# Unit 5

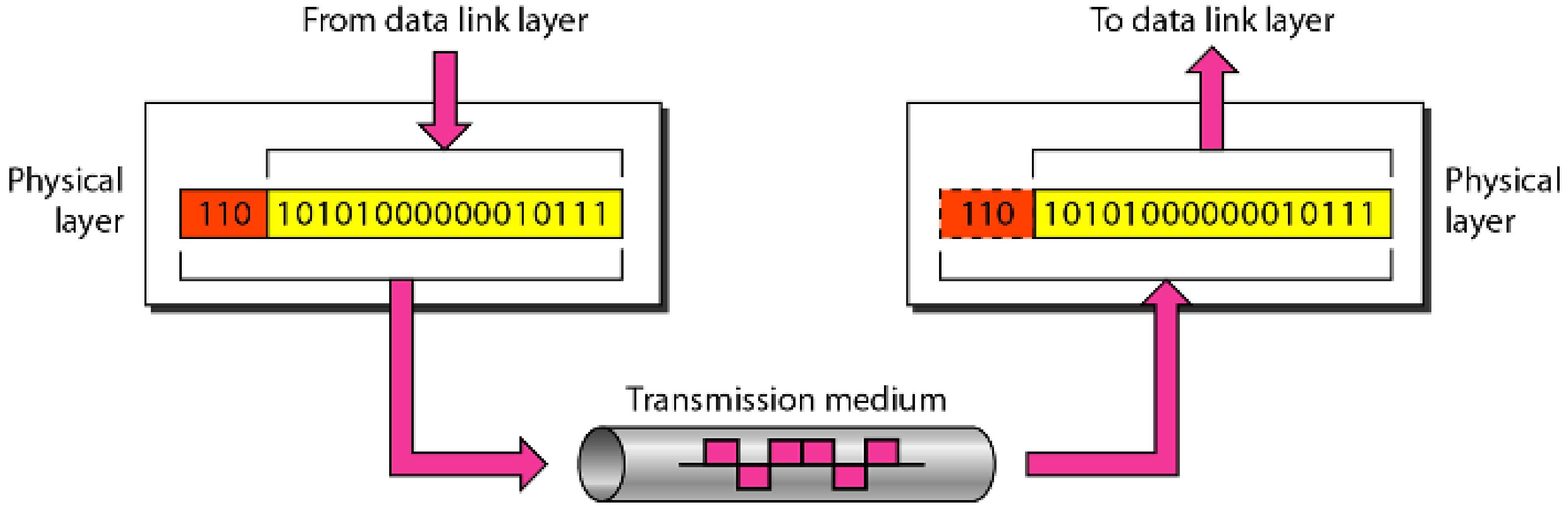
# Unit v

- Physical Layer overview
- Latency, Bandwidth, Delay
- Wireless: 802.11
- Transmission Media : Twisted pair, Coaxial, Fibre
- 802.15, 802.15.4
- 802.16

# UNIT V
# PHYSICAL LAYER CHARACTERISTICS

## Physical layer overview

- The physical layer is responsible for movements of individual bits from one hop (node) to the next.



- The physical layer defines the means of transmitting raw bits rather than logical data packets over a physical link connecting network nodes.
- The bit stream may be grouped into code words or symbols and converted to a physical signal that is transmitted over a hardware transmission medium.
- The physical layer provides an electrical, mechanical, and procedural interface to the transmission medium.
- Within the semantics of the OSI network architecture, the physical layer translates logical communications requests from the data link layer into hardware-specific operations to cause transmission or reception of electronic signals.

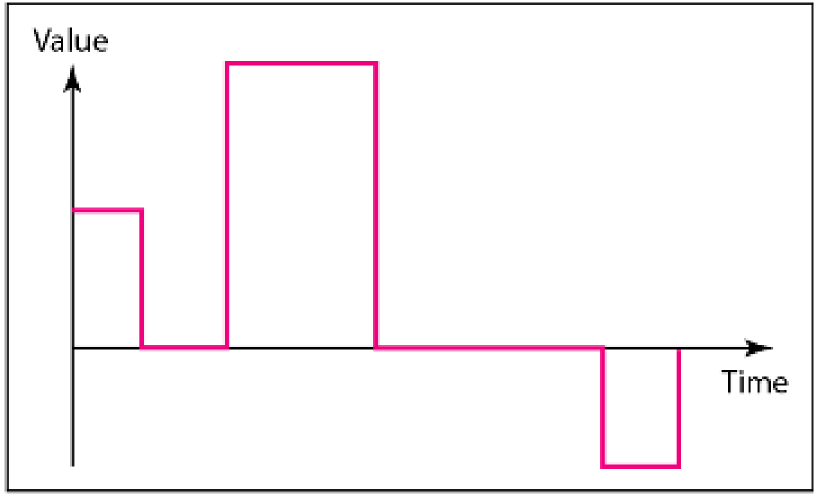
# Data and Signals

- Data are entities that convey meaning (computer file, music on CD)
- Signals are the electric or electromagnetic encoding of data (telephone conversation)
- Computer networks and data/voice communication systems transmit signals
- Data and signals can be analog or digital.

# Analog vs. Digital Signals

- Signals can be interpreted as either analog or digital
- In reality, all signals are analog
- Analog signals are continuous, non-discrete
- Digital signals are non-continuous, discrete

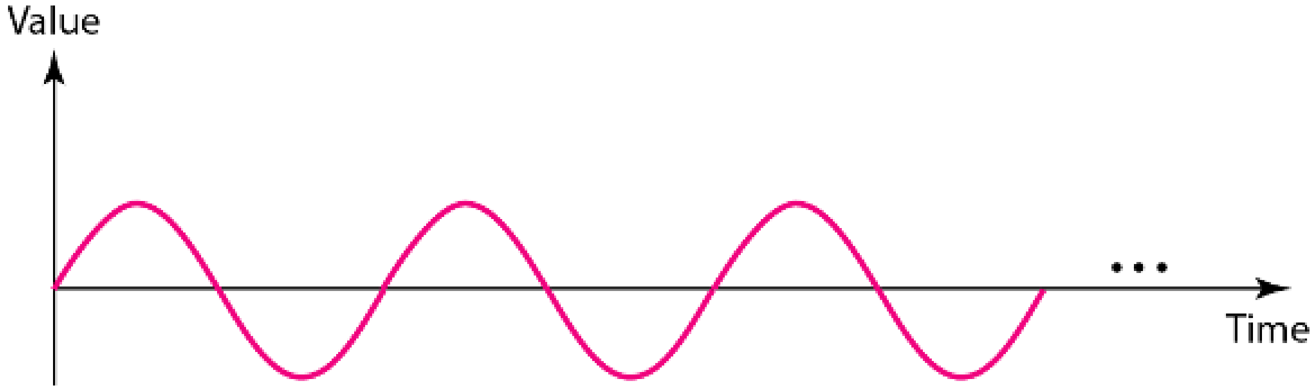

a. Analog signal




b. Digital signal

# Time domain concepts

- Continuous signal
  - Infinite number of points at any given time
- Discrete signal
  - Finite number of points at any given time; maintains a constant level then changes to another constant level
- Periodic signal
  - Pattern repeated over time
- Aperiodic (non-periodic) signal
  - Pattern not repeated over time



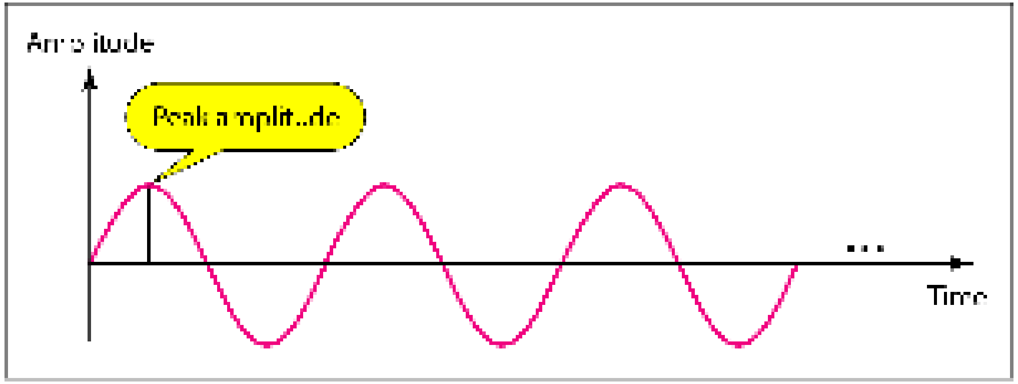
# Signal Properties

- All signals are composed of three properties:
  - Amplitude
  - Frequency
  - Phase

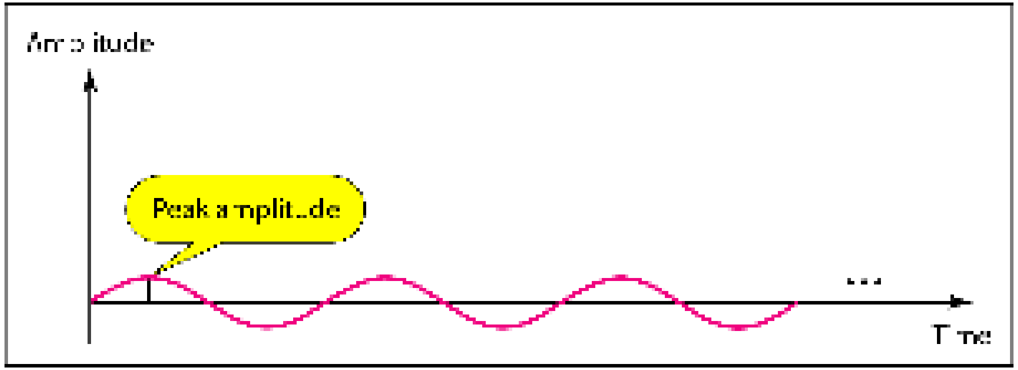
Frequency and period are the inverse of each other.

$$f = \frac{1}{T} \qquad \text{and} \qquad T = \frac{1}{f}$$

*Two signals with the same phase and frequency, but different amplitudes*

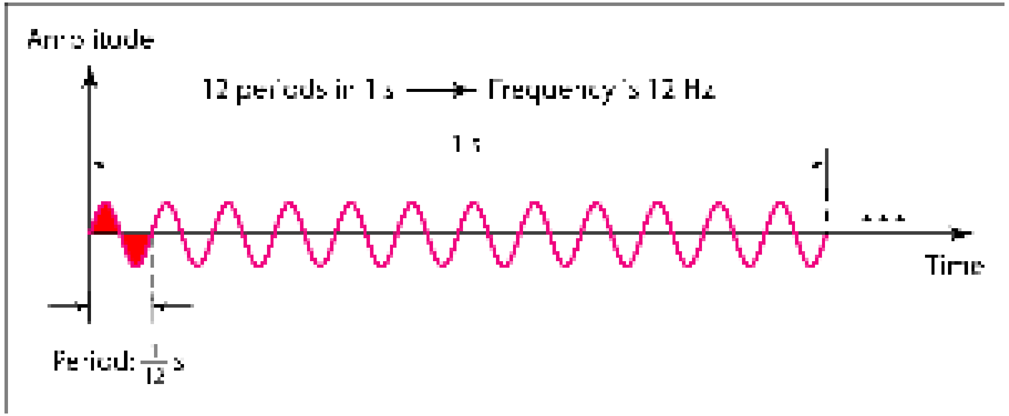



a. A signal with high peak amplitude

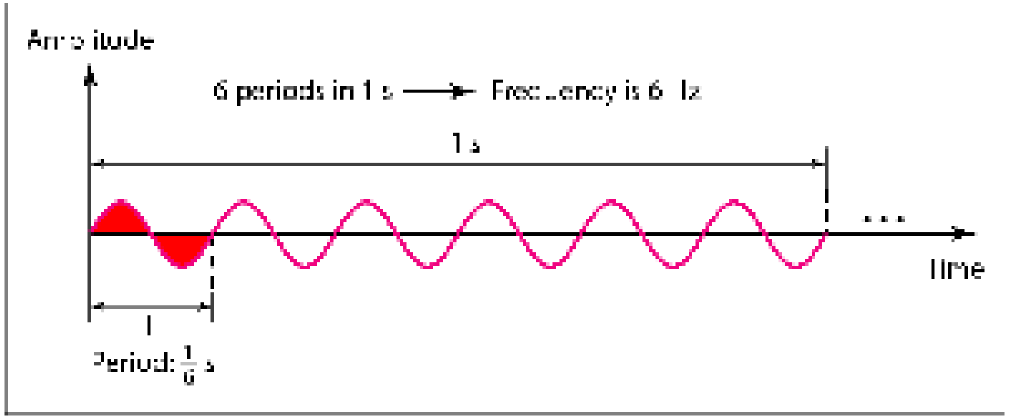



b. A signal with low peak amplitude

*Two signals with the same amplitude and phase, but different frequencies*




a. A signal with a frequency of 12 Hz




b. A signal with a frequency of 6 Hz

## *Units of period and frequency*

| *Unit* | *Equivalent* | *Unit* | *Equivalent* |
|---|---|---|---|
| Seconds (s) | 1 s | Hertz (Hz) | 1 Hz |
| Milliseconds (ms) | $10^{-3}$ s | Kilohertz (kHz) | $10^{3}$ Hz |
| Microseconds (µs) | $10^{-6}$ s | Megahertz (MHz) | $10^{6}$ Hz |
| Nanoseconds (ns) | $10^{-9}$ s | Gigahertz (GHz) | $10^{9}$ Hz |
| Picoseconds (ps) | $10^{-12}$ s | Terahertz (THz) | $10^{12}$ Hz |

### Example

The power we use at home has a frequency of 60 Hz. The period of this sine wave can be determined as follows:

$$\boxed{T = \frac{1}{f} = \frac{1}{60} = 0.0166 \text{ s} = 0.0166 \times 10^{3} \text{ ms} = 16.6 \text{ ms}}$$

- Frequency is the rate of change with respect to time.
- Change in a short span of time means high frequency.
- Change over a long span of time means low frequency.
- If a signal does not change at all, its frequency is zero.
- If a signal changes instantaneously, its frequency is infinite.

# PERFORMANCE

- *Bandwidth*

  *Throughput*

  *Latency (Delay)*

## Bandwidth

In networking, we use the term bandwidth in two contexts.

- The first, bandwidth in hertz, refers to the range of frequencies in a composite signal or the range of frequencies that a channel can pass.
- The second, bandwidth in bits per second, refers to the speed of bit transmission in a channel or link.

*Example*

The bandwidth of a subscriber line is 4 kHz for voice or data. The bandwidth of this line for data transmission can be up to 56,000 bps using a sophisticated modem to change the digital signal to analog.

## Throughput

- It is a measure of how fast we can actually send data through a network.
- A link may have a bandwidth of B bps, but we can send T bps through this link with T always less than B.
- The bandwidth is a potential measurement of a link; the throughput is an actual measurement of how fast we can send data.

## Example

Bandwidth 1 Mbps, device connected to the end may handle only 200 kbps. We cannot send more than 200 kbps through this link.

# *Example*

A network with bandwidth of 10 Mbps can pass only an average of 12,000 frames per minute with each frame carrying an average of 10,000 bits. What is the throughput of this network?

Solution

We can calculate the throughput as

$$\boxed{\text{Throughput} = \frac{12{,}000 \times 10{,}000}{60} = 2 \text{ Mbps}}$$

The throughput is almost one-fifth of the bandwidth in this case.

# Latency(Delay)

- It defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source.

**Latency=Propagation time+ Transmission time + queuing time**

## Propagation Time

- It measures the time required for a bit to travel from the source the source to the destination.

**Propagation time=Distance / Propagation Speed**

- The propagation speed of electromagnetic signals depends on the medium and on the frequency of the signal

# *Example*

What is the propagation time if the distance between the two points is 12,000 km? Assume the propagation speed to be $2.4 \times 10^8$ m/s in cable.

Solution

We can calculate the propagation time as

$$\boxed{\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}}$$

**Transmission Time**

- The first bit leaves earlier and arrives earlier; the last bit leaves later and arrives later.
- The time required for the transmission of a message depends on the size of the message and the bandwidth of the channel.

