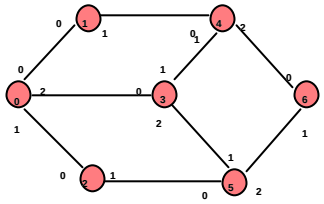
Network Technology: Host-to-Network



Block Overview

2. networking review (sessions 4-8)
   a. host-to-network technologies
   b. internetting
   c. multicasting
   d. transport layer
   e. application protocols
   f. communication architectures

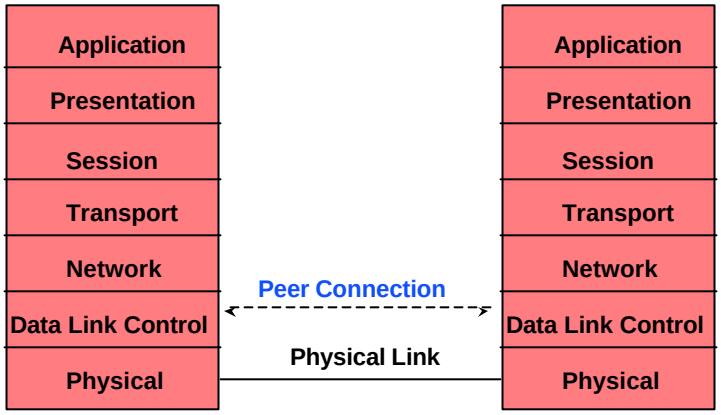
Lecture Overview

- network software stack
- transmission timing
- serial links and protocols
- local area networks
  - contention-based
  - ring-based
  - switch-based

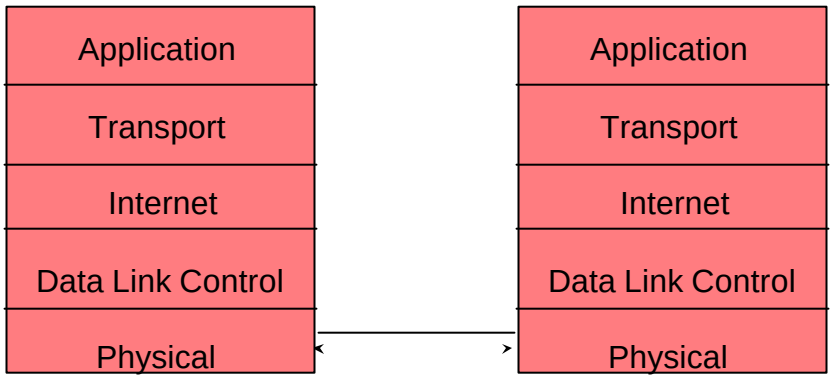
Circuit Switching *vs* Packet Switching

- Circuit Switched Network - provides a continuous connection in the medium from sender to receiver over a path that is established at call setup time (e.g., the telephone system)
- Packet Switched Network - breaks information into discrete chunks (called packets) that ***may be*** individually routed, with successive packets between the same source-destination pair conceivably taking different routes.

OSI 7-layer Reference Model



Internet Protocol Suite Reference Model



The DLC and Physical layers sometimes are referred to collectively as the “host to network” layer

Link Performance - Transmission Time

- To find the time needed to transmit a unit L of information, divide by the link capacity, C
- For example, to transmit a 1.44 MB floppy disk's contents over a 19.2 kbps link:

$t = L/C = (8 \times 1.44 \times 1024^2) / (19.2 \times 10^3) = 629$ s

- This figure holds if we disregard:
  - errors
  - synchronization overhead
  - flow control

Link Performance - Propagation Delay

- In a vacuum, electromagnetic energy travels at the speed of light, c = 186,000 miles/sec
  (or $c = 3 \times 10^8$ meters/sec)
- Light travels more slowly in glass, and electrical signals travel slower along a wire; a reasonable estimate ~30% slower, or ~130,000 miles/sec (or 2.1×10^8 meters/sec)
- Propagation delay, $D = \text{distance}/v_{medium}$

  D = distance in miles/130,000

  = distance in meters/(2.1×10^8)
- Propagation delay is most significant in satellite links,
  one-hop delay is: 2 X 22,300 / 186,000 = .24 seconds
- Round-trip delay is double, or about 1/2 second

