Local-Area Networks

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CS2032 – Principles of Computer Communication

Lesson Outcomes

- After successful completion of this lesson you will be able to:
  - Explain wired networking concepts with Ethernet as the example
  - Identify standards used in Physical and Data Link layers of Wired Networks

Large Picture of Networked Systems

Connecting many stations

Connection strategies

Protocols

Networks

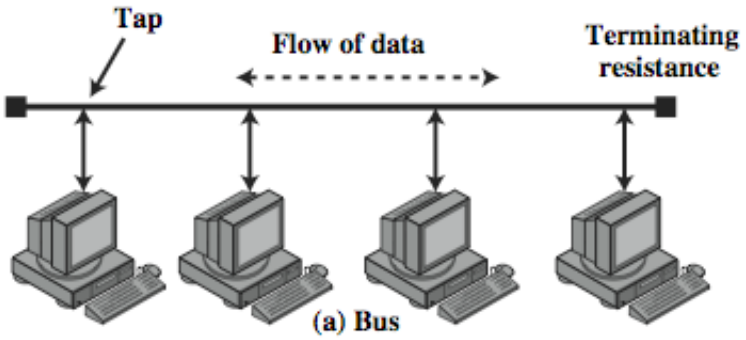
- Depending on geographic area covered by a network and protocols involved:
  - PAN – Personal Area Networks
  - **LAN – Local Area Networks**
    - Usually owned by an organization, interconnects communication equipment, carry internal communication load
  - WAN – Wide Area Networks
  - MAN – Metropolitan Area Networks

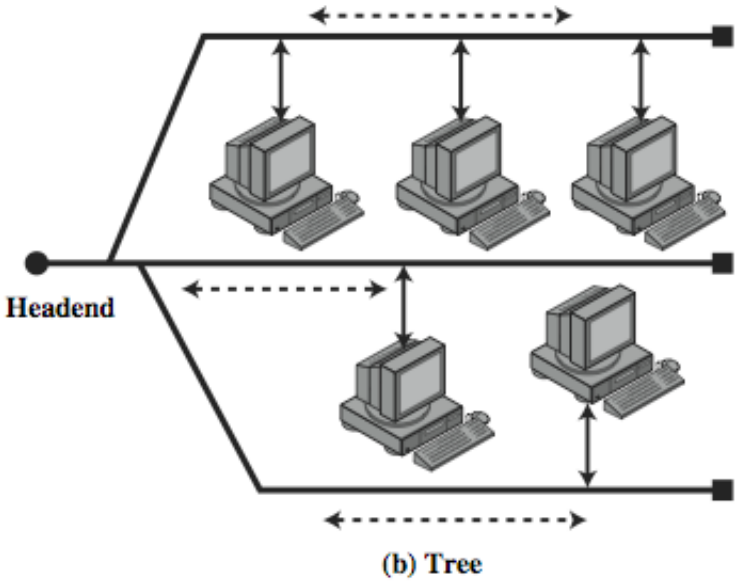
Network Topologies

The way in which the end points or stations attached to the network are interconnected

Bus and Tree Topologies

- A single communication line - Bus
  - Stations are attached through hardware interface called Tap
  - Terminator absorbs signal to remove it from the bus
- Full duplex communication between station and tap
  - All stations can receive signals from all stations
- Simple, extendible
  - Bus can be considered special case of tre



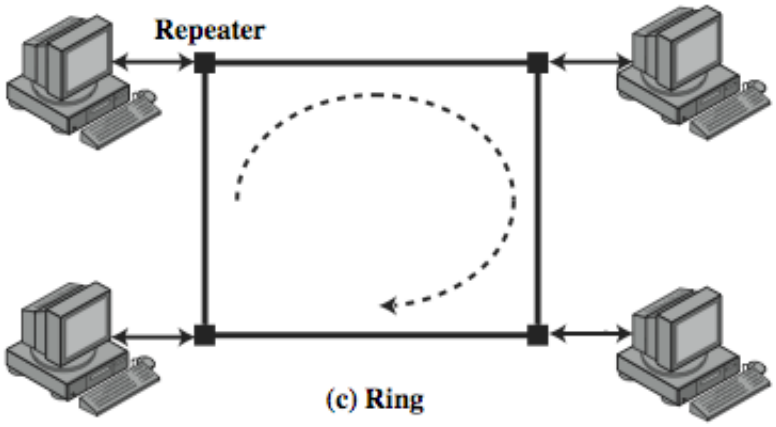


Bus and Tree Topologies (2)

- Two problems:
  - Indicating whom the communication is intended to
  - When to access the shared medium
- Solution
  - Data sent as frames with control information in **header** (e.g. destination address)
  - Media access control protocols

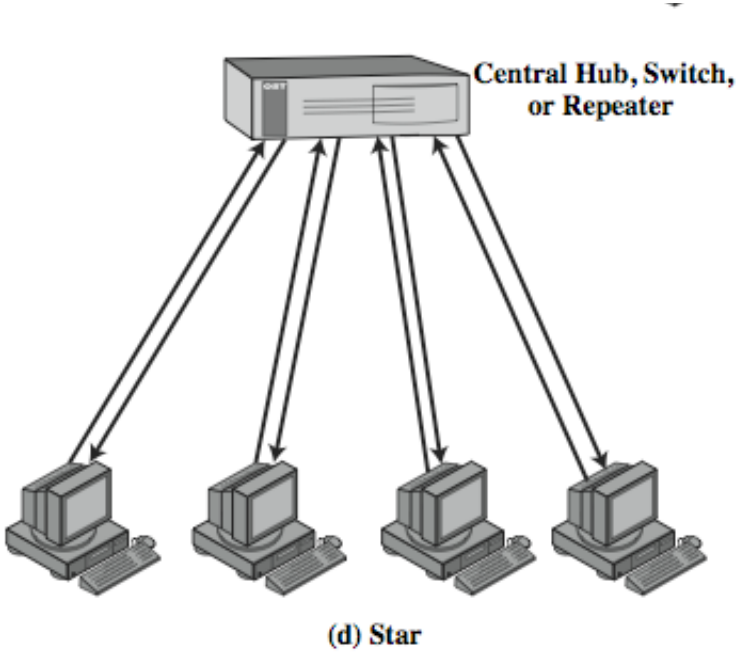
Ring Topology

- A set of repeaters joint with point-to-point link in closed loop
- Unidirectional transmission by repeaters
- Each station is attached to the network at a repeater
- Data transmitted as frames
  - Destination recognizes
  - Removed at source after full circulation
- When to insert frames?
  - Protocols