**Transmission time=Message size/ Bandwidth**

## *Example*

*What are the propagation time and the transmission time for a 2.5-kbyte message (an e-mail) if the bandwidth of the network is 1 Gbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at 2.4 × 108 m/s.*

## *Solution*

*We can calculate the propagation and transmission time as shown on the next slide:*

$$\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

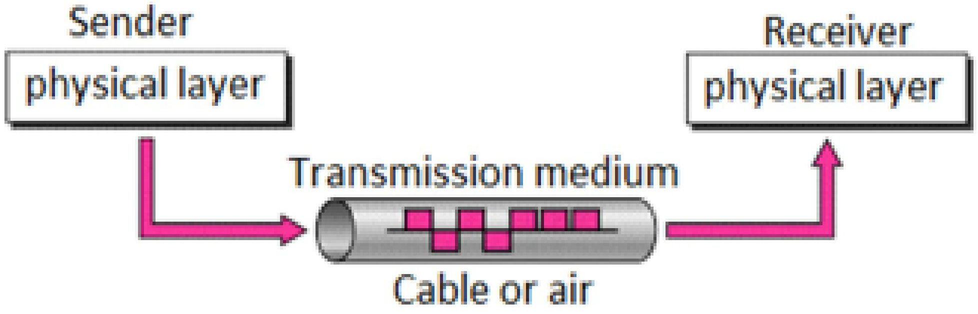
$$\text{Transmission time} = \frac{2500 \times 8}{10^9} = 0.020 \text{ ms}$$

# Queuing Time

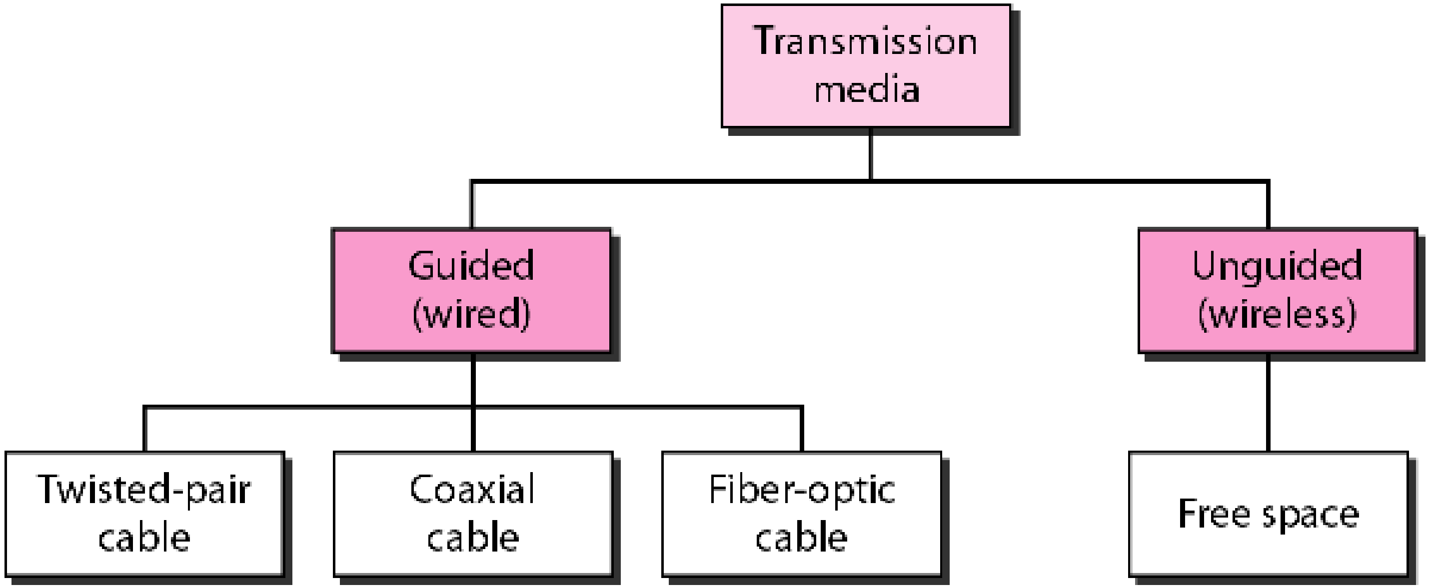
- The time needed for each intermediate or end device to hold the message before it can be processed.
- The queuing time is not a fixed factor; it changes with the load imposed on the network.
- When there is heavy traffic on the network, the queuing time increases.
- An intermediate device, such as a router, queues the arrived messages and processes them one by one.
- If there are many messages, each message will have to wait.

# TRANSMISSION MEDIA

- Sending of data from one device to another is called transmission of data.
- Medium used to transmit the data is called media.
- Transmission of data through medium is called transmission media. So, it is a  pathway that carries the information from sender to receiver.
- We use different types of cables or waves to transmit data.
- Data is transmitted normally in electrical or electromagnetic signals.
- Transmission media are located below the physical layer.
- Computers use signals to represent data.
- Signals are transmitted in from of electromagnetic energy.

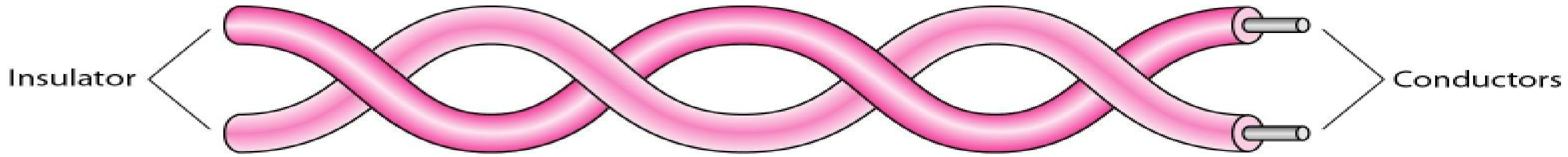


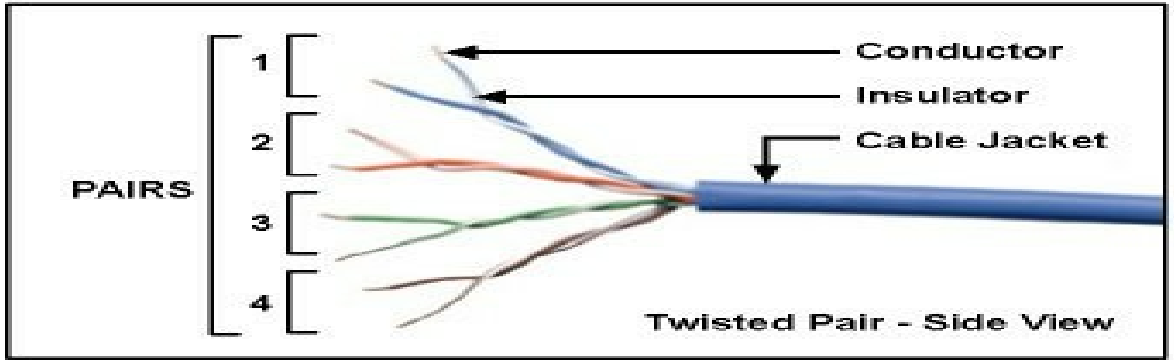
# *Types of transmission media*



# Twisted-pair Cable

- One of the wires carries signal, the other is used only as a ground reference.
- The receiver uses the difference b/w the two levels.
- Twisting increases, the probability that both wires are effected by the noise in the same manner, thus the difference at the receiver remains same.
- Therefore, number of twists per unit length determines the quality of the cable.



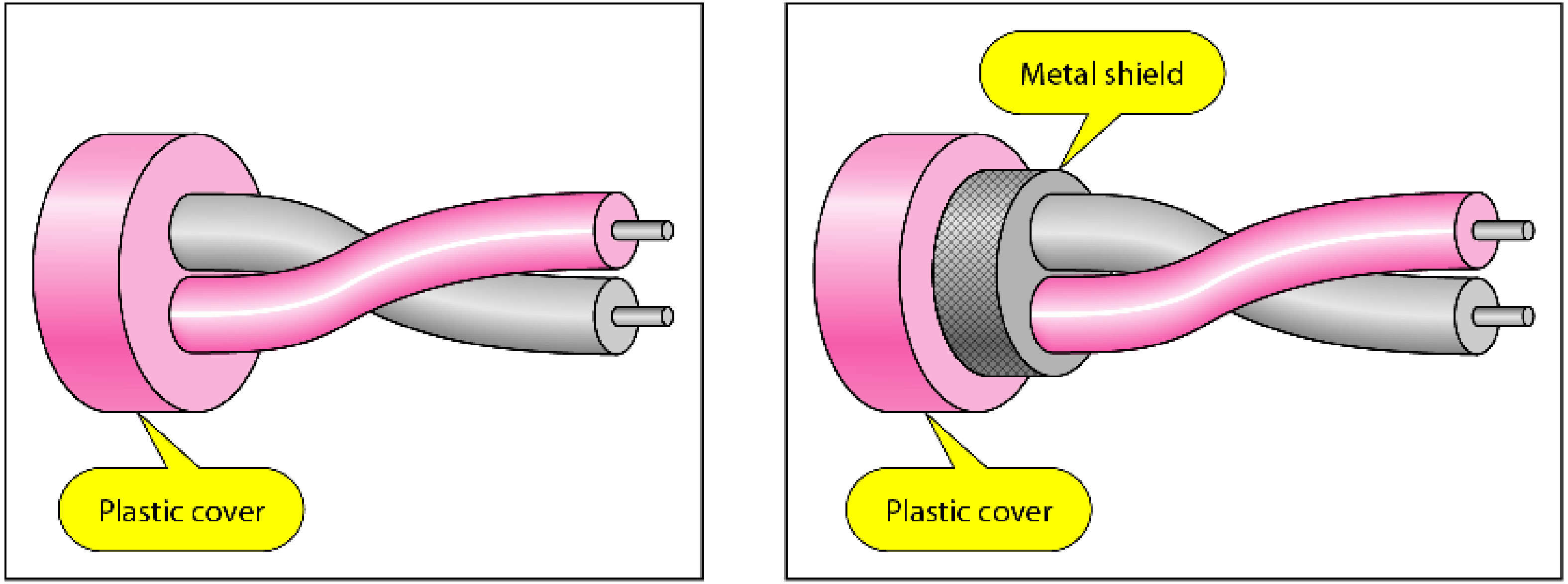



# Twisted Pair - Transmission Characteristics

- analog
  - needs amplifiers every 5km to 6km
- digital
  - can use either analog or digital signals
  - needs a repeater every 2-3km
- limited distance
- limited bandwidth (1MHz)
- limited data rate (100MHz)
- susceptible to interference and noise

# Unshielded Versus Shielded Twisted-Pair Cable

## UTP and STP cables




a. UTP b. STP

# Unshielded Twisted Pair (UTP)

- Ordinary telephone wire
- Cheapest
- Easiest to install
- Suffers from external EM interference
- **Advantages of UTP:**
  - Affordable
  - Most compatible cabling
  - Major networking system
- **Disadvantages of UTP:**
  - Suffers from external Electromagnetic interference

**Applications**:

- Telephone lines connecting subscribers to the central office
- DSL lines
- LAN – 10Base-T and 100Base-T

# Shielded Twisted Pair (STP)

- Metal braid or sheathing that reduces interference
- More expensive
- Harder to handle (thick, heavy)
  - It offers protective sheathing around the copper wire
  - Provides better performance at lower data rates.
  - Not commonly used
  - Installation is easy
  - Distance is only 100-500 meters
  - Special connecters are required.
- **STP Application**
- STP is used in IBM token ring networks.
- Higher transmission rates over longer distances.
- **Advantages of STP:**
  - Shielded
  - Faster than UTP
- **Disadvantages of STP:**
  - More expensive than UTP
  - High attenuation rate

## *Categories of unshielded twisted-pair cables*

| *Category* | *Specification* | *Data Rate (Mbps)* | *Use* |
|---|---|---|---|
| 1 | Unshielded twisted-pair used in telephone | < 0.1 | Telephone |
| 2 | Unshielded twisted-pair originally used in T lines | 2 | T-1 lines |
| 3 | Improved CAT 2 used in LANs | 10 | LANs |
| 4 | Improved CAT 3 used in Token Ring networks | 20 | LANs |
| 5 | Cable wire is normally 24 AWG with a jacket and outside sheath | 100 | LANs |
| 5E | An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference | 125 | LANs |
| 6 | A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate. | 200 | LANs |
| 7 | Sometimes called SSTP (shielded screen twisted-pair). Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk and increases the data rate. | 600 | LANs |

# Twisted Pair - Applications

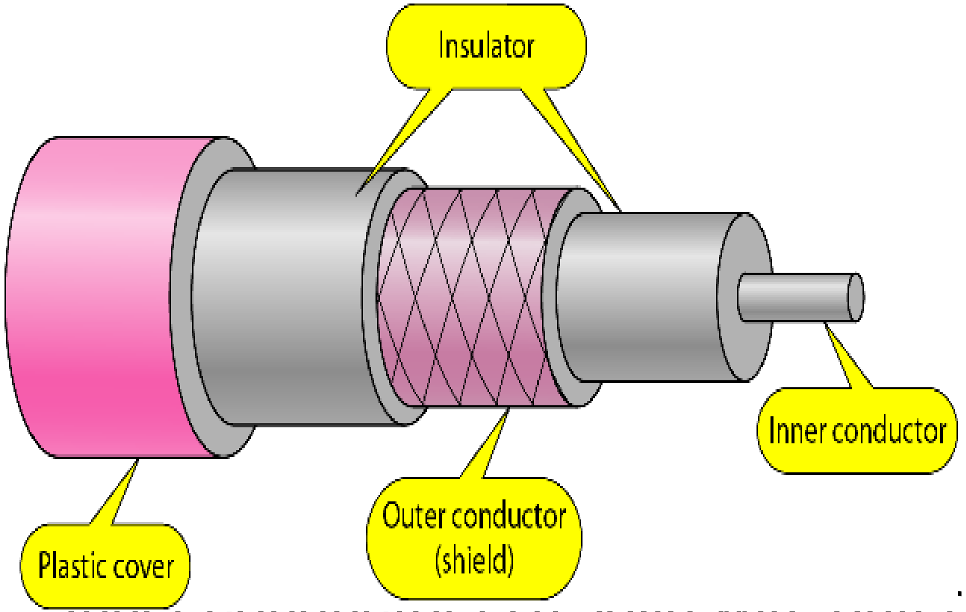
**Applications**

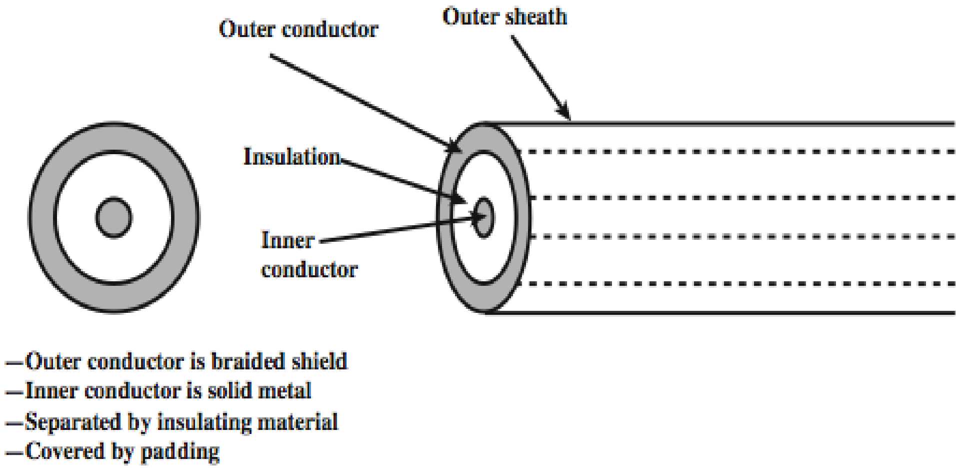
- Most common medium
- Telephone network
- Within buildings
- For local area networks (LAN)

**Pros and Cons**

- Cheap
- Easy to work with
- Low data rate
- Short range

# Guided Media – Coaxial Cable




(b) Coaxial cable

- against noise and a second conductor

# Characteristics

- superior frequency characteristics to TP
- performance limited by attenuation & noise
- analog signals
  - amplifiers every few km
  - closer if higher frequency
  - up to 500MHz
- digital signals
  - repeater every 1km
  - closer for higher data rates

# Applications

- Most versatile medium
- Television distribution
- Long distance telephone transmission
- Can carry 10,000 voice calls simultaneously
- Short distance computer systems links
- Local area networks
- Analog telephone networks
- Cable TV networks
- Traditional Ethernet LAN – 10Base2, 10Base5

