CS4254

Computer Network Architecture and Programming

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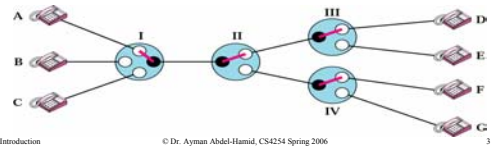
Introduction

Outline

- How is data transferred though the network?
  - Circuit switching versus packet switching
- How do end systems connect to an edge router?
- Physical Media
- Delay in packet-switched Networks

Data Transfer Through the Network 1/6

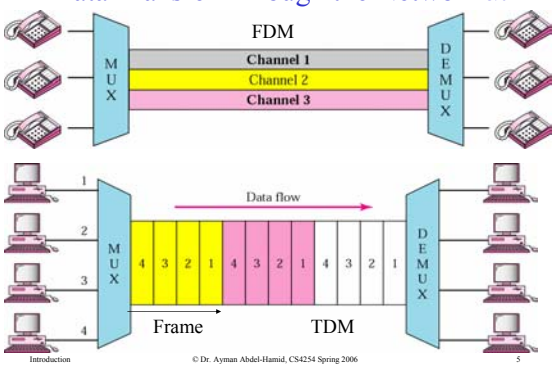
- Circuit-Switching Dedicated circuit per call (Telephone Network)
  - End-end resources reserved for "call"
    - ✓link bandwidth
    - ✓switch capacity
  - dedicated resources: no sharing
  - circuit-like (guaranteed) performance
  - call setup required



Data Transfer Through the Network 2/6

- Circuit-Switching Dedicated circuit per call (Telephone Network)
  - network resources (e.g., bandwidth) divided into "pieces"
  - pieces allocated to calls and resource piece *idle* if not used by owning call *(no sharing)*
  - dividing link bandwidth into "pieces"
    - ✓*frequency division multiplexing* FDM (analog)
    - ✓*time division multiplexing* TDM (digital)

Data Transfer Through the Network 3/6



Data Transfer Through the Network 4/6

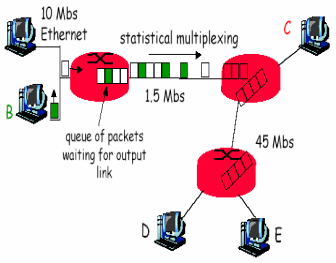
- Packet-Switching Data sent through network in discrete chunks
  - Each end-to-end data stream divided into *packets*
    - ✓Users' packets *share* network resources
    - ✓Each packet uses full link bandwidth
  - Resource contention
    - ✓aggregate resource demand can exceed amount available
    - ✓Congestion → packets queue, wait for link use
    - ✓store and forward → packets move one hop at a time
      - ❑transmit over link
      - ❑wait turn at next link

Data Transfer Through the Network 5/6

Statistical multiplexing

•Connection peak rates allowed to exceed link bandwidth

•Uses statistical information about users and system to provide QoS (Quality of Service)



Data Transfer Through the Network 6/6

•Packet-Switching approaches

➢**datagram network**

✓*destination address* determines next hop

✓routes may change during session

✓analogy: driving, asking directions

➢**virtual circuit network**

✓Requires call setup

✓each packet carries tag (virtual circuit ID), tag determines next hop

✓*fixed path* determined at *call setup time*, remains fixed thru call

✓routers maintain per-call state

Packet-Switching versus Circuit-Switching

•Allows more users to use the network (How?)

•Great for bursty data

➢resource sharing

➢no call setup

•Excessive congestion

➢packet delay and loss

➢protocols needed for reliable data transfer, congestion control

•How to provide circuit-like behavior?

➢bandwidth guarantees needed for audio/video apps

Access Networks

•*How do end systems connect to an edge router?*

➢*Residential access networks*

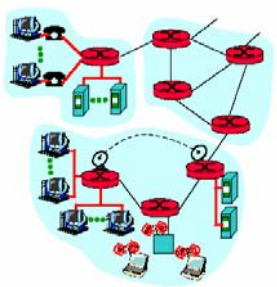
✓Modem dial-up, ISDN, ADSL, and cable modems

➢*Institutional access network* (school, company)

✓LANs

➢*Wireless access networks*

✓Wireless LANs and CDPD



Physical Media 1/6

•physical link: transmitted data bit propagates across link

➢*guided media*

✓signals propagate in solid media: copper, coax, and fiber

➢*unguided media*

✓signals propagate freely, e.g., radio waves

•Guided media → Twisted-Pair (TP)

➢Two insulated copper wires

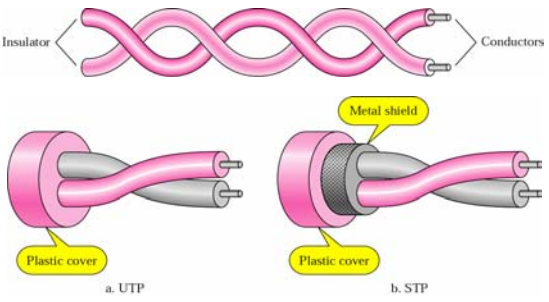
✓Category 3: traditional phone wires, 10 Mbps Ethernet

