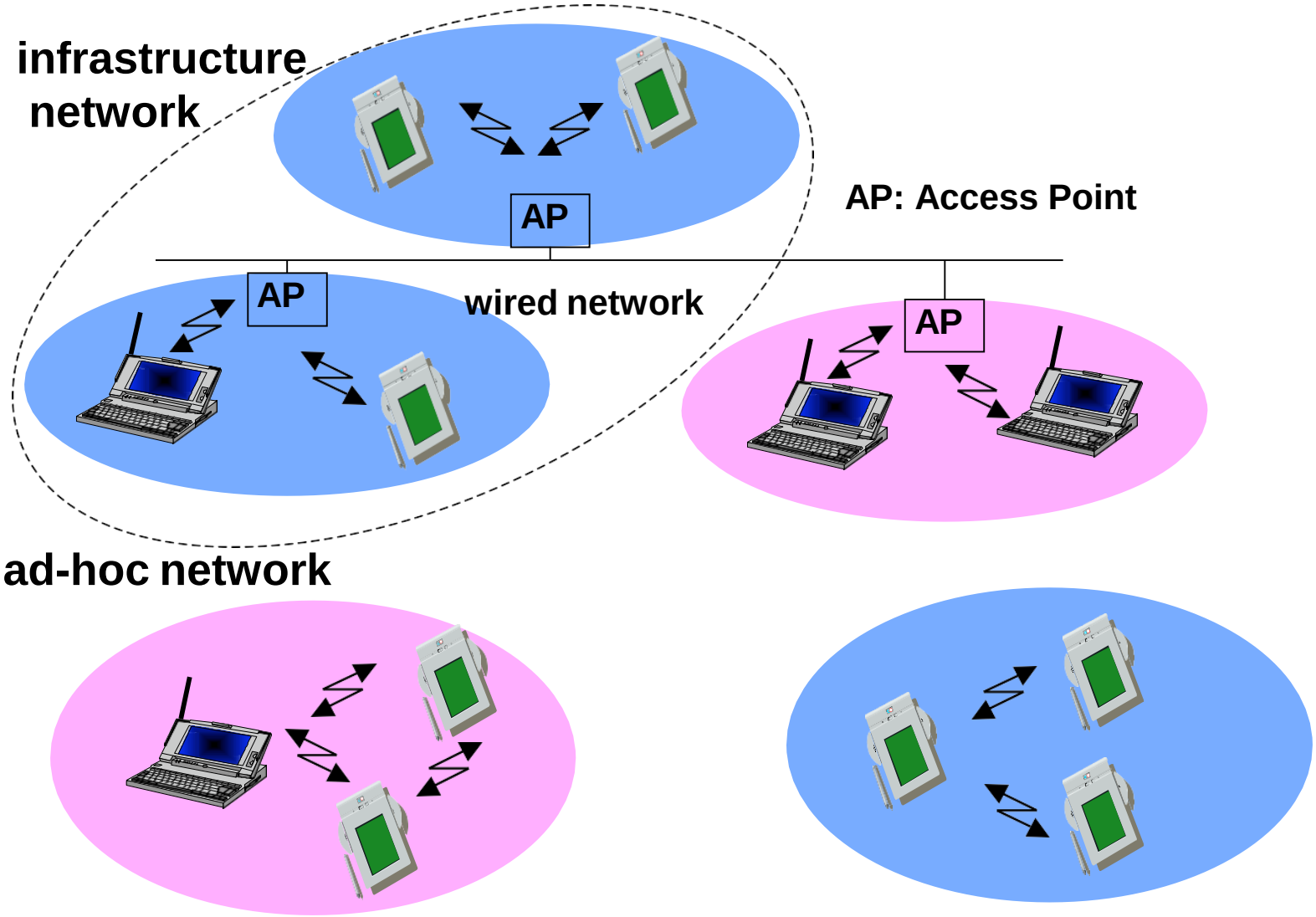
BSS network categories

- Ad-hoc network
- Infrastructure network

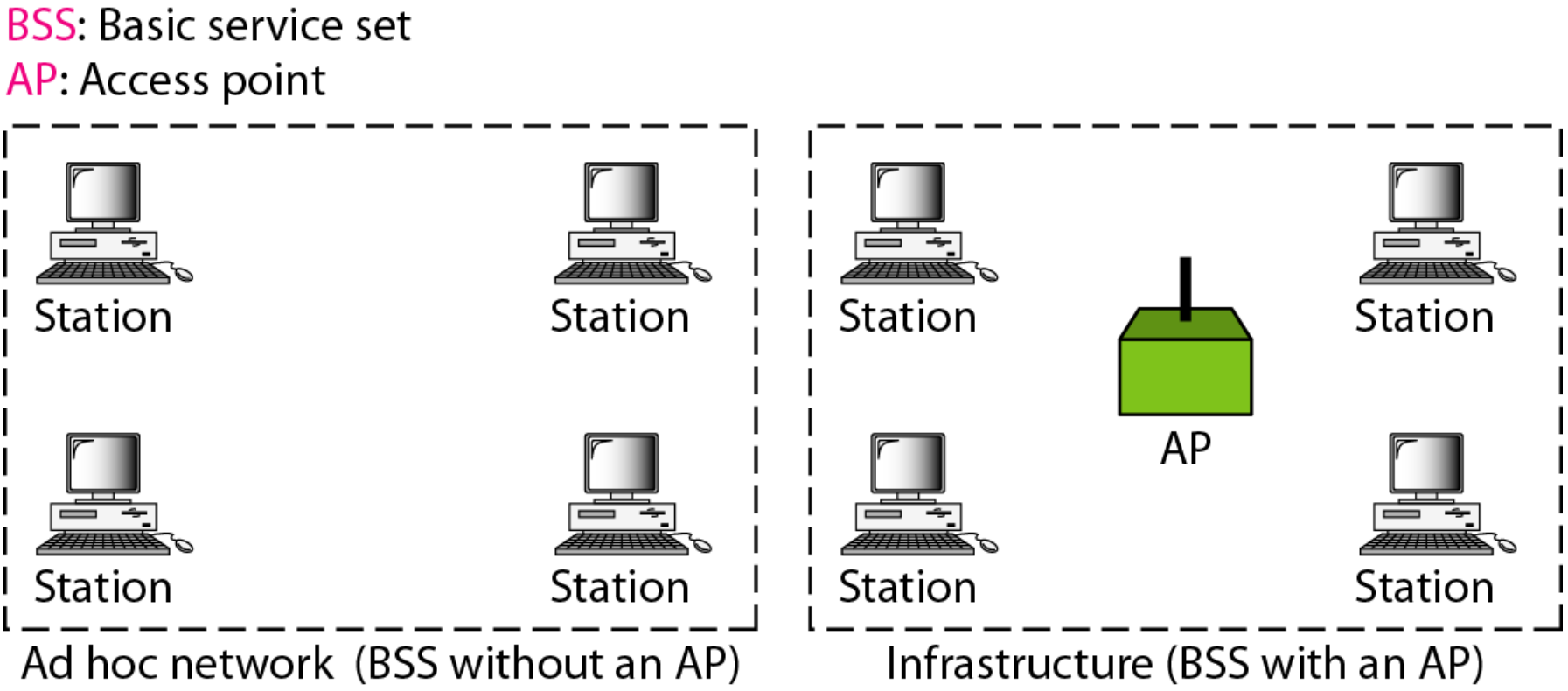
*Note*

**A BSS without an AP is called an ad hoc network;**
**a BSS with an AP is called an infrastructure network.**

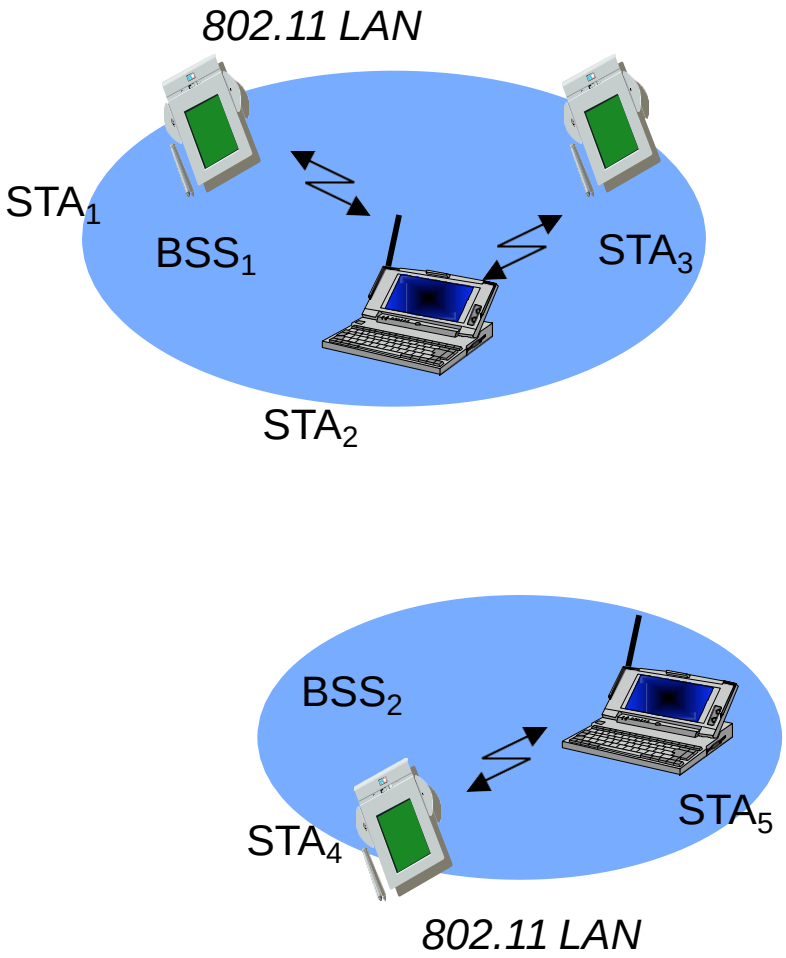
# *Figure:* Basic Service Sets (BSSs)



# *Figure:* Basic Service Sets (BSSs)

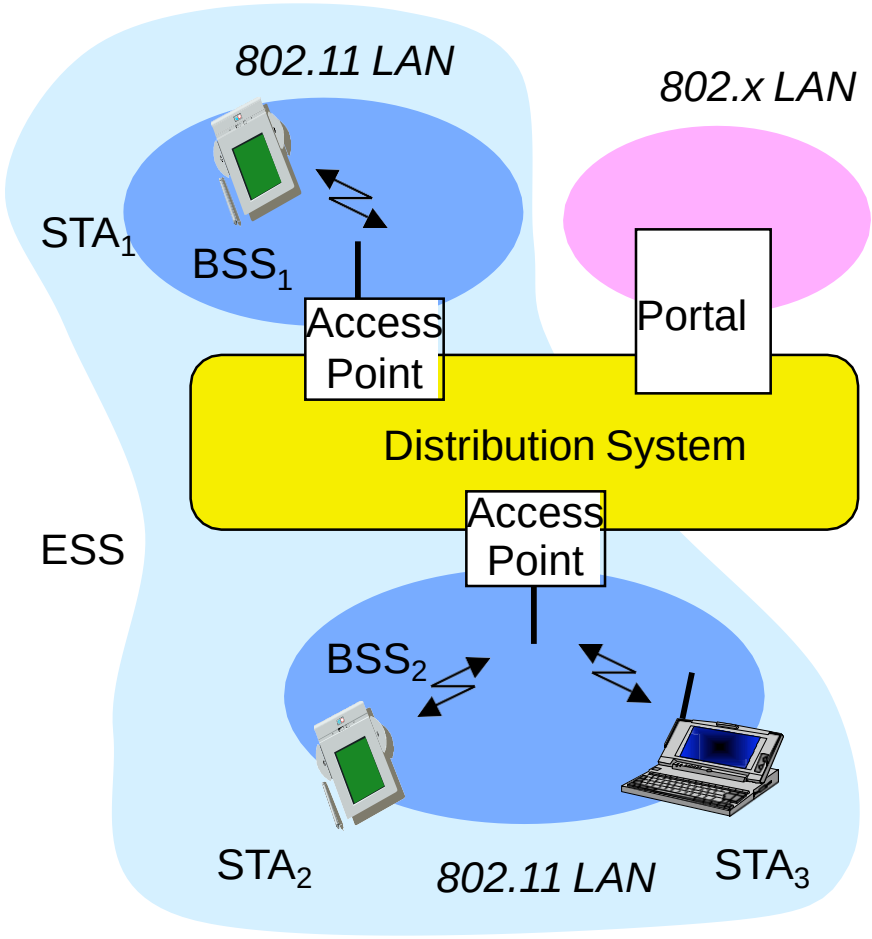


# 802.11: ad-hoc mode




- Direct communication within a limited range
  - o Station (STA): terminal with access mechanisms to the wireless medium
  - o Basic Service Set (BSS): group of stations in range and using the same radio frequency