Digital Transmission

- Today, most commercial communications systems are built digital end-to-end
  - Analog signals are converted to digital at or near the source (A-D conversion)
  - Every amplifier in the transmission path restores the digital signal to clean ones and zeros
  - The analog signal is recovered at or near the receiving end (D-A conversion)
- Result: immunity to noise, lower cost, uniform data format, better security, reliability, and control
- 56kbps modem connections are actually analog max 33.6kbps to service provider, with 56kbps (half duplex) direct digital modulation from service provider to user
  - this only works with best quality dialup circuits

Digital Transmission Of Voice

- Sample analog voice signal at the Nyquist rate = 2 f_H (twice the highest frequency if $f_L = 0$), or
  - 2 X 4000 Hz = 8000 samples per second
- Convert each sample to an 8-bit binary number (called quantizing) using Pulse Code Modulation (PCM)
- Send this digital data as
  - 8 (bit samples) X 8000 (samples per second), or 64,000 bps
- A group of 24 voice channels requires
  - 24 X 64 kbps = 1,536,000 bps
  - which can fit on a T1 carrier channel

Digital Audio Fidelity

- 8-bit PCM is very adequate for telephone use but is not "high fidelity" with regard to either noise or bandwidth
- When a digitally encoded signal is converted back to analog, there is an added "noise of quantization":

$$(S/N)_{PCM} = 2^{2N}$$

thus for 8-bit coding $S/N=2^{16}=65{,}536=48.2dB$
so the noise will be no better than 48.2 dB below maximum possible signal level

- For CDROM quality f_H = 20kHz and f_L = 0; and the sample is encoded in 16 bits; thus
  C = 2 x 20,000 x 16 = 640,000 bps or 640 kbps
  $S/N = 2^{32} = 4.295 \times 10^9 = 96.3$ dB

Digital Hierarchy
(for North America and Japan)

		VOICE CHANNELS
DS0*	64 Kbps	1
DS1("T1")*	1.544 Mbps	24
DS2	6.312 Mbps	96
DS3("T3")*	44.736 Mbps	672
DS4	139.264 Mbps	2,016

* normally available as leased service

Europe uses a different digital hierarchy also based on the 64kbps voice channel
(E1 is 32 channels, 2.048 Mbps)

Integrated Services Digital Network (ISDN)

Common standard for "dial-up digital" circuits
B channel 64 Kbps
D channel 16 Kbps (used for signaling)

Available as

Basic Rate	2B + D
Primary Rate	23B + D
	(30B + D in Europe)

Synchronous Optical Network (SONET)

- A Network of optical carriers installed by the common carriers for most long-distance trunks
- Data Rates occur at multiples of 51.84 Mbps, called Optical Carrier One (OC-1)
- Commonly available data rates include:
  - OC-3 ~155 Mbps
  - OC-12 ~ 622 Mbps
  - OC-24 ~ 1.2 Gbps
  - OC-48 ~ 2.5 Gbps

Asymmetric Digital Subscriber Line (ADSL or just DSL)

- Approach new in 1995
- Basic concept: low capacity from subscriber
- high capacity to subscriber
- This matches typical Internet access patterns
- Delivers up to 9Mbps to home/office
  - returns up to 1Mbps to Internet
  - May also support voice telephone by multiplexing
- Runs over copper lines up to about 3 miles from telephone office
  - longer distance, lower data rate
  - 3 miles: 1.5 Mbps 1.5 miles: 9.0 Mbps

Cable Modem

- Traditional cable television systems were unidirectional
  - all signals flow from “head end” through a tree of fiber/cable and distribution amplifiers
  - little or no capacity for signals flowing back toward head
- Today cable systems are installing two-way flow in order to compete for high-performance Internet service to the home
- The device that enables this at the subscriber end is called a cable modem
  - bypasses the home cable converter
  - data rates of hundreds of kbps to and from Internet
  - upstream transmission contends for a shared channel
  - mechanism is similar to Ethernet - we will study later

