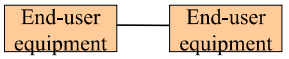
CENG461/ELEC514

Analysis and Design of Computer Communication Networks

Networking Concepts

Communication network?

- Simplest "network"
  - Single link between two pieces of end-user equipment (e.g., PC, telephone)
  - Types of communication links
    - Twisted pair
    - Coaxial cable
    - Optical fiber
    - Wireless links
      - Radio frequencies
      - Infra-red frequencies
      - Free-space optical communication

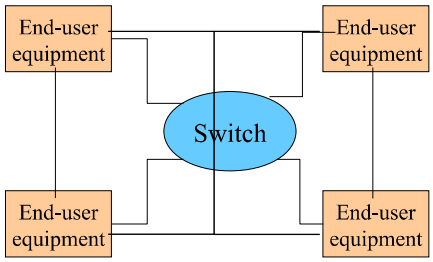


What is needed to send data on communication links?

- Error control
  - Error detection:
    - Parity checks, Checksum, Cyclic Redundancy Code (CRC)
  - Error correction:
    - ARQ (Automatic Repeat reQuest)
    - FEC (Forward Error Correction)
- Flow control: handles rate mismatch between sender and receiver
  - Window based flow control
  - Rate based flow control

Switches

- Connect multiple links and route traffic from one link to another



Why use a switch?

- If there are N endpoints (end-user equipment), then how many links are needed for full mesh connectivity?
- How many physical links are needed if these endpoints are connected through a switch?

Answers

- Number of direct links needed to connect N nodes is $\frac{N(N-1)}{2}$
- N links – since we only need one link from an endpoint to a switch

Cost of using a switch?

- Switch cost
- Can all endpoints have full connectivity at all times to all other endpoints?
  - Yes, with multiplexing on the links

Concept of multiplexing

- Time division multiplexing
  - Allows data from different sessions to be combined at different times on to the same line
  - How many DS0s (64Kbps data/voice channel) in a T1 (1.544Mbps)?
- Frequency Division Multiplexing (FDM) and Wavelength Division Multiplexing (WDM)
  - Difference between FDM and WDM?
  - Relation between frequency and wavelength

Answers

- 24 DS0s in a T1
- Term WDM is the same as FDM at optical frequencies – see EM spectrum chart
- Speed of light c = λf

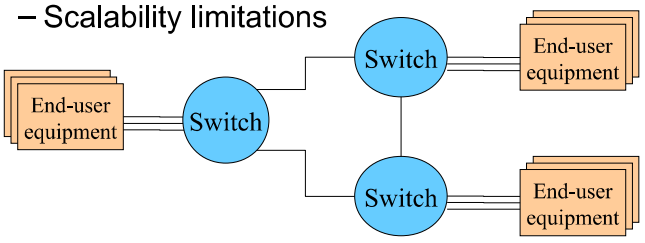
λ: wavelength; f: frequency

Types of switches

- Circuit switches: Position-based switching
  - Switch consults a table to determine output port on which to send data bits based on their arriving position
    - "Position": Interface (space), time slot and/or wavelength
  - Space division switch: switch based on input interface
  - Time division switching: interface + time slot
  - Wavelength division switching: interface + wavelength
  - No buffers
- Packet switches: Label-based switching
  - Switch consults a table to determine output port on which to send the packet based on value of label (in packet header)
  - Label could be changed on outgoing port or could stay the same
  - Have buffers to hold packets

Network of switches

- Expand 1-switch network to a multi-switch network
- Why not build one gigantic switch?
  - Scalability limitations



Different types of networks

- A network is defined by its "switching mode" and its "networking mode"
- Circuit switching vs. packet switching
  - Circuit-switching: switching based on position (space, time, λ) of arriving bits
  - Packet-switching: switching based on information in packet headers
- Connectionless vs. connection-oriented networking:
  - CL: Packets routed based on address information in headers
  - CO: Connection set up (resources reserved) prior to data transfer