# 802.11: infrastructure mode




- Station (STA)
  - o terminal with access mechanisms to the wireless medium and radio contact to the access point
- Basic Service Set (BSS)
  - o group of stations using the same radio frequency
- Access Point
  - o station integrated into the wireless LAN and the distribution system
- Portal
  - o bridge to other (wired) networks
- Distribution System
  - o interconnection network to form one logical network (EES: Extended Service Set) based on several BSS

# ii). Extended Service Set (ESS)

An ESS is made up of two or more BSSs with APs.

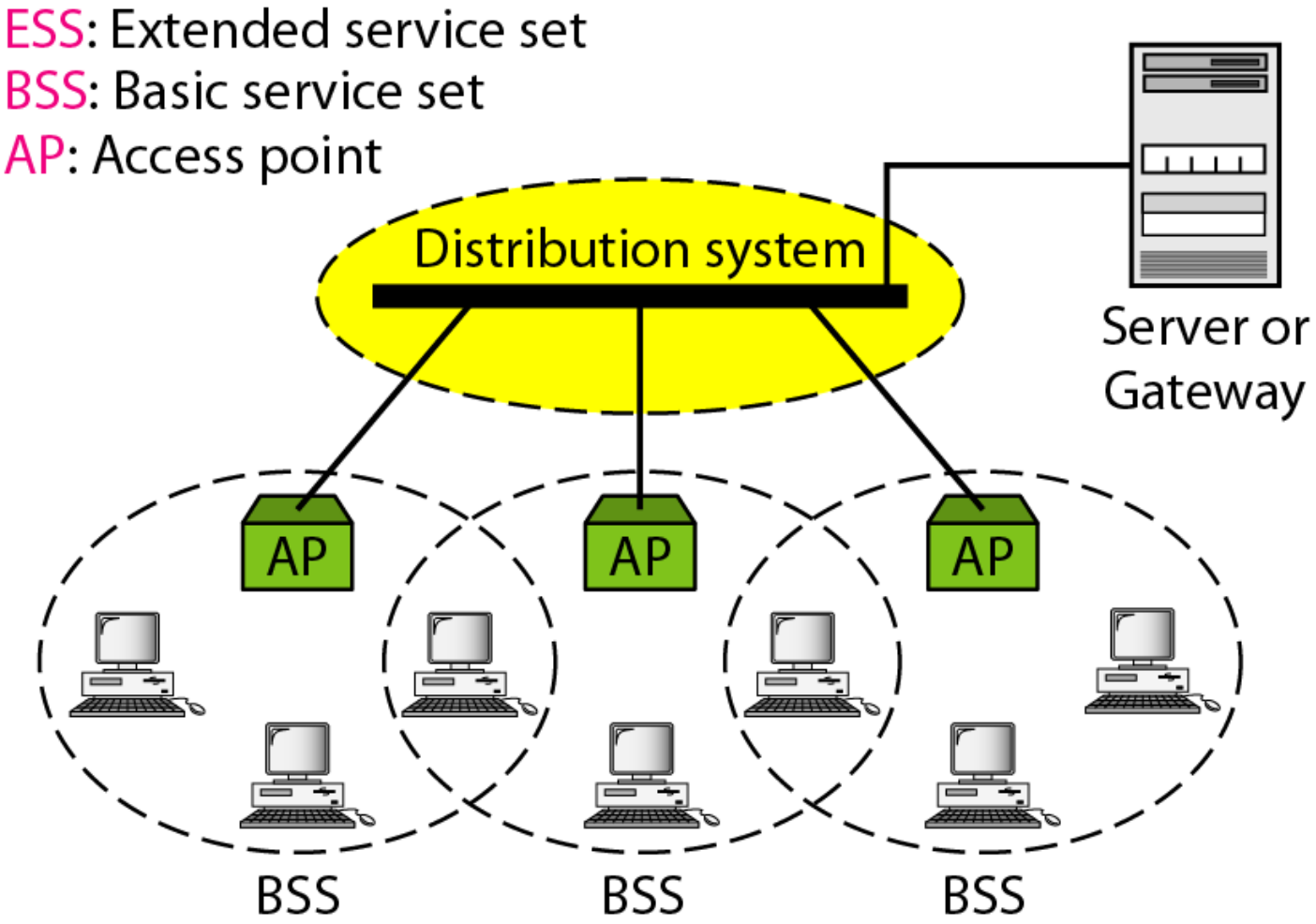
In this case, the BSSs are connected through a distribution system, which is usually a wired LAN. The distribution system connects the APs in the BSSs.

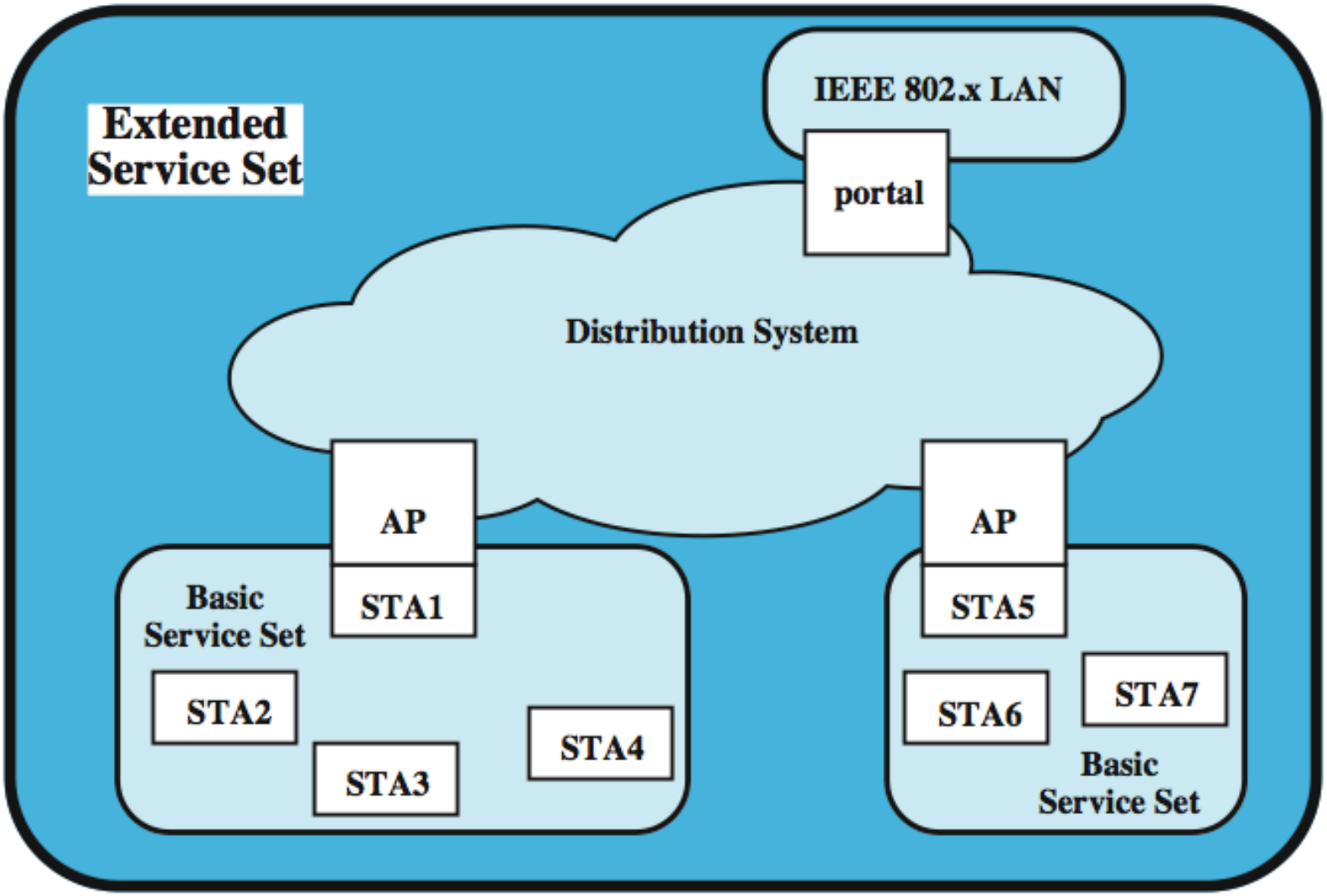
IEEE 802.11 does not restrict the distribution system; it can be any IEEE LAN such as an Ethernet.

The extended service set uses two types of stations:
mobile and stationary.

The mobile stations are normal stations inside a BSS.
The stationary stations are AP stations that are part of a wired LAN.

