Chapter2: Networking Hardware, Smart Chips, and IoT Sensors

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Course Overview

1. Introduction to Computer Networks
2. Network Classification by Geography
   - Local Area Network (LAN)
   - Metropolitan Area Network (MAN)
   - Wide Area Network (WAN)
3. Network Hardware and Equipment
   - Hub
   - Repeater
   - Bridge
   - Switch
   - Router
4. Network Cabling and Topology
5. Smart Chips & IoT Technologies

What is a Computer Network?

Definition

A **computer network** is a set of devices (nodes) connected by communication links. A node can be a computer, printer, or any device capable of sending/receiving data.

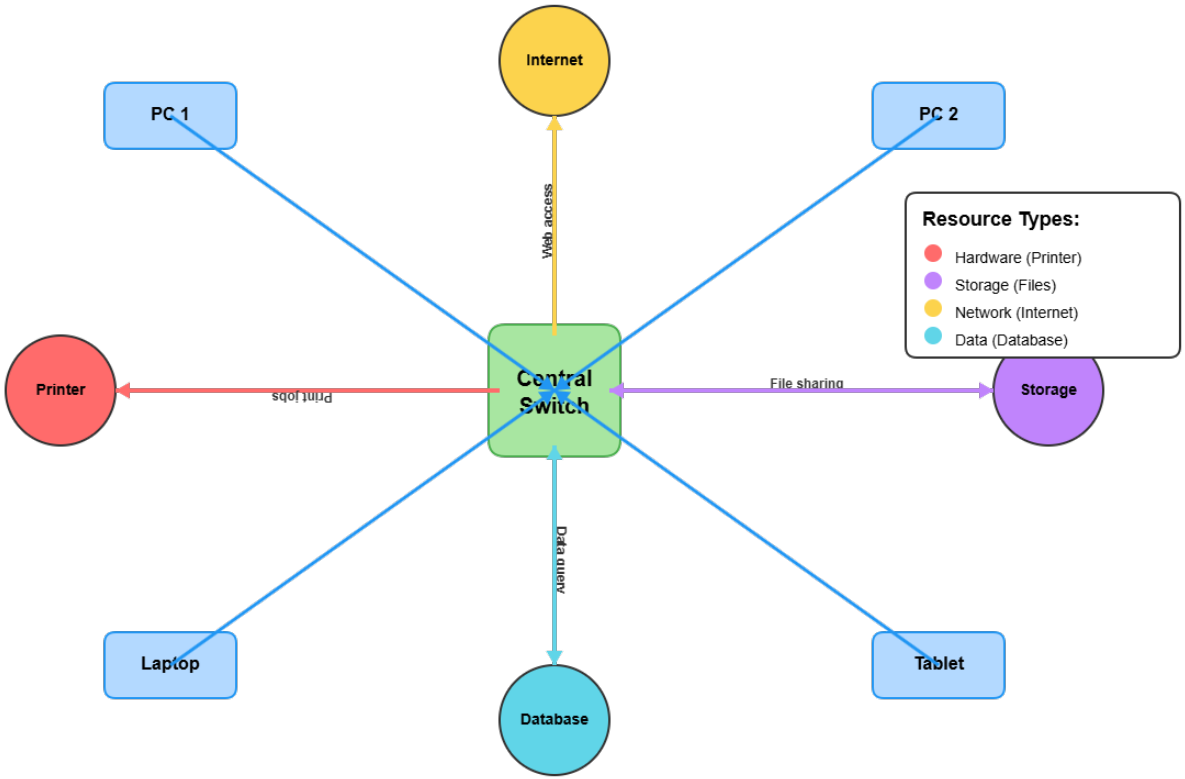
Key Components:

- Nodes/Devices
- Communication Links
- Network Hardware
- Network Software
- Transmission Medium

Purposes:

- Resource Sharing
- Communication
- Data Storage
- Internet Access
- Cost Reduction