Data Link Protocols

- Data Link protocols implement a frame service on top of the unreliable physical bit transfer service provided by the physical layer
- To make this service reliable, Data Link protocols must protect against:
  - transmission errors
  - receiver overload
- Mechanisms used include:
  - error detection
  - sequence numbering
  - frame acknowledgement
  - time-out and retransmission

CRC Capabilities

- CRC can detect:
  - all but $1/2^n$ errors for an n+1 bit divisor
  - all single-bit errors
  - all double-bit errors with well chosen polynomial
  - burst errors up to n bits, and most larger bursts

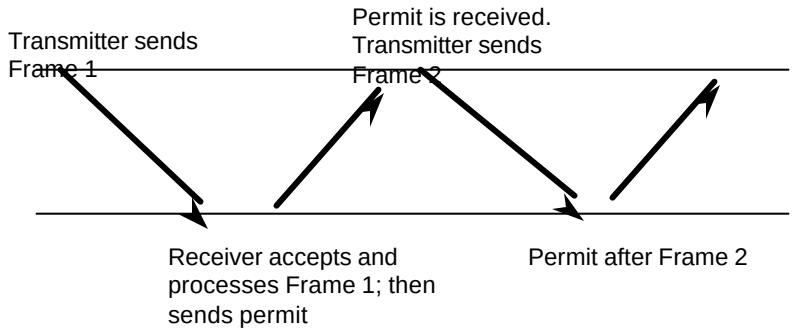
Data Link Timing Principles

Total time between peer DLCs for a frame is the sum of:

- Frame transmit time T_F = L/C (length / rate)
  - both directions, for reliable DLC
  - reply T_A could be different from send T_F, but in most full-duplex systems reply is piggybacked on a data frame
- Link propagation delay D = distance/v_{medium}
  - also both directions
- Processing time at sending end P_F
- Processing time at receiving end for acknowledgement P_A (if any)

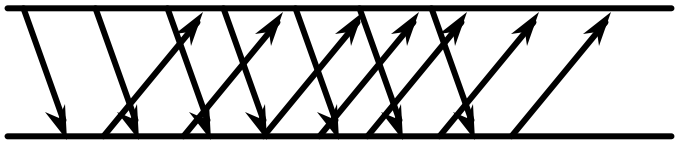
A Stop-and-Wait Protocol For Reliable Links

- Even given a reliable physical layer, the rate of flow from sender to receiver must still be controlled so as not to overrun the receiver's processing ability.
- The simplest possible protocol uses acknowledgements to relay permission to send from the receiver to the transmitter



More Efficient Protocols

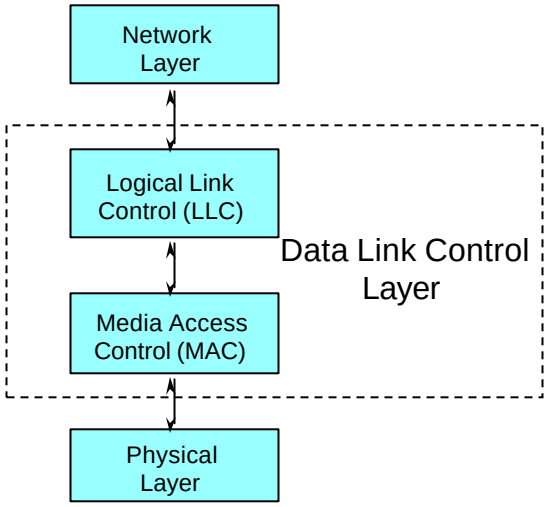
- To use high-capacity links more efficiently, packets must be pipelined in the link
- This requires that several packets can be unacknowledged at the same time.



Point to Point Protocol

- PPP is an Internet direct link protocol.
- When using an ISP, a home station can function as a *shell account* or a full blown Internet host.
  - Each end of link needs an assigned IP address (we will learn why when we get to network layer) but, in PPP, IP addresses can be dynamically assigned.
- PPP handles error detection, supports multiple protocols, allows IP addresses, permits authentication.
  - Framing
  - Link Control Protocol
  - Allows network-layer options to be negotiated

