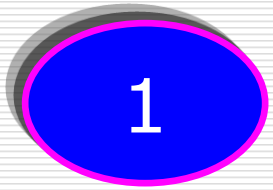


# WIRELESS SENSOR NETWORK

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# Introduction

- Electrical/ Electronic Communication of information can be of two types:
  a) Analog communication: Information is analog in nature
  b) Digital communication: Information is digital in nature
- These days, mostly **digital information** is communicated
- Sources/ forms of digital information are:
  **a)** **Digital output signals** of digital devices (digital sensors, instruments, cameras, controllers etc.)
  **b)** **Digital signals** obtained by A-to-D conversion of analog output signals of analog devices (analog sensors, instruments, controllers etc.)
  **c)** **Data** output of digital computers/ data processors.
- As digital information now is largely in the form of data, digital communication is frequently called **data communication**.

# Communication Topologies

- Basically, two communication topologies are used:

  A. Point-to-Point Communication:
  Communication between two devices (transceivers) connected by a signal transmission link.
  B. Communication Network:
  Communication among more than two devices, called as nodes, interconnected by a signal transmission network.

- **Nodes** have at least two basic things/capabilities:

  A. Computer or data processor (micro-processor or micro-controller) for data processing

  B. Transmitter plus receiver (transceiver) for communication

- Since these communication networks in most of cases and at most of times communicate data, they are widely referred to as **Data Communication Networks, or just Data Networks.**

# Data Network Categories (1)

- Depending on coverage area, ownership, user group and communication technology used, a data network may be categorized as:
  1. Local area network (LAN)
  2. Personal area network (PAN)
  3. Metropolitan area network (MAN)
  4. Wide area network (WAN)
  5. The Internet
  6. Intranet

- Local area network (LAN):
  - Network within a building or campus
  - Most of the LANs are privately owned
  - LAN is used by an organization or a group of individuals
  - Works on a single communication technology
  - Acts as a building block of many larger data networks

# Data Network Categories (2)

- Personal area network (PAN):
  - Special case (smaller version) of LAN
  - Network within a room or hall of a building
  - Always privately owned
  - Used by an individual
  - Works on a single communication technology.
- Metropolitan area network (MAN):
  - Special case (larger version) of LAN
  - Interconnects devices in a town or city
  - Public or privately owned
  - Used by public or an organization
  - Works on a single communication technology.

# Data Network Categories (3)

- Wide area network (WAN):
  - Covers a wide area (a town, state or country)
  - Involves interconnection of two or more LANs
  - LANs are in general privately owned
  - Interconnecting links are often public communication lines
  - User is generally the public
  - Involves several communication technologies.
- The Internet:
  - Popularly known as the network of networks
  - Can be seen as an extension of WAN
  - Involves interconnection of LANs and WANs
  - Has global coverage for both private and public communications
  - Services on Internet are provided through a hierarchy of local, regional, national and international Internet service providers
  - Communication across the Internet is defined by TCP/IP protocol suite

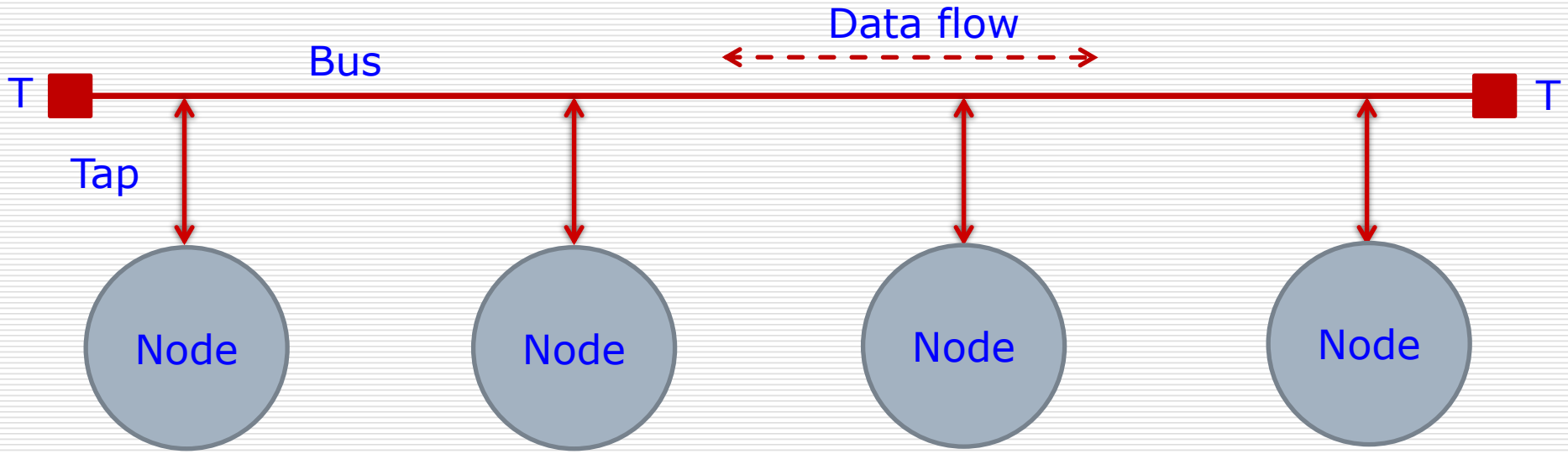
# Data Network Categories (4)

- Intranet:
  - Intranet is an implementation of Internet technologies within an organization
  - Privately owned by the organization
  - Covers the organization
  - Connected to the Internet.