Star Topology

- One station is a logical communication center
  1. Central node to operate as broadcast (e.g.hub)
  2. Central node as frame switching device
- Any two stations must communicate through the central station



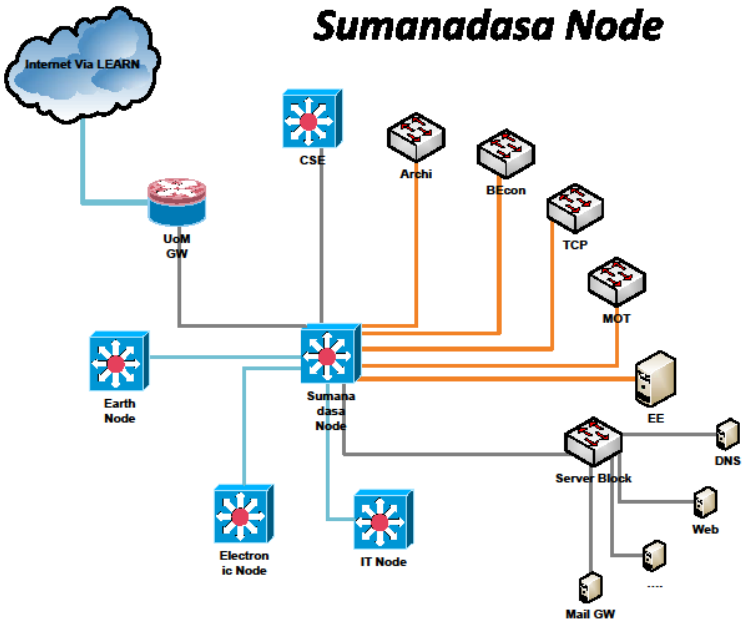
(d) Star

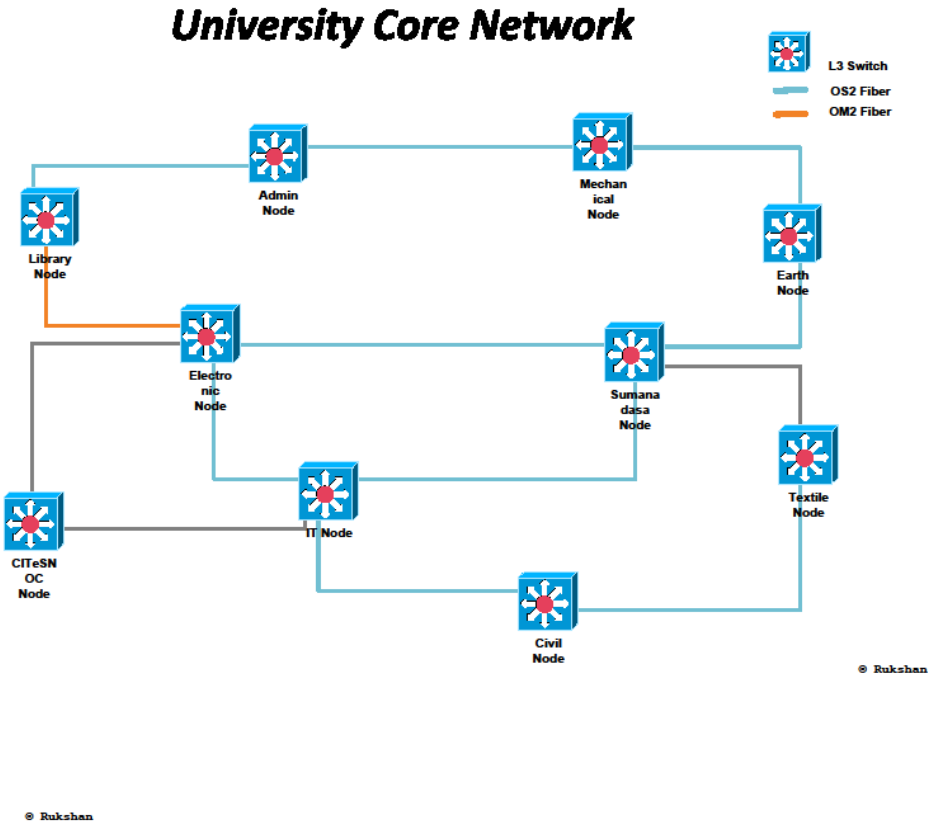
Choice of Topology

- Reliability
- Expandability
- Performance
- Depend on overall design, media, wiring layout, and access control

Topologies in Practice

- University Network





Protocols

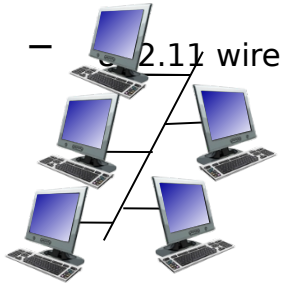
A set of rules and the manner in which stations begin and proceed communication

 A lot of **software** to make networks work

Multiple access links, protocols

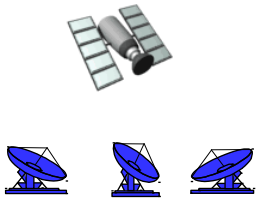
two types of “links”:

- point-to-point
  - PPP for dial-up access
  - point-to-point link between Ethernet switch, host
- *broadcast (shared wire or medium)*
  - old-fashioned Ethernet
  - upstream HFC
  - 802.11 wireless LAN



shared wire (e.g., cabled Ethernet)

shared RF (e.g., 802.11 WiFi)



shared RF (satellite)

humans at a cocktail party (shared air, acoustical)

Multiple access protocols

- single shared broadcast channel
- two or more simultaneous transmissions by nodes: interference
  - *collision* if node receives two or more signals at the same time

multiple access protocol

- distributed algorithm that determines how nodes share channel, i.e., determine when node can transmit
- communication about channel sharing must use channel itself!
  - no out-of-band channel for coordination

An ideal multiple access protocol

given: broadcast channel of rate R bps

desiderata:

1. when one node wants to transmit, it can send at rate R.
2. when M nodes want to transmit, each can send at average rate R/M
3. fully decentralized:
   - no special node to coordinate transmissions
   - no synchronization of clocks, slots
4. simple

MAC protocols: taxonomy

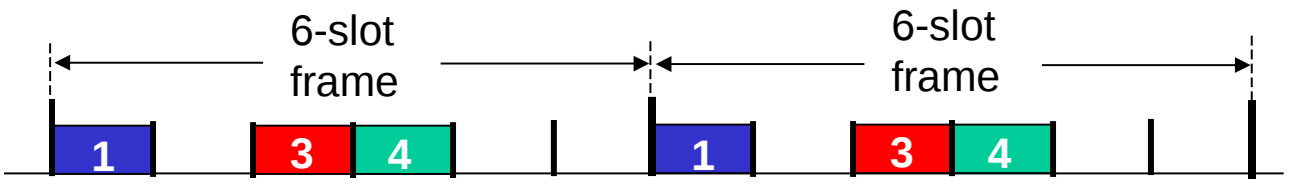
three broad classes:

- *channel partitioning*
  - divide channel into smaller “pieces” (time slots, frequency, code)
  - allocate piece to node for exclusive use
- *random access*
  - channel not divided, allow collisions
  - “recover” from collisions
- *“taking turns”*
  - nodes take turns, but nodes with more to send can take longer turns

Channel partitioning MAC protocols: TDMA

TDMA: time division multiple access

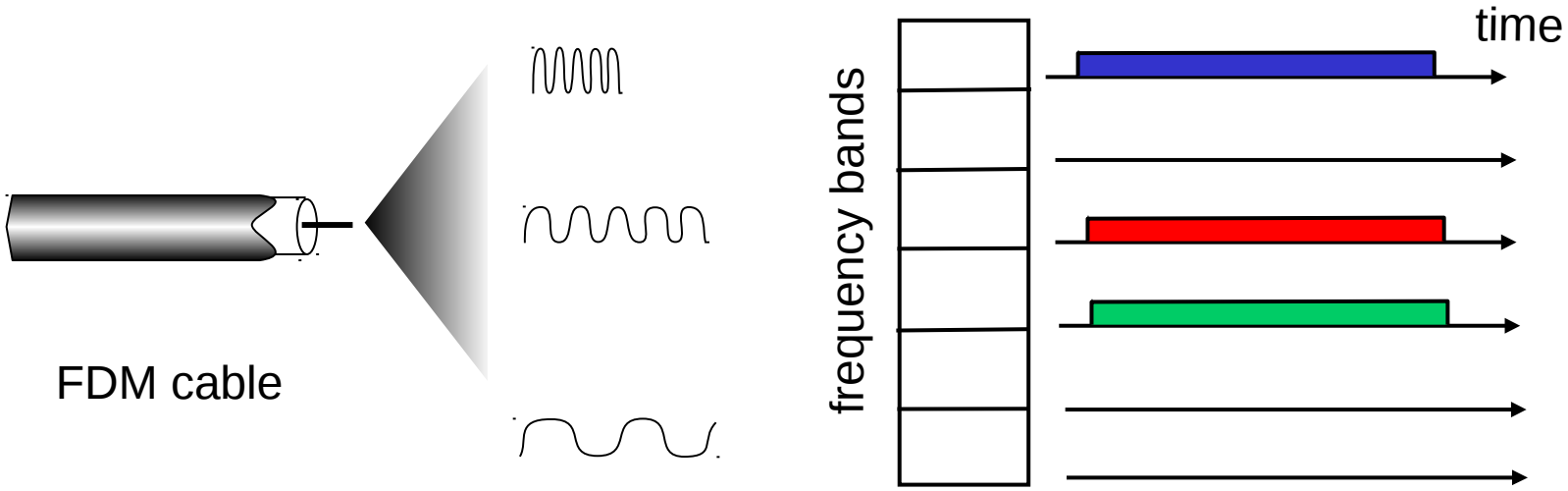
- access to channel in "rounds"
- each station gets fixed length slot (length = pkt trans time) in each round
- unused slots go idle
- example: 6-station LAN, 1,3,4 have pkt, slots 2,5,6 idle



Channel partitioning MAC protocols: FDMA

FDMA: frequency division multiple access

- channel spectrum divided into frequency bands
- each station assigned fixed frequency band
- unused transmission time in frequency bands go idle
- example: 6-station LAN, 1,3,4 have pkt, frequency bands 2,5,6 idle



Random access protocols

- when node has packet to send
  - transmit at full channel data rate R.
  - no *a priori* coordination among nodes
- two or more transmitting nodes → “collision”,
- random access MAC protocol specifies:
  - how to detect collisions
  - how to recover from collisions (e.g., via delayed retransmissions)
- examples of random access MAC protocols:
  - slotted ALOHA
  - ALOHA
  - CSMA, CSMA/CD, CSMA/CA

CSMA (carrier sense multiple access)