**Categories of coaxial ca**

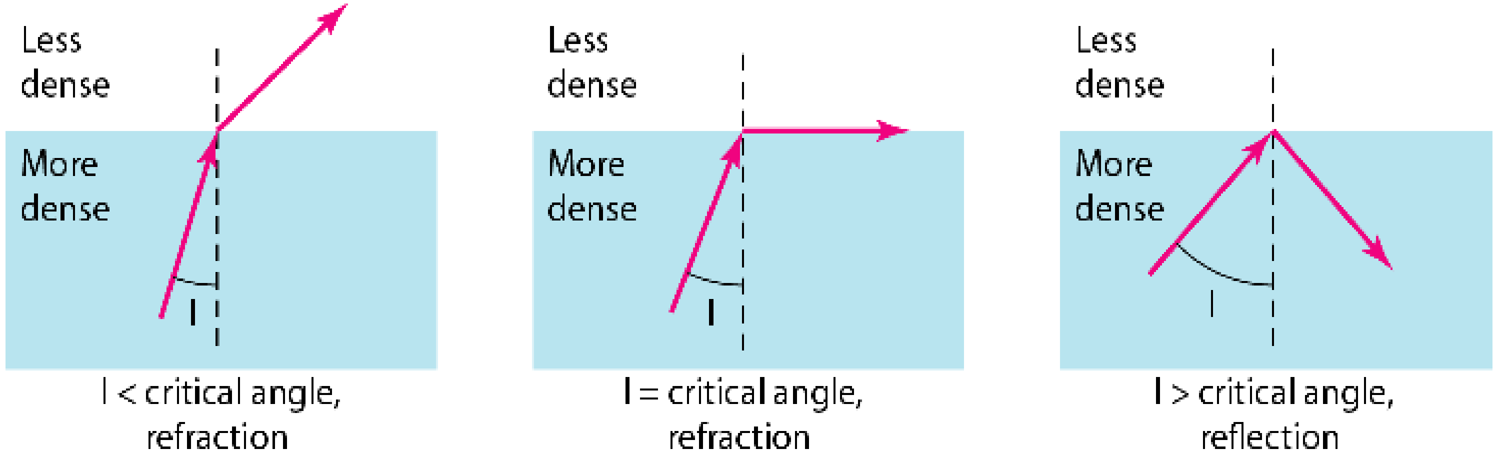
| *Category* | *Impedance* | *Use* |
|---|---|---|
| RG-59 | 75 Ω | Cable TV |
| RG-58 | 50 Ω | Thin Ethernet |
| RG-11 | 50 Ω | Thick Ethernet |

# Guided Media – Fiber-Optic Cable

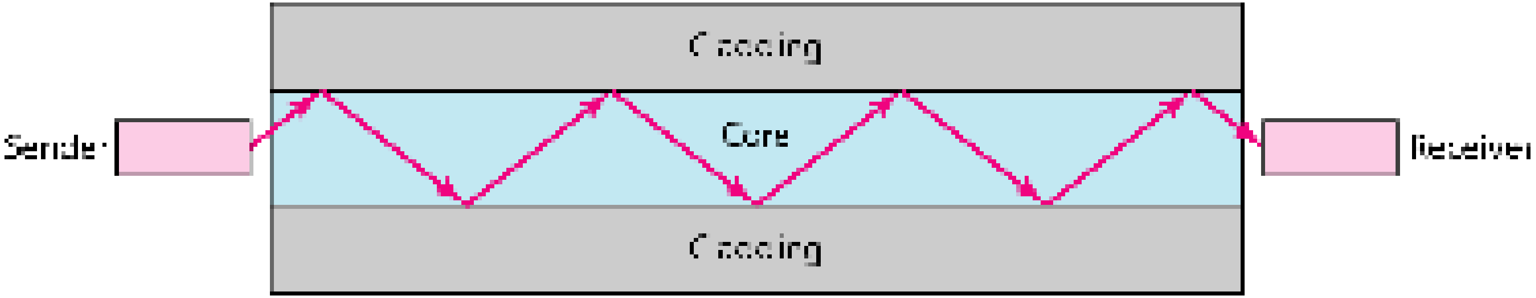
Fiber-optic cable transmit signals in the form of light.

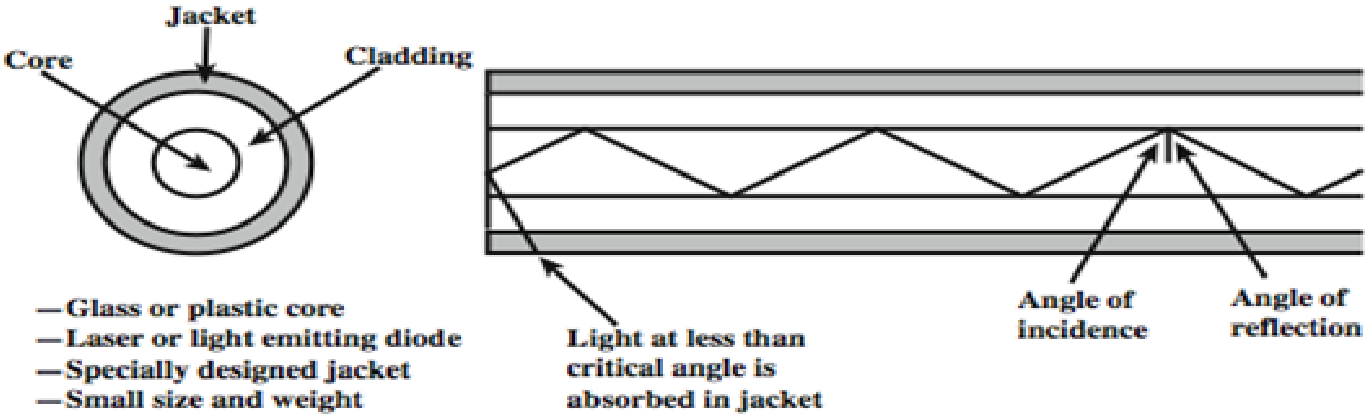
## Bending of light ray

- Angle of Incidence (I): the angle the ray makes with the line perpendicular to the interface between the two substances
- Critical Angle: the angle of incidence which provides an angle of refraction of 90-degrees.



- Uses reflection to guide light through a channel
- Core is of glass or plastic surrounded by Cladding
- Cladding is of less dense glass or plastic



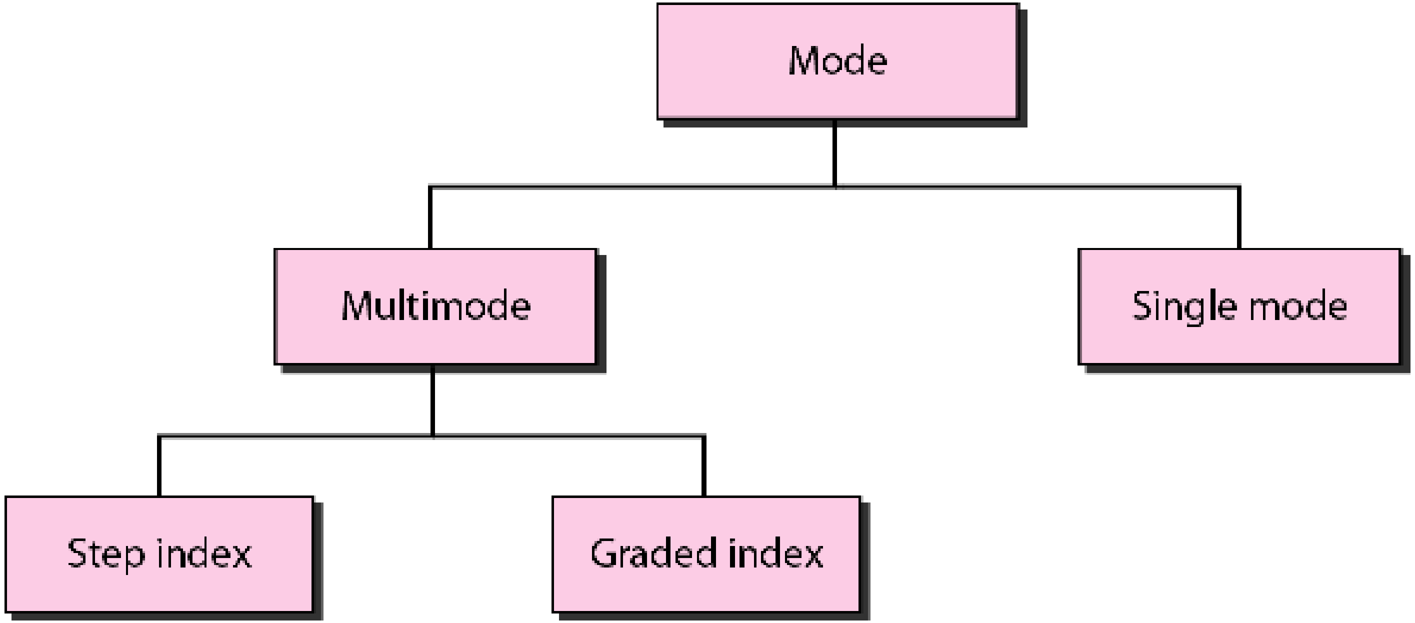

(c) Optical fiber

# Optical Fiber - Transmission Characteristics

- uses total internal reflection to transmit light
    - effectively acts as wave guide for $10^{14}$ to $10^{15}$ Hz
- can use several different light sources
    - Light Emitting Diode (LED)
        - cheaper, wider operating temp range, lasts longer
    - Injection Laser Diode (ILD)
        - more efficient, has greater data rate
- relation of wavelength, type & data rate

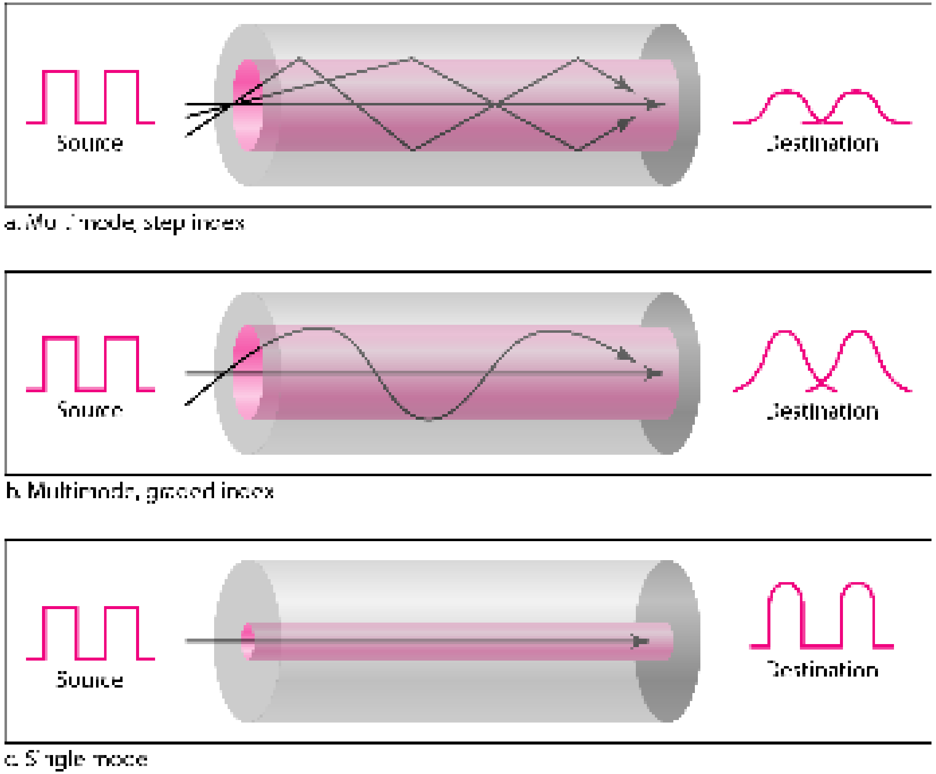
# Guided Media – Fiber-Optic Cable

## Propagation Modes



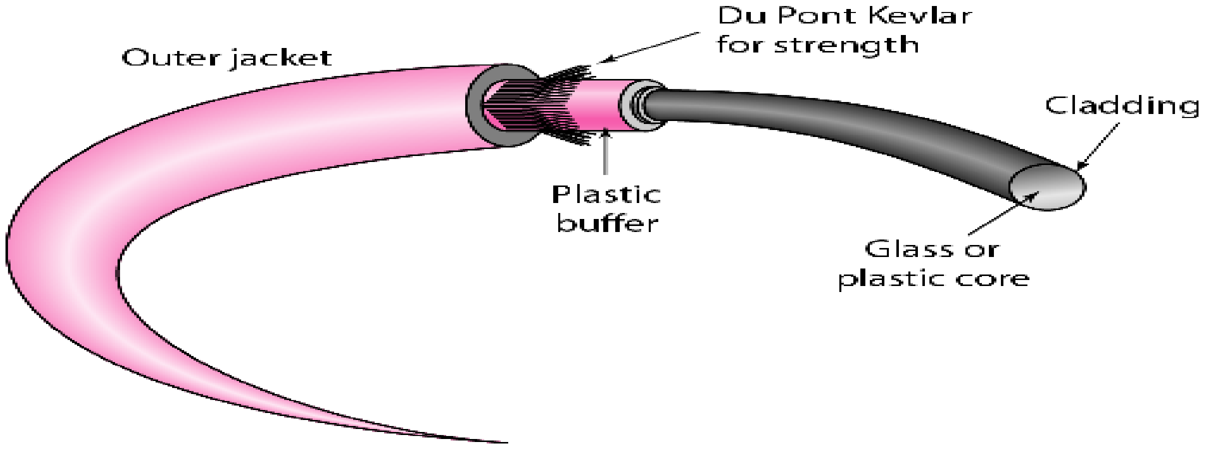
# Guided Media – Fiber-Optic Cable

## Propagation Modes



a. Multimode, step index
b. Multimode, graded index
c. Single mode

# Fiber Construction




**Applications**:

- The fiber optic cable is often found in backbone networks because its bandwidth is cost effective.
- Telecommunications
- Local Area Networks
  100Base-FX network (Fast Ethernet)
  100Base-X
- Cable TV– backbone
- CCTV
- Medical Education

# Fiber Optic Advantages

- Greater capacity (bandwidth of up to 2 Gbps).
- Smaller size and lighter weight.
- Lower attenuation.
- greater repeater spacing
  - 10s of km at least
- More resistance to corrosive materials
- immunity to environmental interference.
- highly secure due to tap difficulty and lack of signal radiation.

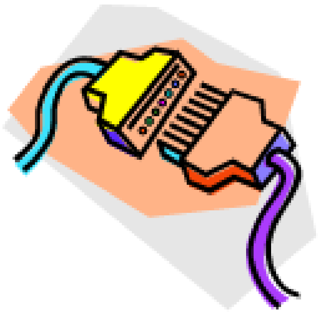
# Fiber Optic Disadvantages

- Installation and maintenance need expertise
- Much more expensive
- requires highly skilled installers
- adding additional nodes is difficult

# Wireless LANs

# LAN/WLAN World

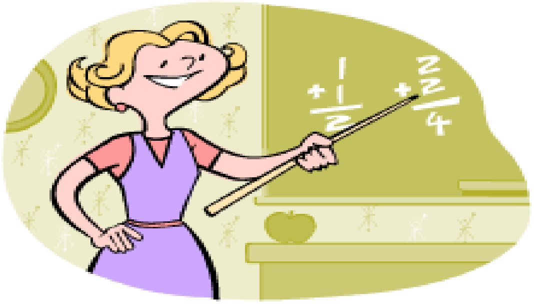
- LANs provide connectivity for interconnecting computing resources at the local levels of an organization
- Wired LANs
  - Limitations because of physical, hard-wired infrastructure



- Wireless LANs provide
  - Flexibility
  - Portability
  - Mobility
  - Ease of Installation

# Wireless LAN Applications

- Medical Professionals
- Education
- Temporary Situations
- Airlines
- Security Staff
- Emergency Centers



# IEEE 802.11 Wireless LAN Standard

- In response to lacking standards, IEEE developed the first internationally recognized wireless LAN standard – IEEE 802.11
- IEEE published 802.11 in 1997, after seven years of work
- Scope of IEEE 802.11 is limited to Physical and Data Link Layers.