# LAN Topologies

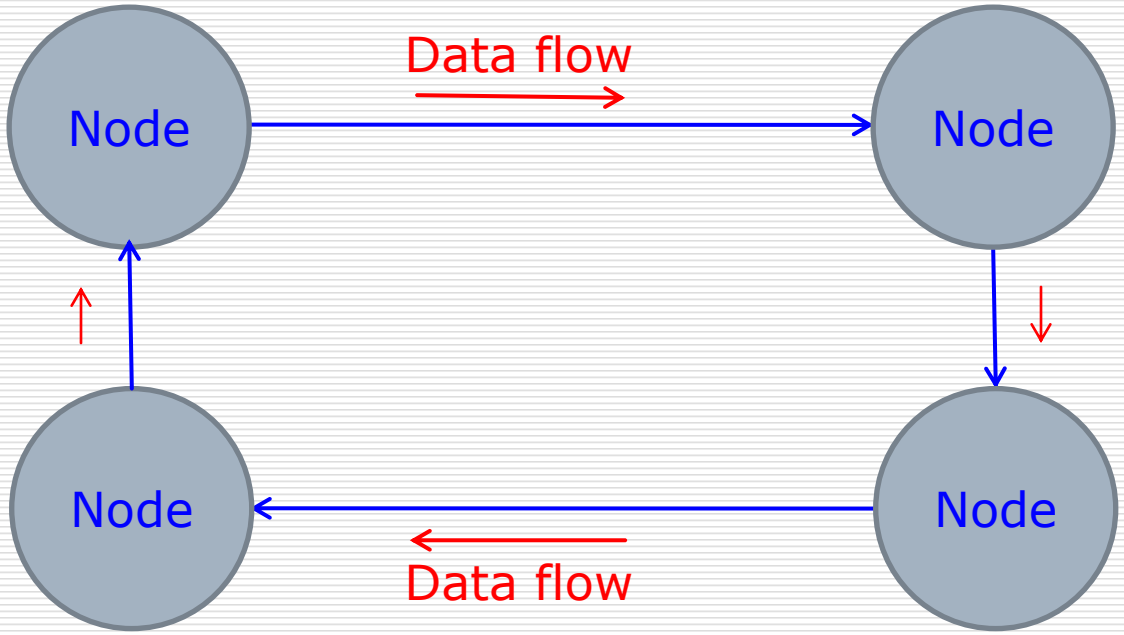
- Network topology means the structure of a network, including physical arrangement of communicating devices or nodes
- LAN being the building block of all data networks, LAN topology is important in determining the structure of any larger data network also.
- Five basic LAN topologies:
  1. Bus
  2. Ring
  3. Star
  4. Tree
  5. Mesh

# Bus (or Multidrop) Topology



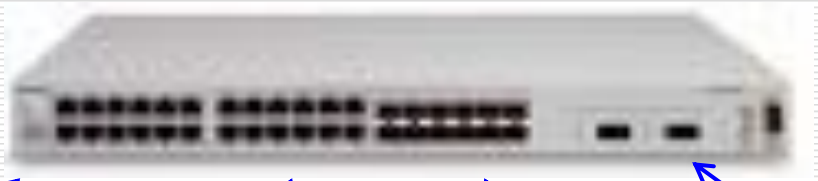

- Bus is a linear transmission medium
- Data flow is bidirectional
- Nodes are connected through taps taken from bus
- Terminator (T) absorbs signal, thus avoids echo

# Ring (or Loop) Topology

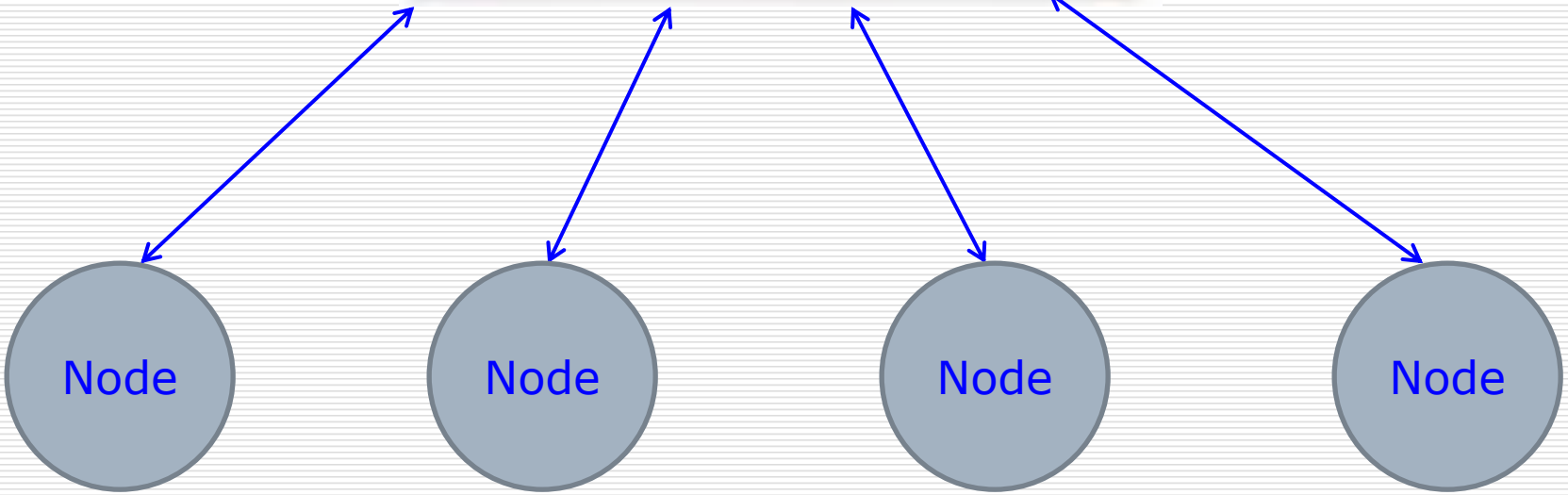



- Nodes are connected in tandem (series) to form closed loop
- Data flows through nodes
- Data flow is unidirectional
- Each node acts as a repeater : It receives data on one link and transmits bit-by-bit on other link to next node