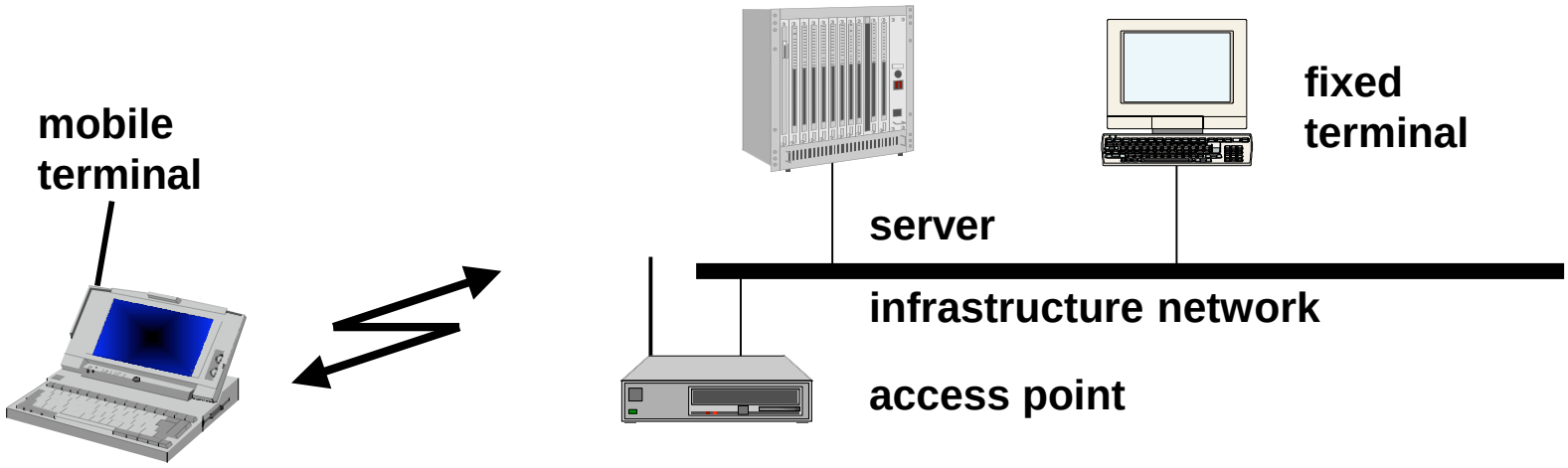
# *Figure:* Extended Service Set (ESS)

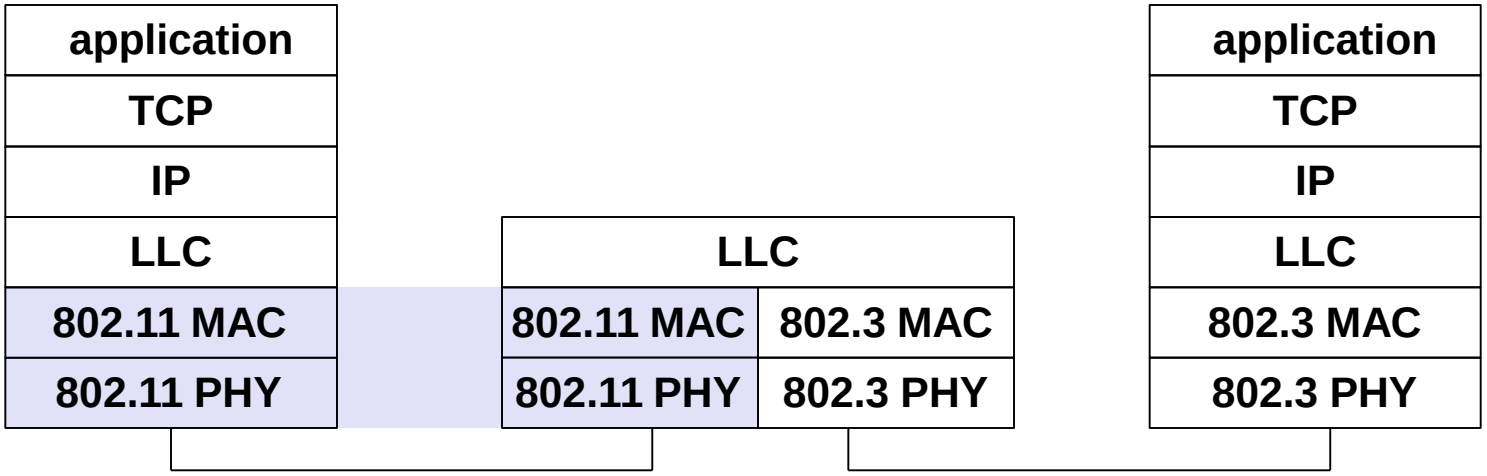




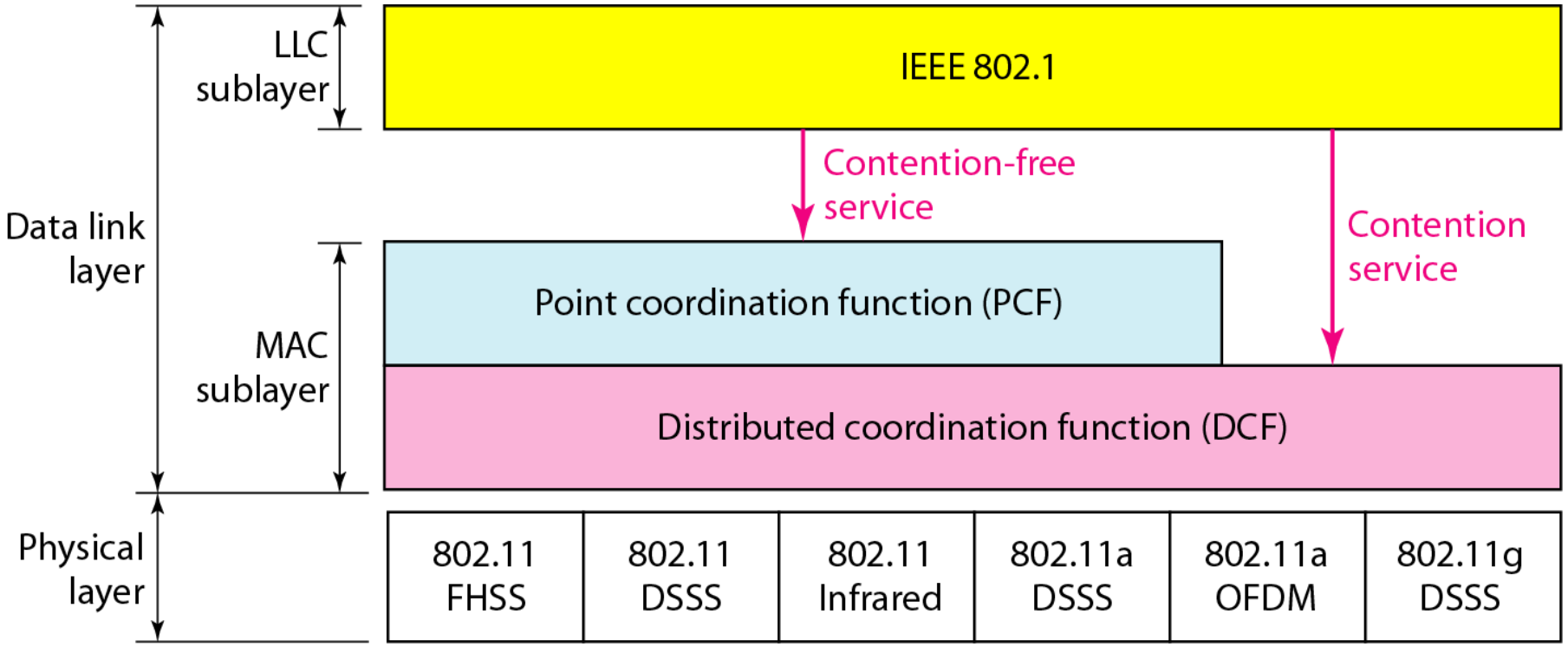

STA = station
AP = access point

# IEEE standard 802.11



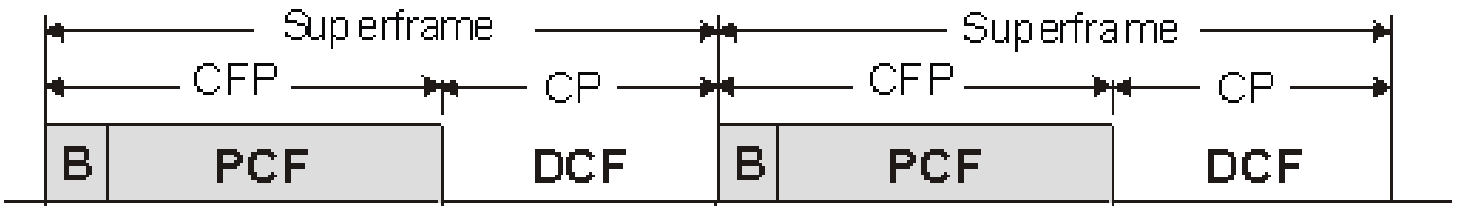



# 2. MAC Sublayer



# DCF and PCF

- PCF and DCF operate concurrently within the same BSS.
- The two access methods alternate, with a contention-free period (CFP) followed by a contention period (CP).




- DCF: fundamental access method of IEEE 802.11 MAC, implemented in all STAs.
  - known as CSMA/CA

# PCF

- Supports time-bounded services.
- Lets stations to have priority access to the wireless medium.
- Polling stations one by one (centralized operation)
- Coordinated by Point Coordinator (PC), typically collocated with the AP.
- PCF has higher priority than the DCF.
- Beacon frame is a management frame that maintains the synchronization of the timers in the stations and delivers protocol related parameters.

# DCF MAC Requirements

- To avoid interference among simultaneous transmissions
  - But enable as many non-interfering transmission as possible
  - Maintain fairness among transmissions
- No centralized coordinators: fully distributed operations
- No clock synchronization: asynchronous operations

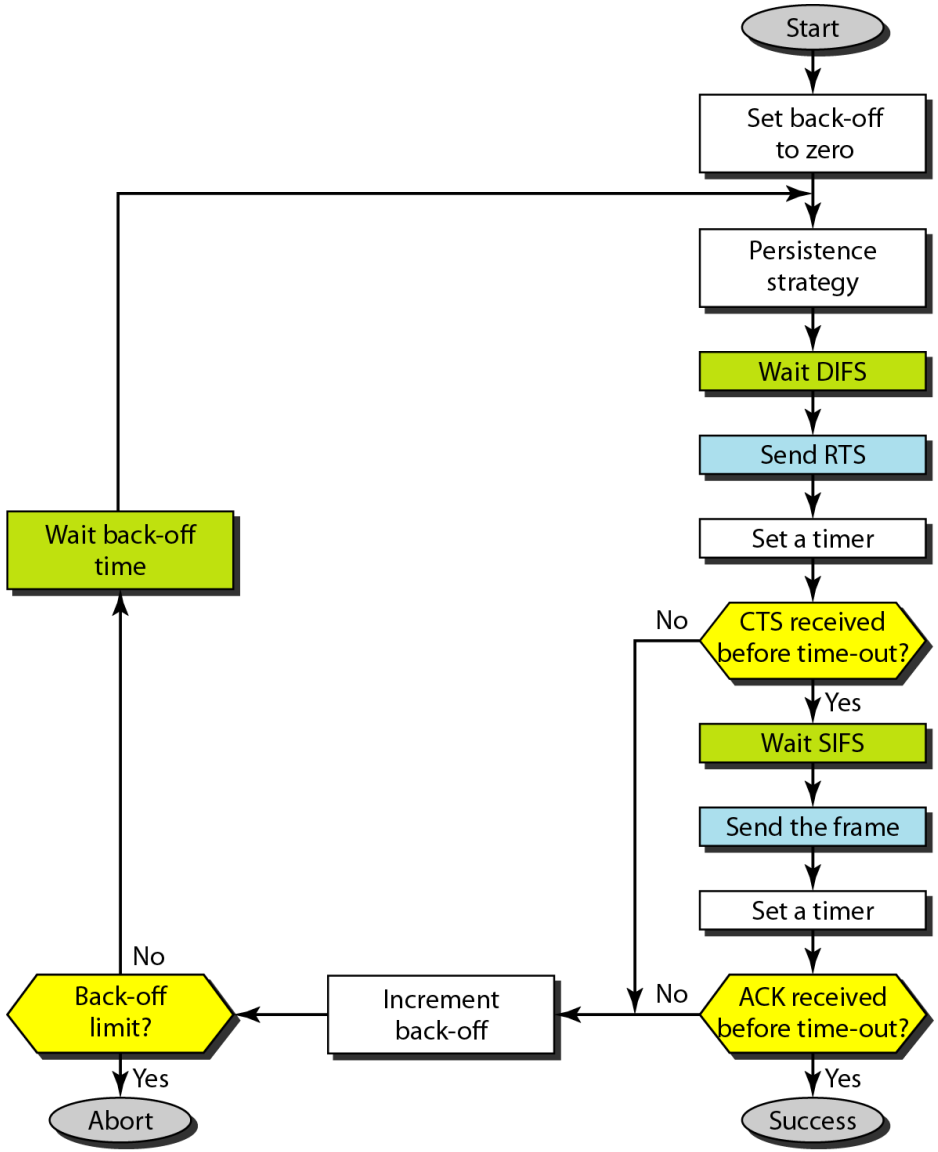
# CSMA/CA

- DCF sub-layer uses CSMA/CA
  - if station has frame to send it listens to medium
  - if medium idle, station may transmit
  - else waits until current transmission completes
- No collision detection since on wireless network, so use collision avoidance (backoff and RTS/CTS)
- DCF includes delays that act as a priority scheme
  - DIFS: DCF inter-frame space
  - SIFS: short inter-frame space (SIFS < DIFS)

