What we'll cover today

- SONET
- Error detection
- Flow control
- Ethernet

SONET

- Standard for long-distance transmission over optical networks
- Multiple low-speed links multiplexed onto a high-speed link
- Clock-based framing
  - sentinel bit pattern at start of frame
  - each frame is 810 bytes long
- Encoding:
  - header is encoded NRZ
  - body is encoded by XORing data with a 127-bit pattern

Error handling

- Errors will occur in transmission!
  - phone lines: $10^{-5}$ to $10^{-8}$
  - fiber: $10^{-9}$ to $10^{-15}$
- Ways to handle errors:
  - error detection -- now
  - error correction: typically only used in wireless (very lossy) networks -- later
Error detection

- Idea: add extra info to a frame to determine if any errors have occurred in transmission
- Frames with errors are discarded
- Mechanisms:
  - Parity bits
  - Checksum – later
  - CRC

Use of parity bits

- Idea: Add one bit to each group of 7 data bits to “balance” the 1s
- Odd parity: strive for odd number of bits
- Even parity: strive for even number of bits
- 2-D parity:
  - each row and column has a parity bit, AND
  - each frame has a parity bit

How effective is 2D parity?

- Can detect all errors of 1-3 bits
- Can correct all errors of 1 bit
- Can detect most 4-bit errors
- Not effective at detecting error bursts

CRC

- Cyclic redundancy check
- Powerful at detecting errors of large numbers of bits, including burst errors
- Uses polynomials
Binary polynomials

- Example: 11010101 = $x^7 + x^6 + x^4 + x^2 + 1$
- Binary polynomial math:
  - addition/subtraction are XOR operations
  - can divide polynomials of the same degree, or if dividend polynomial is of a higher degree than divisor polynomial

CRC: method

- Pick $C(x)$, a divisor polynomial of order $k$ that will not divide evenly into most common bit error patterns
- Let $M(x)$ be the original message and $T(x)$ the transmitted message
- $T(x) = M(x) \ast x^k$
- Divide $T(x)$ by $C(x)$
- $T(x) = T(x) – \text{remainder}$

Common CRC polynomials

- CRC-32: $x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$
  - Ethernet, ATM, Token Ring
- CRC-10: $x^{10} + x^9 + x^5 + x^4 + x + 1$
  - ATM
- CRC-8: $x^8 + x^3 + x + 1$
  - ATM

Flow control

- There has to be some order as to how we send frames out on the network
- Increases the reliability of the transmission
- Mechanisms
  - ACKs
  - timeouts
  - retransmissions
- ARQ = automatic repeat request
Flow control mechanisms

- Stop-and-wait
- Sliding window

Stop-and-wait

- Send one frame, set timer, wait for ACK, send next frame
  - retransmit frame if timer expires before ACK received
- Need a sequence number in each frame so that duplicates can be distinguished from new frames
  - Q: what is the range of sequence numbers?
- Does not utilize link bandwidth well!

Stop-and-wait: Examples

Sliding window

- Allows the transmission of up to $N$ frames
- $N$ is the window size
  - max number of frames that can be in transit at any given time
- Each time sender receives an ACK, it can send another frame
- Sender retransmits frame if timer expires before ACK received
  - buffers all unACKed frames
Sliding window: receiver side

- Receiver's window can be anywhere from 1 frame to $N$ frames
- Discards any frames with sequence numbers above or below the current window range
- Sends cumulative ACKs (ACKs the highest in-sequence frame received, even if frames with higher sequence numbers have been received)
  - Q: how can we improve upon this scheme?

Sliding window: example

- Note: sequence numbers must be $[0, (N + 1)/2]$
  - assuming send window = receive window

Ethernet

- officially IEEE 802.3
- Local area network (LAN) standard technology
- Types
  - Standard (10 Mbps)
  - Fast Ethernet (100 Mbps) and Gigabit Ethernet (1 Gbps)
  - Related technologies: Token ring (IEEE 802.5), FDDI

Ethernet: The basics

- Uses same principles as ALOHA (an early packet radio network)
- CSMA/CD technology
  - CSMA = Carrier Sense Multiple Access
  - CD = Collision Detection
Physical aspects of Ethernet

- Coax cable -- 10BaseT
  - <=100 m
  - cables connect into a hub, which can connect to other hubs, ...
  - “star configuration”
- Can support 1024 hosts, theoretically
  - ~200 in practice
- Half-duplex

Frame

- Preamble: synchronization
- Type: upper-level protocol to which this frame belongs
- Body: minimum 46 bytes, maximum 1500 bytes

Receiver

- All frames are broadcast
- Host “listens” to all frames on the link, copies frames destined for it off of the link
  - sniffers operate in “promiscuous” mode, copying all packets off of the link
- Each host has a unique MAC address
  - 6 pairs of hexadecimal digits, separated by colons