CSMA: listen before transmit:

if channel sensed idle: transmit entire frame

- if channel sensed busy, defer transmission

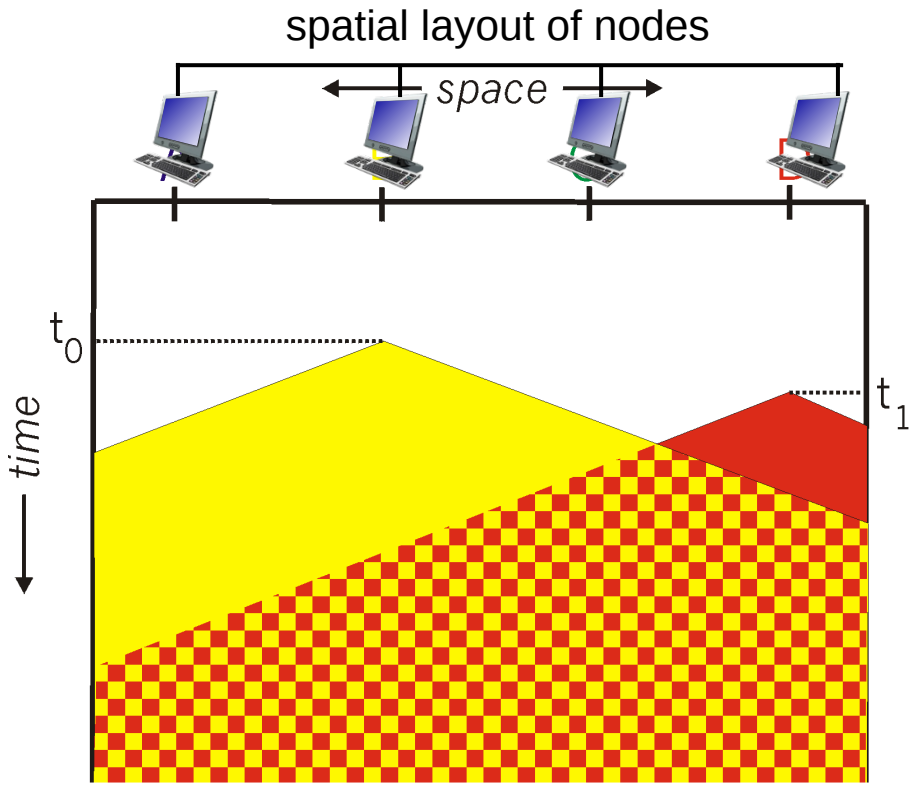
- human analogy: don’t interrupt others!

CSMA collisions

- collisions *can* still occur:

  propagation delay means two nodes may not hear each other's transmission

- collision: entire packet transmission time wasted
  - distance & propagation delay play role in in determining collision probability



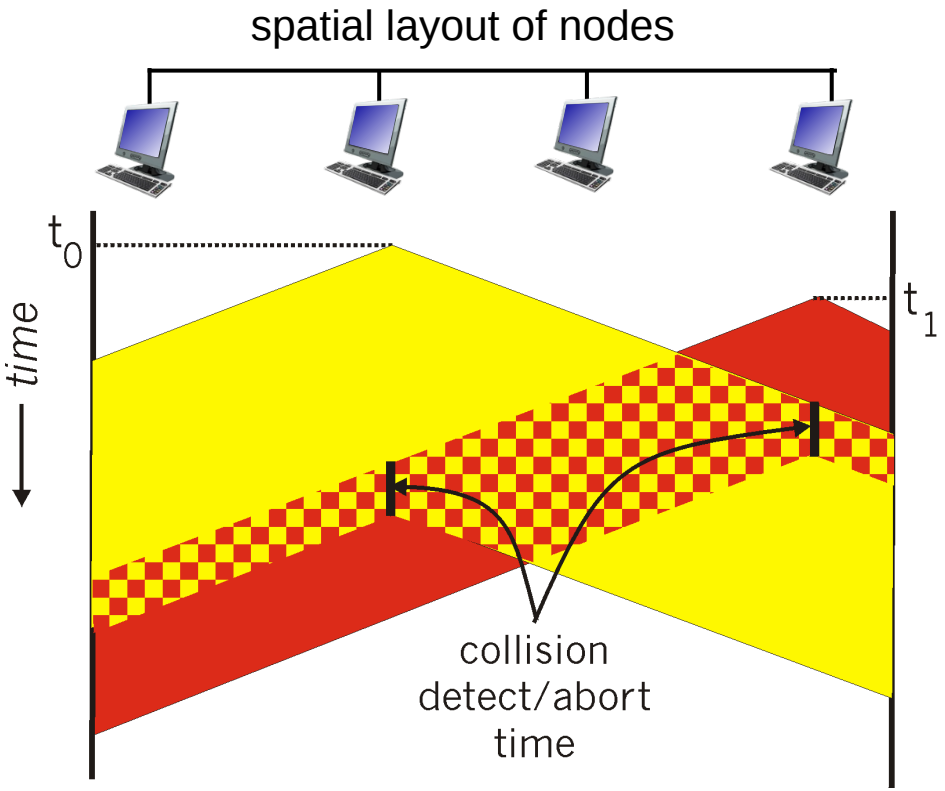
CSMA/CD (collision detection)

CSMA/CD: carrier sensing, deferral as in CSMA

- collisions *detected* within short time
- colliding transmissions aborted, reducing channel wastage

- collision detection:
  - easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - difficult in wireless LANs: received signal strength overwhelmed by local transmission strength
- human analogy: the polite conversationalist