Basic Network Illustration

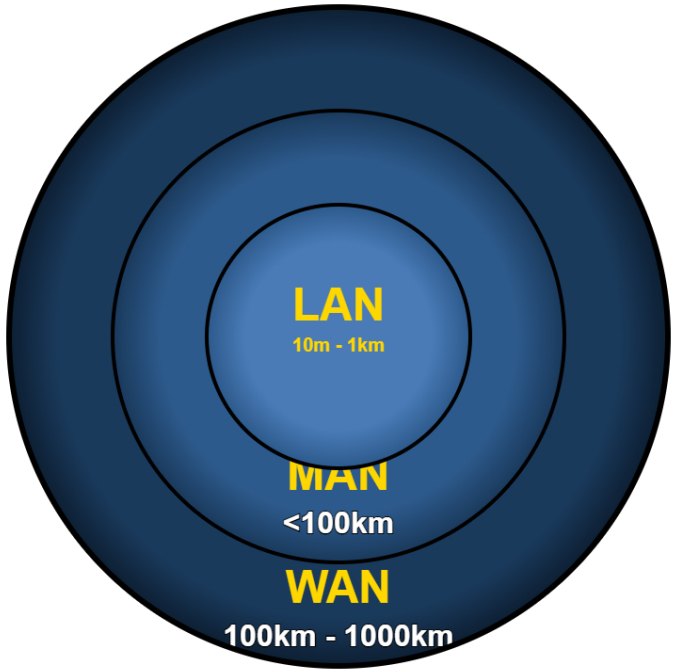


All devices communicate through the central switch, enabling resource sharing

Network Communication

All devices are connected through a central switch, enabling communication and resource sharing.

Network Types by Geographic Coverage



Three Main Types

LAN (Local) $<$ **MAN** (Metropolitan) $<$ **WAN** (Wide Area)

Local Area Network (LAN)

Definition

A **LAN** is a small, high-speed network covering a close geographical area, used to link devices in a single office, building, or campus.

Characteristics:

- Limited coverage (meters)
- High-speed transmission (100 Mbps to 10 Gbps typical for modern LANs)
- Direct connection
- Private ownership
- Few interconnected systems

Applications:

- Office networks
- School computer labs
- Home networks
- Small businesses
- Building connectivity

LAN Network Diagram

High-Speed Local Connectivity

All devices directly connected via switch with speeds up to 10 Gbps.

Metropolitan Area Network (MAN)

Definition

A **MAN** is an extension of LAN to spread over a city. It may be a single network or multiple LANs sharing resources.

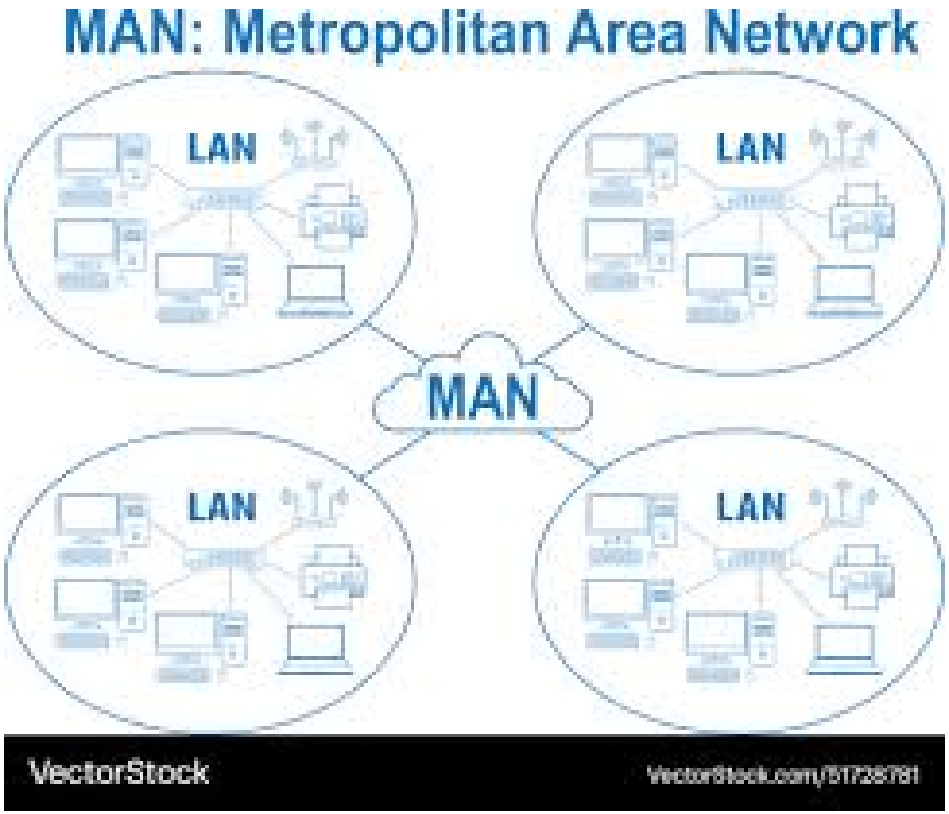
Characteristics:

- Covers entire city
- Larger than LAN
- Smaller than WAN
- Moderate to high speed
- Interconnects LANs
- Often fiber optic backbone

Applications:

- City government networks
- Cable TV networks
- University campuses
- Bank branches in city
- Municipal Wi-Fi

MAN Network Diagram



City-Wide Connectivity

Multiple LANs connected via fiber optic backbone covering entire metropolitan area.