# Star Topology

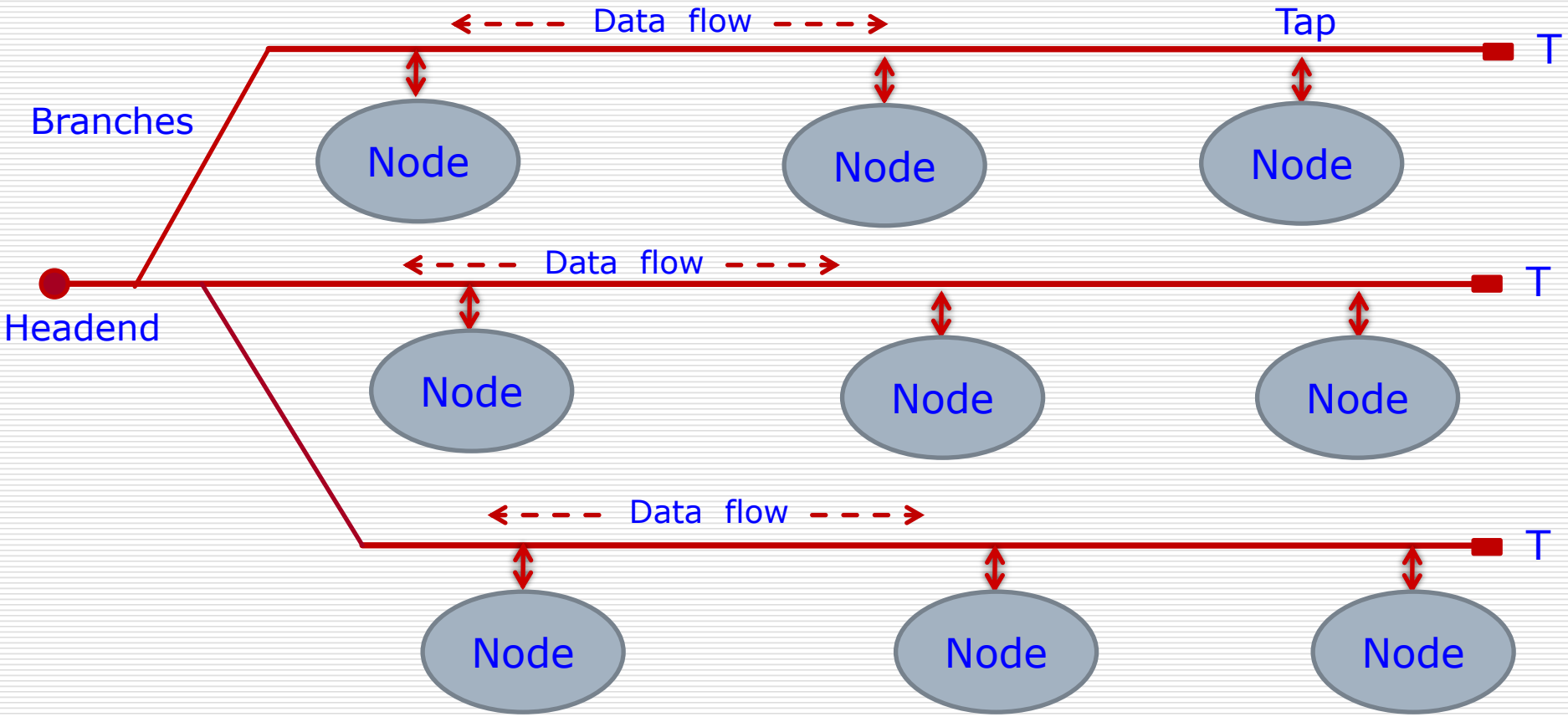


Central node



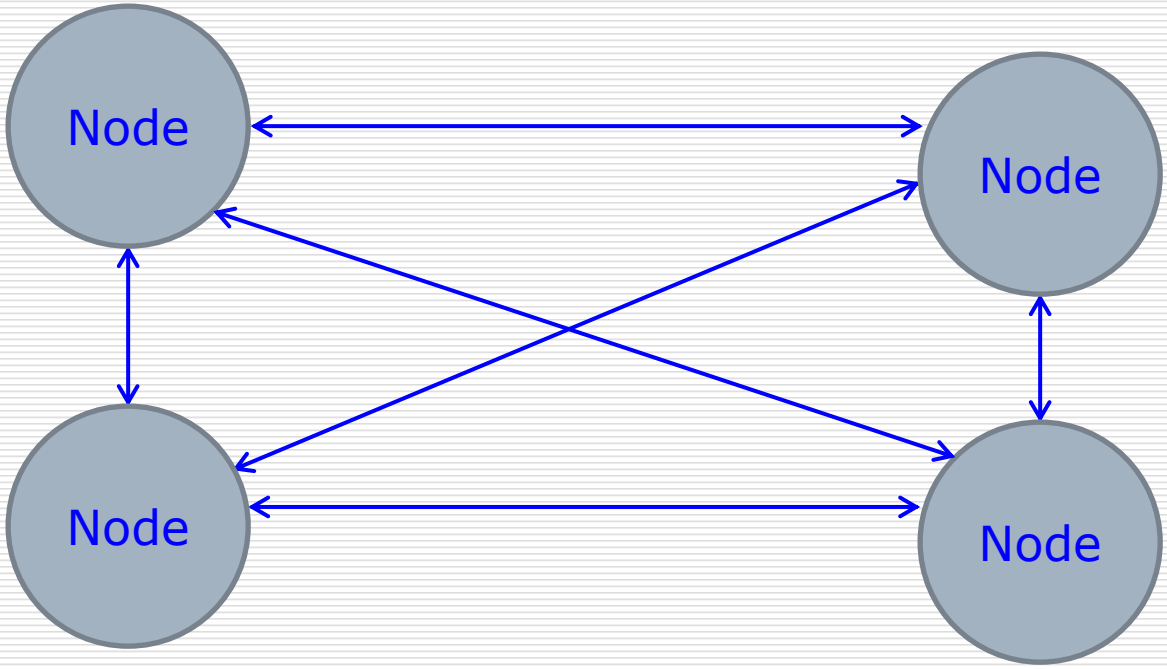

- Network is comprised of point-to-point circuits
- Central node: Hub or switch
- Hub: Operates in broadcasting mode
- Switch: Operates as frame-switching device

# Tree Topology




- Generalization of bus topology
- Each branch may have further branches, which may be called as sub-branches.