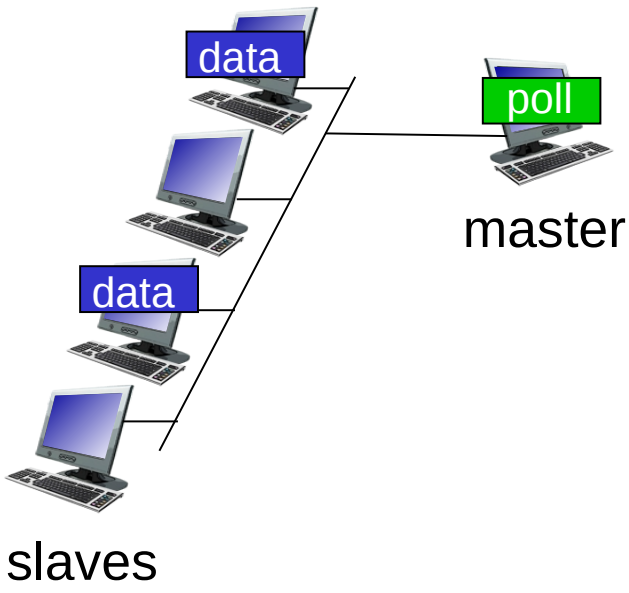
CSMA/CD (collision detection)



“Taking turns” MAC protocols

polling:

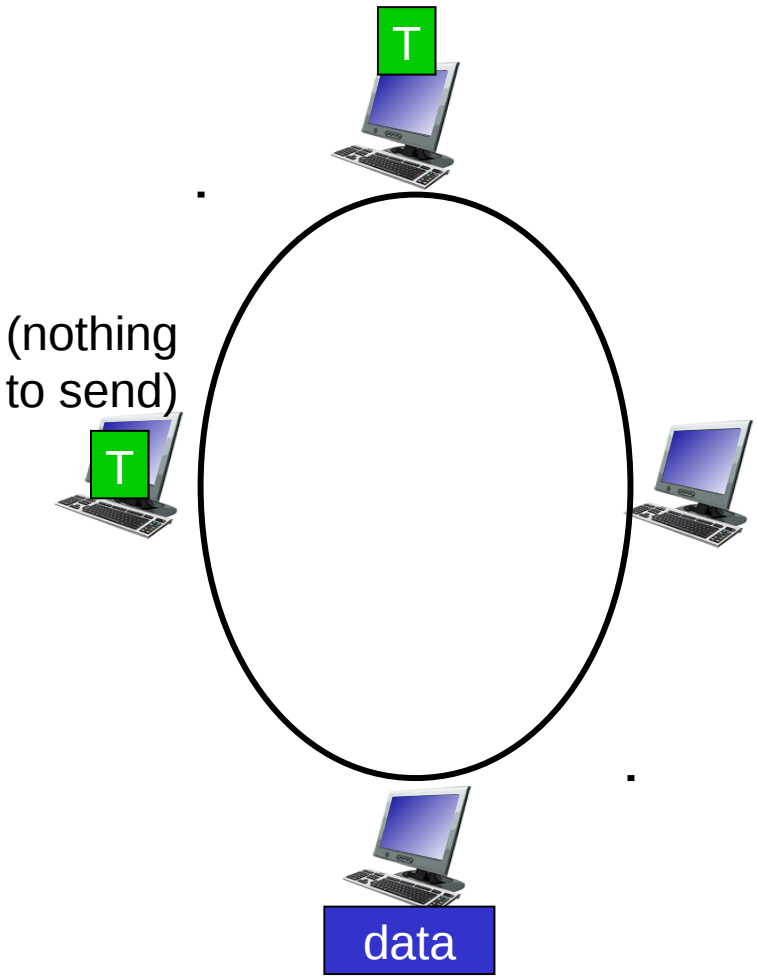
- master node “invites” slave nodes to transmit in turn
- typically used with “dumb” slave devices
- concerns:
  - polling overhead
  - latency
  - single point of failure (master)