# Benefits of 802.11 Standard

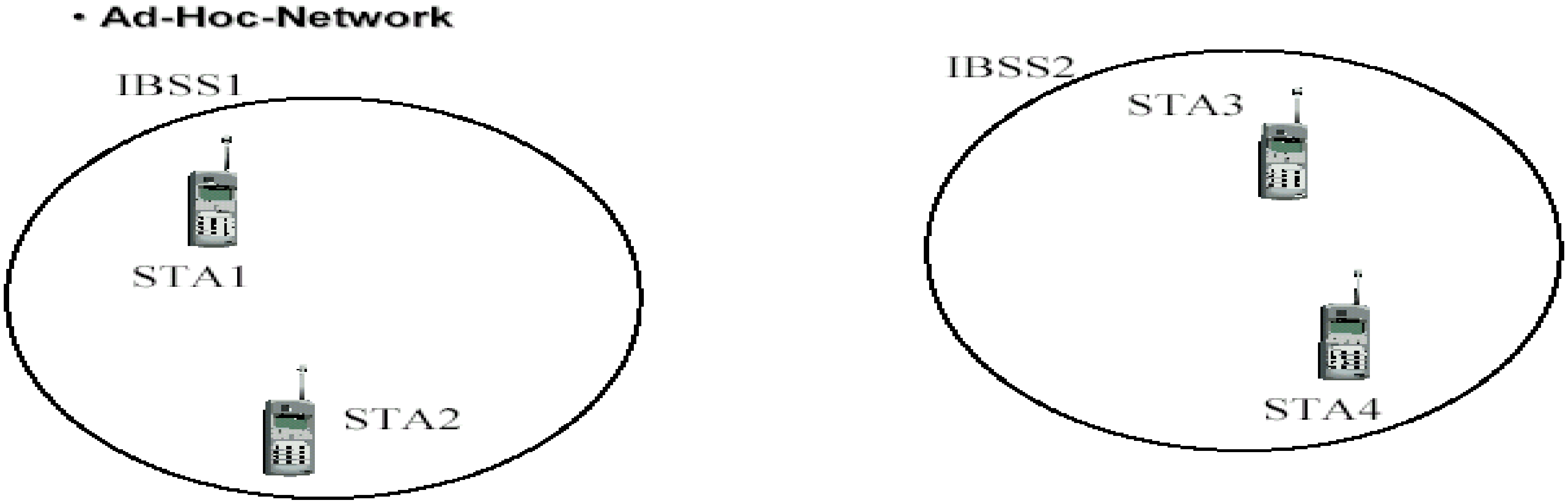
- Appliance Interoperability
- Fast Product Development
- Stable Future Migration
- Price Reductions
- The 802.11 standard takes into account the following significant differences between wireless and wired LANs:
  - Power Management
  - Security
  - Bandwidth

# IEEE 802.11 Terminology

- Access point (AP): A station that provides access to the DS.
- Basic service set :

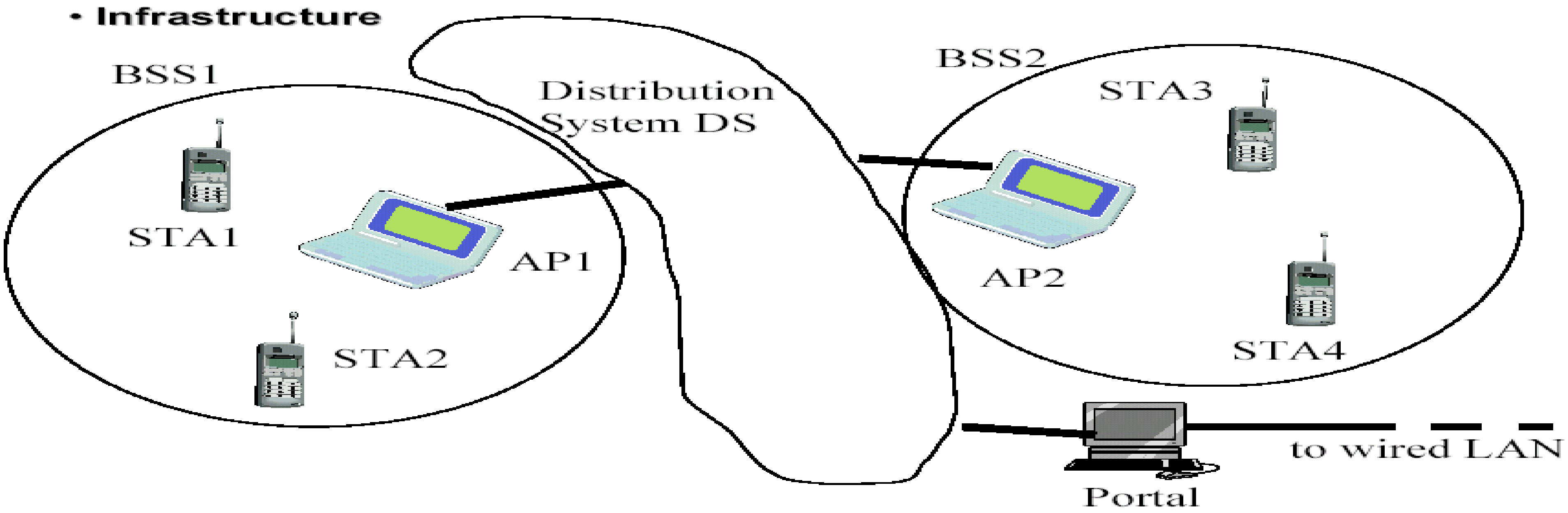
  a set is of stationary or mobile wireless stations and an optional central base station, known as the access point (AP).
- Distribution system (DS): A system used to interconnect a set of BSSs to create an ESS.
  - DS is implementation-independent. It can be a wired 802.3 Ethernet LAN, 802.4 token bus, 802.5 token ring or another 802.11 medium.
- Extended service set (ESS):Two or more BSS interconnected by DS
  - 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.

# WLAN Topology
# Ad-Hoc Network



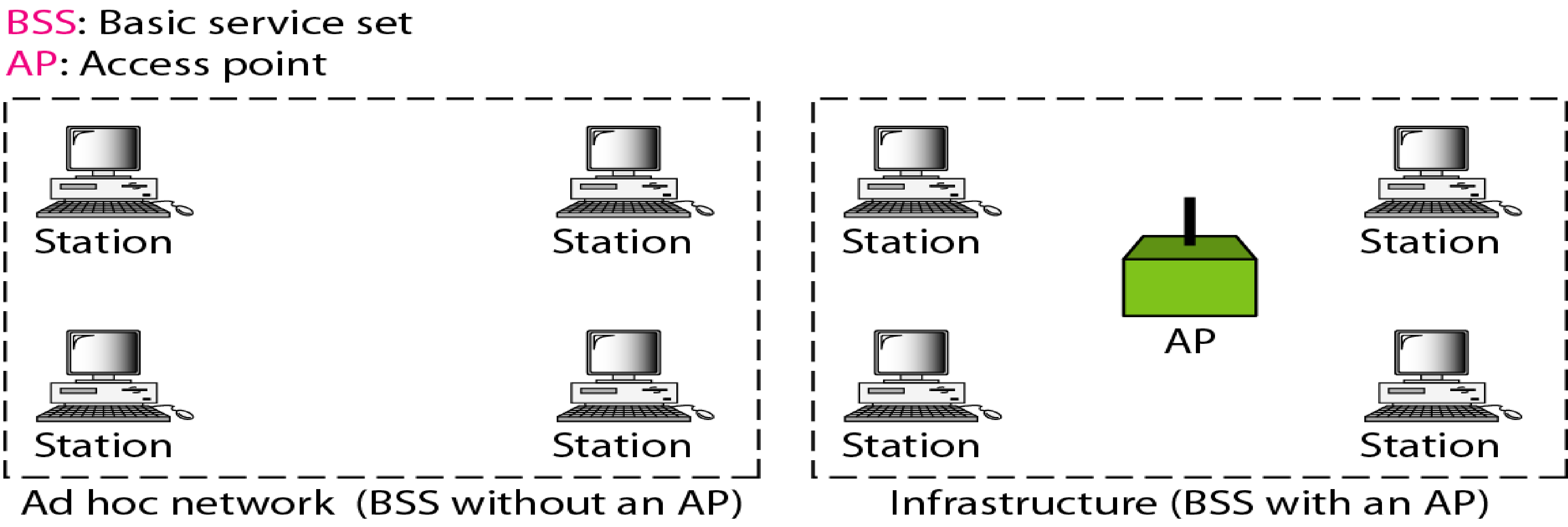

The BSS without an AP is a stand-alone network and cannot send data to other BSSs.
they can locate one another and agree to be part of a BSS.

# WLAN Topology
# Infrastructure



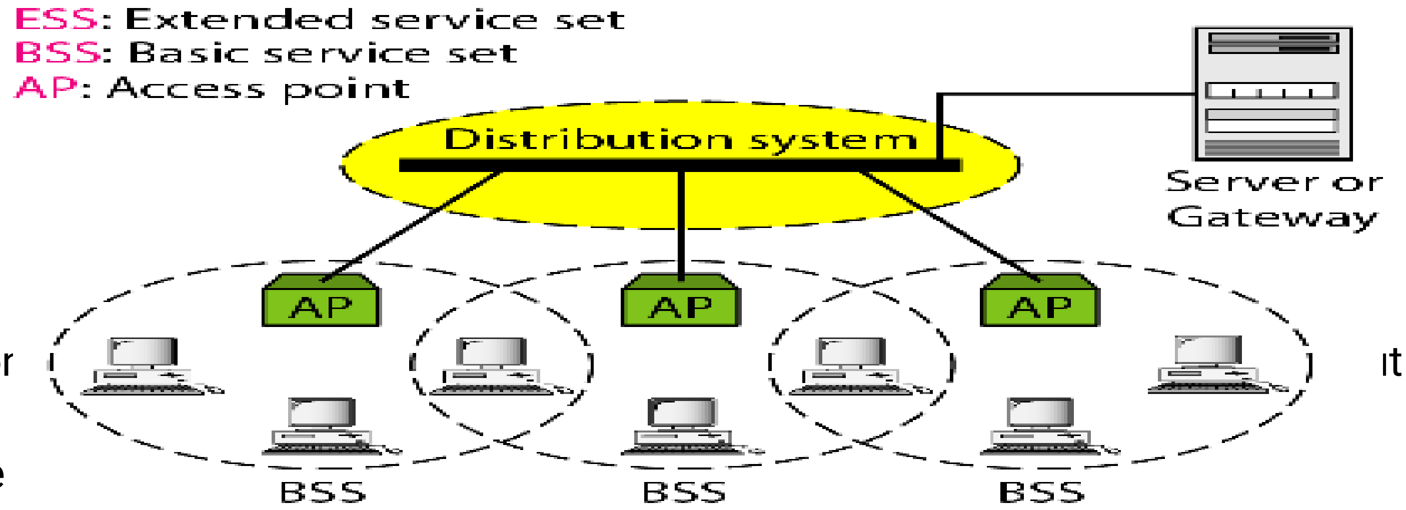

EX: cellular network if we consider each BSS to be a cell and each AP to be a base station.

*Basic service sets (BSSs)*



# Distribution of Messages

- Distribution service (DS)
  - Used to exchange MAC frames from station in one BSS to station in another BSS




- When BSSs are cor ... ıt the use of an AP.
- Note that a mobile

# *Station Types*

IEEE 802.11 defines three types of stations based on their mobility in a wireless LAN:

- no-transition

  A station is either stationary (not moving) or moving only inside a BSS

- BSS-transition

  station can move from one BSS to another, but the movement is confined inside one ESS.

- and ESS-transition mobility.

  A station can move from one ESS to another

# IEEE 802.11 Medium Access Control

- MAC layer covers three functional areas:
  - Reliable data delivery
  - Access control
  - Security

# MAC Sublayer

IEEE 802.11 defines two MAC sublayers:

- the distributed coordination function (DCF).
- and point coordination function (PCF).

# MAC Sublayer

- Distributed Coordination Function (DCF)
  - Distributed access protocol
  - Contention-Based
  - Makes use of CSMA/CA rather than CSMA/CD for the following reasons:
  - Wireless LANs cannot implement *CSMAfCD for three reasons:*

1. For collision detection a station must be able to send data and receive collision signals at the same time( costly stations and increased bandwidth requirements).

2. Collision may not be detected because of the hidden station problem.

3. The distance between stations may result in Signal fading which prevent a station at one end from hearing a collision at the other end.

  - Suited for ad hoc network and ordinary asynchronous traffic

# *CSMAICA* in wireless LAN

1. station senses the medium (checking the energy level at carrier frequency):

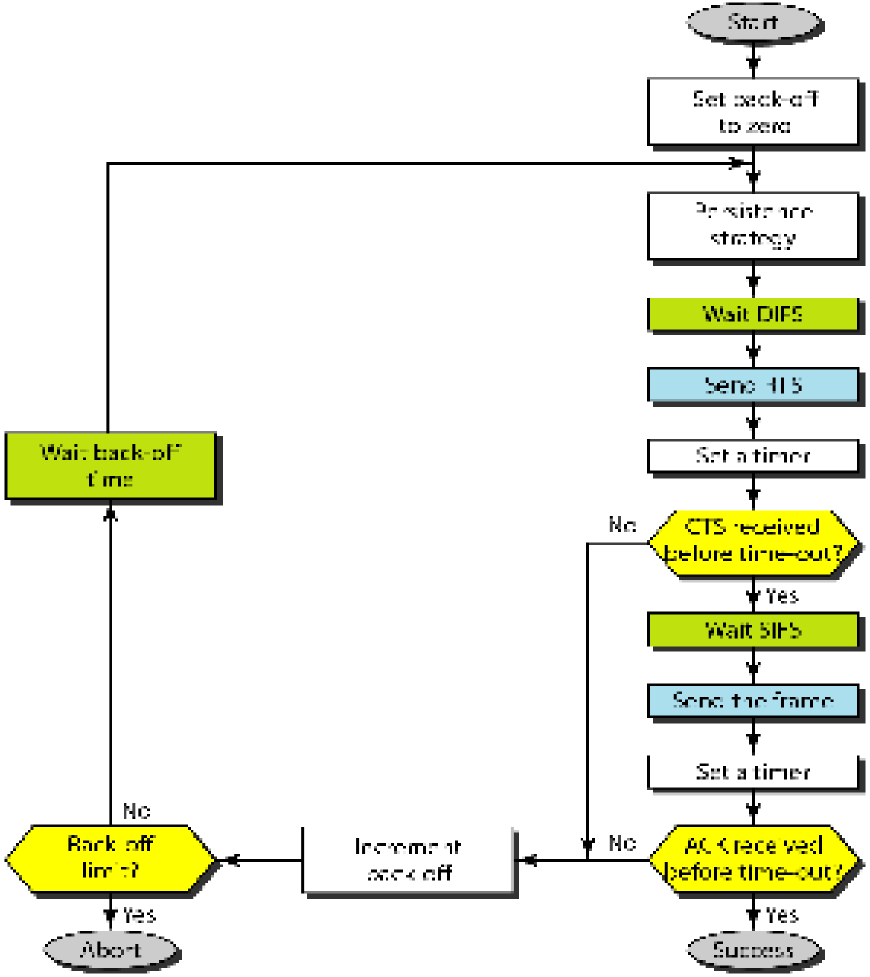
   a. uses a persistence strategy with back-off until the channel is idle.

   b. if idle channel , waits for of time called distributed interframe space (DIFS); then sends a request to send (RTS) Control frame .

2. the destination station receive RTS and waite for short interframe space (SIFS), than send clear to send (CTS) control frame,(ready to receive data)

3. The source station sends data after waiting an amount of time equal to SIFS.

4. The destination station, after waiting for time equal to SIFS, sends an acknowledgment



# *collision avoidance CSMAICA*

- network allocation vector (NAV) used to avoid collision.
  - RTS frame includes the duration of time that it needs to occupy the channel.
  - stations affected by this transmission create a timer called (NAV)
  - the network allocation vector (NAV) shows the time must pass before these stations allowed to check the channel for idleness.
- there is no mechanism for collision detection, if the sender has not received a CTS frame from the receiver, assumes there has been a collision ,the sender tries again.

# MAC Sublayer

- Point Coordination Function (PCF)
  - an optional access method on top of DCF
  - Implemented in an infrastructure network (not in an ad hoc network).
  - Contention-Free
  - mostly for time-sensitive transmission services like voice or multimedia.
  - The AP performs polling stations one after another, sending any data they have to the AP.

# MAC Sublayer

- To give priority to PCF over DCF, another set of interframe spaces has been defined:

❖ SIFS - Short Inter Frame Spacing

  ❖ Used for immediate response actions e.g ACK, CTS

❖ PIFS - Point Inter Frame Spacing

  ❖ PIFS (PCF IFS) is shorter than the DIFS.