# Mesh Topology

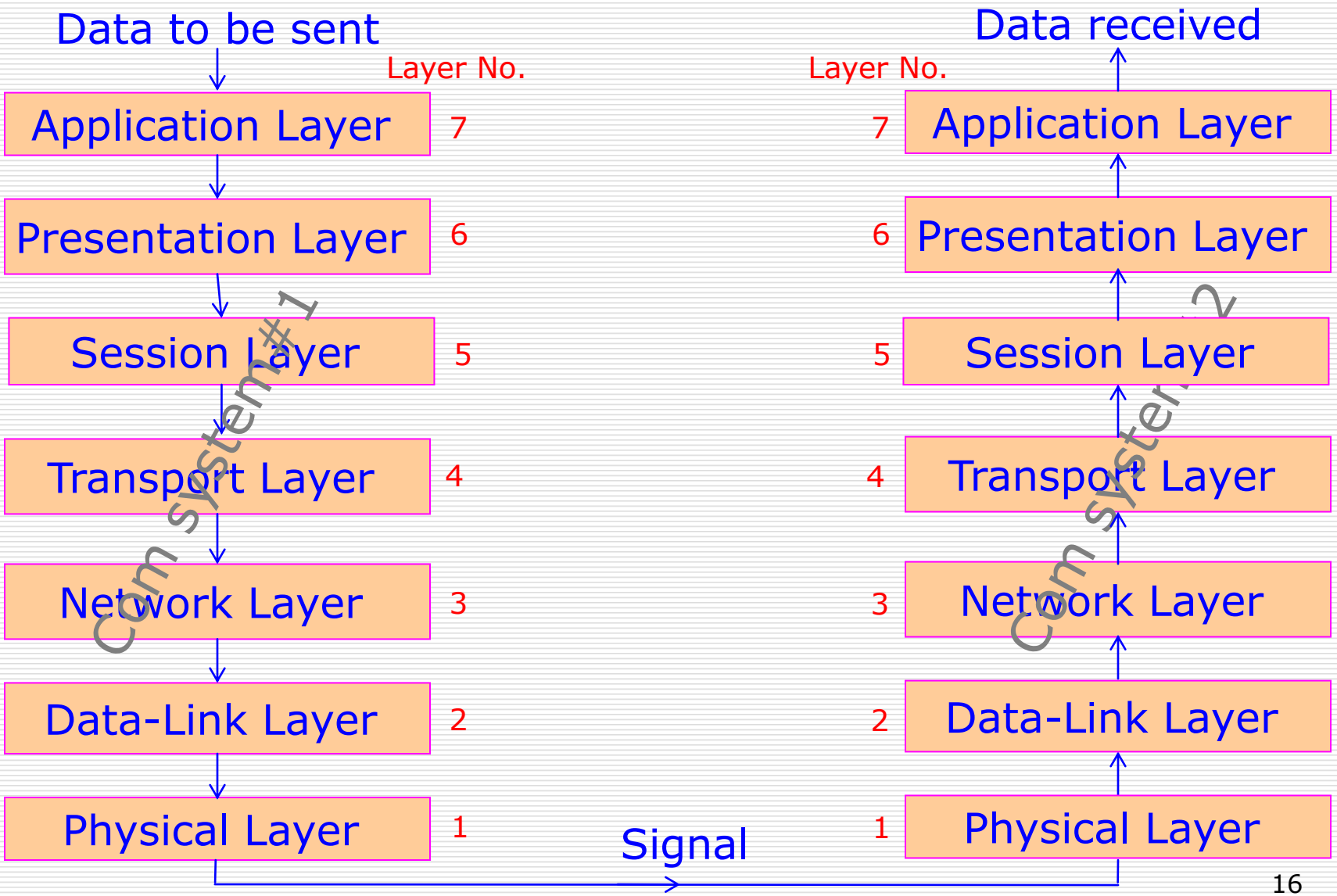



- Every node has bidirectional links to other nodes
- Less traffic problems, high reliability, high security
- **Fully-Connected Mesh :**
  Each node is connected to every other node in the network
  Total number of links = n(n-1)/2 for 'n' nodes
  Number of I/O ports on each node = (n-1)