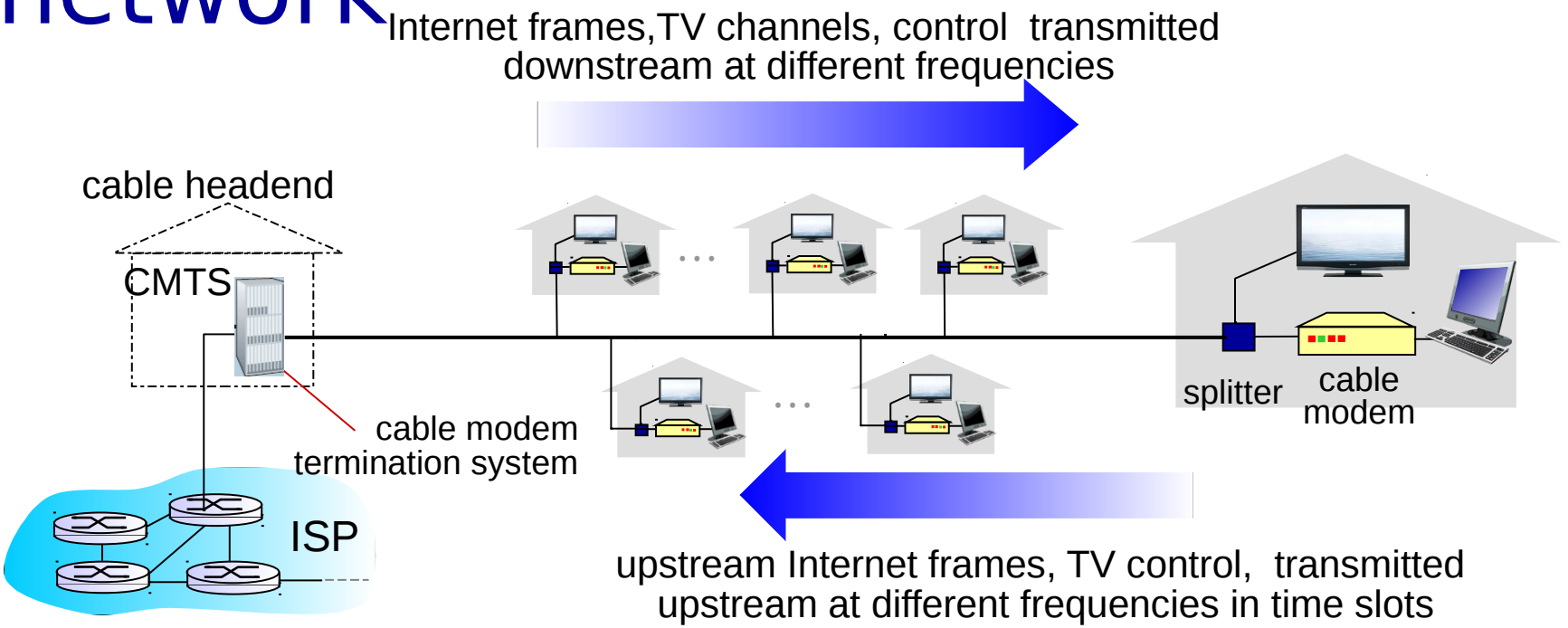
“Taking turns” MAC protocols

token passing:

- control token passed from one node to next sequentially.
- token message
- concerns:
  - token overhead
  - latency
  - single point of failure (token)



Cable access network



- multiple 40Mbps downstream (broadcast) channels
  - single CMTS transmits into channels
- multiple 30 Mbps upstream channels
  - *multiple access: all* users contend for certain upstream channel time slots (others assigned)

Summary of MAC protocols

- *channel partitioning,* by time, frequency or code
  - Time Division, Frequency Division
- *random access* (dynamic),
  - ALOHA, S-ALOHA, CSMA, CSMA/CD
  - carrier sensing: easy in some technologies (wire), hard in others (wireless)
  - CSMA/CD used in Ethernet
  - CSMA/CA used in 802.11
- *taking turns*
  - polling from central site, token passing
  - bluetooth, FDDI, token ring

MAC addresses

- 32-bit IP address:
  - *network-layer* address for interface
  - used for layer 3 (network layer) forwarding
- MAC (or LAN or physical or Ethernet) address:
  - function: *used 'locally" to get frame from one interface to another physically-connected interface (same network, in IP-addressing sense)*
  - 48 bit MAC address (for most LANs) burned in NIC ROM, also sometimes software settable
  - e.g.: 1A-2F-BB-76-09-AD

hexadecimal (base 16) notation
(each "number" represents 4 bits)

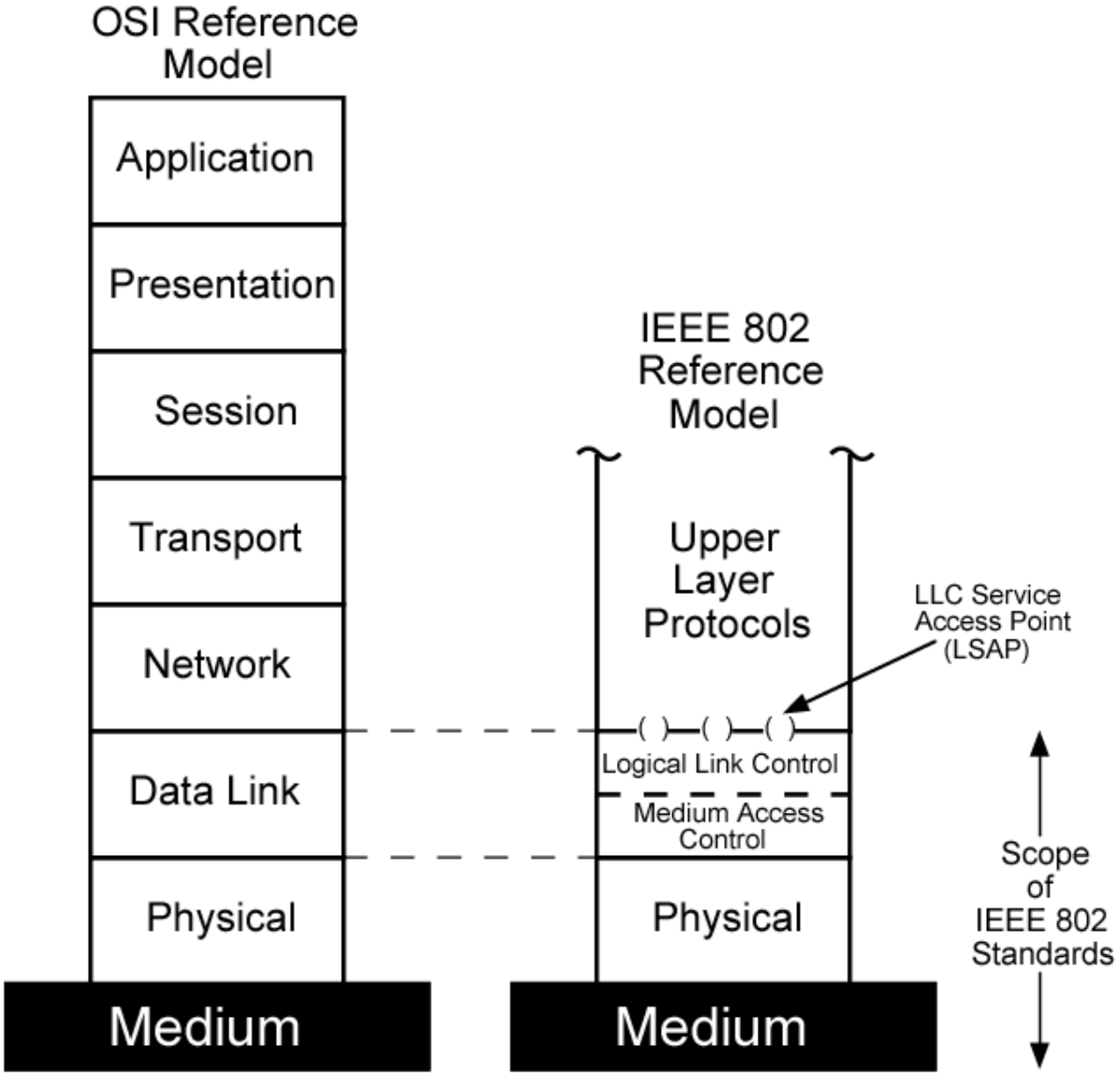
IEEE Standards for WiredNetwork

Specifies range of data rates, topologies, transmission media

e.g.