Switching modes \ Networking modes	Connectionless	Connection-oriented
Packet-switching	IP, SS7	MPLS IP + RSVP ATM, X.25
Circuit-switching		Telephone network, SONET/SDH, WDM

Congestion control

- What is it?
  - The purpose of a network is to allow sharing of resources
  - This means if demand is high, there could be competition for resources from multiple users
  - What are network resources:
    - Link capacity (bandwidth)
    - Switch buffer space (only in packet switches)

Congestion control

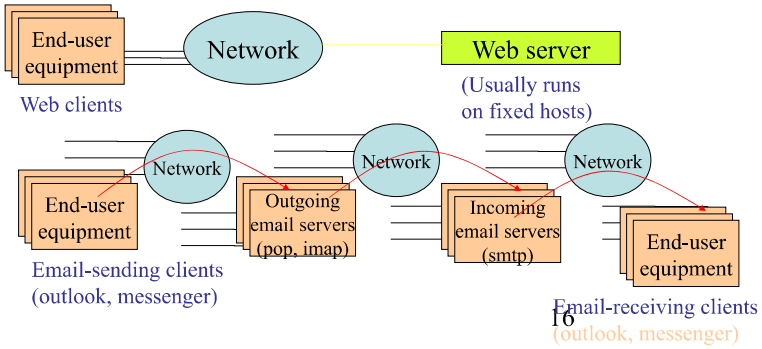
- In CO networks
  - Congestion control: mostly preventive
  - Connection Admission Control (CAC)
    - Check availability of bandwidth and buffer resources before admitting a connection
    - CS CO networks: congestion will not occur once circuits are admitted
    - PS CO networks: congestion can occur after connection is admitted if connection admission is based on statistical multiplexing
      - Have some supplemental reactive congestion control scheme

Congestion control

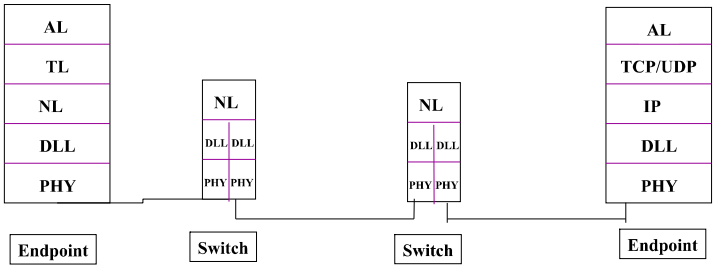
- In CL networks
  - Have packet switches detect congestion and send reactive messages asking sender to slow down
  - e.g., IP routers implement Explicit Congestion Notification (ECN) procedures
  - Transport layer protocol in the end-system responds to the congestion indication and reduce traffic load

Applications

- Most Internet applications are client-server based



TCP/IP Protocol Stacks



- OSI model: two more layers between AL and TL
  - Session layer and presentation layer
- PHY: Physical; DLL: Data Link Layer; NL: Network Layer; TL: Transport Layer; AL: Application Layer

Example protocols

- AL protocols: http, smtp, ftp, PCM voice,…
- TL protocols: TCP, UDP, RTP, …
- NL protocols: IP, ATM
- DLL protocols: PPP, HDLC
- PHY protocols: DS0, DS1

Functions of protocol layers

- PHY: sends bits across a link
- DLL: error control and flow control on a link
- NL: switching (routing), multiplexing, congestion control
- TL: error control, flow and congestion control on an end-to-end basis
- AL: functions specific to the application

Performance Metrics

- Service-Level Agreement Common Metrics (backbone ISP)
  - Network availability
  - Network latency
  - Average and maximum jitter
  - Data delivery (packet losses)
  - Throughput

SLA examples:

- http://www.us.ntt.net/support/sla/network.cfm
- http://www.att.com/gen/general?pid=6622