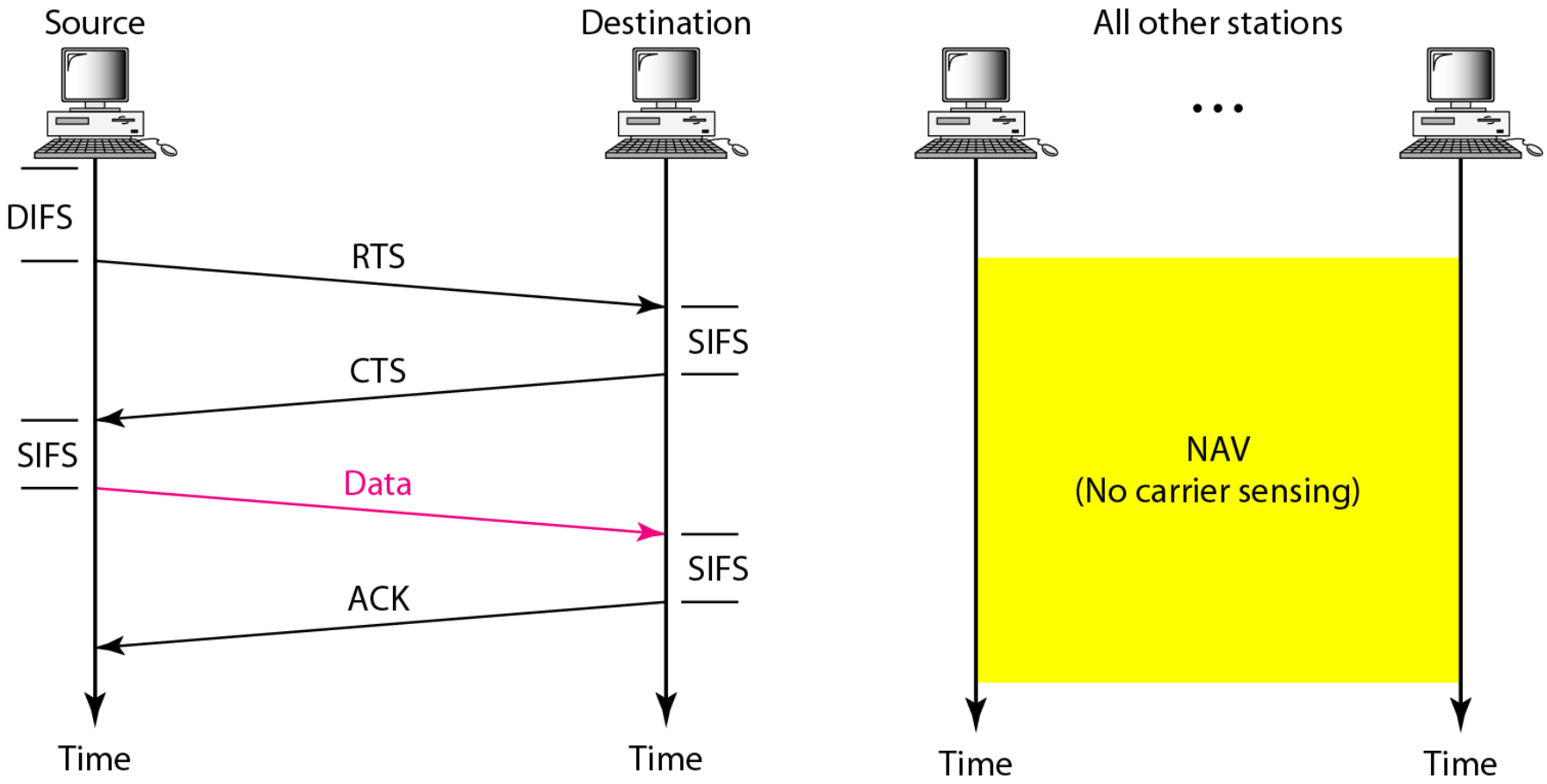
# Back-off Interval

- When channel is busy, choose a back-off interval in the range [0, *cw*] (concept similar to non-persistent).
- Count down the back-off interval when medium becomes idle.
- Count down is suspended if medium becomes busy again.
- When back-off interval reaches 0, transmit RTS.
- Binary exponential back-off in 802.11 DCF:
  - When a node fails to receive CTS, *cw* is doubled up (up to an upper bound).
  - When a data transfer completes successfully, *cw* is reset to $cw_{min}$.

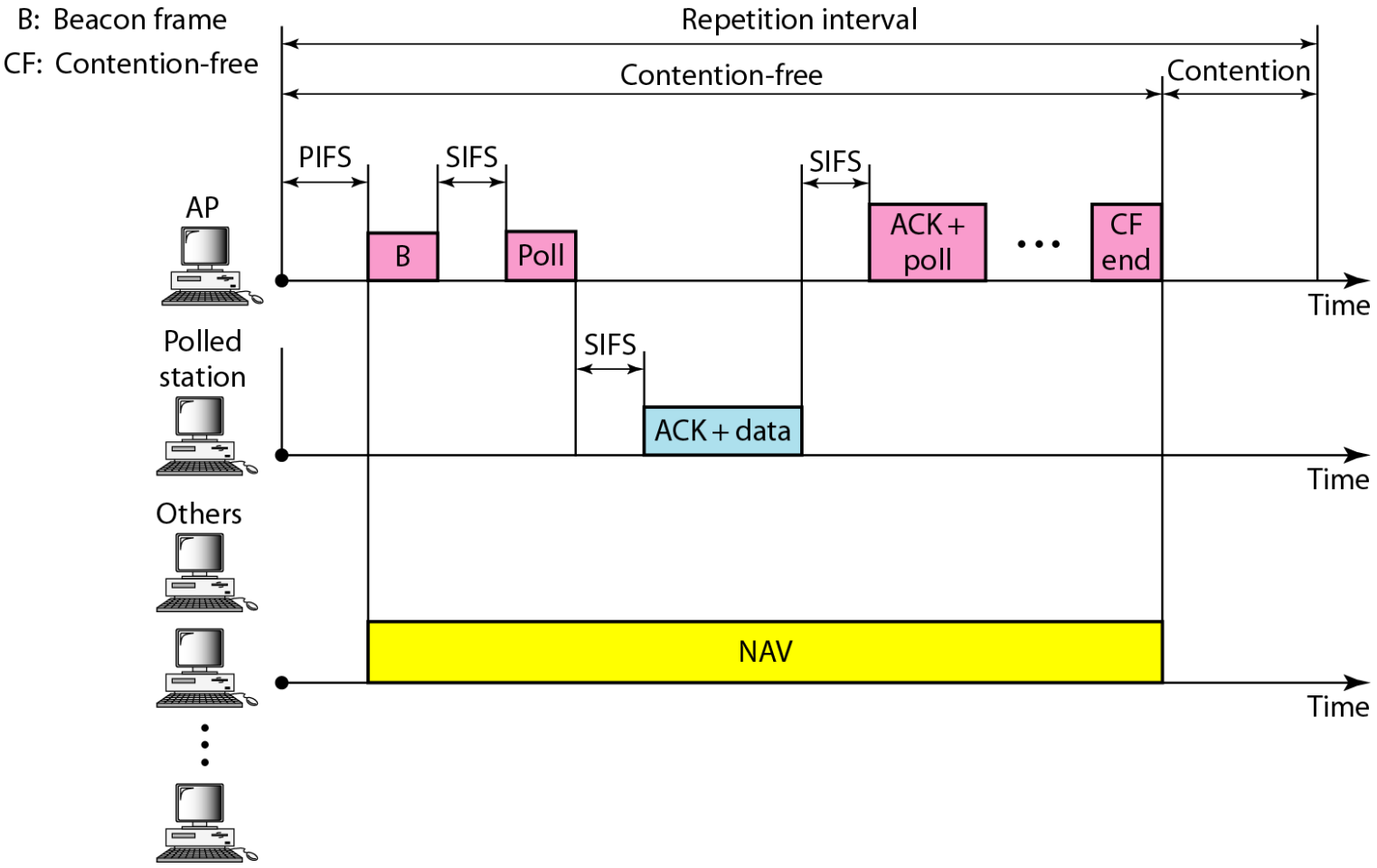
# *Figure:* CSMA/CA flowchart



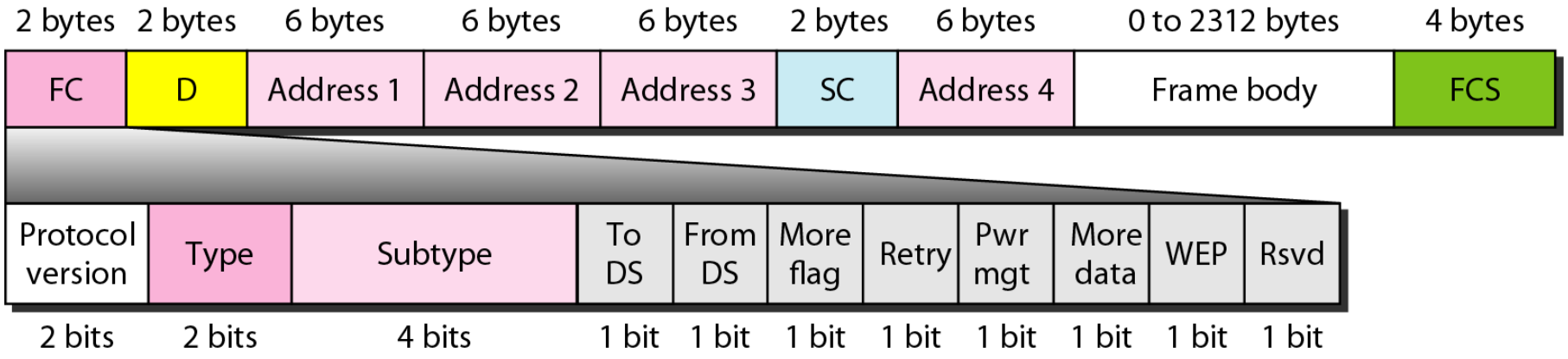
# *Figure:* CSMA/CA and NAV



# *Figure:* Example of repetition interval



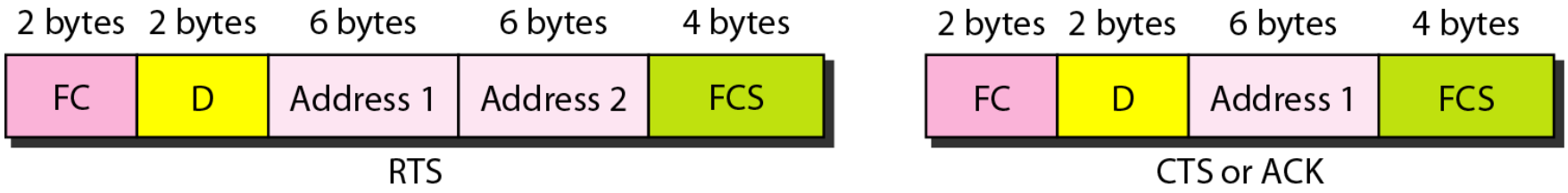
# *Figure:* Frame format



# *Table:* Subfields in FC field

| *Field* | *Explanation* |
|---|---|
| Version | Current version is 0 |
| Type | Type of information: management (00), control (01), or data (10) |
| Subtype | Subtype of each type (see Table 14.2) |
| To DS | Defined later |
| From DS | Defined later |
| More flag | When set to 1, means more fragments |
| Retry | When set to 1, means retransmitted frame |
| Pwr mgt | When set to 1, means station is in power management mode |
| More data | When set to 1, means station has more data to send |
| WEP | Wired equivalent privacy (encryption implemented) |
| Rsvd | Reserved |