Standard	Description
802.2	Logical Link Control
802.3	**Ethernet and firstmile**
802.4	Token Bus
802.5	Token Ring
802.7	Broadband LAN using coaxial cables

IEEE 802 in OSI Model



IEEE 802 Reference Model

- Specification for transmission media and topology below physical layer
- Physical Layer
  - Encoding/decoding signals
  - Preamble generation/removal for synchronization
  - Bit transmission/reception
- Above physical layer services to LAN users
  1. On transmission, assemble data into frames with address and error-detection fields
  2. On reception, disassemble frame and perform address recognition and error detection

IEEE 802 Reference Model (2)

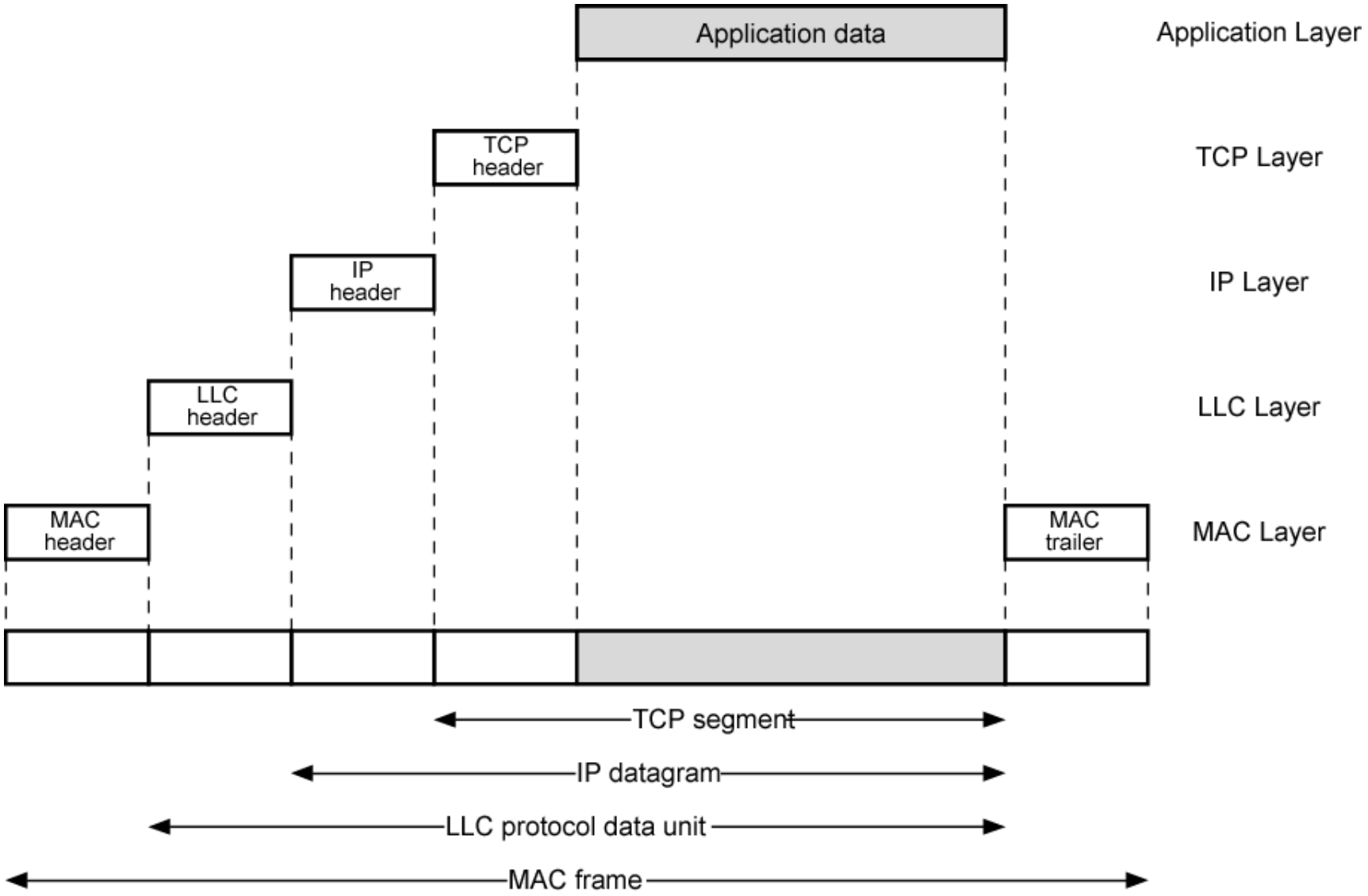
3. Govern access to the LAN transmission media
4. Provide interface to higher layers and perform flow control and error control