Wide Area Network (WAN)

Definition

A **WAN** is a collection of networks (or LANs) spreading over large geographical areas, spanning cities, countries, or continents.

Characteristics:

- Large coverage
- Slower than LANs
- Indirect connections
- Service provider owned
- Multiple topologies
- Complex infrastructure

Applications:

- Multinational companies
- Internet backbone
- Banking networks
- Global telecom
- Cloud services

WAN Network Diagram

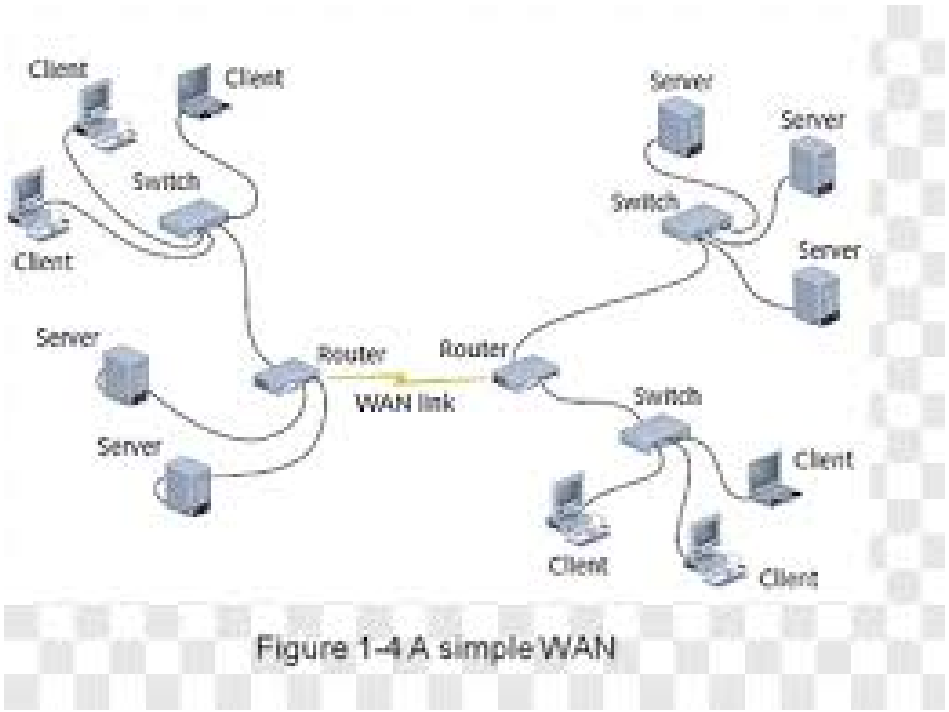


Figure 1-4 A simple WAN

Global Connectivity

WAN connects LANs across continents through service provider infrastructure.

Network Hardware Overview

Network Devices

Hardware components used to build and interconnect computer networks, operating at different types of network.

Devices We'll Cover:

1. Hub
2. Repeater
3. Bridge
4. Switch
5. Router

Hub

Definition

A **hub** is a network device used to connect systems or nodes. It has direct point-to-point connections to each node.