# *Figure:* Control frames



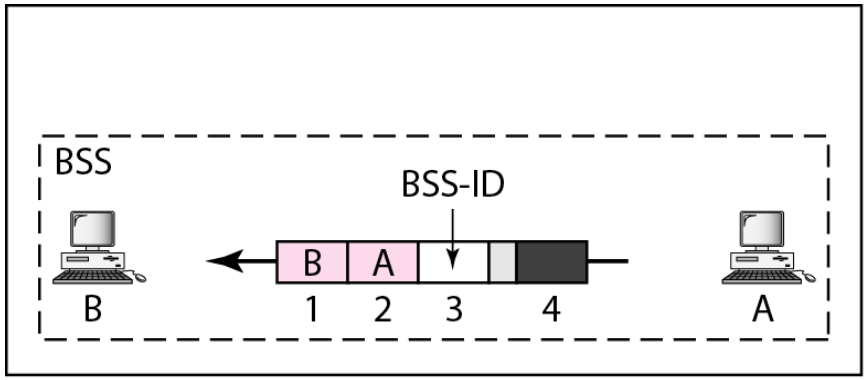
## *Table:* Values of subfields in control frames

| *Subtype* | *Meaning* |
|---|---|
| 1011 | Request to send (RTS) |
| 1100 | Clear to send (CTS) |
| 1101 | Acknowledgment (ACK) |

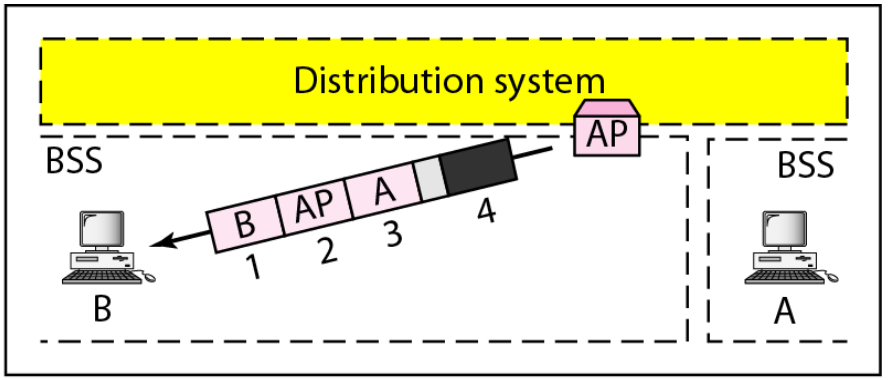
## *Table:* Addresses

| *To DS* | *From DS* | *Address 1* | *Address 2* | *Address 3* | *Address 4* |
|---|---|---|---|---|---|
| 0 | 0 | Destination | Source | BSS ID | N/A |
| 0 | 1 | Destination | Sending AP | Source | N/A |
| 1 | 0 | Receiving AP | Source | Destination | N/A |
| 1 | 1 | Receiving AP | Sending AP | Destination | Source |

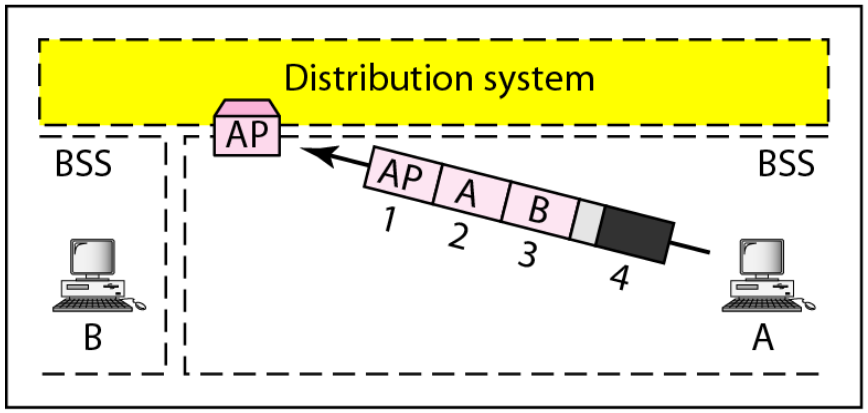
# *Figure:* Addressing mechanisms



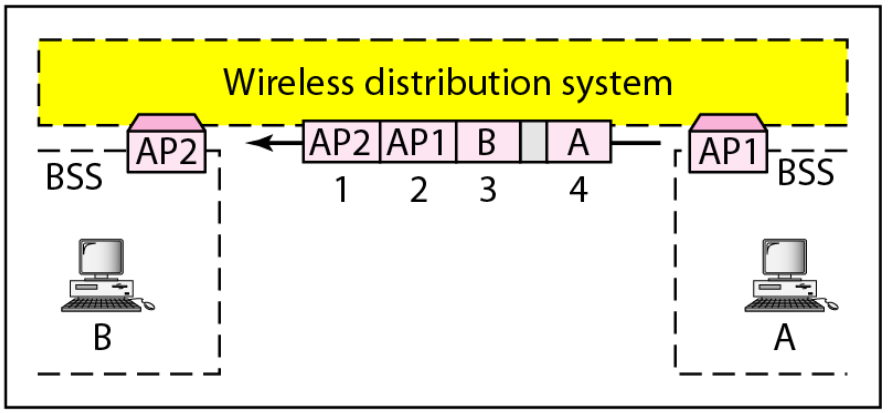

a. Case 1




b. Case 2

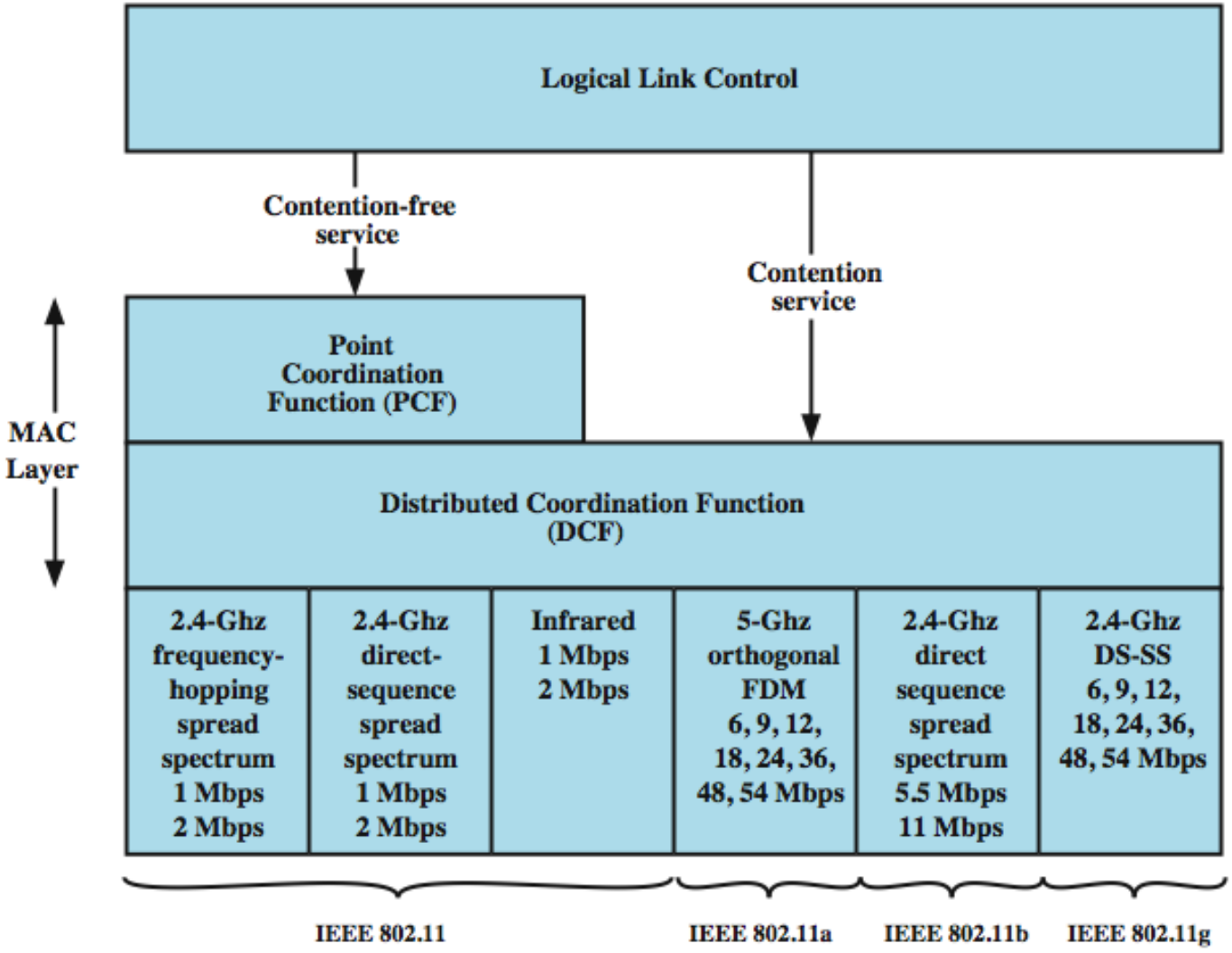



c. Case 3

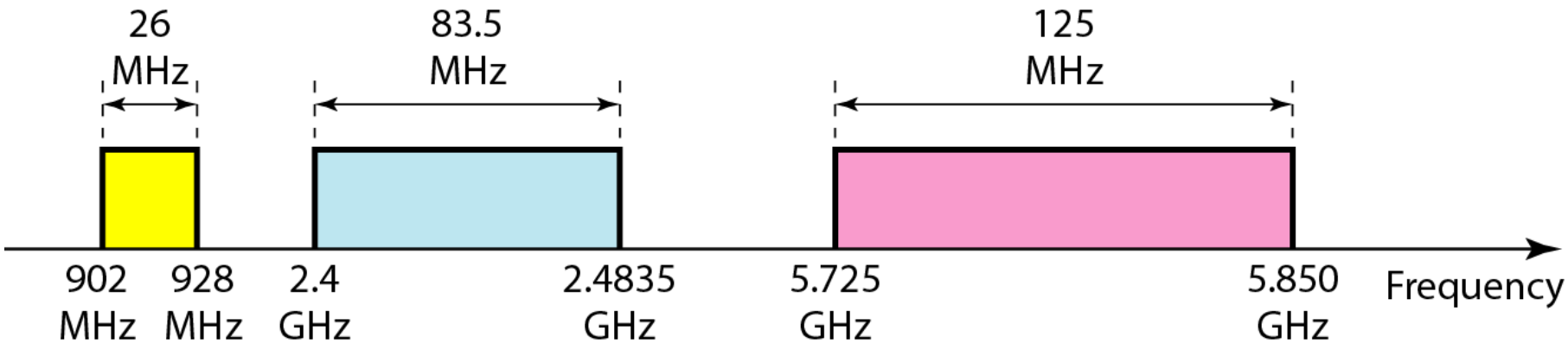



d. Case 4

# *Figure:* MAC layers in IEEE 802.11 standard



## *Figure:* Industrial, scientific, and medical (ISM) band



# 3. Physical Layer

- 2 radio ranges (2.4 GHz and 5 GHz), 1 IR
  - data rates ranging from 1 Mbps to 54 Mbps