- if, at the same time, a station wants to use only DCF and an AP wants to use PCF, the AP has priority.

# MAC Sublayer

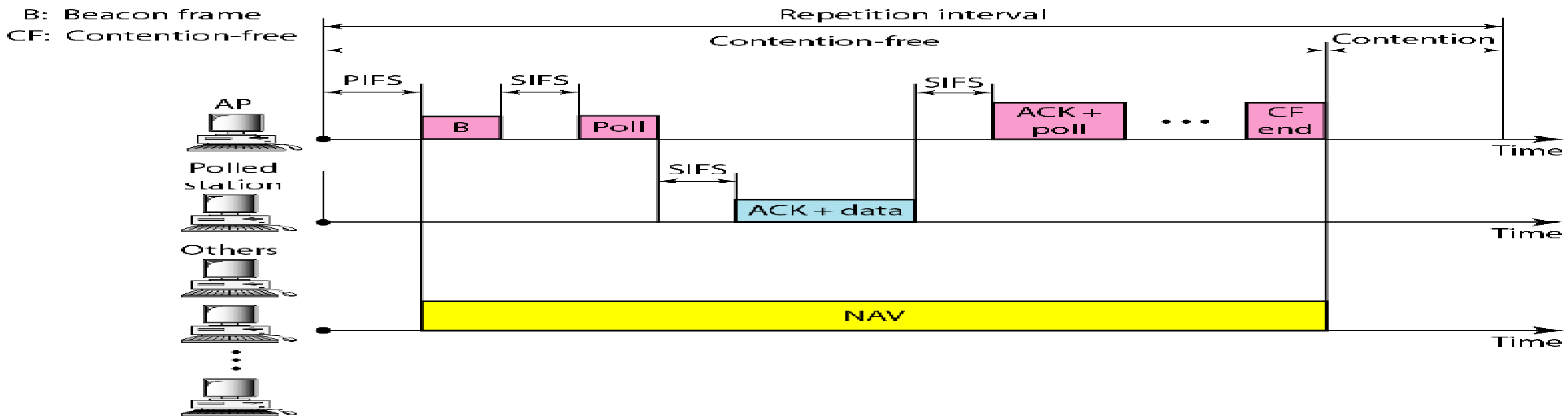
- Repetition interval has been designed to cover both contention-free (PCF) and contention-based (DCF) traffic to allow DCF accessing the media.

- The repetition interval starts with control frame, called a beacon frame.

- When the stations hear the beacon frame, they start their NAV for the duration of the contention-free period of the repetition interval.

# MAC Sublayer

- repetition interval used by the PC (point controller) stations.
- At the end of the contention-free period, the PC sends a CF end (contention-free end) frame to allow the contention-based stations to use the medium.

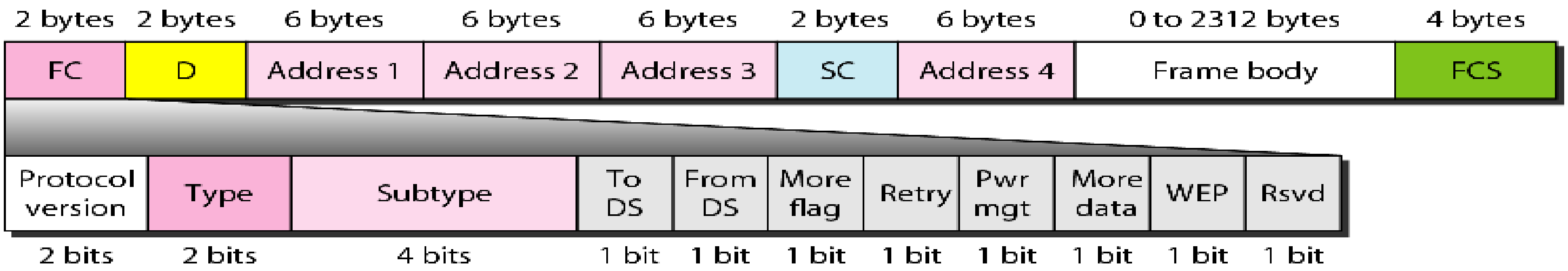


# Fragmentation

- The wireless environment is very noisy.
- corrupt frame has to be retransmitted.
- Fragmentation is recommended.
  - the division of a large frame into smaller ones.
- It is more efficient to resend a small frame than a large one.

# MAC Frame Format

❖ The MAC layer frame consists of nine fields



# MAC Frame Format

- Frame control : 2 bytes long and defines the type of frame and some control information.

- D: In all frame types except one, this field defines the duration of the transmission that is used to set the value of NAV. In one control frame, this field defines the frame ID.

- Addresses: There are four address fields, each 6 bytes long. The meaning of each address field depends on the value of the *To DS and From DS subfields* .

# MAC Layer Frames

- Sequence control: This field defines the sequence number of the frame to be used in flow control.
- Frame body: This field can be between 0 and 2312 bytes, it contains information based on the type and the subtype defined in the FC field.
- FCS: The FCS field is 4 bytes long and contains a CRC-32 error detection sequence.

# Frame Types

- IEEE 802.11 has three categories of frames:
  - management frames:

    used for the initial communication between stations and access points.
  - control frames.

    used for accessing the channel and acknowledging frames


RTS


CTS or ACK

# Frame Types

| *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 |

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

# Addressing Mechanism

- IEEE 802.11 addressing mechanism specifies four cases defined by the value of the two flags in the FC field, *To DS and From DS.*

# Addressing Mechanism

- Case 1: 00, To DS = 0 and From DS = 0
  - This means that the frame is not going to a distribution system and is not coming from a distribution system.
  - The ACK frame should be sent to the original sender.

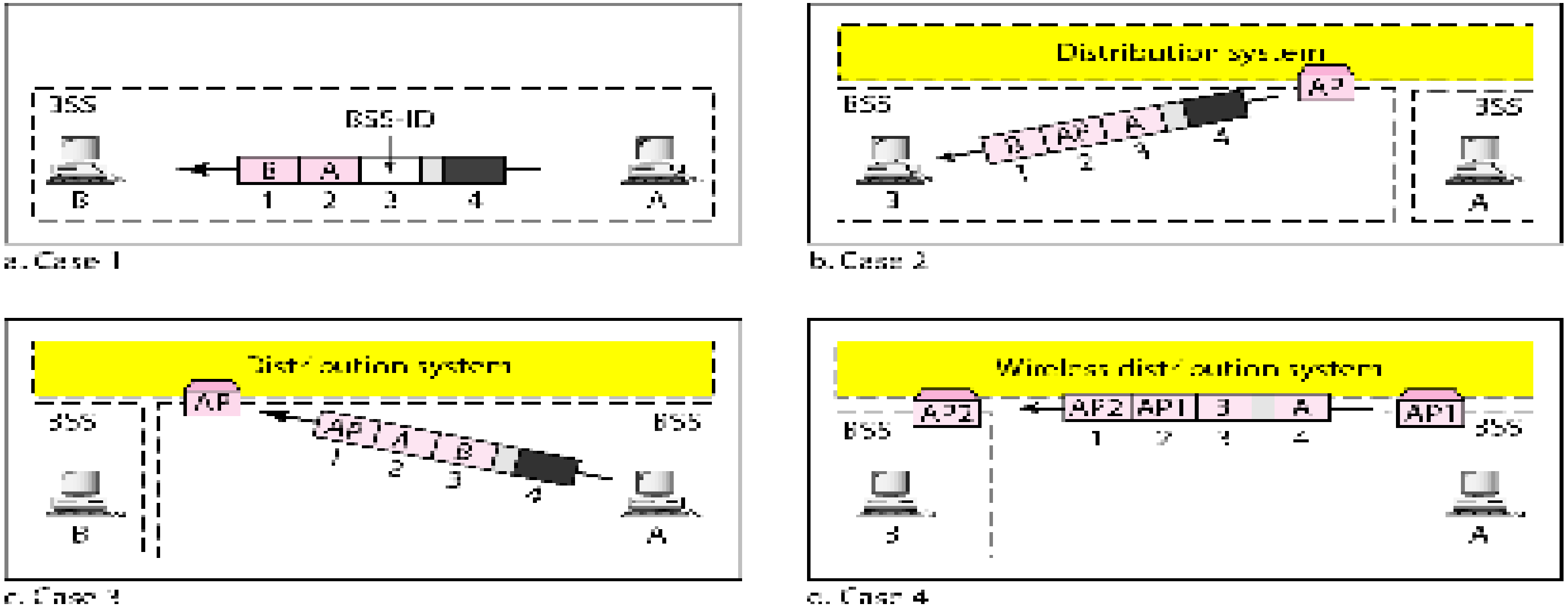
- Case 2: 01, In this case, To DS = 0 and From DS = 1.
  - This means that the frame is coming from a distribution system (coming from an AP ).
  - The ACK should be sent to the AP. The addresses are as address 3 contains the original sender of the frame (in another BSS).

# Addressing Mechanism

- Case 3: 10, To DS =1 and From DS =O.
  - This means that the frame is going to a distribution system ( frame is going from a station to an AP)
  - The ACK is sent to the original station. address 3 contains the final destination of the frame (in another BSS).
- o Case 4:11, To DS =1 and From DS =1.
  - This is the case in which the distribution the frame is going from one AP to another AP in a wireless distribution system.
  - We do not need to define addresses if the distribution system is a wired LAN because the frame in these cases has the format of a wired LAN frame (Ethernet, for example).
  - Here, we need four addresses to define the original sender, the final destination, and two intermediate APs.