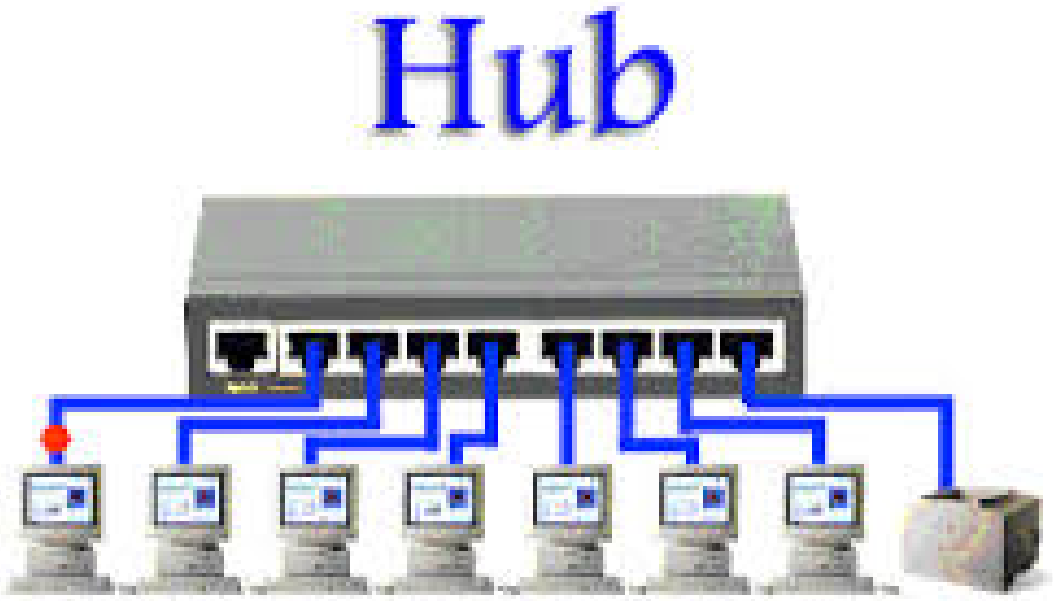
Characteristics:

- No intelligence
- Broadcasts data
- High collision rate
- Shared medium
- Inexpensive
- Largely obsolete

How it Works:

1. Receives data on input port
2. Broadcasts to ALL ports
3. All devices receive data
4. Only intended recipient processes

Hub Diagram



Broadcast Behavior

Hub broadcasts data from one device to ALL connected devices, causing collisions and security concerns.

Repeater

Definition

A **repeater** regenerates or amplifies data signals so they can travel to another segment of cable, extending network reach.

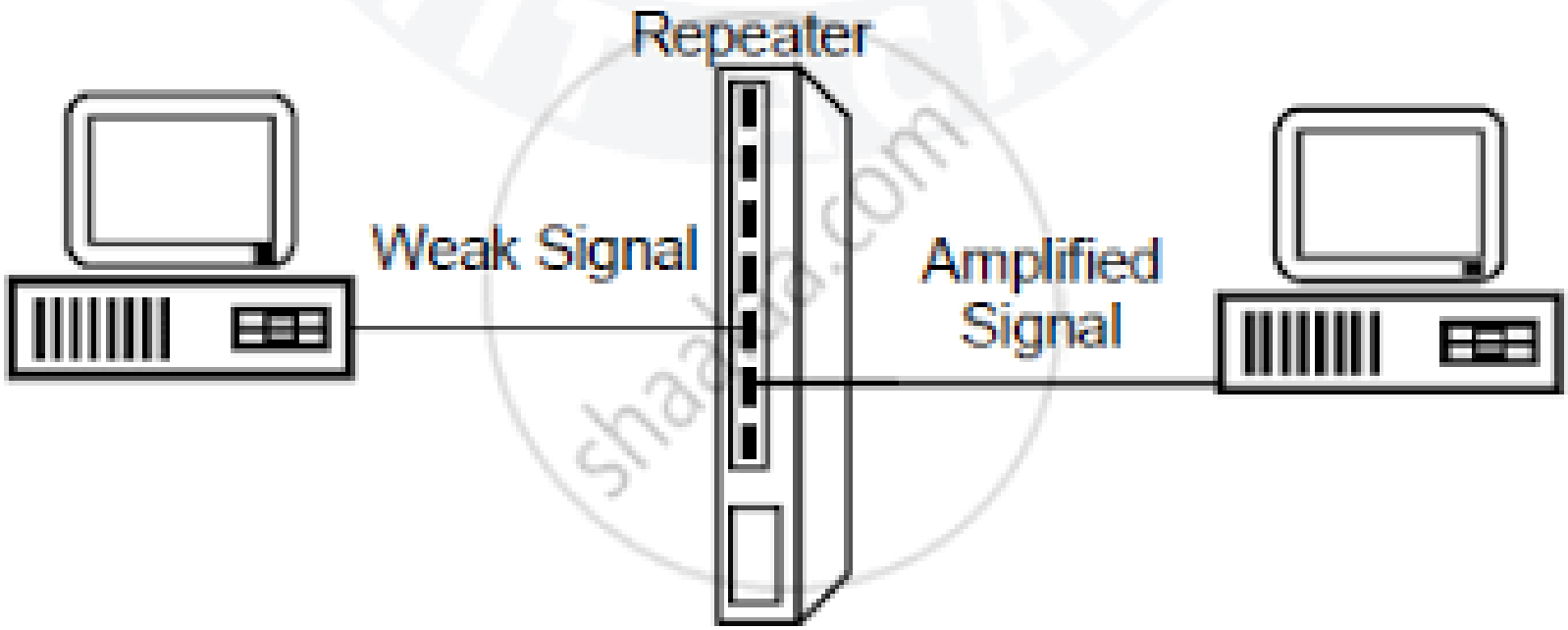
Characteristics:

