Local Area Networks (LAN)  
- Sharing Transmission Media by Computers -

- Classifications of Computer Networks: LAN, MAN, WAN
- Point-To-Point Connection and Shared Medium
- LAN Topology: Star, Ring, Bus
- Typical LANs
  - Ethernet (CSMA/CD)
  - LocalTalk (CSMA/CA)
  - Wireless LAN
  - Token Ring
  - FDDI
  - ATM
- Unicast, Broadcast, Multicast
Classifications of Computer Networks

**LAN – Local Area Network**: A network that spans a small geographic area, such as a single building or buildings close to each other.
Examples: Ethernet, LocalTalk, Token Ring, FDDI, ATM

**PAN – Personal Area Network**

**MAN – Metropolitan Area Network**: A network that can span a geographic area the size of a city.
Example: DQDB

**WAN – Wide Area Network**: A network that can span a large geographic area, e.g., multiple cities, countries or continents.
Examples: ARPANET, X.25, Frame Relay, SMDS, ATM
Point-to-Point network provides a dedicated link between any two computers/devices → Fully Connected

- Dedicated link: used by only two computers and not shared with others
- High security and privacy
- \((N^2-N)/2\) links are needed for \(N\) computers/devices
  - 45 links (\(N=10\)), 4950 links (\(N=100\)), 499500 links (\(N=1000\))
- Such a network is not practical because of its high cost and inflexibility
Shared Communication Channel/Medium in LAN

Key natures of LAN:
- **Media type:** wired/wireless, twisted pair/cable/fiber, radio/infrared
- **Topology:** network shape/connection method
- **Protocol:** how to use shared medium, media access control technique
  a) TDM: only one computer can send data in a time
  b) Frame: transfer element, each type of LAN has its own frame format
- **Bit rate/speed:** usually from 1Mbps~1Gbps
LAN Basic Topologies

Star Topology

Ring Topology

Bus Topology
LAN Basic Topologies (cont.)

- Ring
- Mesh
- Star
- Fully Connected
- Line
- Tree
- Bus
**Ethernet – Bus Topology**

**Media:** Coax cable, twisted pair, fiber

**Topology:** Logic bus (physically may be bus or star)

**Transmit:** Only one can transmit at any time, all others receive transmission

**Speed:** 10Mbps, 100Mbps (Fast Ethernet) and 1000Mbps (Gigabit Ethernet)

**Status:** Most popular LAN and widely used

**History:**
- Invented at Xerox (Palo Alto Research Center) in 1970s
- Defined a DIX standard by Digital Equipment, Intel and Xerox
- IEEE currently controls Ethernet standards
  - Project 802.3 – Ethernet
    - Define media, voltages, encoding, data rates, frames, wiring, ...
All computers connect to a bus but only one can transmit at a time. Who can? No central controller/manager when computers transmit on the bus!!

Ethernet employs CSMA to coordinate transmissions among multiple computers.

**CSMA** (Carrier Sense with Multiple Access)
- **MA** (Multiple Access): multiple computers are attached, any can access bus
- **CS** (Carrier Sense): a computer listens to carrier before sending data
  - waits if medium/bus is busy (another computer is transmitting)
  - transmits if medium/bus is idle (no one transmits)
When to Start Transmit – CSMA/CD

Even with CSMA, two computers may transmit simultaneously:
- Both find it idle and begin transmitting in almost the same time.
- Two signals exist in the medium, interfere each other, call collision.

**CD (Carrier Detection)**
- Monitor outgoing signal.
- Stop transmissions after collision is detected.
- Each waits random time in $[0, S]$.
- Listen to the bus and transmit again if it is idle.
- Wait random time in $[0, 2S]$ if collisions are detected again.
- Double the waiting time range $[0, 2^kS]$ when $k+1$ collisions are detected.

→ Called exponential backoff, very effective in practical.
CSMA/CD Flowchart

Start

Assemble a frame

Attempt ← 1

Is some other station transmitting?