❑ IEEE 802.11

- ➢ 2.4 GHz band frequency hopping spread spectrum (FHSS)
- ➢ 2.4 GHz band direct sequence spread spectrum (DSSS)
- ➢ Baseband infrared

❑ IEEE 802.11a

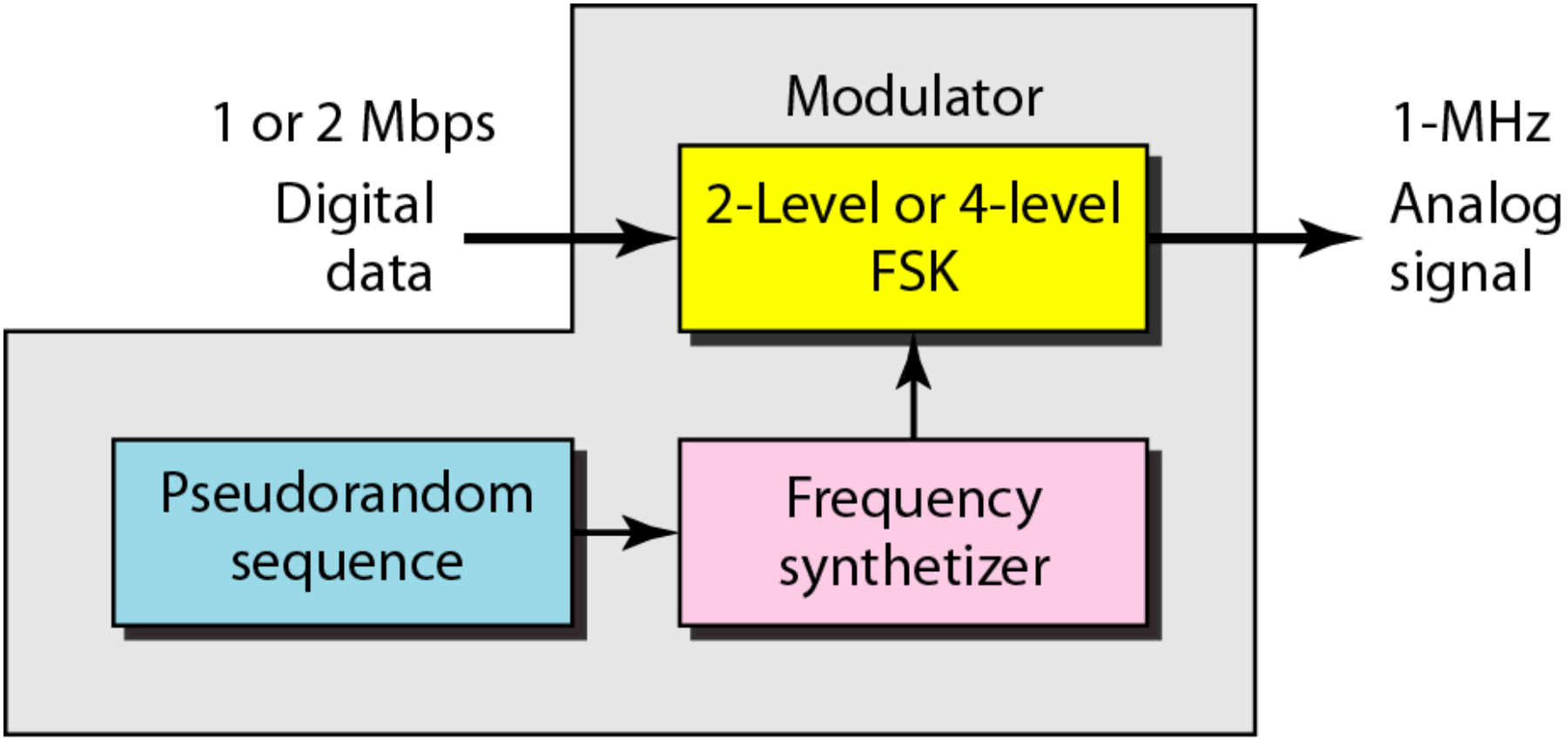
❑ IEEE 802.11b

❑ IEEE 802.11g

# 2.4GHz band FHSS

– Frequency changed within a specified band in a pseudo-random fashion, known only to transmitters and receivers
– Uses a pseudorandom number generator to produce the sequence of frequencies hopped to
– min. 2.5 frequency hops/s (USA), two-level GFSK modulation
– Uses 79 channels, each 1 MHz wide, starting at the low end of the 2.4 GHz band
– If all stations use same seed to the generator and stay synchronized in time => they will hop to same frequencies simultaneously
– The time interval spent at each frequency: dwell time
    - Adjustable parameter, but < 400 ms
– Intruder not knowing the hopping sequence & dwell time cannot eavesdrop on transmissions

## *Figure:* Physical layer of IEEE 802.11 FHSS



# 2.4GHz band DSSS

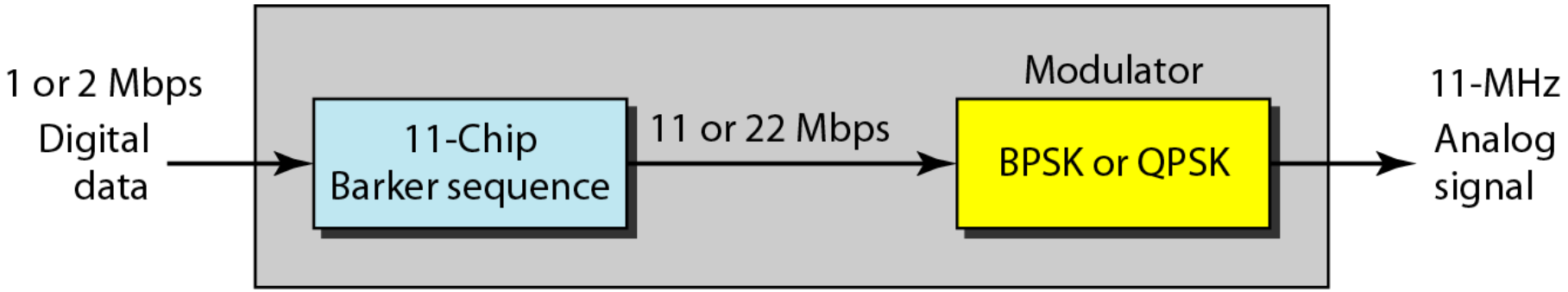
– A spreading code is used to spread and despread the transferred data

– Each wireless station has its own spreading code

– DBPSK or DQPSK modulation (Differential Binary Phase Shift Keying or Differential Quadrature PSK)

– Chipping sequence: +1, -1, +1, +1, -1, +1, +1, +1, -1, -1, -1 (Barker code)

# *Figure:* Physical layer of IEEE 802.11 DSSS



# Baseband Infrared

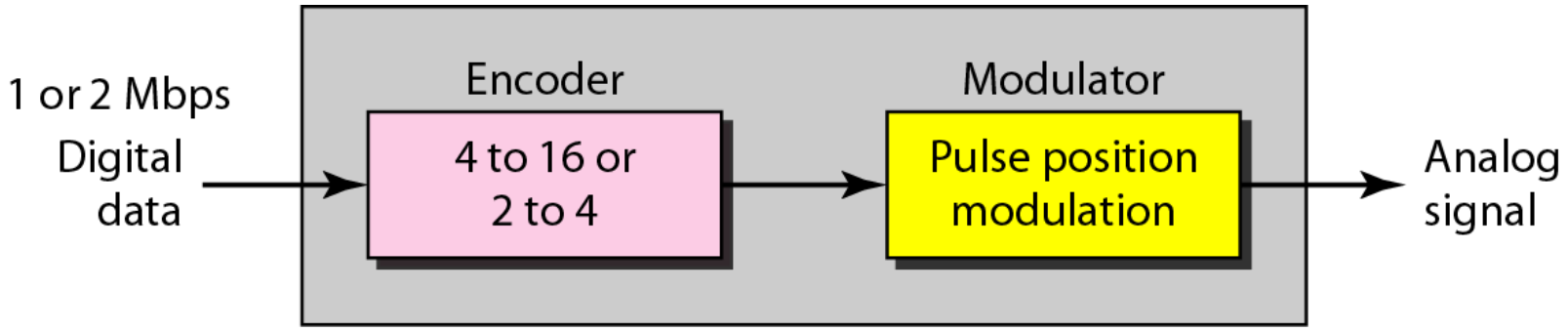
– Infrared technique (for remote controls of TV sets)

– 850-950 nm, diffuse light, typically 10 m range

– Data rates 1-2 Mbps

– Infrared signals cannot penetrate walls, so cells in different rooms are well isolated from each other

# *Figure:* Physical layer of IEEE 802.11 infrared



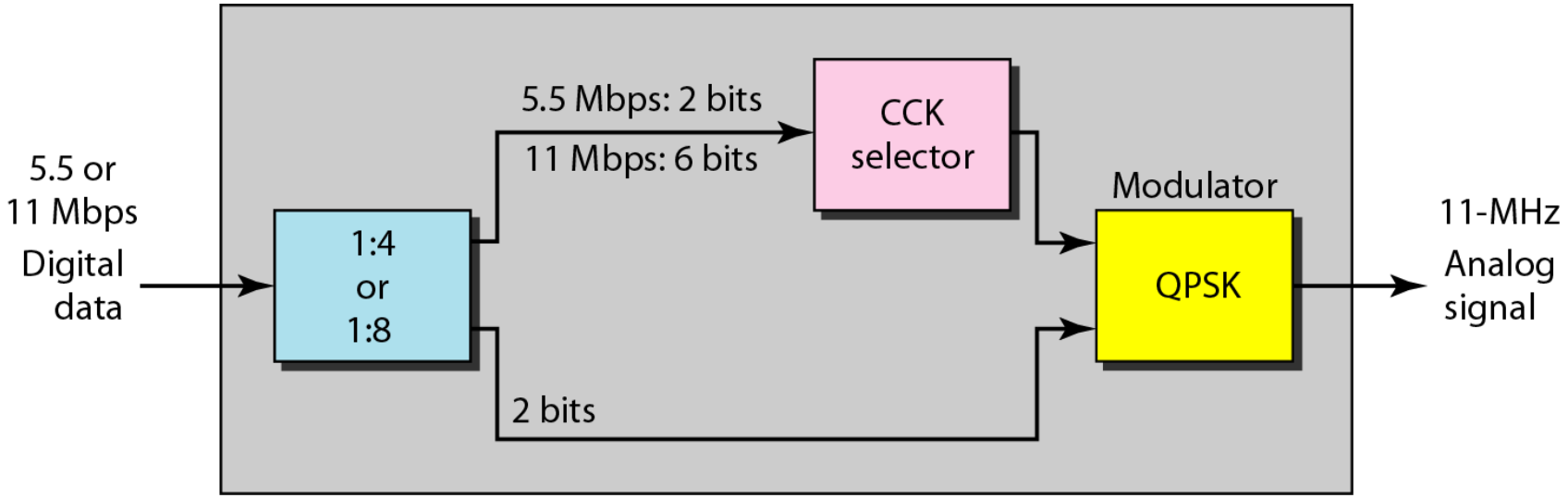
# IEEE 802.11 a, b, g

- IEEE 802.11a
  - o Makes use of 5-GHz band
  - o Provides rates of 6, 9 , 12, 18, 24, 36, 48, 54 Mbps
  - o Uses orthogonal frequency division multiplexing (OFDM)
  - o Sub-carrier modulated using BPSK, QPSK, 16-QAM or 64QAM