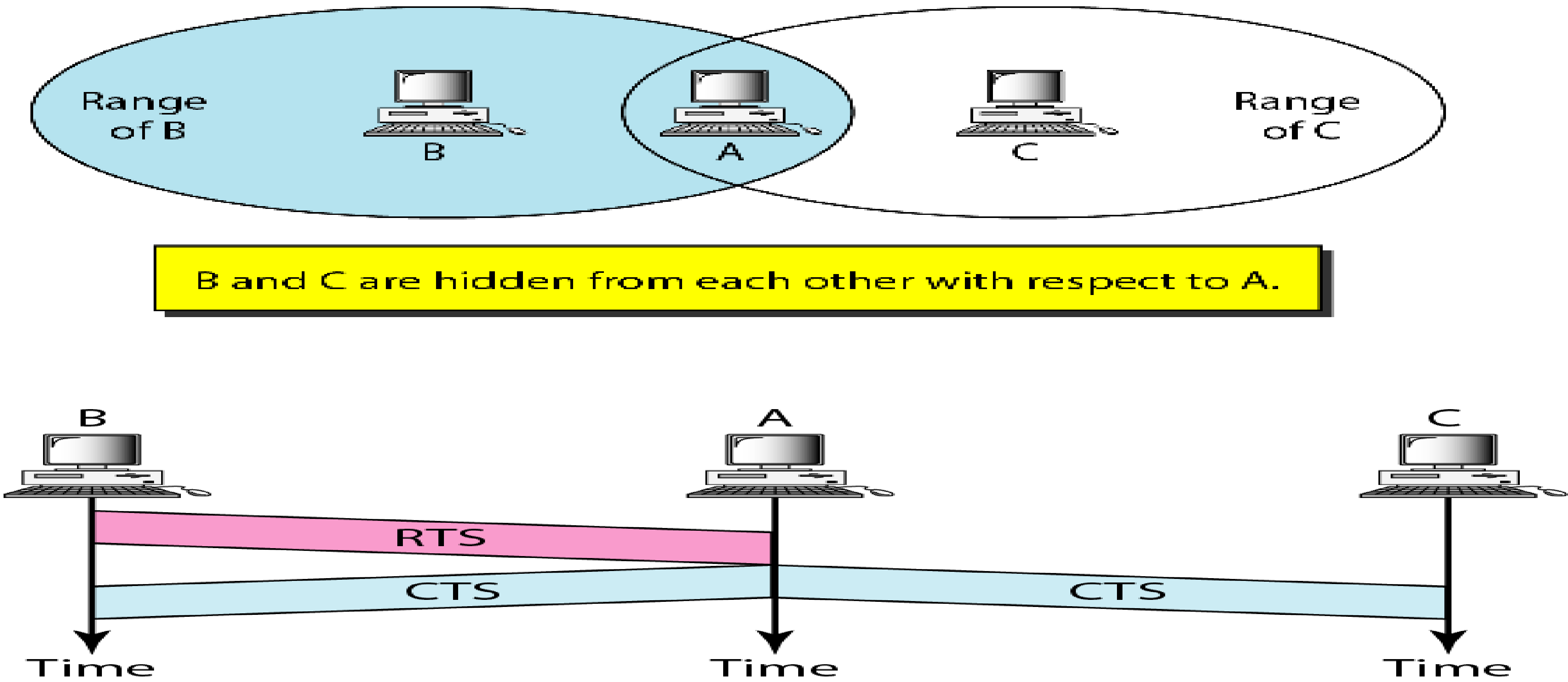
# Addressing Mechanism

| 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 |

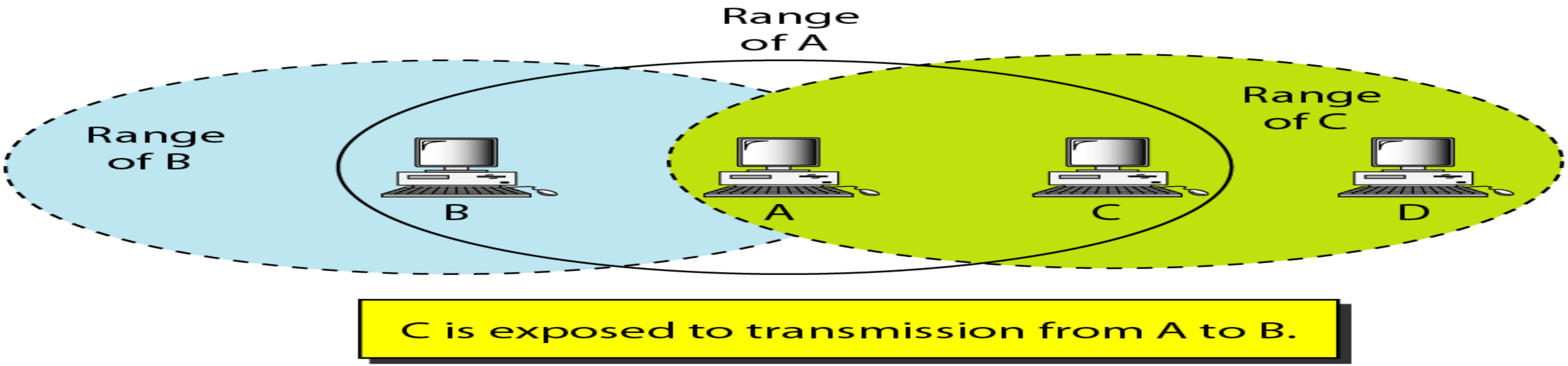


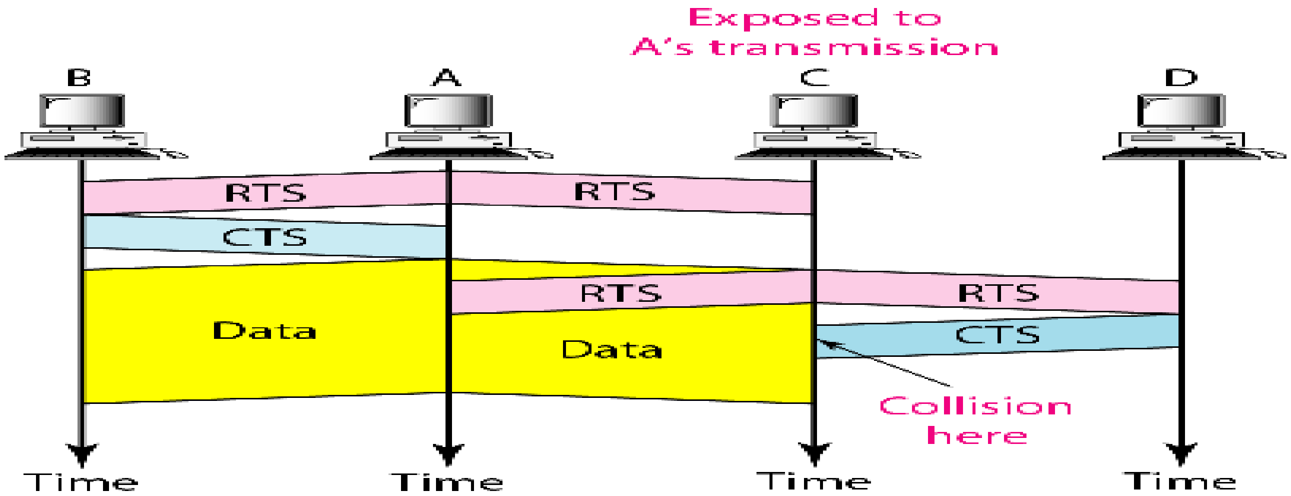

a. Case 1
b. Case 2
c. Case 3
d. Case 4

# Hidden Station Problem



# Exposed Station Problems



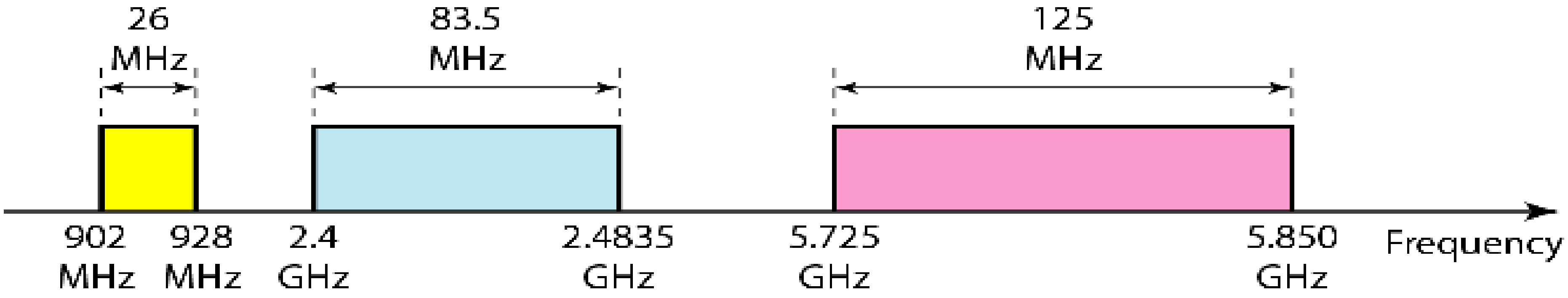



# Physical Media Defined by Original 802.11 Standard

| *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 |

# Industrial-Scientific-Medical (ISM) band

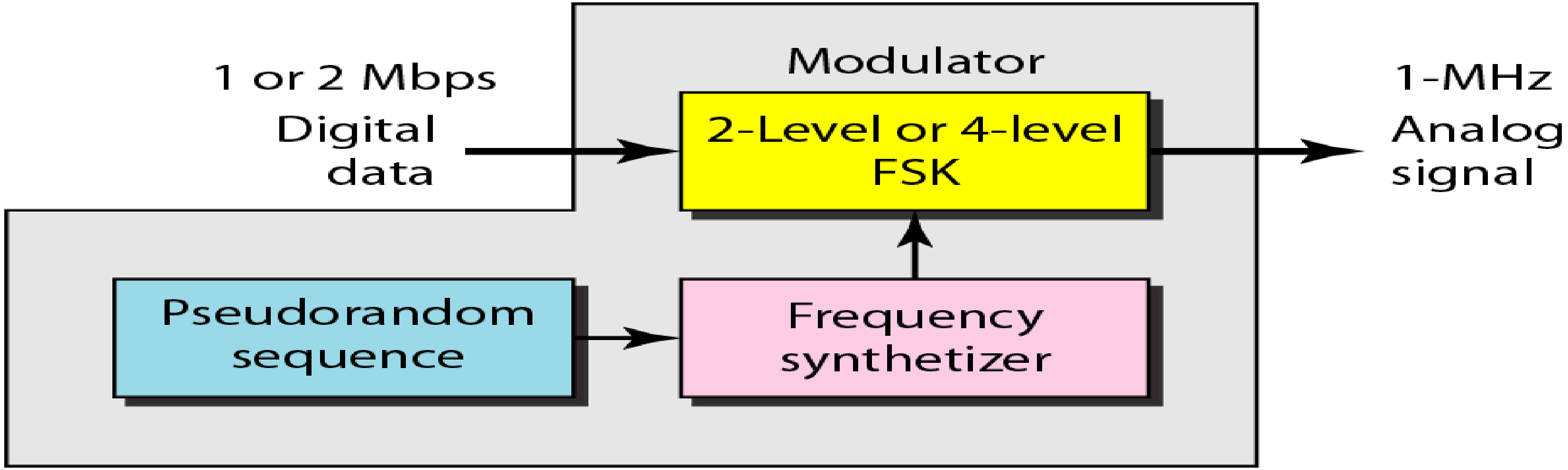
- The 2.4GHz ISM band is divided into 79 bands of 1MHz



# Physical layer of IEEE 802.11 FHSS

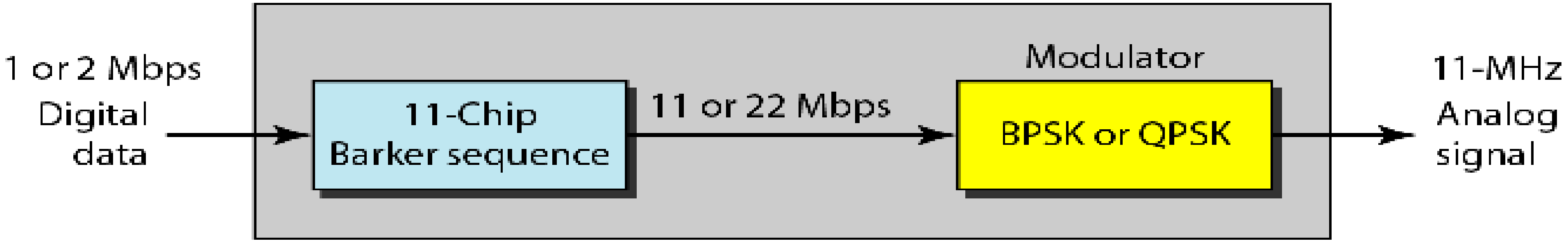
- In Frequency Hopping Spread Spectrum (FHSS) the sender sends on one carrier frequency for a short amount of time, then hops to another carrier frequency for the same amount of time, and so on. After N hop-pings, the cycle is repeated.

- Spreading makes it difficult for unauthorized persons to make sense of the transmitted data



# Physical layer of IEEE 802.11 DSSS

- In Direct Sequence Spread Spectrum (DSSS) each bit sent by the sender is replaced by a sequence of bits called a chip code.
- To avoid buffering, the time needed to send one chip code must be the same as the time needed to send one original bit.
- DSSS is implemented at the physical layer and uses a 2.4GHz ISM band



# Physical layer of IEEE 802.11a OFDM

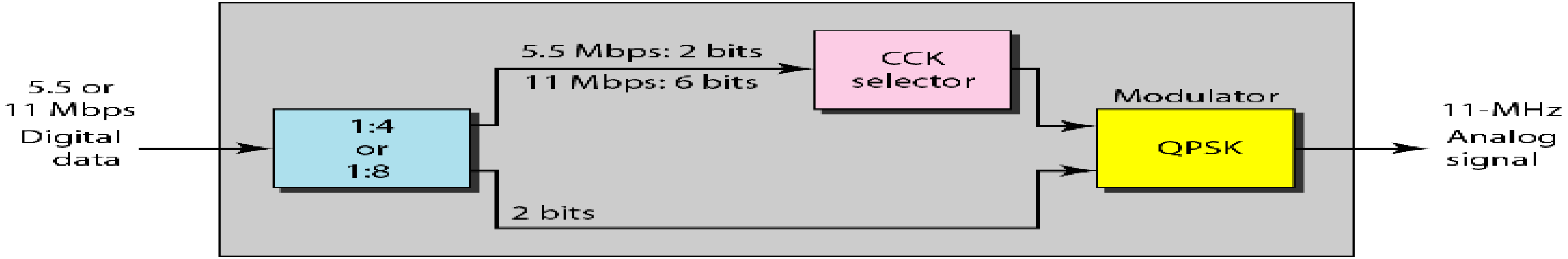
- IEEE 802.11a describes the orthogonal frequency-division multiplexing (OFDM) method for signal generation in the 5GHz ISM band

- OFDM is the same as FDM with one major difference:
    - All the subbands are used by one source at a given time
    - Sources conend with one another at the data link layer for access

- OFDM uses PSK (18Mbps) and QAM (54Mbps) for modulation

# Physical layer of IEEE 802.11b

- IEEE 802.11b describes the high-rate DSSS method for signal generation at 2.4GHz ISM band.
- This is similar to DSSS except for the encoding method, which is called **complementary code keying (CCK)**
- CCK encodes 4 or 8 bits to one CCK symbol



# Physical Media Defined by Original 802.11 Standard

- IEEE 802.11 FHSS(Frequency-hopping spread spectrum)
  - Operating in 2.4 GHz ISM band
  - Lower cost, power consumption
  - Most tolerant to signal interference
- IEEE 802.11 DSSS (Direct-sequence spread spectrum)
  - Operating in 2.4 GHz ISM band
  - Supports higher data rates
  - More range than FH or IR physical layers
- IEEE 802.11 Infrared
  - Lowest cost
  - Lowest range compared to spread spectrum
  - Doesn’t penetrate walls, so no eavesdropping

# IEEE 802.11a , IEEE 802.11b and IEEE 802.11g

- IEEE 802.11a
  - Makes use of 5-GHz band
  - Provides rates of 6, 9 , 12, 18, 24, 36, 48, 54 Mbps
  - Uses orthogonal frequency division multiplexing (OFDM)
- IEEE 802.11b
  - 802.11b operates in 2.4 GHz band
  - Provides data rates of 5.5 and 11 Mbps
  - Complementary code keying (CCK) modulation scheme
- IEEE 802.11g
  - 802.11g operates in 2.4 GHz band
  - Provides data rates of 22 and 54 Mbps
  - Uses orthogonal frequency division multiplexing (OFDM)

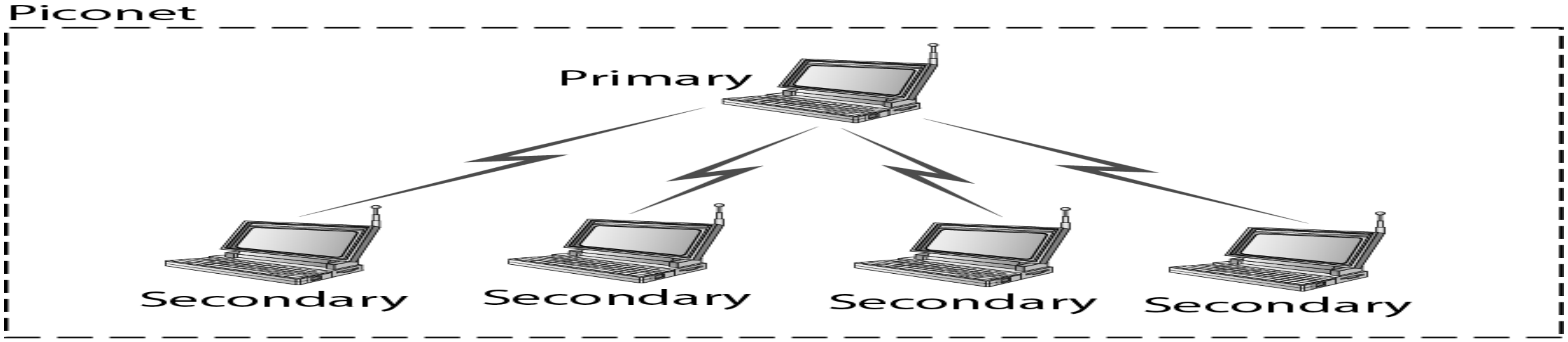
# BLUETOOTH

- 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.

- **Bluetooth defines two types of networks: piconet and scatternet.**

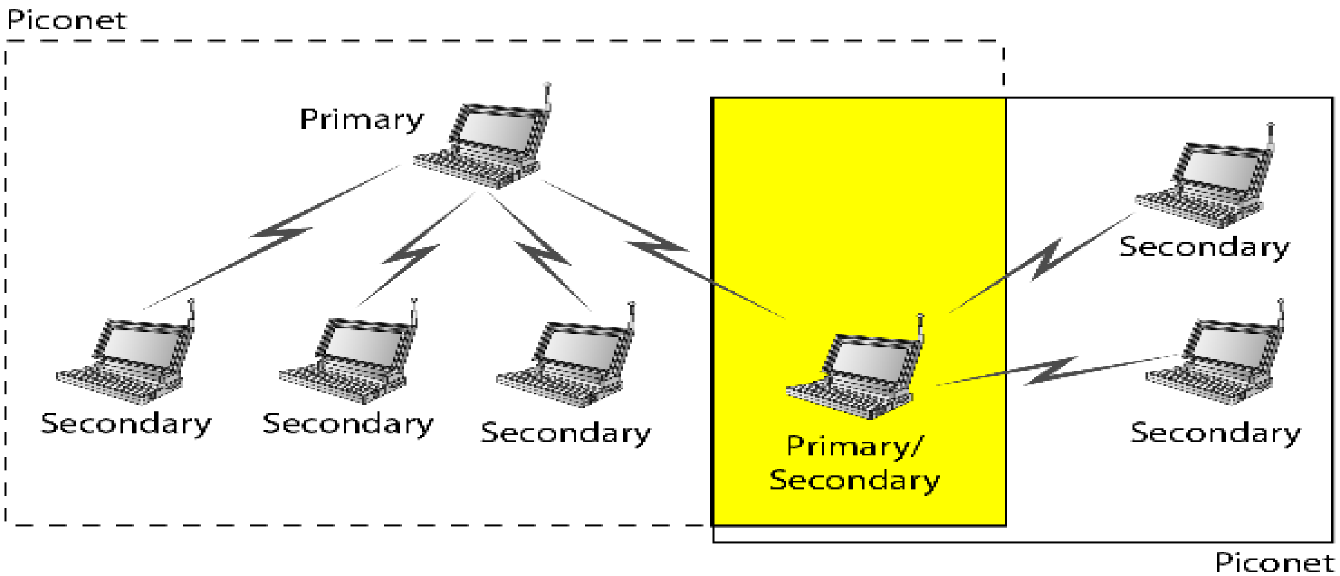
# Piconet

- A Bluetooth network is called a piconet, or a small net.
- It can have up to eight stations, one of which is called the master; the rest are called slaves.
- Maximum of seven slaves. Only one master.
- Slaves synchronize their clocks and hopping sequence with the master.
- But an additional eight slaves can stay in parked state, which means they can be synchronized with the master but cannot take part in communication until it is moved from the parked state.



# Scatternet

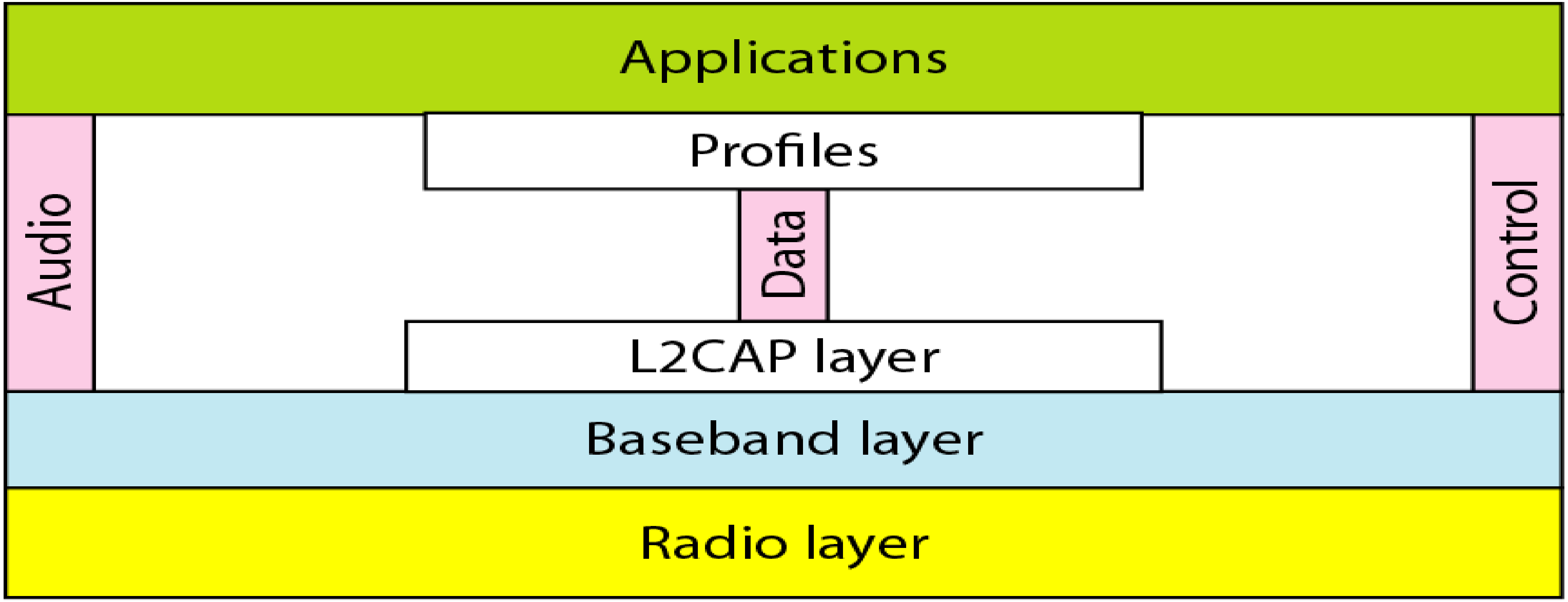
- Piconets can be combined to form what is called a scatternet.
- A slave station in one piconet can become the master in another piconet.
- Bluetooth devices has a built-in short-range radio transmitter.