Yes → Recovered

No → Transmit 1st bit of the frame

Collision detected?

Yes → Collision recovery subalgorithm

No → Transmission finished?

Yes → End

No → Not recovered

Frame transmission failed (too many collisions)

Transmit next bit of the frame

Frame transmitted successfully

There is data from user to send

Phys. Addresses are used (MAC addresses)
Inventors of Ethernet

Robert Metcalfe (1946, US)  
David R. Boggs (1950, US)  
- Developed at Xerox PARC, 1973-1974

- Metcalfe identifies the day Ethernet: May 22, 1973, circulated a memo titled "Alto Ethernet" containing a rough scheme.
- Boggs identifies another date as birth of Ethernet: November 11, 1973, the first day the system actually functioned.
- The two would co-invent Ethernet, with Metcalfe generating the ideas and Boggs figuring out how to build the system.
- Patented with the 2 & Thacker, Lampson (75)
- Metcalfe, Boggs, "Ethernet: Distributed Packet Switching for Local Computer Networks". Communications of the ACM (1976)
LocalTalk – Bus Topology

Media: Coax cable, twisted pair
Topology: Logic bus (physically may be bus or star)
Transmit: Only one can transmit at any time, all others receive transmission
Speed: 230.4 kbps
Status: IEEE Project 802.4, Apple’s Macintosh computers, low cost & easy install
CSMA/CA: Using CSMA to listen and transmit
CSMA/CA: Using **CA** (collision avoidance) rather than **CD** (collision detection)
  - send a short message to reserve the bus if it is idle
  - transmit a frame if reservation is successful (no collision)
  - listen and reserve again
**Wireless LAN – Bus Topology**

**Media:** Air (infrared, spread spectrum, narrowband microwave)

**Topology:** Logic bus

**Transmit:** Only one can transmit, not all others can receive transmission depended upon transmitting energy and distance

**Speed:** 1~10Mbps (infrared), 1~20Mbps (spread), 10~100Mbps (MW)

**Status:** IEEE Project 802.11, many products from different companies

**CSMA/CA:** Using CSMA to listen and transmit

Using **CA (collision avoidance)** rather than CD (collision detection)
- send a RTS message to reserve the medium if it is idle
- transmit a frame if receiving a destination’s CTS (no collision)
- listen and reserve again

**RTS:** Request To Send, **CTS:** Clear To Send → Hidden node problem
CSMA/CA Flowchart (IEEE802.11)

1. Start
2. Assemble a Frame
3. Is the Channel Idle?
   - If NO, Wait for Random Backoff Time
   - If YES, Not Using IEEE 802.11 RTS/CTS Exchange
     - Transmit RTS
     - CTS Received?
       - If NO, Using IEEE 802.11 RTS/CTS Exchange
       - If YES, Transmit Application Data
4. END
Wireless LAN

- Wireless LAN: small range (< 100m)
- IEEE 802.11 (similar to Ethernet)
  - Defined by IEEE (Institute for Electrical and Electronic Engineers)
  - Access control: CSMA/CD (only one can send each time similar to TDMA, listen and transmit if no other transmission, otherwise wait)
  - Speed: 2Mbps (infrared), >10Mbps (Microwave, 2.4/5.2GHz)
- HIPERLAN
  - Defined by ETSI (European Telecommunication Standard Institute)
  - Access control: dynamic TDMA
  - Speed: 25Mbps (5GHz) and 155Mbps (17GHz)
- HomeRF
  - Access control: similar IEEE 802.11 with priority and reservation control
  - Speed: 10Mbps (2.4GHz), supports both data, voice and streaming
- Bluetooth
  - Defined by Bluetooth Special Interest Group (SIG, industry)
  - Access control: TDD (Time Division Duplex) with circuit and packet switch
  - Speed: 1M~10bps
All stations (computers/devices) on shared-media LAN receive all transmissions. Each station assigned unique number, called station address or **hardware address** fixed by manufacturer, configured manually or electronically provided dynamically by software. A sender specifies destination address and source address in its frame header.
Packet can be sent to:
- Single destination (station address) called **unicast** (1-to-1)
- All stations (a special address), called **broadcast** (1-to-all)
- Subset of stations (special addresses), called **multicast** (1-to-m)