- IEEE 802.11b
  - o Provides data rates of 5.5 and 11 Mbps
  - o DSSS and complementary code keying (CCK) modulation

- IEEE 802.11g
  - o Extends data rates to up to 54 Mbps
  - o Uses OFDM, in the 2.4 GHz band

# *Figure:* Physical layer of IEEE 802.11b



## *Table:* Physical layers

| *IEEE* | *Technique* | *Band* | *Modulation* | *Rate (Mbps)* |
|---|---|---|---|---|
| 802.11 | FHSS | 2.4 GHz | FSK | 1 and 2 |
| | DSSS | 2.4 GHz | PSK | 1 and 2 |
| | | Infrared | PPM | 1 and 2 |
| 802.11a | OFDM | 5.725 GHz | PSK or QAM | 6 to 54 |
| 802.11b | DSSS | 2.4 GHz | PSK | 5.5 and 11 |
| 802.11g | OFDM | 2.4 GHz | Different | 22 and 54 |

# BLUETOOTH

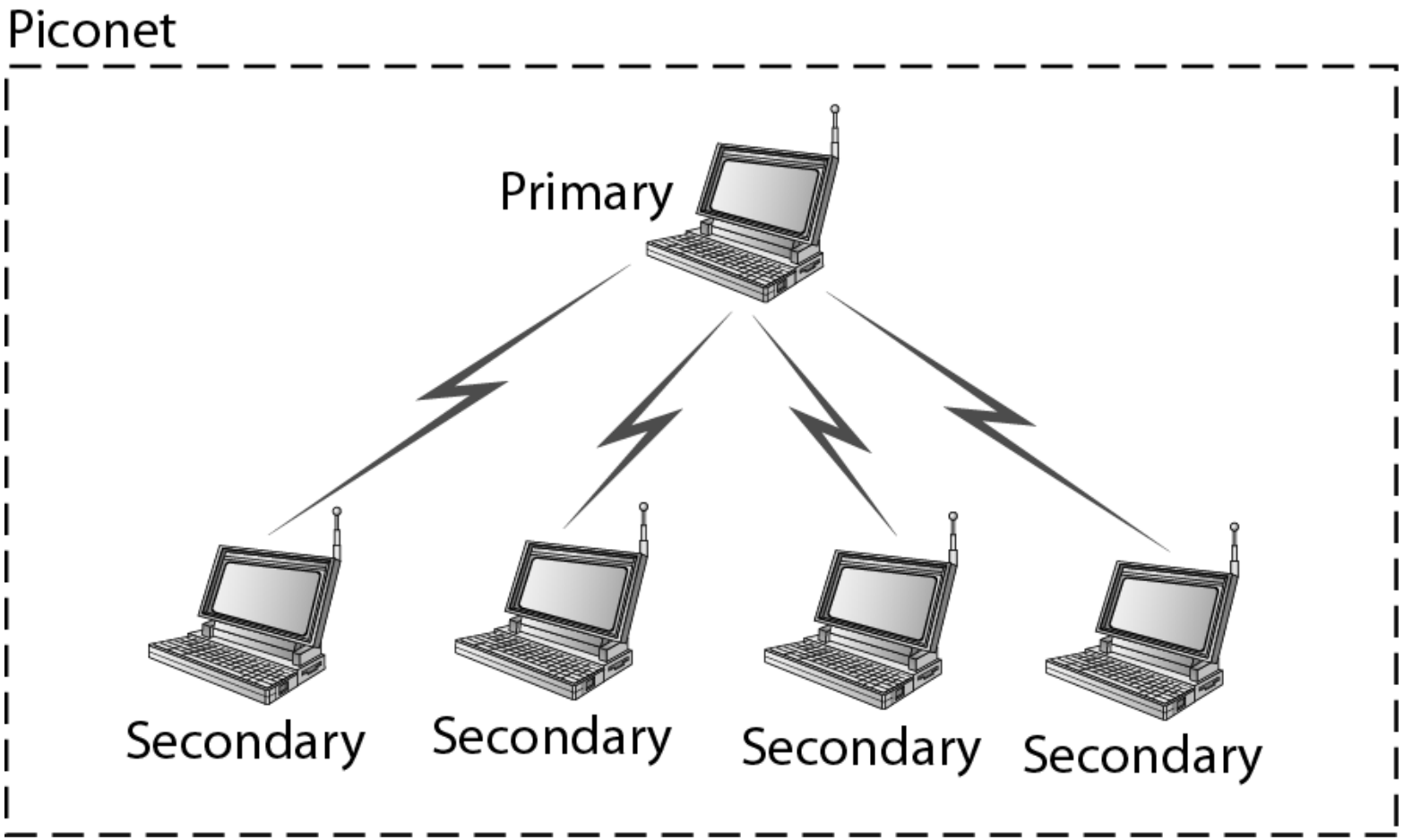
Bluetooth is a wireless LAN technology designed to connect devices of different functions such as telephones, notebooks, computers, cameras, printers, coffee makers, and so on.

A Bluetooth LAN is an ad hoc network, which means that the network is formed spontaneously.