- Signal regeneration
- No filtering
- No intelligence
- Extends distance

Applications:

- Extend Ethernet cables
- Connect building segments
- Amplify wireless signals
- Extend fiber optic runs

Repeater Diagram



Signal Regeneration

Repeater receives weakened signal, regenerates it, and transmits strong signal to extend network distance beyond normal limits (typically 100m for Ethernet).

Bridge

Definition

A **bridge** connects two networks and divides collision domains. It uses MAC addresses to forward and filter frames.

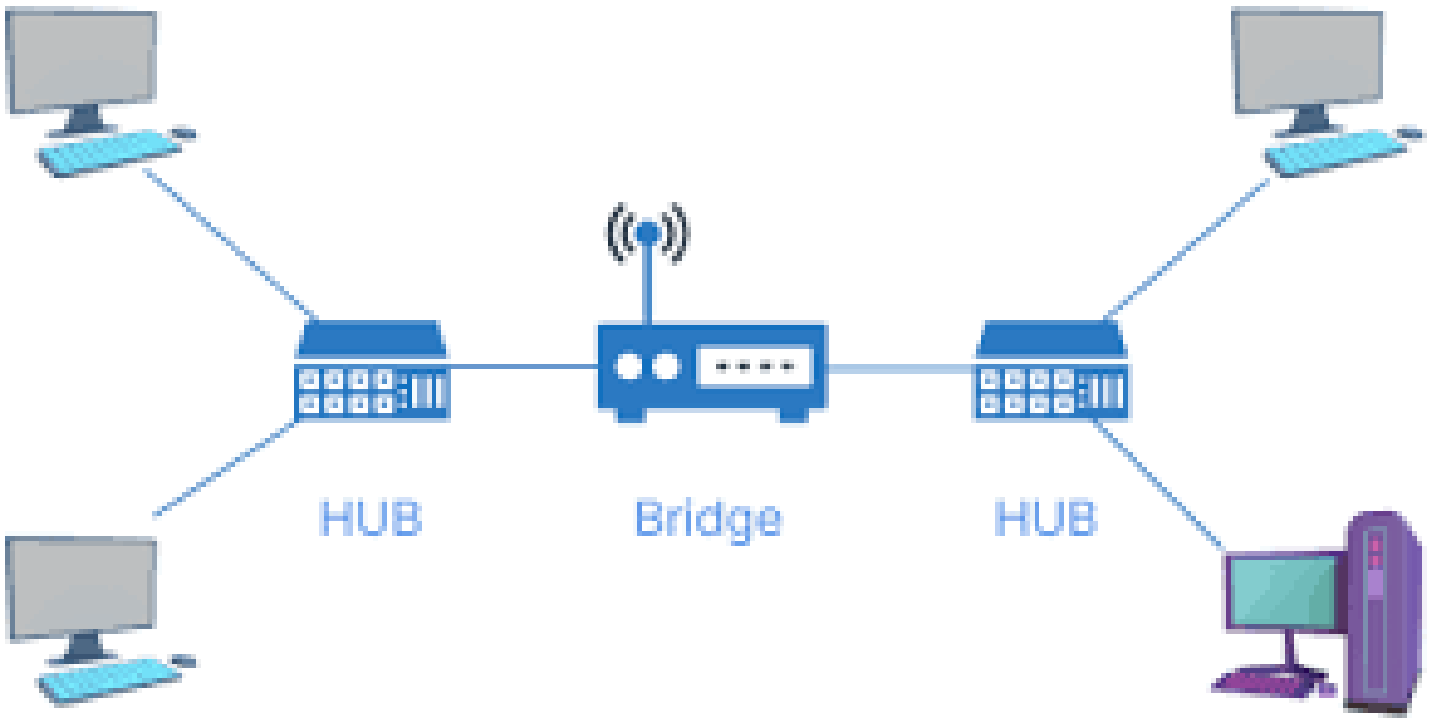
Characteristics:

- Uses MAC addresses
- Divides collision domains
- Filters messages
- Builds forwarding table
- More intelligent than hub

Functions:

- Filtering
- Forwarding
- Learning

Bridge Diagram



Intelligent Forwarding

Bridge learns MAC addresses and forwards messages only to destination network, reducing traffic and collisions.