✓Category 5: 100Mbps Ethernet

✓Two varieties: UTP (Unshielded TP) and STP (Shielded TP)

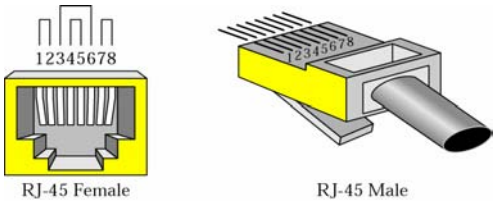
Physical Media 2/6

•Guided media → Twisted-Pair (TP)



Physical Media 3/6

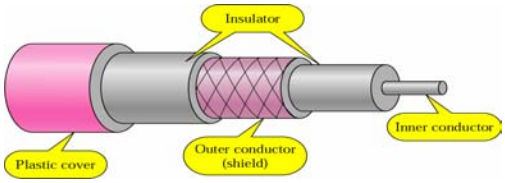
•Guided media → Twisted-Pair (TP)



UTP Connector (RJ stands for Registered Jack)

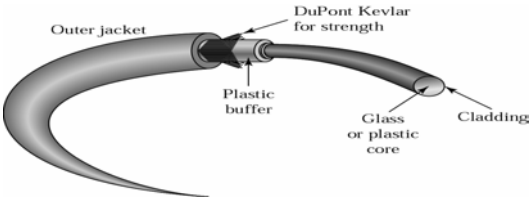
Physical Media 4/6

•Guided media → Coaxial Cable
- ➢wire (signal carrier) within a wire (shield)
  - ✓baseband: single channel on cable
  - ✓broadband: multiple channels on cable
- ➢Bidirectional
- ➢common use in 10Mbps Ethernet



Physical Media 5/6

•Guided media → Fiber-Optic
- ➢glass fiber carrying light pulses
- ➢high-speed operation
  - ✓100Mbps Ethernet
  - ✓high-speed point-to-point transmission (e.g., 5 Gbps)
- ➢low error rate

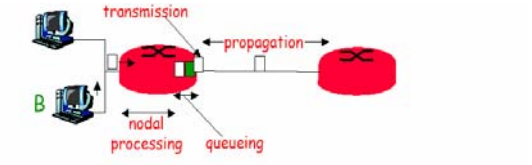


Physical Media 6/6

•Unguided media → Wireless
- ➢signal carried in electromagnetic spectrum (bidirectional)
- ➢propagation environment effects: reflection, obstruction by objects, and interference
- ➢Wireless link types
  - ✓Infrared (300 GHz to 400 THz)
  - ✓Radio and microwave (3 KHz to 300 GHz)
    - ❑Radio: multicast communication such as radio, television, and paging systems
    - ❑Microwave: unicast communication such as cellular telephones, satellite, and wireless LANs
  - ✓Wireless LAN: 2Mbps, 11Mbps, and 54 Mbps
  - ✓Satellite
    - ❑up to 50Mbps channel (or multiple smaller channels)
    - ❑270 msec end-to-end delay
    - ❑geosynchronous (GEO) versus LEO satellites

Delay in Packet-Switched Networks 1/4

•Packets experience delay on end-to-end path
•Four sources of delay at each hop
- ➢*Nodal processing*, *Queuing delay*, *transmission delay*, and *propagation delay*



Delay in Packet-Switched Networks 2/4

•Nodal processing
- ➢check bit errors and determine output link

•Queuing delay
- ➢time waiting at output link for transmission
- ➢depends on congestion level of router

•Transmission delay
- ➢R=link bandwidth (bps)
- ➢L=packet length (bits)
- ➢time to send bits into link = L/R

•Propagation delay
- ➢d = length of physical link
- ➢s = propagation speed in medium (~2×10^8 m/sec)
- ➢propagation delay = d/s

Delay in Packet-Switched Networks 3/4

•Transmission delay versus Propagation delay

➢*The transmission delay*

✓the amount of time required for the network entity to push out the packet

✓function of the packet's length and the transmission rate of the link

✓has nothing to do with the distance between two network entities

➢*The propagation delay*

✓is the time it takes a bit to propagate from one network entity to the next

✓a function of the distance between the two network entities

✓has nothing to do with the packet's length or the transmission rate of the link.

Delay in Packet-Switched Networks 4/4

•Queuing Delay

R=link bandwidth (bps)
L=packet length (bits)
a=average packet arrival rate (packets/sec)

traffic intensity = *La*/*R*

•*La*/*R* ~ 0: average queuing delay small
•*La*/*R* <= 1: delays become large
•*La*/*R* > 1: more "work" arriving than can be serviced