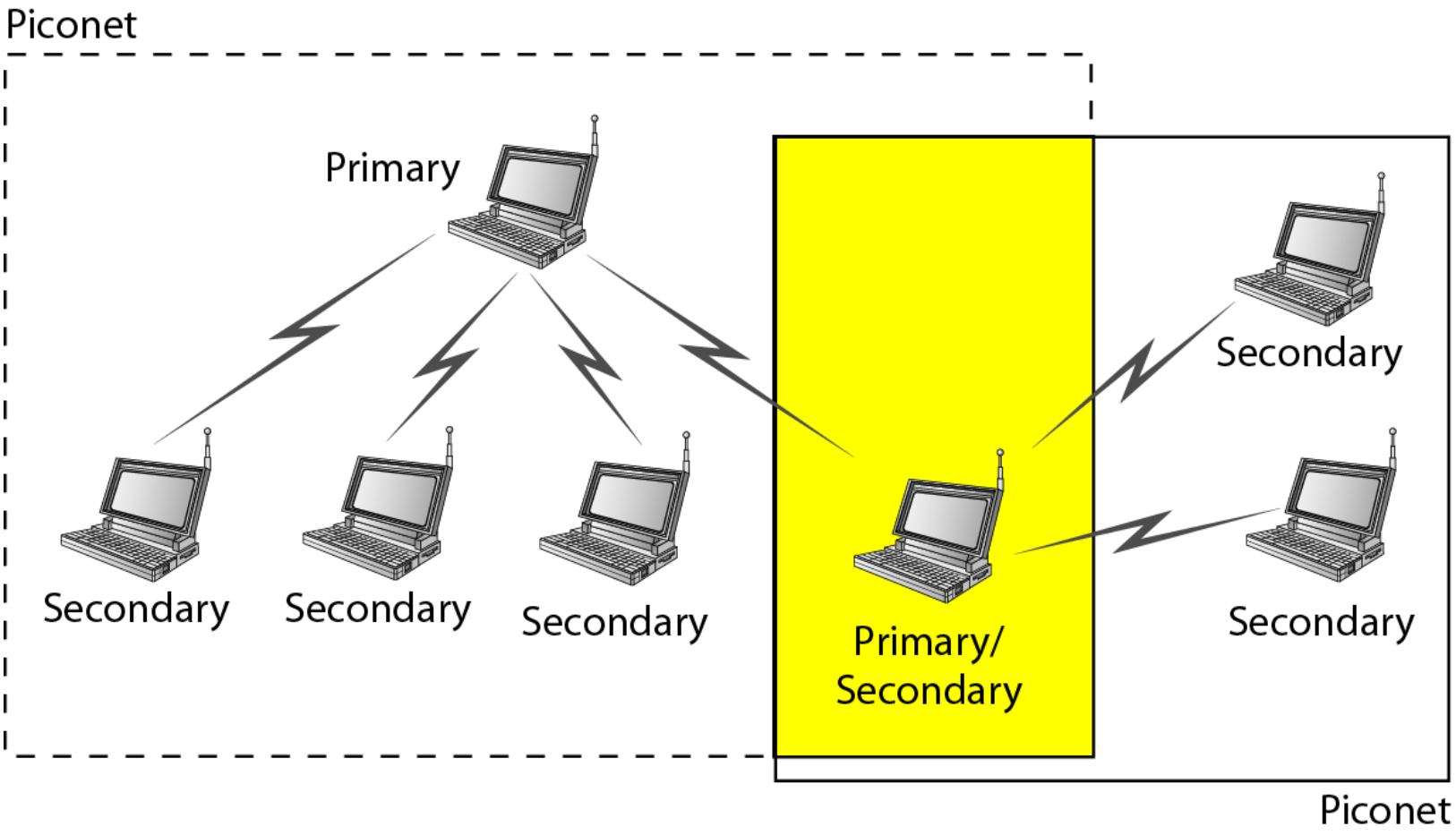
***Topics discussed in this section:***

- **Architecture**
- **Bluetooth Layers**
- **Base band Layer**
- **L2CAP**

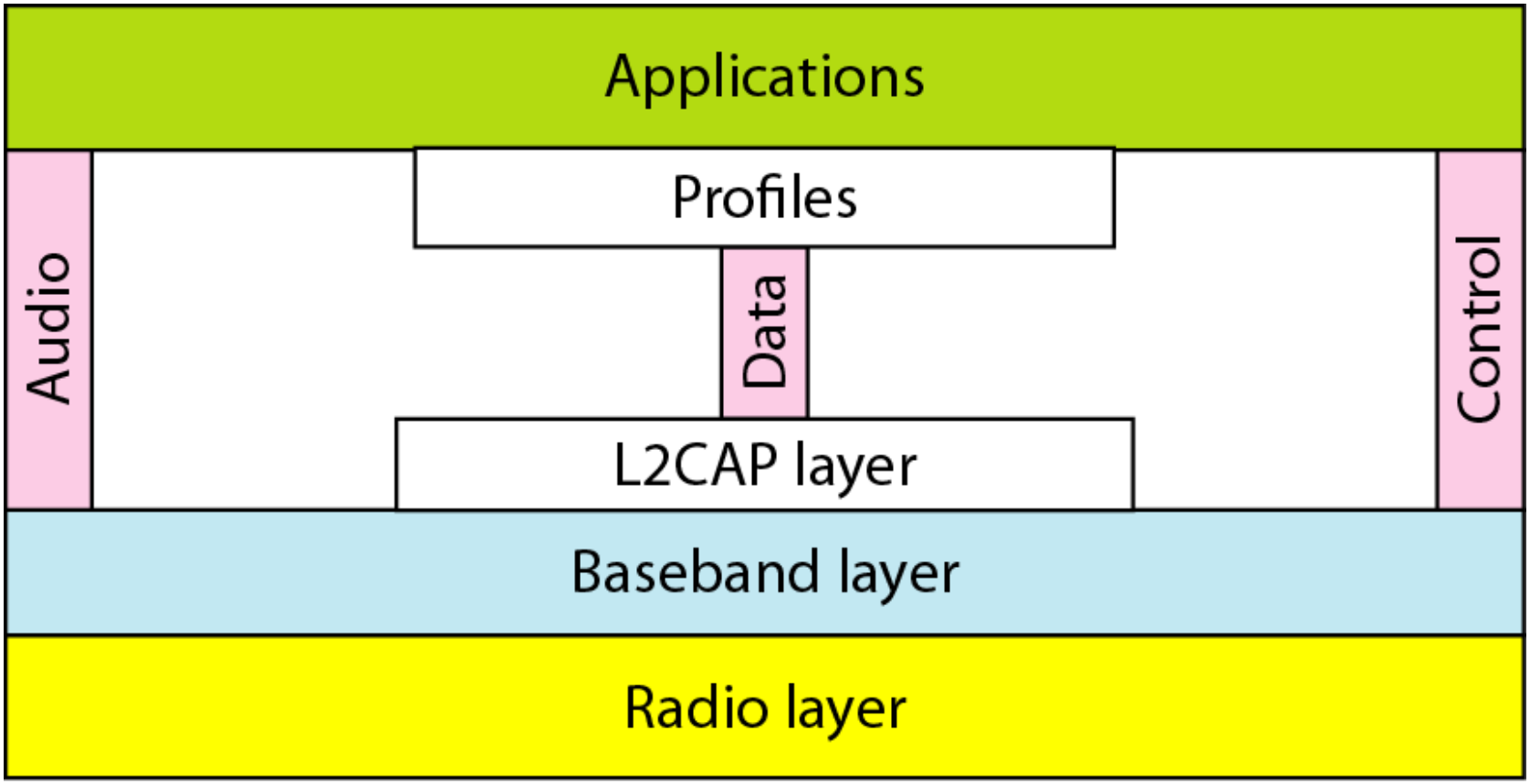
## *Figure:* Piconet



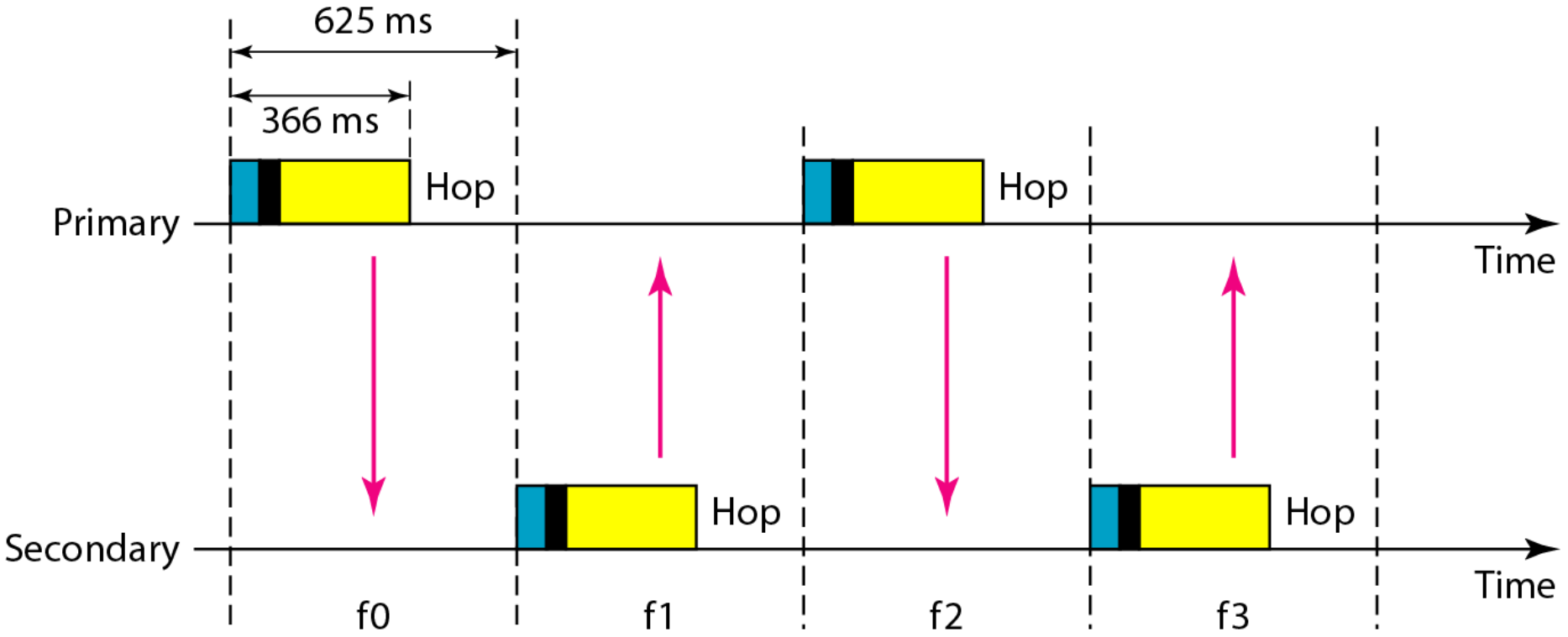
# *Figure:* Scatternet



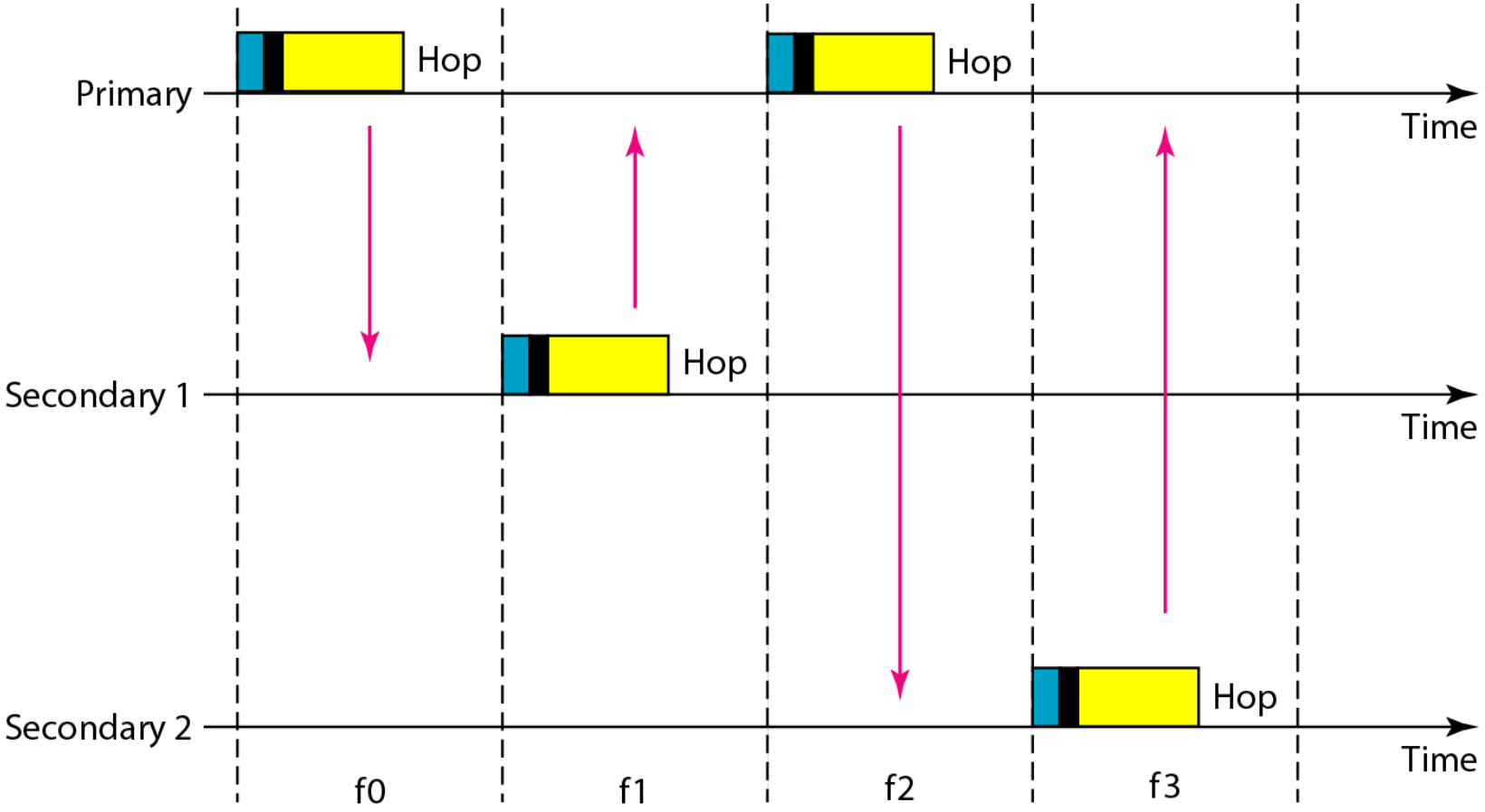
## *Figure:* Bluetooth layers



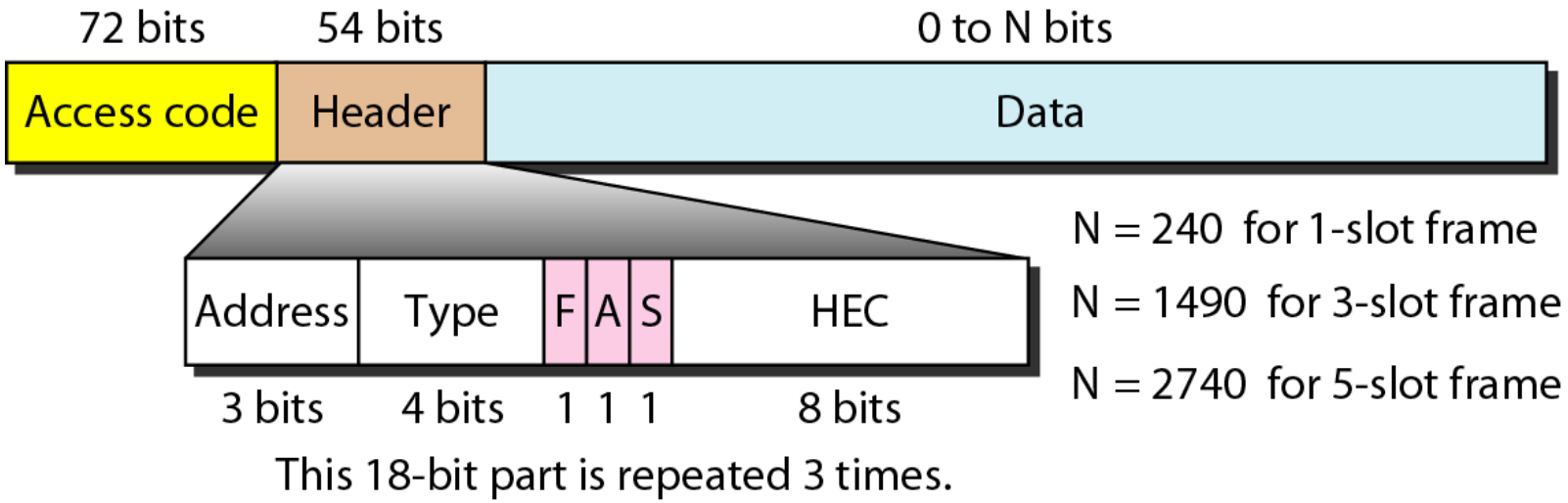
# *Figure:* Single-secondary communication



# *Figure:* Multiple-secondary communication



# *Figure:* Frame format types



# *Figure:* L2CAP data packet format

Questions?