# Bluetooth layers

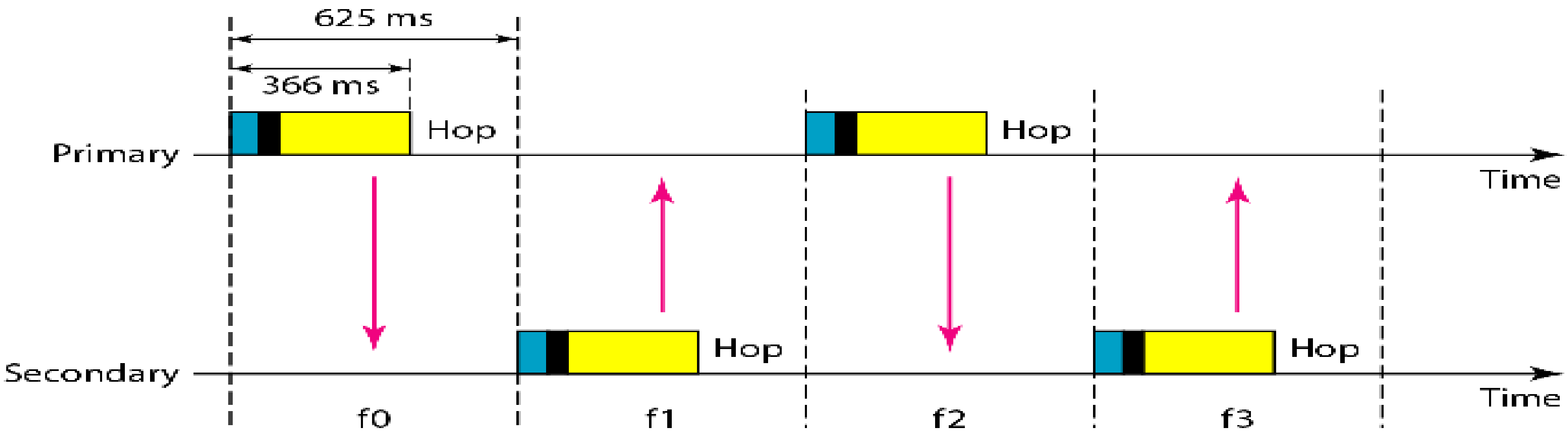
- Radio Layer: Roughly equivalent to physical layer of the Internet model. Physical links can be synchronous or asynchronous.
  - Uses Frequency-hopping spread spectrum [Changing frequency of usage]. Changes it modulation frequency 1600 times per second.
  - Uses frequency shift keying (FSK )with Gaussian bandwidth filtering to transform bits to a signal.
- Baseband layer: Roughly equivalent to MAC sublayer in LANs. Access is using Time Division (Time slots).
  - Length of time slot = dwell time = 625 microsec. So, during one frequency, a sender sends a frame to a slave, or a slave sends a frame to the master.
- Time division duplexing TDMA (TDD-TDMA) is a kind of half-duplex communication in which the slave and receiver send and receive data, but not at the same time (half-duplex). However, the communication for each direction uses different hops, like walkie-talkies.

# Bluetooth layers



# Single-secondary communication

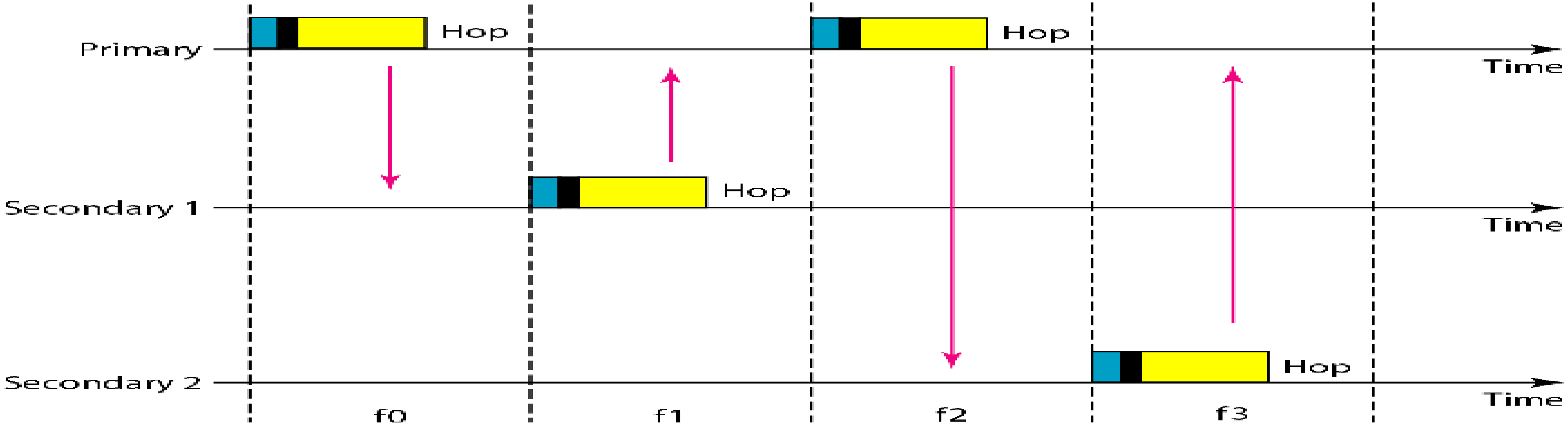
- **Also called Single-slave communication**
  - Master uses even-numbered slots
  - Slave uses odd-numbered slots



# Multiple-secondary communication

## Also called Multiple-slave communication

- Master uses even-numbered slots
- Slave sends in the next odd-numbered slot if the packet in the previous slot was addressed to it.



# Physical Links

- Synchronous connection-oriented (SCO)
  - Latency is important than integrity.
  - Transmission using slots.
  - No retransmission.
- Asynchronous connectionless link (ACL)
  - Integrity is important than latency.
  - Does like multiple-slave communication.
  - Retransmission is done.
- L2CAP (Logical Link Control and Adaptation Protocol)
  - Equivalent to LLC sublayer in LANs.
  - Used for data exchange on ACL Link. SCO channels do not use L2CAP.
  - Frame format has 16-bit length [Size of data coming from upper layer in bytes], channel ID, data and control.
  - Can do Multiplexing, segmentation and Reassembly, QoS [with no QoS, best-effort delivery is provided] and Group mangement [Can do like multicast group, using some kind of logical addresses].

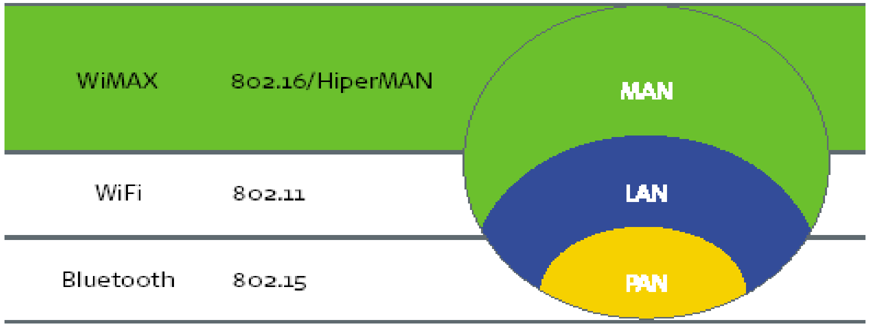
# L2CAP data packet format

# SUMMARY

- The wireless LAN access method is CSMA/CA.
- The network allocation vector (NAV) is a timer for collision avoidance.
- The MAC layer frame has nine fields. The addressing mechanism can include up to four addresses.
- Wireless LANs use management frames, control frames, and data frames.
- Bluetooth is a wireless LAN technology that connects devices (called gadgets) in a small area.
- A Bluetooth network is called a piconet. Multiple piconets form a network called a scatternet.
- The Bluetooth radio layer performs functions similar to those in the Internet model's physcial layer.
- The Bluetooth baseband layer performs functions similar to those in the Internet model's MAC sublayer.
- A Bluetooth network consists of one master device and up to seven slave devices.
- •A Bluetooth frame consists of data as well as hopping and control mechanisms. A frame is one, three, or five slots in length with each slot equal to 625 μs.

# Wireless networks

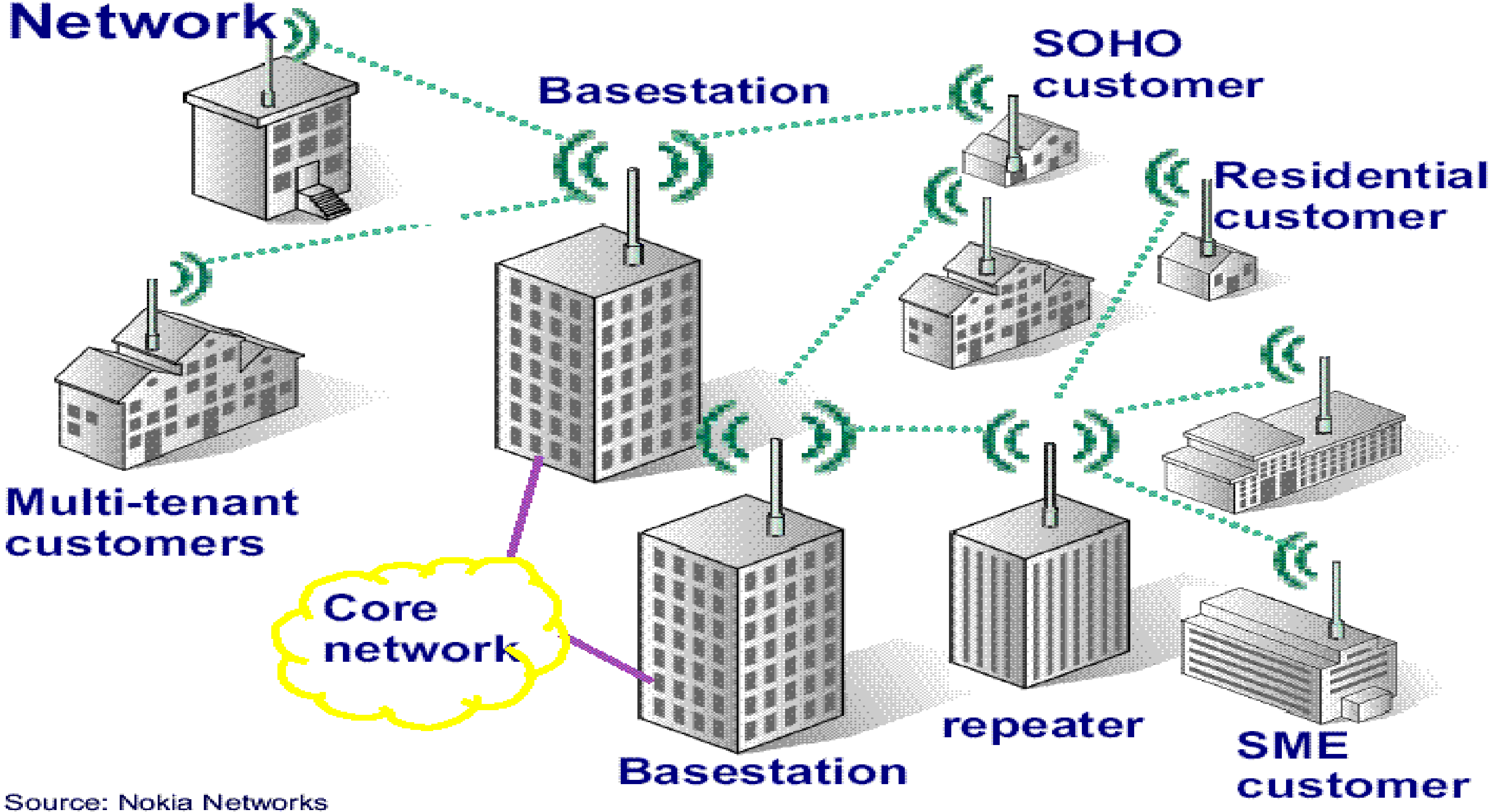
- Wireless PANs (Bluetooth – IEEE 802.15)
  - very low range
  - wireless connection to printers etc
- Wireless LANs (WiFi – IEEE 802.11)
  - infrastructure as well as ad-hoc networks possible
  - home/office networking
- Multihop Ad hoc Networks
  - useful when infrastructure not available, impractical, or expensive
  - military applications, emergencies




Wireless standards and their networking environments

- Wireless MANs (WiMAX-802.16)
  - Similar to cellular networks
  - traditional base station infrastructure systems

# WirelessMAN: Wireless Metropolitan Area Network




Source: Nokia Networks

# WiMAX

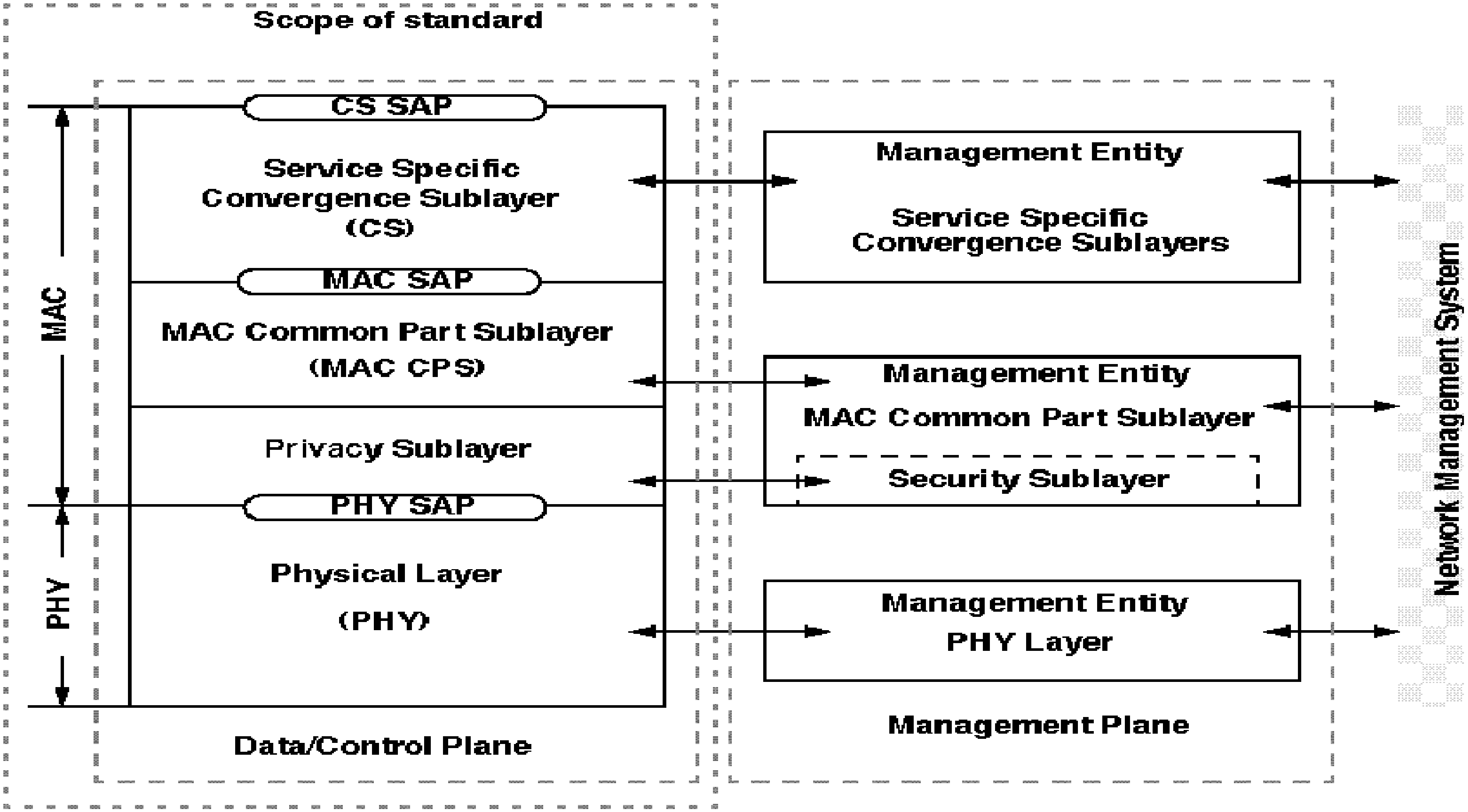
- Goal: Provide high-speed Internet access to home and business subscribers, without wires.
- Base stations (BS) and subscriber stations (SS)
- Centralized access control to prevents collisions
- Supports applications with different QoS requirements
- WiMAX is a subset of IEEE 802.16 standard