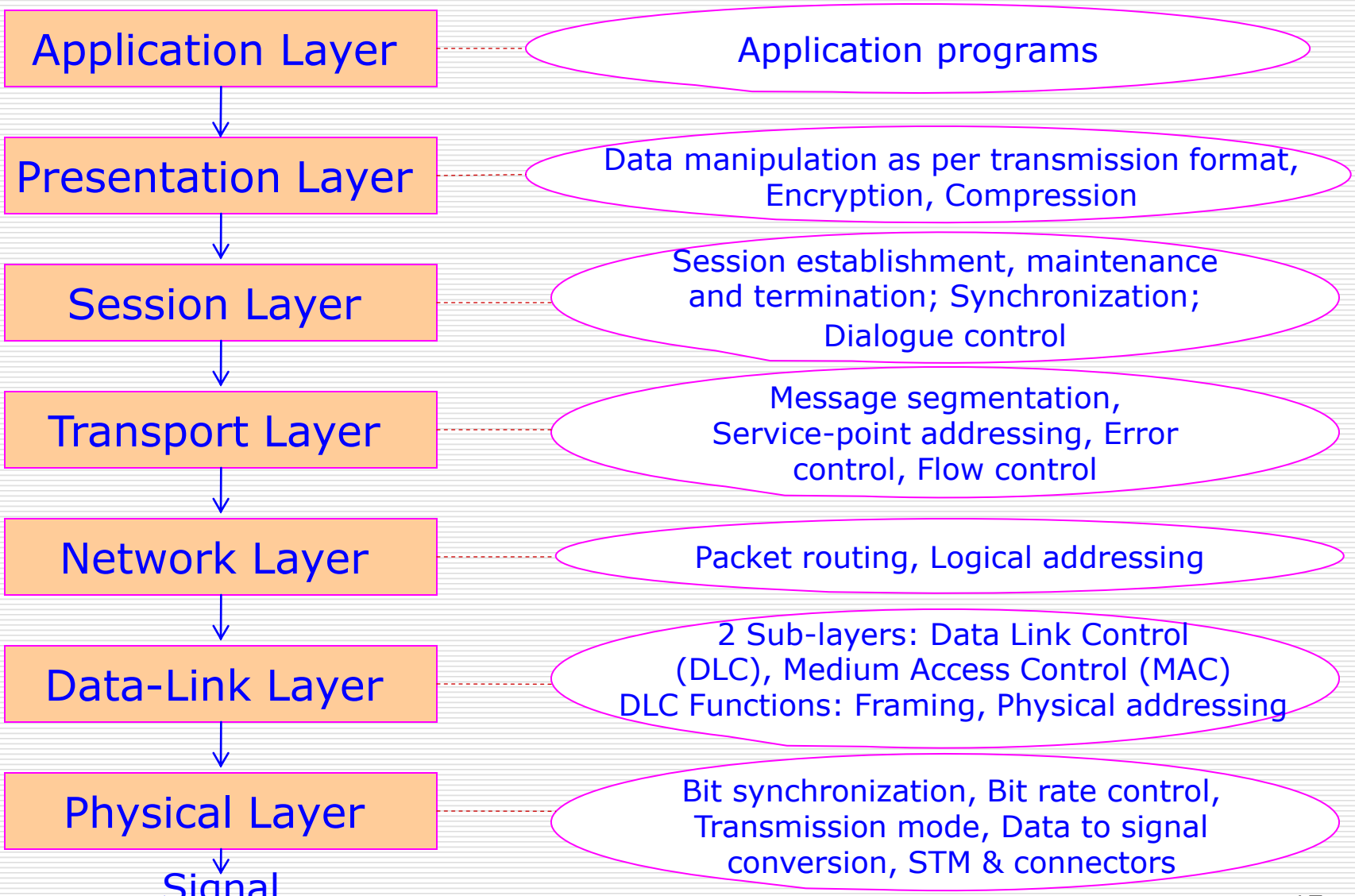
# 7-Layer OSI Model of Communication Systems

- Model was developed and issued by International Standards Organization (ISO)
- OSI: Open System Interconnection
- Reference model of communication systems
- Defines 7 layers of functions in a communication system
- For use as reference "to identify and classify the different functions of a given communication system"
- Not a standard or set of prescriptions for a communication system to adhere to
- A communication system may not have all the 7 layers
- Depending on the application, some layers may be absent
- A communication protocol or a standard may not define all the 7 layers.