**Ethernet**
- Each station has 48 bits (6 bytes) unique address assigned by manufacturer
- Broadcast address: all 1s address (1111...11)
- Multicast address: [1xx...x], half of addresses reserved for multicast
Ethernet Frame Format

- **Preamble**: 64bits (8 bytes) for receiver synchronization with incoming signal
- **Destination address** and **source address**
- **Frame type** (2 bytes):
  - `0000~05DC` Reserved for use with IEEE LLC/SNAP
  - `0800` Internet IP Version 4
  - `8008` AT&T Corporation
  - `8014` Silicon Graphics Corporation network games
  - `8137-8138` Novell Corporation IPX
  - `...`
- **Data or Payload**: Minimum 46 bytes and maximum 1500 bytes
- **CRC (4 bytes)**: Cyclic redundancy check
Token Ring – Ring Topology

Media: Twisted pair (TW), fiber

Topology: Logic ring (physically may be ring or star)

Transmit: Bits flow in single direction from sender, next, destination to send

Speed: 4, 16 or 100Mbps

Status: IEEE Project 802.5, first developed by IBM

Token: A permission to send data across the ring.

- Only one token in a ring and the token rotates one by one.
- If no data to be sent, computer passes received token to the next.
- When a computer obtains the token, it can send a **single** packet.
- A packet travels around entire ring and finally arrives source.

**Token frame (3 bytes)**

- SD: Start Delimiter
- AC: Access Control
- ED: End Delimiter
- FC: Frame Control
- FS: Frame Status

**Data frame**

- SD AC FC DAdd SAdd
- Payload
- CRC ED FS

Up to 4550 bytes
**FDDI - Ring Topology**

**Media:** Fiber (Fiber Distributed Data Interconnect) or cable (CDDI)

**Topology:** Two rings

**Transmit:** Bits can flow in 2 directions for improving reliability

**Speed:** 100 Mbps

**Status:** ANSI standard, expensive than Ethernet and Token Ring

**Token:** A permission to send data across the ring.

- Only one token in a ring and the token rotates one by one.
- If no data to be sent, computer passes received token to the next.
- When a computer obtains the token, it can send a single packet.
- A packet travels around entire ring and finally arrives source.

**Data frame:**

- SD FC ED

**Token frame:** (3 bytes)

- SD FC DAdd SAdd

**Payload**

- Up to 4550 bytes

**Features:** multiple frames for MM data or RT trans.
ATM LAN – Star Topology

ATM: Asynchronous Transmission Mode
Media: Fiber
Topology: Star
Transmit: More than one can transmit because of using switch
Speed: 25, 45, 155, 622 Mbps
Status: ATM Forum and ATM Consortium, high speed for multimedia com
Switch: Each station connects to switch with full-duplex connections. Computers send data independently and simultaneously. Packet size is very small, 53 bytes, called cell.
Very expensive
Exercise 4

1. Prove that the total number of links in a point-to-point network with N computers is \((N^2-N)/2\).

2. For each of bus, star and ring topologies, discuss the consequences if a station has broken.

3. In most technologies, a sending station can choose the amount of data in a frame, but the frame header is a fixed size. Calculate the percentage of bits in a frame devoted to the header, trailer and preamble for the largest and smallest Ethernet frame.

4. Assume a one megabyte file must be send from one computer to another (both are connected to a same 10BaseT Ethernet). What is the minimum time to send the file across the network? What is the minimum time across a Fast Ethernet? Across a gigabit Ethernet?

5. Give the definitions and examples of unicast, broadcast and multicast, respectively.