DLC Refinement for Local Area Networks



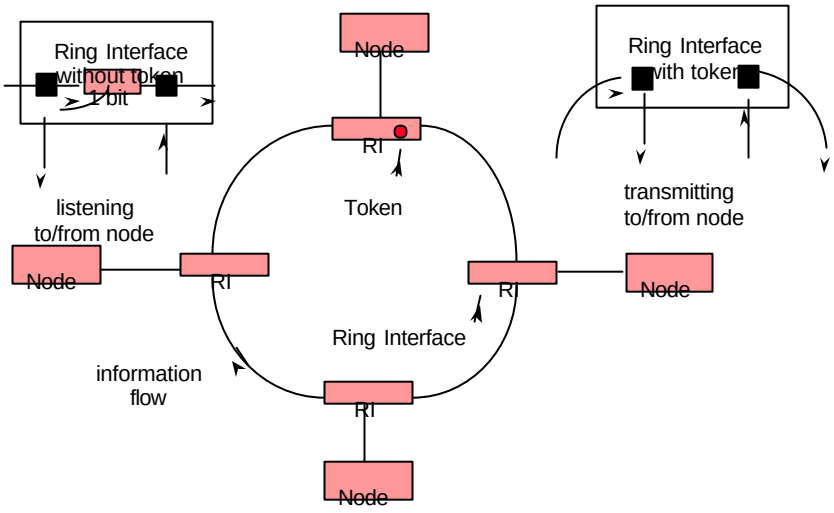
Contention-Based LAN: CSMA / CD Rules

- Rules for Carrier Sense Multiple Access with Collision Detection:
  - If the channel is busy, then defer transmission to the next slot with some probability. (This can be 1.)
  - If the channel is quiet, then send the frame; continue listening to the transmission.
  - If a collision occurs, then abort the transmission and send a short jamming signal.
  - Wait a random number of slots before trying again.

Token Passing Ring

- A token is circulated around the ring and can be seized by an active node; only the holder of the token is permitted to send frames.
- Rules:
  - Only one node has the token.
  - To send, a node must have the token.
  - Absent the token, a node must copy all incoming frames to its output.
  - A specific rule (different for different token passing protocols) is defined for relinquishing the token. Usually, after sending one frame.
  - When a frame returns to the sender, the sender removes the frame from ring.

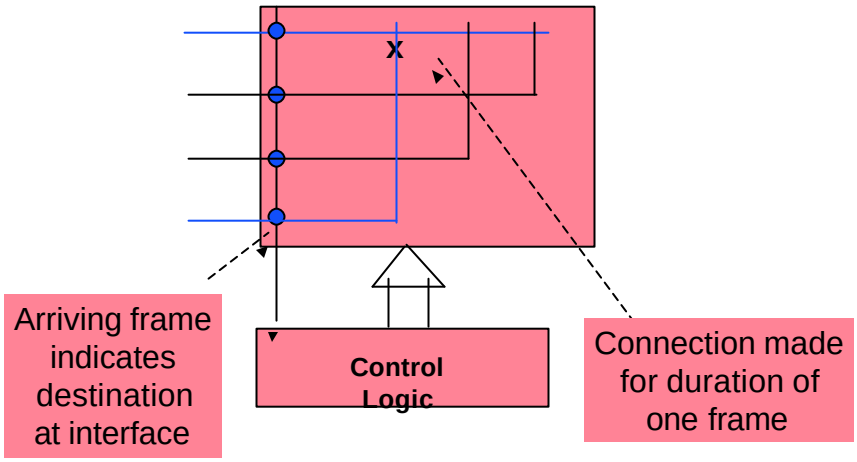
Token Passing Ring - Example



Switched Ethernet

- Where multiple stations are using an Ethernet, collisions limit the effective data rate to about 4 Mbps sustained, with a peak rate of 10 Mbps
- Replacing the 10BASET hub with a true switch allows any two stations to communicate at the full data rate
  - (10 Mbps for 10BASET, 10BASE5, or 10BASE2; and 100 Mbps for 100BASET)
- Switched approach takes advantage of the standard Ethernet interface but offers much higher system performance
- In delay calculations, collisions are replaced by blocking probability
- Gigabit Ethernet is available - optical fiber links with switching
  - still expensive but no doubt will become less so

Logical Function of Ethernet Switch



(actual function: switch buffers frame from input and forwards to output)