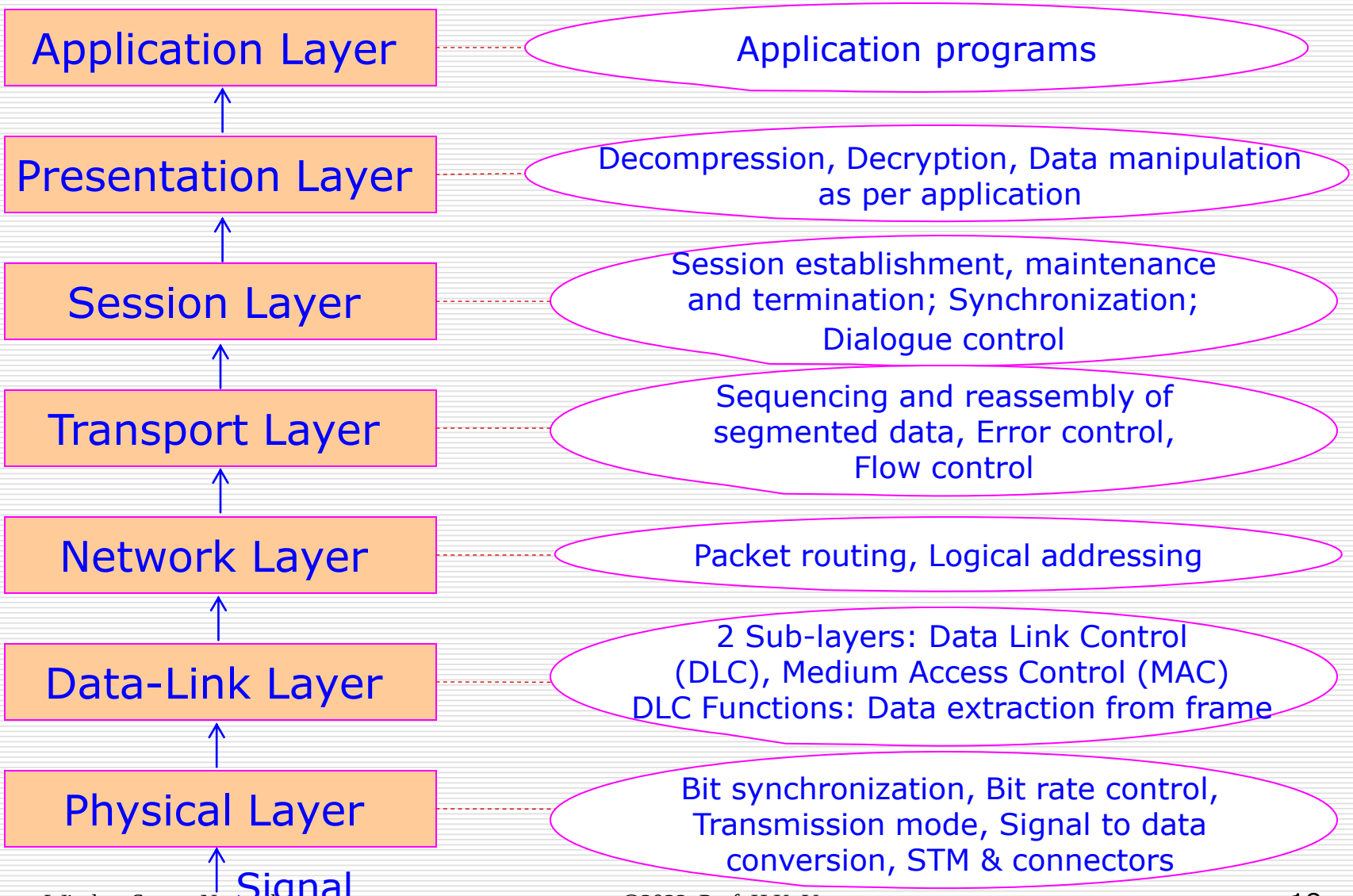
# Data Transfer Between Systems



# Functions of 7 Layers at Transmitting End



# Functions of 7 Layers at Receiving End



# Wireless LAN or WLAN

1. WLAN is a wireless network of microprocessor-based devices or nodes.
2. Advantages of WLAN
   - Easy and fast deployment
   - Nomadic and mobile access
   - Connecting field devices in inaccessible locations.

3. Major Issues with WLAN
   - Noise & interference
   - Interception & eavesdropping
   - Jamming

4. Share of WLANs in LAN-market is increasing fast.

# ISM Microwave-Frequency Bands

- License-free microwave frequency bands
- For Industrial, Scientific and Medical purposes
- Only low-power transmissions (upto 1W) allowed
- Three ISM bands:
  - ISM-900: A frequency band around 900 MHz
  - ISM-2.4: A frequency band between 2.4 & 2.5 GHz
  - ISM-5: A frequency band a little above 5 GHz
- ISM-900 Band: 900-MHz devices are least expensive
- ISM-2.4 Band : Most widely used ISM band
- ISM-5 Band : 5-GHz devices are most expensive.

# Basics of Wireless Sensor Network (WSN)

- WSN is a wireless (radio-frequency or RF) network of microprocessor-based wireless sensor nodes

- A WS Node has at least 3 basic things/capabilities:
  A. One or more sensors for sensing/measurement
  B. Micro-processor or micro-controller for data processing
  C. RF transmitter and receiver for communication

- Application areas of WSN:
  1. Where sensors are located at inaccessible or difficult-to-access places
  2. Where sensors are either mobile or portable
  3. Where quick deployment of sensor network is required
  4. Where ad-hoc networking of sensor nodes is required.

# Special Requirements of WSN

1. Low latency or small end-to-end delay
2. High data security
3. High network security
4. Low power consumption or long battery life
5. Operation in an ISM frequency band
6. Low bandwidth or data rate is adequate

# Technology/Protocol Options for WSN

Technologies/protocols along with the governing standards are listed below:

1. Zigbee/IEEE 802.15.4
2. WiFi/IEEE 802.11
3. Bluetooth/IEEE 802.15.1

# Zigbee/IEEE 802.15.4

- Zigbee technology addresses needs of industrial measurement and control (automation)
- Promoted by Zigbee Alliance, a consortium of 150+ companies
- Includes Honeywell, Motorola, Phillips, Samsung, Mitsubishi
- Zigbee conforms to IEEE 802.15.4 standard
- IEEE 802.15.4 is named as "Low-Rate Wireless PAN Standard"
- IEEE 802.15.4 defines only Physical and MAC layers
- Zigbee supports networking of fixed, portable and moving devices (sensor nodes).

# Zigbee Technology

- Developed to meet special requirement of wireless sensor and actuator networks, namely
  - Low latency
  - Low bandwidth
  - Long battery life
  - High data security
- Not attractive for business communication networks because of low data rate.

# Main Features of Zigbee

- Data rates: 20, 40 & 250 Kbps
- Topologies: Star and Mesh
- MAC logic: CSMA/CA
- Device addressing: Dynamic
- Transmission technique: Direct Sequence Spread Spectrum (DSSS)
- Transmitter power: 1 mW or more
- Range: 10 m or more
- Frequency bands
  - ISM-900: Channel BW = 2MHz, Data rate = 20 & 40 kbps
  - ISM-2.4: Channel BW = 5MHz, Data rate = 250 kbps

# IEEE 802.15.4 Specified Devices

Standard specifies 2 type of devices:

- Full-Function Device (FFD)
  - Can talk to any other device
  - Can perform job of Network (or PAN) Coordinator
  - Can also function as a normal device

- Reduced-Function Device (RFD) or Normal Device
  - Can function only as an end device (terminal node)
  - Can't function as Network Coordinator
  - Simpler in design than FFD

# Network (PAN) Coordinator

- There is only one node in a network functioning as the Network Coordinator (NC) or PAN Coordinator.
- NC can communicate directly with any other device.
- Main functions of network coordinator:
  a) Generally, it initiates all network communications
  b) Transmits beacon in beaconing system used for "periodic data transfers"