# IEEE 802.16 standards

- 802.16.1 (10-66 GHz, line-of-sight, up to 134Mbit/s)
- 802.16.2 (minimizing interference between coexisting WMANs)

- 802.16a (2-11 Ghz, Mesh, non-line-of-sight)
- 802.16b (5-6 Ghz)
- 802.16c (detailed system profiles)

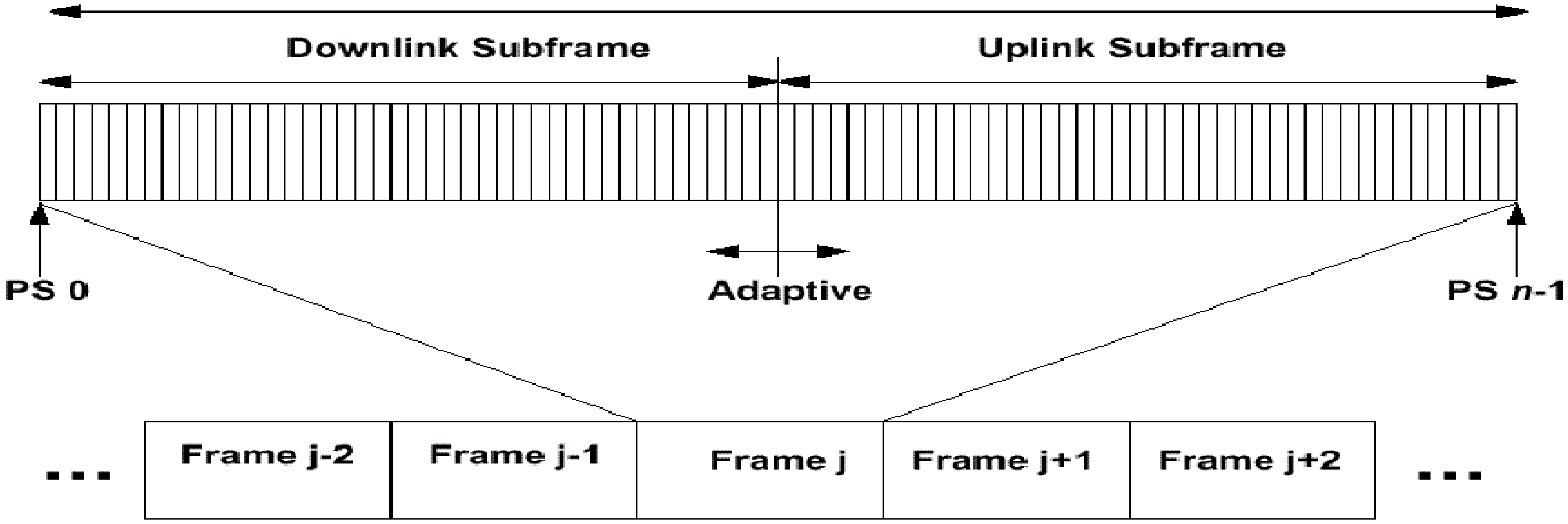
- P802.16e (Mobile Wireless MAN)


Scope of standard
CS SAP
Service Specific
Convergence Sublayer
(CS)
MAC SAP
MAC Common Part Sublayer
(MAC CPS)
Privacy Sublayer
PHY SAP
Physical Layer
(PHY)
MAC
PHY
Data/Control Plane
Management Entity
Service Specific
Convergence Sublayers
Management Entity
MAC Common Part Sublayer
Security Sublayer
Management Entity
PHY Layer
Management Plane
Network Management System

# Physical layer

- Allows use of directional antennas
- Allows use of two different duplexing schemes:
  - Frequency Division Duplexing (FDD)
  - Time Division Duplexing (TDD)
- Support for both full and half duplex stations
- Adaptive Data Burst profiles
  - Transmission parameters (e.g. Modulation, FEC) can be modified on a frame-by-frame basis for each SS
  - Profiles are identified by ”Interval Usage Code”

# Time Division Duplexing (TDD)

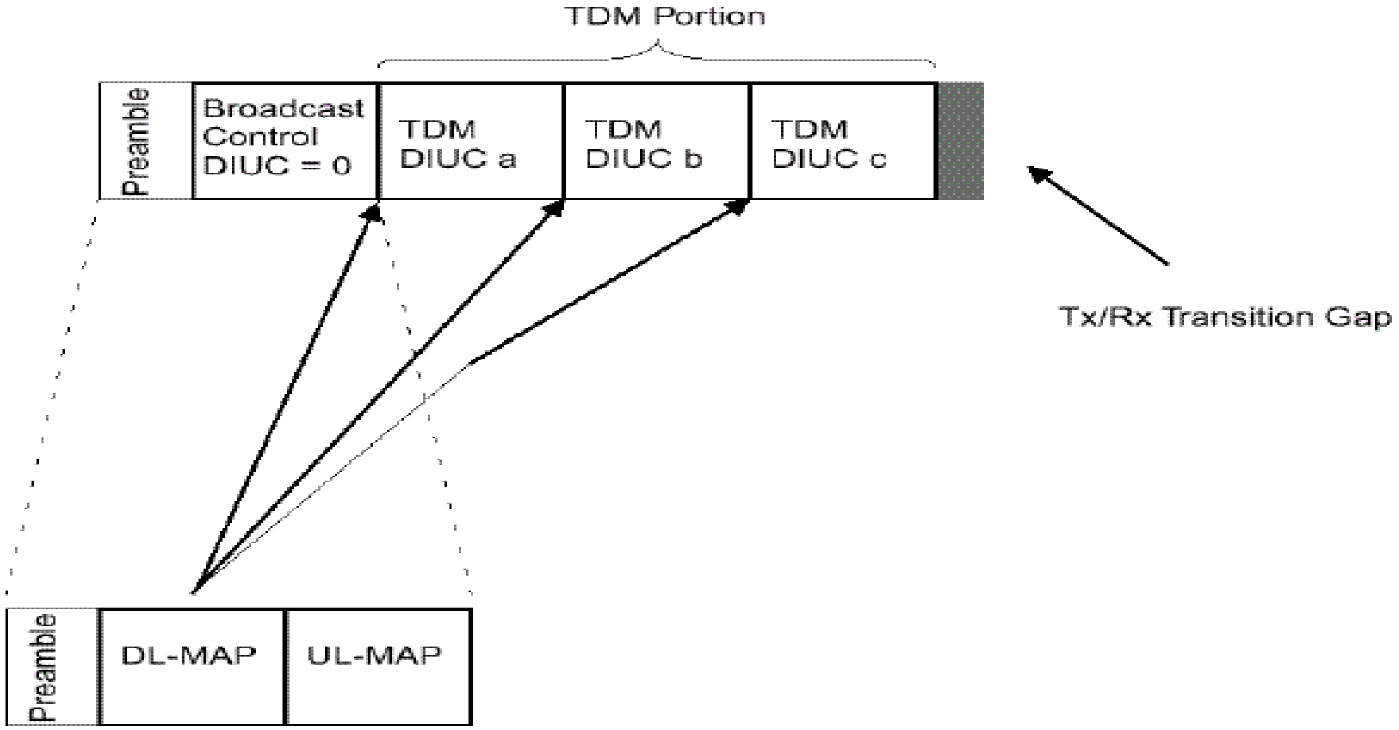


# Media Acces Control (MAC)

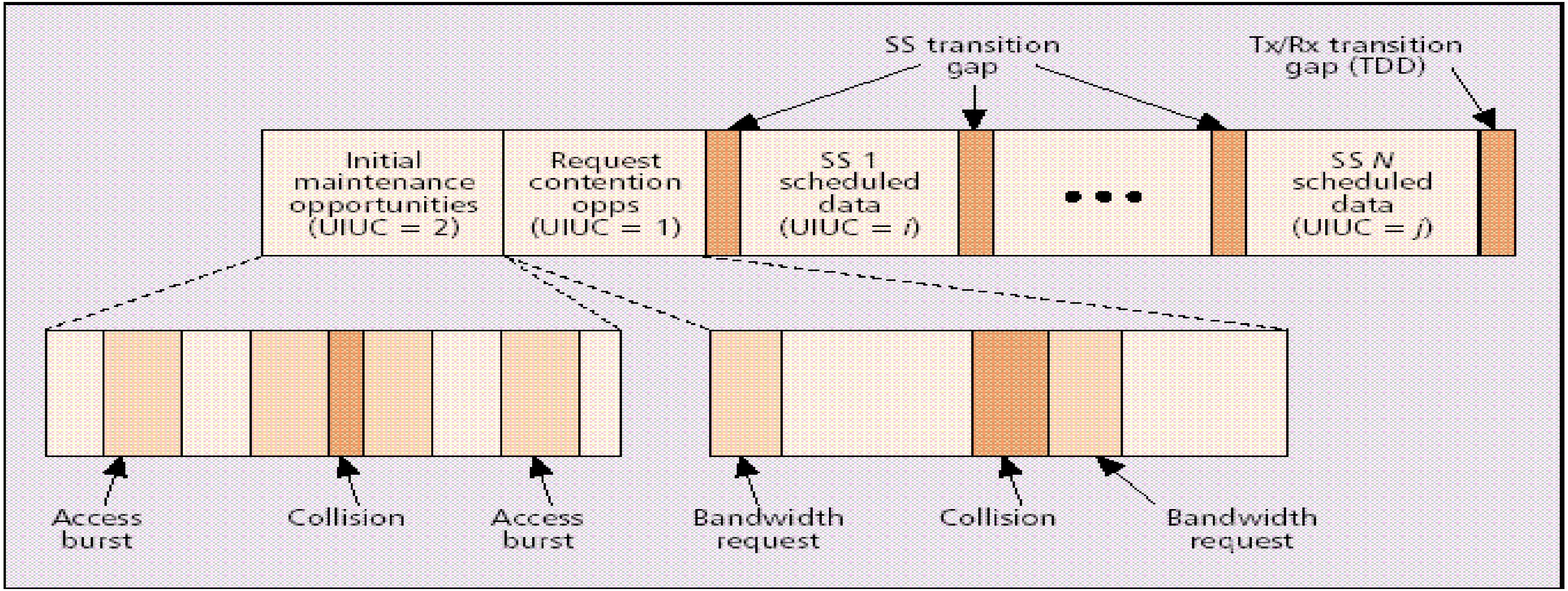
- Connection oriented
    - Connection ID (CID), Service Flows

- Channel access: decided by BS
  - UL-MAP
    - Defines uplink channel access
    - Defines uplink data burst profiles
  - DL-MAP
    - Defines downlink data burst profiles
  - UL-MAP and DL-MAP are both transmitted in the beginning of each downlink subframe

# TDD Downlink subframe



# Uplink subframe



# Uplink periods

- Initial Maintenance opportunities
  - Ranging - to determine network delay and to request power or profile changes
  - Collisions may occur in this interval

- Request opportunities
  - SSs request bandwith in response to polling from BS
  - Collisions may occur in this interval

- Data grants period
  - SSs transmit data bursts in the intervals granted by the BS
  - Transition gaps between data intervals for synchronization

# Bandwidth request

- SSs may request bandwidth in 3 ways:
  - Use the ”contention request opportunities” interval upon being polled by the BS
  - Send a standalone MAC message called ”BW request” in an allready granted slot
  - Piggyback a BW request message on a data packet

# Bandwidth allocation

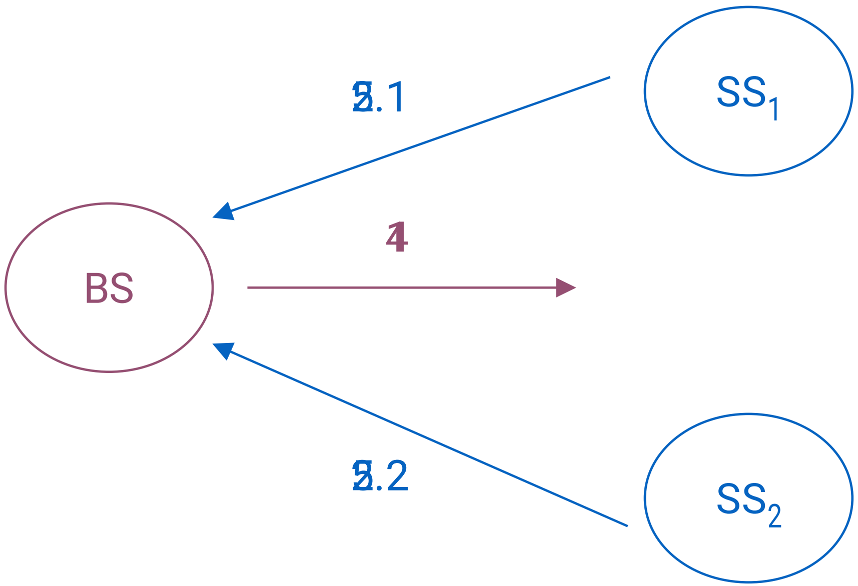
- BS grants/allocates bandwidth in one of two modes:
  - Grant Per Subscriber Station (GPSS)
  - Grant Per Connection (GPC)
- Decision based on requested bandwidth and QoS requirements vs available resources
- Grants are notified through the UL-MAP

# Bandwidth Request-Grant Protocol

1. BS allocates bandwidth to SSs for transmitting bandwidth request.

2.1 $SS_1$ transmits bandwidth requests.

2.2 $SS_2$ transmits bandwidth requests.




4. BS allocates bandwidth to SSs for transmitting data based on their bandwidth requests. Bandwidth is also allocated for requesting more bandwidth.

5.1 $SS_1$ transmits data and bandwidth requests.

5.2 $SS_2$ transmits data and bandwidth requests.

# Scheduling services

- Unsolicited Grant Service (UGS)
  - Real-time, periodic fixed size packets (e.g. VoIP)
  - No periodic bandwith requests required

- Real-Time Polling Service (rtPS)
  - Real-time, periodic variable sizes packets (e.g MPEG)
  - BS issues periodic unicast polls

- Non-Real-Time Polling Service (nrtPS)
  - Variable sized packets with loose delay requirements (FTP)
  - BS issues unicast polls regularly (not necessarily periodic)
  - Can also use contention requests and piggybacking

- Best Effort Service
  - Never polled individually
  - Can use contention requests and piggybacking

# Example

Total Uplink Bytes = 100

2 SS and 1 BS

$SS_1$ Demands:

UGS = 20

rtPS = 12

nrtPS = 15

BE = 30

$SS_2$ Demands:

UGS = 10

rtPS = 10

nrtPS = 15

BE = 20

Total Demand Per Flow:
UGS = 30
rtPS = 22
nrtPS = 30
BE = 50

| Flows: | UGS | rtPS | nrtPS | BE |
|---|---|---|---|---|
| 1st Round | 40 | 30 | 20 | 10 |
| | 30 | 22 | 20 | 10 |
| Excess Bytes = 18 | | | | |
| 2nd Round | 30 | 22 | 20+12 | 10+6 |
| | 30 | 22 | 32 | 16 |
| Excess Bytes = 2 | | | | |
| 3rd Round | 30 | 22 | 30 | 16+2 |
| | 30 | 22 | 30 | 18 |

$SS_1$ Allocation = 20 +12 + 15 + 9 = 56

$SS_2$ Allocation = 10 +10 + 15 + 9 = 44