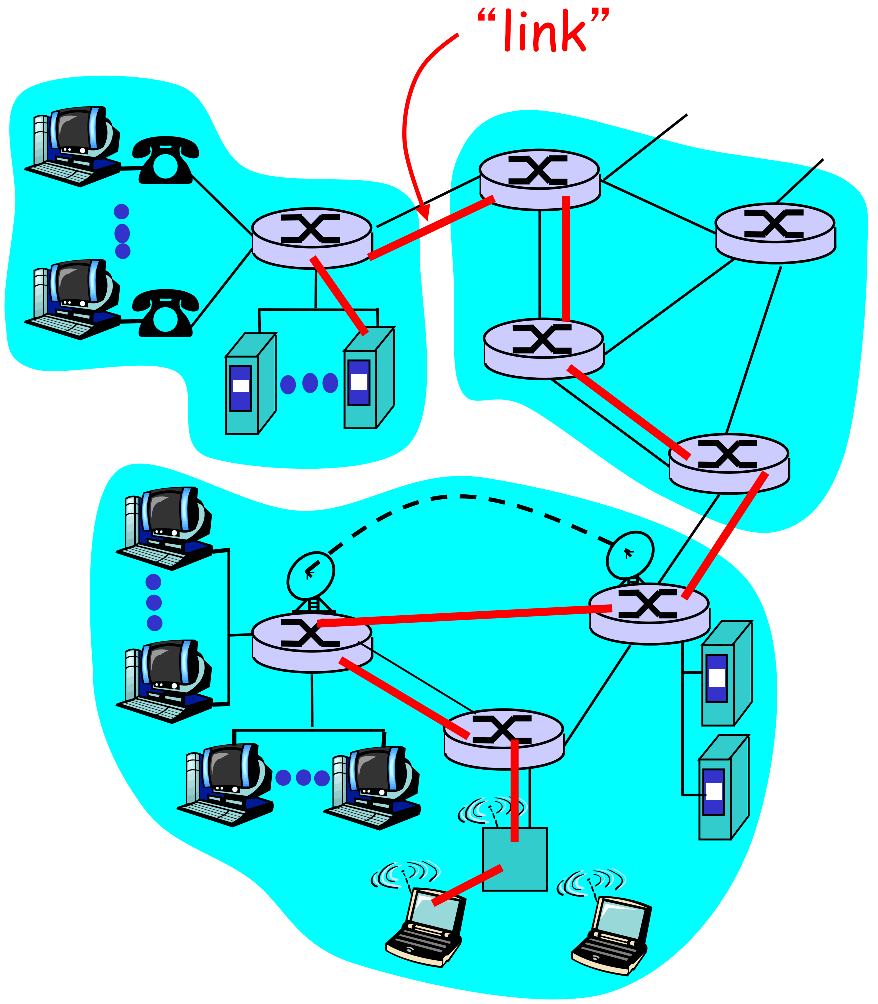
Data Link Layer: Introduction

Some terminology:

- hosts and routers are **nodes**
  (bridges and switches too)
- communication channels that connect adjacent nodes along communication path are **links**
  - wired links
  - wireless links
  - LANs (local area networks)
- layer 2 PDU ("packet") referred to as **frame**, which encapsulates a layer-3 packet, e.g., an IP datagram



What Does Data Link Layer Do?

Data link layer has responsibility of transferring frames from one node to adjacent node over a *single* link

- An IP packet from host A to host B may traverses different links using different data link protocols
  - 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 reliable data delivery
- Different link protocols are not inter-operable!
  - IP packets are encapsulated/decapsulated with appropriate data link protocol header over each link
  - IP protocol and IP routers glue the links ("physical networks") together and provide end-to-end data delivery!

Data Link Layer Functions

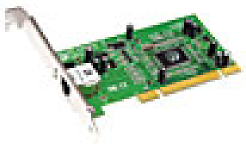
- Framing
  - sender (transmitter): encapsulate datagram into frame, adding header, trailer, transmit frame
  - receiver: detect beginning of frames, receive frame, decapsulate frame, stripping off header, trailer
- Link Access (Media Access Control)
  - determine whether it's Okay to transmit over the link
    - particularly important when link shared by many nodes
      - also an issue over "half-duplex" point-to-point link (why?)
    - need media access control (MAC)
  - "physical addresses" identify sender/receiver on a link!
    - particularly important when link shared by many nodes, while over point-to-point link, not necessary
    - "physical addresses" often referred to as "MAC" addresses
      - different from IP addresses (which are logical & global)!