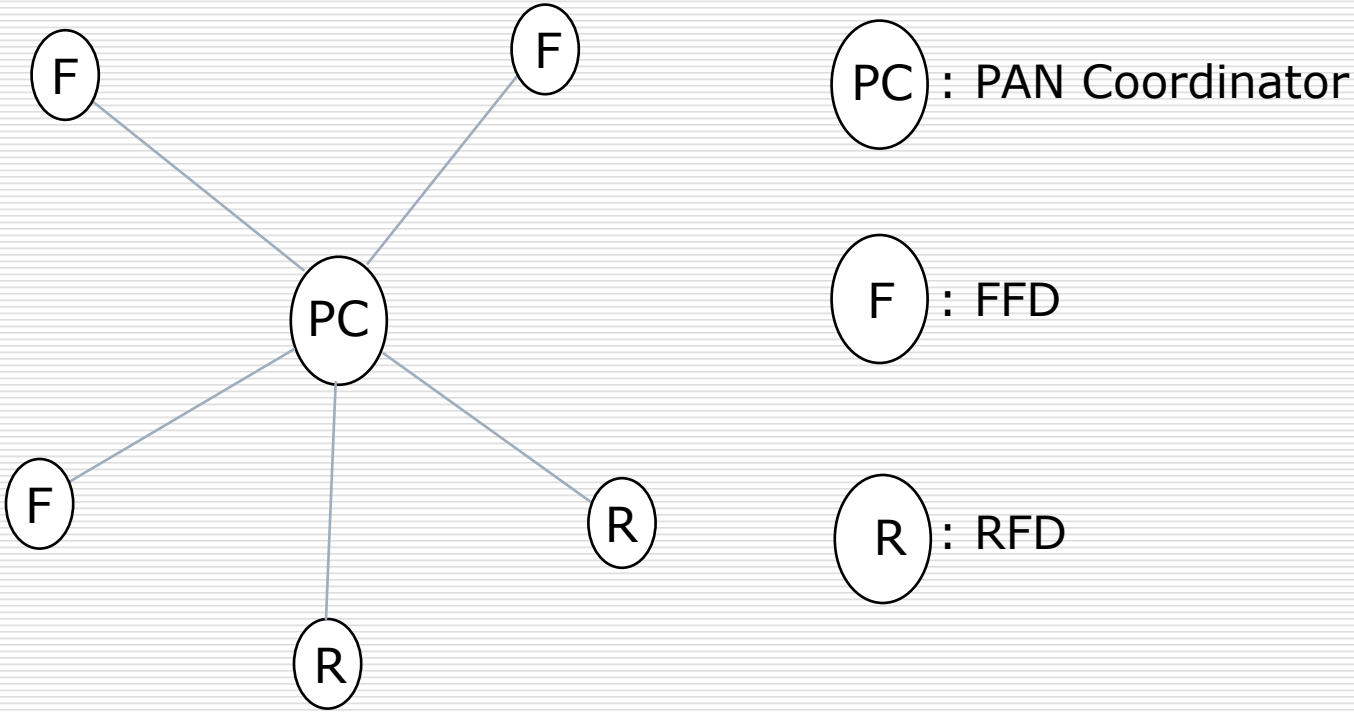
# IEEE 802.15.4 MAC Protocol

- MAC protocol is Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA)
- Data transfer protocols are designed to avoid collisions
- MAC protocol supports 2 network topologies:
  - Star topology
  - Mesh (peer-to-peer) topology
- MAC protocol supports 3 types of data transfers:
  - Periodic data transfer
  - Intermittent data transfer
  - Guaranteed time-slot data transfer

# Types of Data Transfers

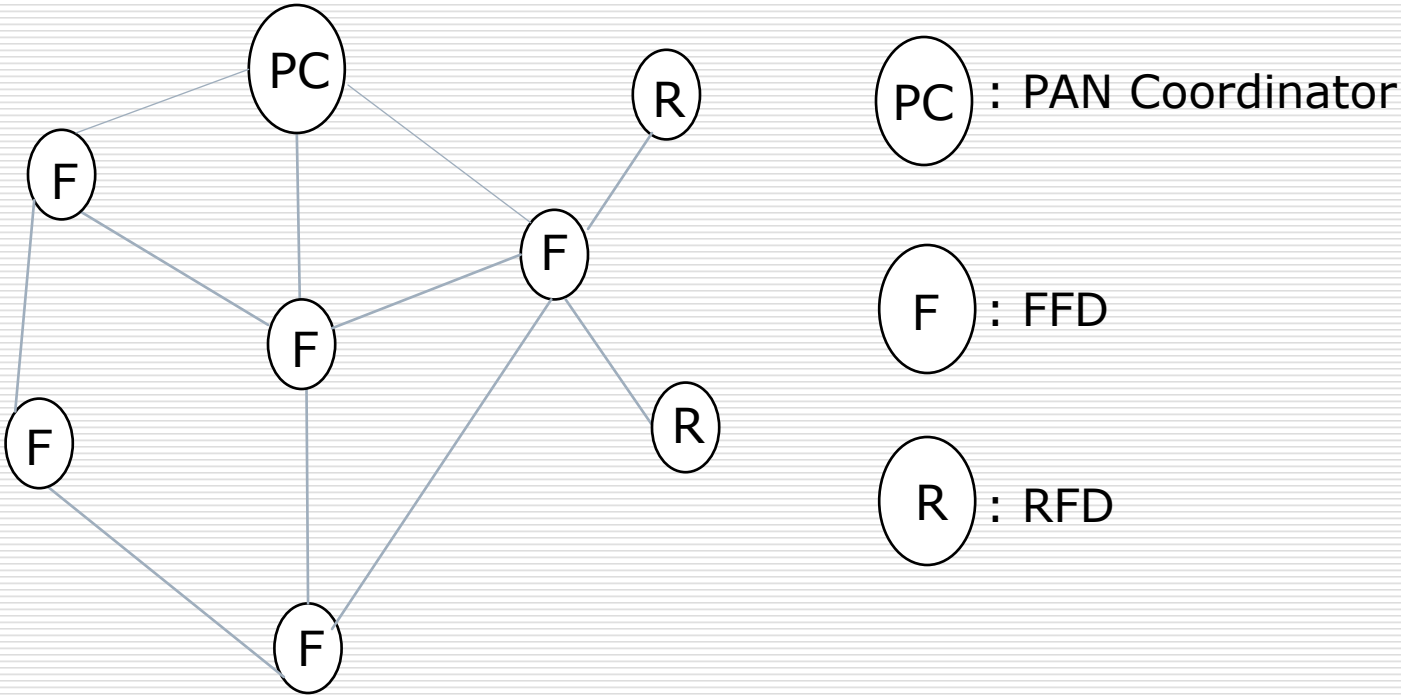
1. Periodic Data Transfer
   - Beaconing system to handle data
   - Beacon is sent by Network Coordinator periodically
   - Period can vary from 15.36 ms to 2.5 min
   - Period is a trade off between message latency and power consumption
   - Devices wakes up, send data and then go back to sleep mode
2. Intermittent Data Transfer
   - Network coordinator sends message as and when data is required from a node
   - The device getting message sends data and then goes back to sleep mode
3. Guaranteed Time-slot Data Transfer
   - Certain time slots are allotted to devices to transmit data without contention
   - Low-latency data transfer

# Zigbee Star Topology




- PAN Coordinator (PC) forms central node
- PAN Coordinator has to be a FFD
- Each other node can be either FDD or RFD.