Switch

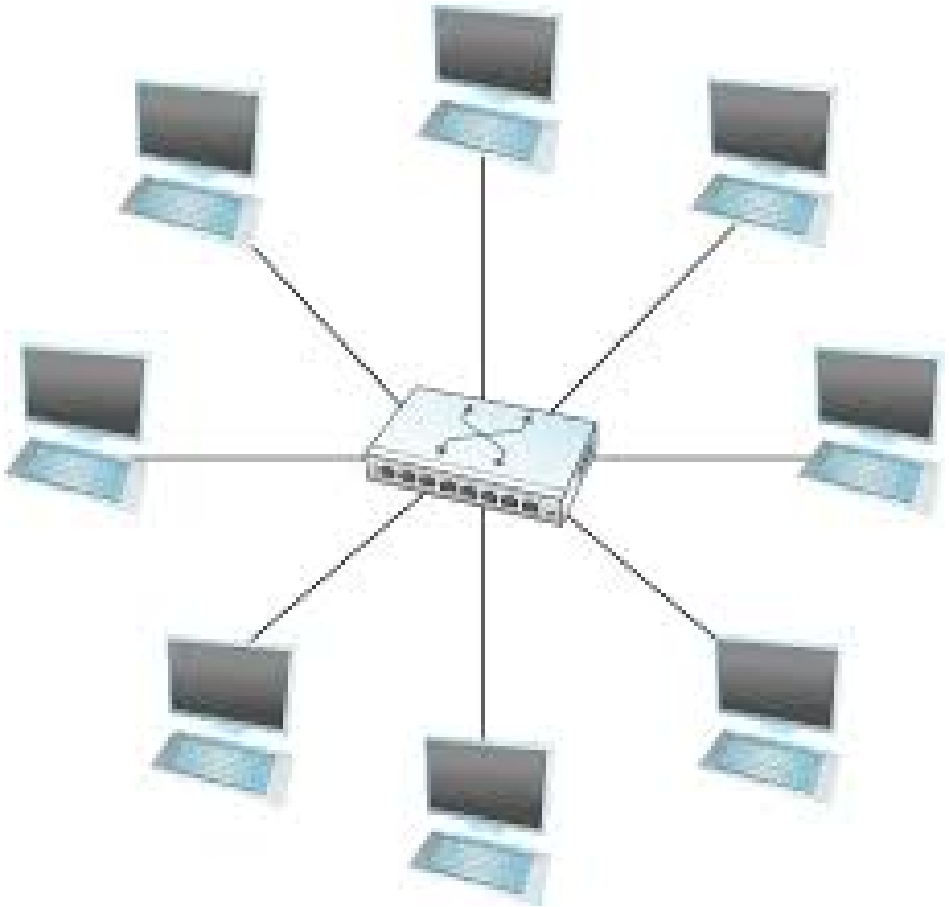
Definition

A **switch** is similar to a bridge with more interfaces. It provides dedicated bandwidth and direct communication between nodes.

Characteristics:

- Uses MAC addresses
- Each port = collision domain
- Wire-speed forwarding
- Most efficient for LANs

Switch Diagram



Dedicated Paths

Switch creates dedicated connection between communicating devices, eliminating collisions and providing full bandwidth per port.

