EE 122 Housekeeping

- Welcome back. This is 122.
- Schedule has been changed. Check website.
- Project phase 2 due on Apr 11
- Our journey through the layers:
  - Application
  - Transport
  - Network
  - Link
  - Physical (Wireless)

The Data Link Layer

Our goals:

- understand principles behind data link layer services:
  - error detection, correction
  - sharing a common medium: multiple access
  - link layer addressing
- discussion of various link layer technologies, particularly the Ethernet
- 802.11 Wi-Fi and other wireless technologies will be discussed in greater detail later.

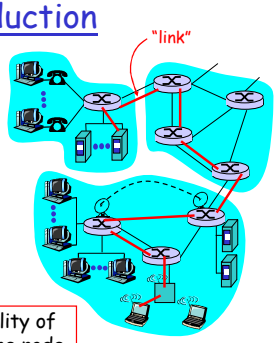
Link Layer

- Introduction and services
- Error detection and correction
- Multiple access protocols
- Link-Layer Addressing
- Ethernet

Link Layer: Introduction

Some terminology:

- hosts and routers are **nodes**
- communication channels that connect adjacent nodes along communication path are **links**
  - wired links
  - wireless links
  - LANs
- layer-2 packet is a **frame**, encapsulates datagram



data-link layer has responsibility of transferring datagram from one node to adjacent node over a link

Link layer: context

- Datagram transferred by different link protocols over different links:
  - e.g., Ethernet on first link, frame relay on intermediate links, 802.11 on last link
- Each link protocol provides different services
  - e.g., may or may not provide rdt over link

Link Layer Services

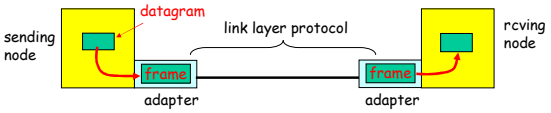
- Framing, link access:
  - encapsulate datagram into frame, adding header, trailer
  - channel access if shared medium
  - "MAC" addresses used in frame headers to identify source, dest
    - different from IP address!
- Reliable delivery between adjacent nodes
  - we learned how to do this already (chapter 3)!
  - seldom used on low bit error link (fiber, some twisted pair)
  - wireless links: high error rates
    - Q: why both link-level and end-end reliability?

Link Layer Services (more)

Error Detection and Correction:
- errors caused by signal attenuation, noise.
- receiver detects presence of errors:
  - signals sender for retransmission or drops frame
- receiver identifies *and corrects* bit error(s) without resorting to retransmission

Half-duplex and full-duplex
- with half duplex, nodes at both ends of link can transmit, but not at same time

Adaptors Communicating



- link layer implemented in "adaptor" (aka NIC)
  - Ethernet card, PCMCI card, 802.11 card
- sending side:
  - encapsulates datagram in a frame
  - adds error checking bits, rdt, flow control, etc.
- receiving side
  - looks for errors, rdt, flow control, etc
  - extracts datagram, passes to rcving node

Link Layer

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- Multiple access protocols
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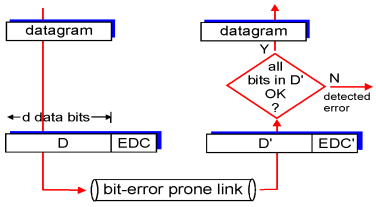
Error Detection and Correction

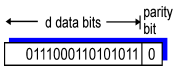
EDC= Error Detection and Correction bits (redundancy)
D = Data protected by error checking, may include header fields

- Error detection not 100% reliable!
  - protocol may miss some errors, but rarely
  - larger EDC field yields better detection and correction

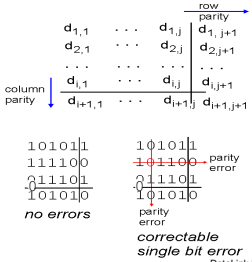


Parity Checking

Single Bit Parity:
Detect how many errors?



Two Dimensional Bit Parity:
Detect how many bit errors?
Correct how many errors?



General Parity-Check Codes

- A general parity check code adds k parity checks to n data bits
- Data rate = n/(n+k) information bits per code bits
- Minimum Hamming distance d is the minimum number of bit flips to get from one possible transmitted sequence (codeword) to another.
- Can detect if there are less than d errors.
- Can correct if there are less than d/2 errors.
- Performance under burst errors also important

Another example: checksum

Goal: detect "errors" (e.g., flipped bits) in transmitted segment (note: used at transport layer *only*)

Sender:

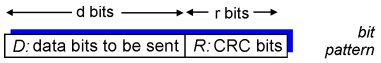
- treat segment contents as sequence of 16-bit integers
- checksum: addition (1's complement sum) of segment contents
- sender puts checksum value into UDP checksum field

Receiver:

- compute checksum of received segment
- check if computed checksum equals checksum field value:
  - NO - error detected
  - YES - no error detected. *But maybe errors nonetheless?* More later ….

Cyclic Redundancy Check (CRC)

- view data bits, D, as a binary number
- choose r+1 bit pattern (generator), G (leftmost and rightmost bits are both 1)
- goal: choose r CRC bits, R, such that
  - <D,R> exactly divisible by G (modulo 2)
  - receiver knows G, divides <D,R> by G. If non-zero remainder: error detected!
  - can detect how many burst errors?
- widely used in link layer technologies



bit pattern

$D * 2^r$ XOR R

mathematical formula

CRC Example

Want:

$D \cdot 2^r$ XOR R = nG

equivalently:

$D \cdot 2^r = nG$ XOR R

equivalently:

if we divide $D \cdot 2^r$ by G, want remainder R

$$R = \text{remainder}\left[\frac{D \cdot 2^r}{G}\right]$$