# Zigbee Mesh (Peer-to-Peer) Topology




- Every node in the mesh is connected to each of other nodes by radio link
- All nodes in the mesh are FFDs
- One of FFDs is configured as PAN Coordinator (PC)
- RFDs can be connected only as end devices to a node in the mesh.

# Advantages and Limitations of Zigbee

- Advantages of Zigbee
  - Small bandwidth requirement
  - Low latency
  - Low power requirement
  - Low complexity
  - Low message overhead
  - Low cost
- Limitations of Zigbee
  - Low data rate
  - Small range

# Comparison of Zigbee with WiFi & Bluetooth (1)

| S. No. | Feature | Zigbee | WiFi | Bluetooth |
|---|---|---|---|---|
| 1 | Data rates | 20, 40 and 250 kbps | 2, 11 and 54 Mbps | 1 Mbps |
| 2 | Range | 50-100 m | 200-500 m | 1-10 m |
| 3 | Network size | Personal area network | Local area network | Pico-net |
| 4 | Topologies supported | Star and Mesh | Star | Mesh |
| 5 | ISM frequency bands | 900 MHz 2.4 GHz | 2.4 GHz & 5 GHz | 2.4 GHz |
| 6 | MAC | CSMA/CA Ad-hoc Peer-to-peer | CSMA Point-to-hub | Ad-hoc |
| 7 | Routing | Multi-hop | Single-hop | Single-hop |

Continued

# Comparison of Zigbee with WiFi & Bluetooth (2)

| S. No. | Feature | Zigbee | WiFi | Bluetooth |
|---|---|---|---|---|
| 8 | Modulation techniques | DSSS | DSSS<br>FHSS<br>OFDM | FHSS |
| 9 | Latency | Very low<br>(30 ms) | High<br>(3-5 s) | Very high<br>(10 s) |
| 10 | Network scalability | Very high<br>(65,000 nodes) | Good<br>(255 nodes) | Poor<br>(7 nodes) |
| 11 | Power consumption | Very low | High | Medium |
| 12 | Battery life | Long | Very short | Short |
| 13 | Data security | Very high | Very high | Very high |
| 14 | Market trend | Establishing | Established | Established |

# Spread Spectrum

- Spread-spectrum is a group of modulation techniques by which a signal generated with a particular bandwidth is deliberately spread in the frequency domain, resulting in a signal with a wider spectrum or bandwidth.
- Reasons for using these techniques:
  1. To secure communications by increasing resistance to interference, noise, and jamming.
  2. To increase data security by preventing detection.
  3. To enable multiple-access communication.

# Spread Spectrum Techniques

- Following spread-spectrum techniques are available:
  A. Frequency-hopping spread spectrum (FHSS)
  B. Direct-sequence spread spectrum (DSSS)
  C. Time-hopping spread spectrum (THSS)
  D. Chirp spread spectrum (CSS)
  E. Combinations of these techniques
- The first two of these techniques (FHSS and DSSS) are very widely used.
- Both FHSS and DSSS employ pseudo-random number sequences to determine and control the spreading pattern of the signal across the allocated bandwidth.
- Pseudo-random number sequences are created using pseudo-random number generators.

# Frequency-Hopping Spread Spectrum (FHSS)

- It is a method of transmitting radio signals by rapidly changing the carrier frequency among many distinct frequencies occupying a large frequency band.
- The changes are controlled by a code known to both transmitter and receiver.
- The code is based on creating a pseudo-random number sequence.
- Available frequency band is divided into smaller sub-bands.
- Signal rapidly changes, that is "hops", its carrier frequency among the centre frequencies of these sub-bands in a predetermined (pseudo-random) order.
- Interference at a specific frequency will only affect the signal during a short interval, while providing no extra protection against wideband noise.

# Benefits of FHSS

1. FHSS signals are highly resistant to narrow-band interference because the signal keeps hopping from one frequency sub-band to another frequency sub-band.
2. Signals are difficult to intercept, if the frequency-hopping pattern is not known.
3. Jamming is also difficult if the pattern is unknown. A malicious individual may be able to jam the signal for a single hopping period only, if the spreading sequence is not known.
4. FHSS transmissions can share a frequency band with many types of conventional transmissions with minimal mutual interference. This is because FHSS signals add minimal interference to narrowband communications, and vice versa.

# Direct-Sequence Spread Spectrum (SS)

- In DSSS, the message bits are modulated by a pseudo-random bit sequence, known as a spreading sequence.
- Each bit in the spreading-sequence is known as a chip and has a much shorter duration (larger bandwidth) than the original message bits.
- The modulation of the message bits scrambles and spreads the pieces of data, and thereby results in a bandwidth size nearly identical to that of the spreading sequence.
- The spreading sequence created by transmitter is known to receiver. Receiver uses the same spreading sequence to demodulate the received signal in order to reconstruct the information signal.
- The smaller the chip duration, the larger the bandwidth of the resulting DSSS signal and better the resistance against interference.

# Benefits of DSSS

1. High resistance against interference.
2. High resistance to unintended and intended jamming.
3. The code division multiple access (CDMA) property of DSSS allows multiple transmitters to share the same channel within the limits of the cross-correlation properties of their spreading sequences.