- 1 ,2, 3 above by MAC and 4 by LLC
- Reason for sub-layering into MAC and LLC

  Shared access to medium not found in traditional Layer 2

  For same LLC several MAC options

LAN Protocols in Context



Ethernet

History back to1973– PhD thesis by Robert Metcalfe

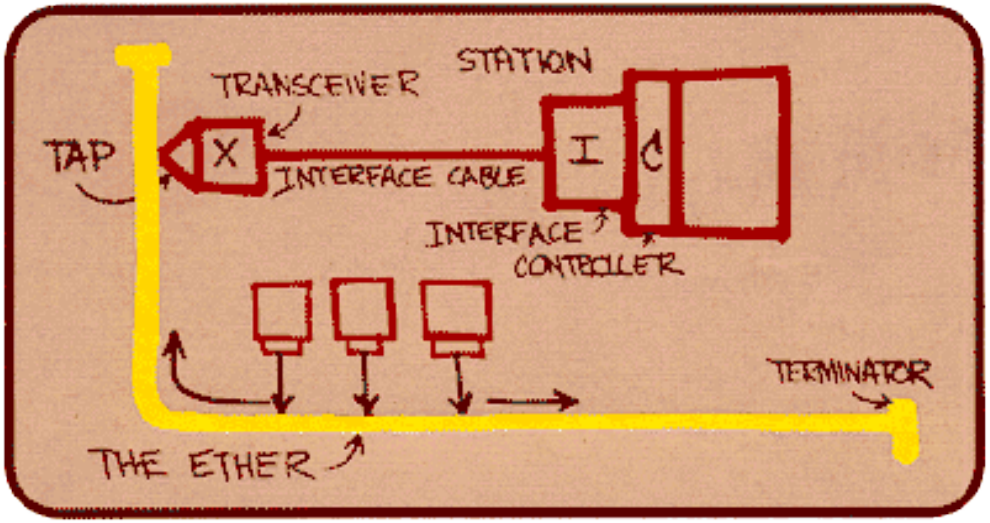
Named after “**ether**” the imaginary substance that many once believed to occupy all space and was the medium for light.

Became IEEE802.3 Standard

Ethernet

“dominant” wired LAN technology:

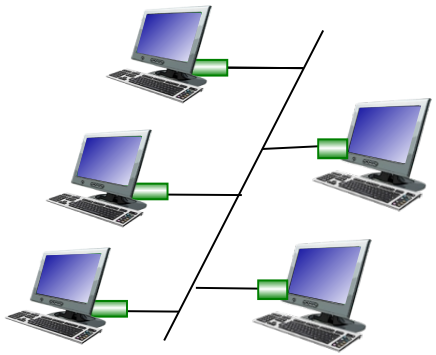
- cheap $20 for NIC
- first widely used LAN technology
- simpler, cheaper than token LANs and ATM
- kept up with speed race: 10 Mbps – 10 Gbps



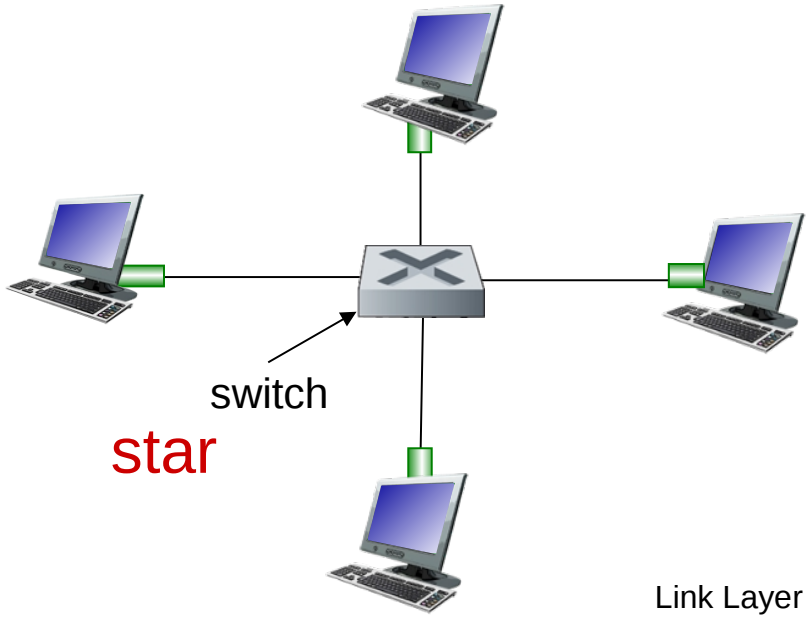
Metcalfe’s Ethernet sketch

Ethernet: physical topology

- *bus:* popular through mid 90s
  - all nodes in same collision domain (can collide with each other)
- *star:* prevails today
  - active *switch* in center
  - each “spoke” runs a (separate) Ethernet protocol (nodes do not collide with each other)



bus: coaxial cable



star

Ethernet frame structure

sending adapter encapsulates IP datagram (or other network layer protocol packet) in Ethernet frame

preamble:

- 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
- used to synchronize receiver, sender clock rates

Ethernet frame structure (more)

- *addresses:* 6 byte source, destination MAC addresses
  - if adapter receives frame with matching destination address, or with broadcast address (e.g. ARP packet), it passes data in frame to network layer protocol
  - otherwise, adapter discards frame
- *type:* indicates higher layer protocol (mostly IP but others possible, e.g., Novell IPX, AppleTalk)
- *CRC:* cyclic redundancy check at receiver
  - 

Ethernet: unreliable, connectionless

- *connectionless:* no handshaking between sending and receiving NICs
- *unreliable:* receiving NIC doesn't send acks or nacks to sending NIC
  - data in dropped frames recovered only if initial sender uses higher layer rdt (e.g., TCP), otherwise dropped data lost
- Ethernet's MAC protocol: unslotted *CSMA/CD wth binary backoff*

LAN Characteristics

	Fast Ethernet	Gigabit Ethernet	Fiber Channel	Wireless LAN
Data Rate	100 Mbps	1Gbps, 10Gbps, 100Gbps	100 Mbps-3.2Gbps	1 Mbps – 54 Mbps
Transmission Media	UTP, STP, optical fiber	UTP, shielded cable, optical fiber	optical fiber, coaxial cable, STP	Freespace
Access Method	CSMA/CD	Switched	Switched	CSMA/Polling
Supporting	IEEE 802.3	IEEE 802.3	Fiber Channel	IEEE 802.11

Thank You