Router

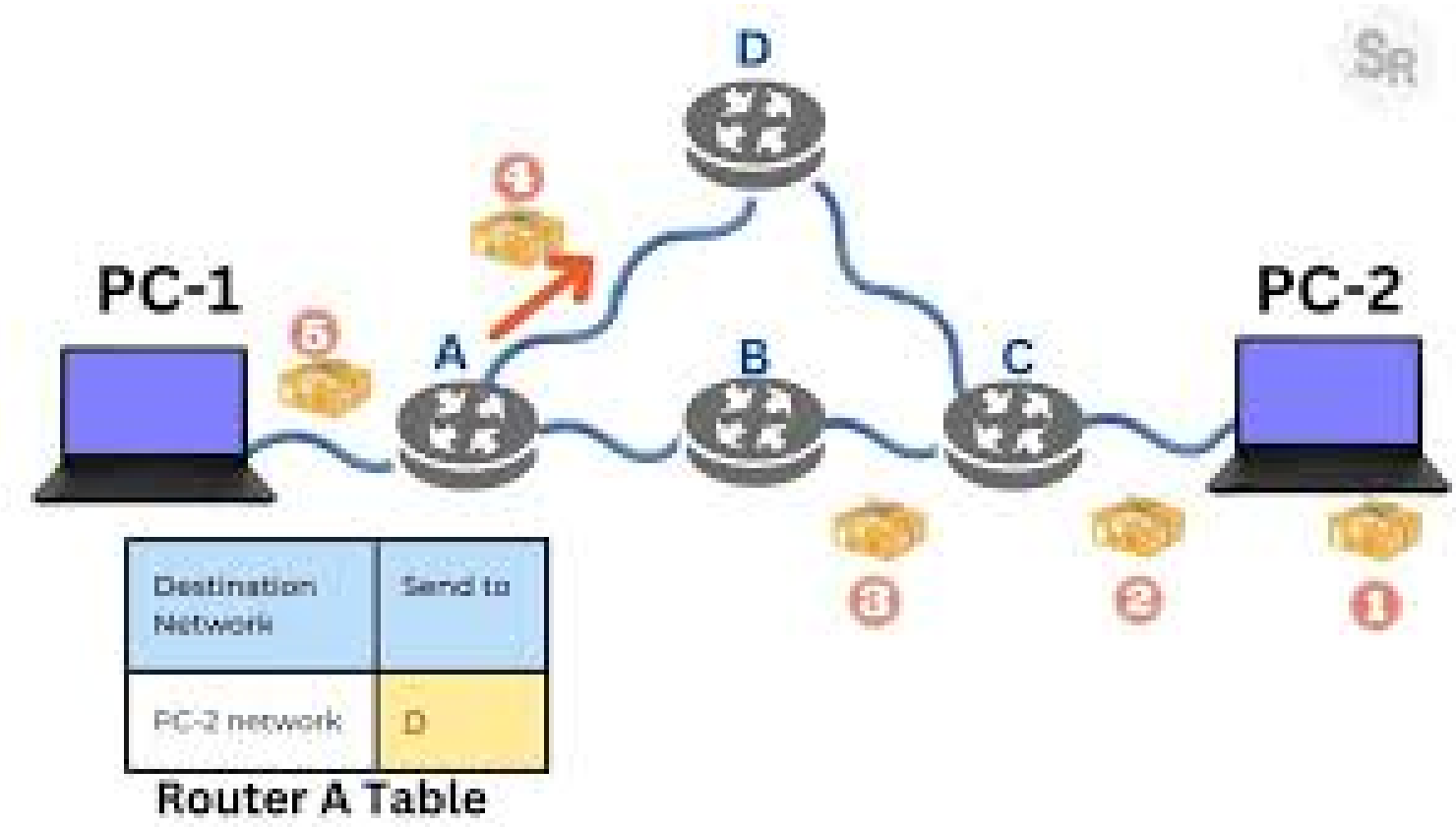
Definition

A **router** connects different types of networks with different architectures or protocols. It uses IP addresses for routing data.

Characteristics:

- Uses IP addresses
- Connects different networks
- Path selection
- Divides broadcast domains
- Network interconnection

Router Diagram



Network Interconnection

Router intelligently forwards packets between different networks using IP addresses and routing tables.

Network Device Comparison

Device	Layer	Address	Intelligence	Primary Function
Hub	1	None	None	Signal broadcast
Repeater	1	None	None	Signal amplification
Bridge	2	MAC	Low	LAN segmentation
Switch	2	MAC	Medium	Fast frame switching
Router	3	IP	High	Network interconnection

Device Selection

Choose devices based on network requirements: switches for LANs, routers for network interconnection.

Network Transmission Media

Wired Media:

- **Twisted Pair Cable**
  - UTP (Unshielded)
  - STP (Shielded)
  - Cat5e, Cat6, Cat7
  - Max: 100m, 10 Gbps
- **Coaxial Cable**
  - Cable TV networks
  - Better bandwidth
- **Fiber Optic**
  - Single-mode (long)
  - Multi-mode (short)
  - Very high speed

Wireless Media:

- **Wi-Fi**
  - WLAN connectivity
  - 802.11 standards
- **Bluetooth**
  - Short-range
  - Device pairing
- **Cellular**
  - Mobile networks
  - 4G/5G
- **Satellite**
  - Long-distance
  - Remote areas

Exercise: Network Design for a Two-Floor Building I

Practical Application of Network Hardware Concepts

Scenario You are tasked with designing a network for a small company building with two floors:

First Floor:

- 2 Desktop computers
- 1 Network printer (shared resource)

Second Floor:

- 8 Desktop computers
- 1 Server (hosting database application)

Requirements:

- All devices must only communicate with with the database server or printer
- All computers must access the printer on the first floor
- All computers must access the database server on the second floor

Exercise: Network Design for a Two-Floor Building II

Practical Application of Network Hardware Concepts

- The solution must minimize cost while considering the collision problem when it has high impact.

