Computer Networks

Link Layer Services
Error Correction and Detection

Based on Computer Networking, 4th Edition by Kurose and Ross

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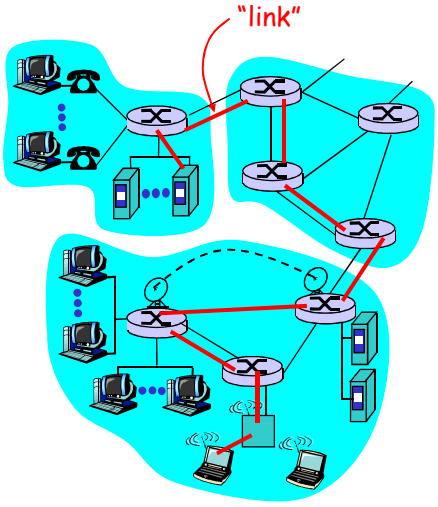
Link Layer: Introduction

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



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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

transportation analogy

- trip from Princeton to Lausanne
  - limo: Princeton to JFK
  - plane: JFK to Geneva
  - train: Geneva to Lausanne
- tourist = datagram
- transport segment = communication link
- transportation mode = link layer protocol
- travel agent = routing algorithm

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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?

Flow Control:

- pacing between adjacent sending and receiving nodes

Error Detection:

- errors caused by signal attenuation, noise.
- receiver detects presence of errors:
  - signals sender for retransmission or drops frame

Error Correction:

- 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

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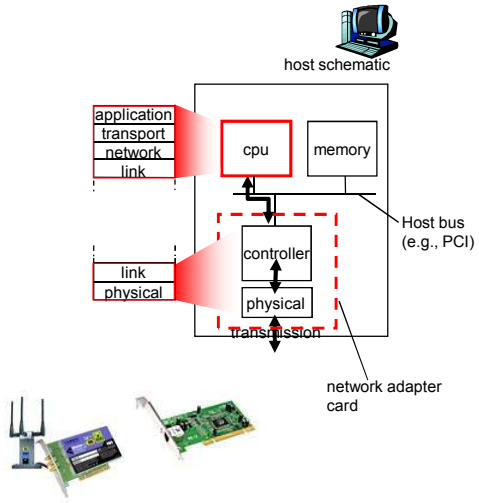
Where Is the Link Layer Implemented?

- in each and every host
- link layer implemented in "adaptor" (aka *network interface card* NIC)
  - Ethernet card, PCMCI card, 802.11 card
  - implements link, physical layer
- attaches into host's system buses
- combination of hardware, software, firmware



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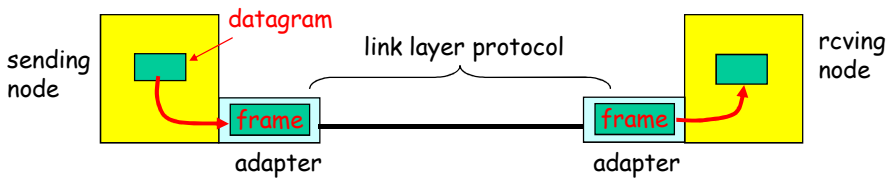
Adaptors Communicating

- 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
- adapter is semi-autonomous
- link & physical layers



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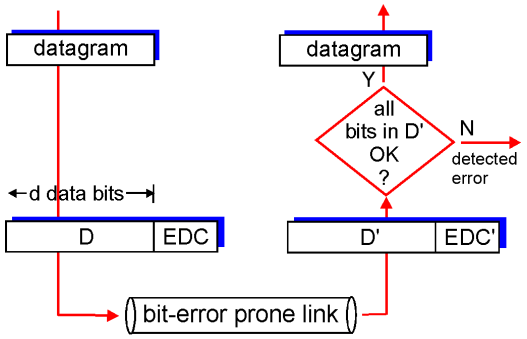
Error Detection

- 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



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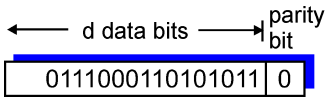
Parity Checking

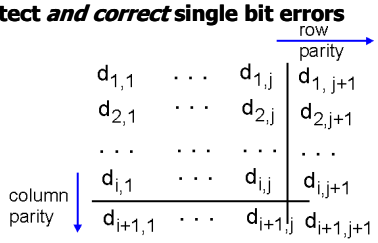
Single Bit Parity:

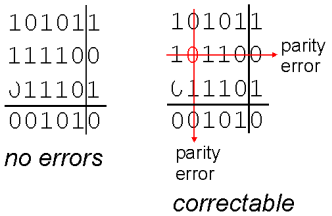
Detect single bit errors



Two Dimensional Bit Parity:

Detect *and correct* single bit errors





no errors

correctable single bit error

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Internet 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?*

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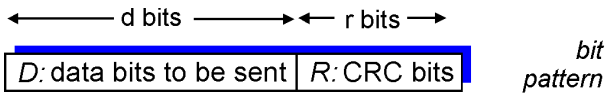
Checksumming: Cyclic Redundancy Check

- view data bits, D, as a binary number
- choose r+1 bit pattern (generator), G
- 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 all burst errors less than r+1 bits
- widely used in practice (802.11 WiFi, ATM)



bit pattern

$D * 2^r$ XOR R

mathematical formula

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CRC example

Want:

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

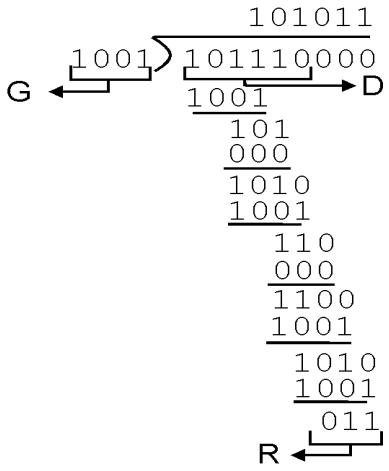
equivalently:

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

equivalently:

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

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



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