Smart Chips & IoT Technologies

What is RFID?

RFID uses electromagnetic fields to automatically identify and track tags attached to objects. Tags contain electronically stored information that can be read from several meters away.

Passive RFID

- No battery
- Powered by reader
- Range: up to 10m
- Low cost

Active RFID

- Battery-powered
- Long range: 100m+
- Higher cost
- More features

RFID System Components

Key Components

1. **RFID Tag (Transponder):** Microchip + Antenna
2. **RFID Reader (Interrogator):** Sends and receives RF signals
3. **Backend System:** Processes and stores data

Frequency Bands

Frequency	**Range**	**Applications**
LF (125-134 kHz)	10 cm	Animal ID, Access control
HF (13.56 MHz)	1 m	Smart cards, NFC
UHF (860-960 MHz)	10 m	Supply chain, Retail
Microwave (2.45 GHz)	30 m	Toll collection

RFID Tag Detection Process I

How a Reader Detects an RFID Tag

Detection Steps

The interaction between an RFID reader and tag follows four main steps:

1. **Radio Field Emission**
   - The RFID reader generates an electromagnetic field at a specific frequency
   - Examples: 125 kHz (LF), 13.56 MHz (HF), 860-960 MHz (UHF)
2. **Tag Activation (for passive tags)**
   - Passive tags have no battery
   - They use energy from the reader's radio field to power up
   - The field induces a current in the tag's antenna, which powers the chip
3. **Tag Response**
   - Once activated, the tag transmits its data (typically unique identifier)
   - Uses signal modulation techniques (amplitude or phase modulation)

4. **Reception and Decoding**
   - Reader captures the response and decodes it
   - Sends data to control system (database, software, automation system)
   - System decides action: open gate, log entry, track item, etc.

RFID Applications I

Real-World Use Cases

Supply Chain & Logistics

- **Inventory Tracking:** RFID tags attached to products enable real-time monitoring of stock levels, automatic reordering, and precise location tracking throughout warehouses without manual scanning.

Retail

- **Anti-theft Systems:** RFID tags trigger alarms at store exits if unpaid items are detected, reducing shoplifting while providing faster checkout experiences for customers.

Healthcare

- **Patient Identification:** RFID wristbands ensure accurate patient identification, prevent medical errors, and enable automatic updating of medical records during treatment.

Transportation

- **Toll Collection:** RFID transponders in vehicles enable automatic toll payment without stopping, reducing traffic congestion and improving highway efficiency.

NFC Technology - Overview I

Near Field Communication

What is NFC?

NFC is a short-range wireless technology enabling communication between devices when touched together or brought within a few centimeters (typically ¡ 10cm). Based on RFID but designed for secure, two-way communication.

Key Features

- Very short range (4-10 cm)
- Fast connection (¡ 0.1 second)
- Low power consumption
- Two-way communication
- Secure proximity-based

Operating Modes

1. **Reader/Writer Mode:** Read NFC tags
2. **Peer-to-Peer Mode:** Device-to-device
3. **Card Emulation Mode:** Act as smart card

NFC Applications I

Modern Use Cases

Mobile Payments

- Apple Pay, Google Pay
- Samsung Pay
- Contactless credit cards

Access & Identity

- Digital keys
- Employee badges
- Event tickets
- Secure authentication

Data Sharing

- Contact exchange
- File transfer
- WiFi pairing
- Bluetooth setup

Smart Posters & Tags

- Product information

NFC Applications II

Modern Use Cases

NFC vs RFID

NFC: shorter range (cm), bidirectional, more secure, used for payments/pairing
RFID: longer range (meters), typically one-way, used for tracking/identification

IoT Sensors I

Sensing the Physical World

What are IoT Sensors?

Devices that detect and measure physical properties from the environment and convert them into digital signals for processing and transmission over networks.

Environmental Sensors

- Temperature & Humidity
- Air quality (CO2, VOC)
- Light intensity
- Pressure
- Weather monitoring

Motion & Position

- Accelerometers
- Gyroscopes

Industrial Sensors

- Vibration sensors
- Current/Voltage sensors
- Flow meters
- Level sensors

Biometric Sensors

- Heart rate monitors
- Blood pressure
- Fingerprint scanners