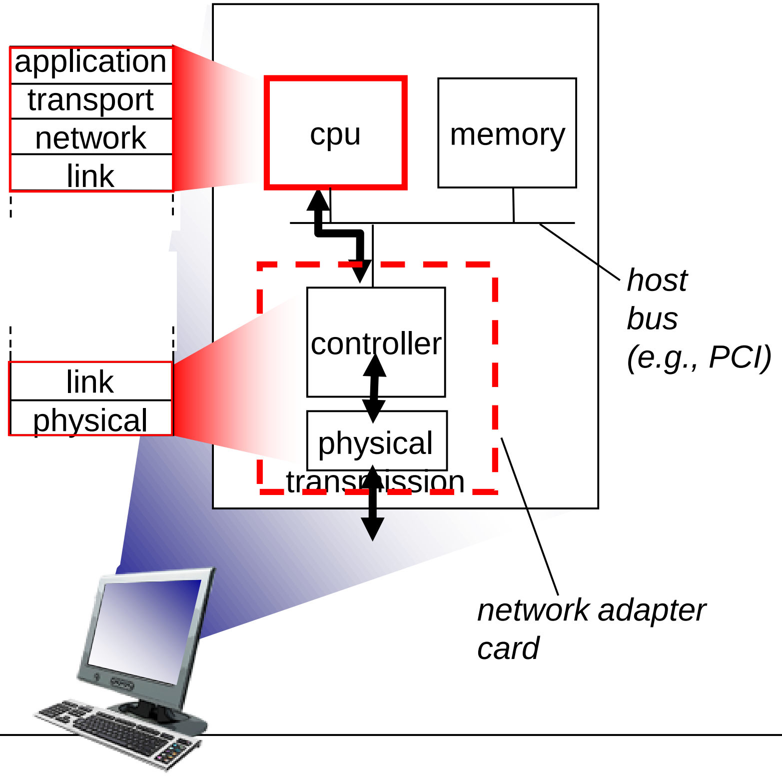
Other Data Link Layer Functions

- Error Detection (commonly implemented)
  - errors caused by signal attenuation, noise, etc.
  - sender computes "checksum", attaches to frame
  - receiver detects presence of errors by verifying "checksum"
    - drops corrupted frame, may ask sender for retransmission
  - Commonly used "checksum": cyclic redundancy code (CRC)
- Reliable delivery between adjacent nodes (optional)
  - using, e.g., go-back-N or selective repeat protocol
    - 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?
- Error Correction (optional)
  - receiver identifies *and corrects* bit error(s) without resorting to retransmission, using forward error correction (FEC) codes
- Flow Control (optional)
  - negotiating transmission rates between two nodes

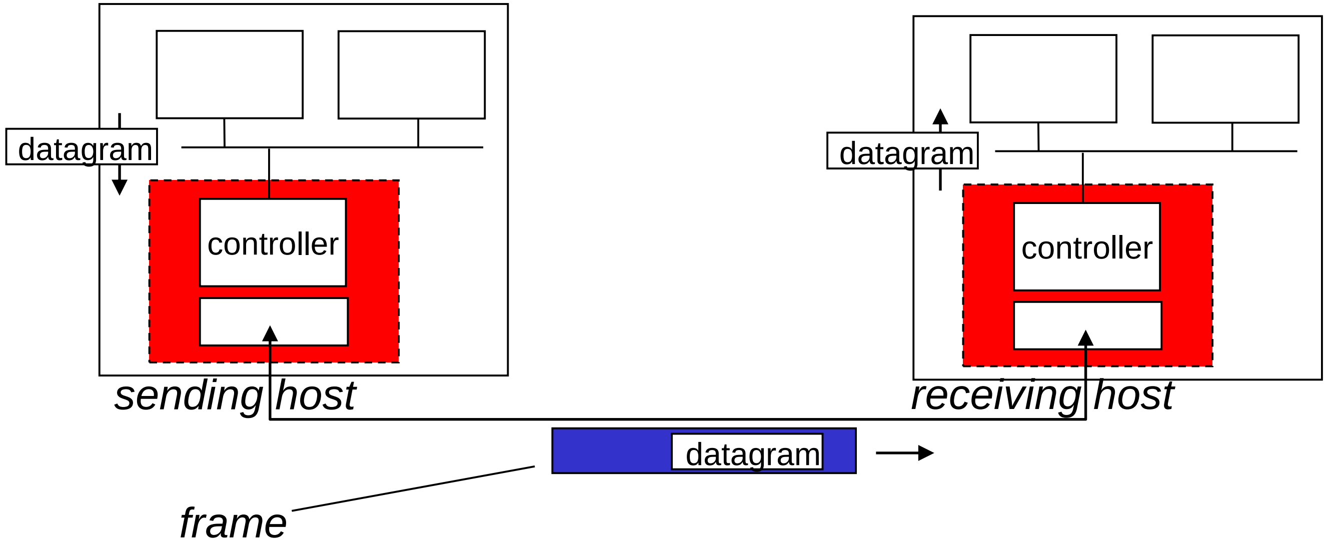
Where is the link layer implemented?

- in each and every host
- link layer implemented in “adaptor” (aka *network interface card* NIC) or on a chip
  - Ethernet card, 802.11 card; Ethernet chipset
  - implements link, physical layer
- attaches into host’s system buses
- combination of hardware, software, firmware





Adaptors Communicating



- sending side:
  - encapsulates datagram in frame
  - adds error checking bits, rdt, flow control, etc.
- receiving side
  - looks for errors, rdt, flow control, etc.
  - extracts datagram, passes to upper layer at receiving side

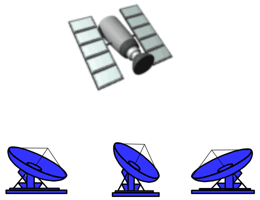
Multiple Access Links and LANs

Two types of “links”:

- point-to-point, e.g.,
  - PPP for dial-up access,
  - point-to-point link between Ethernet switch, host
- broadcast (shared wire or medium), e.g.
  - traditional Ethernet
  - 802.11 wireless LAN

shared wire (e.g., cabled Ethernet)

shared RF (e.g., 802.11 WiFi)

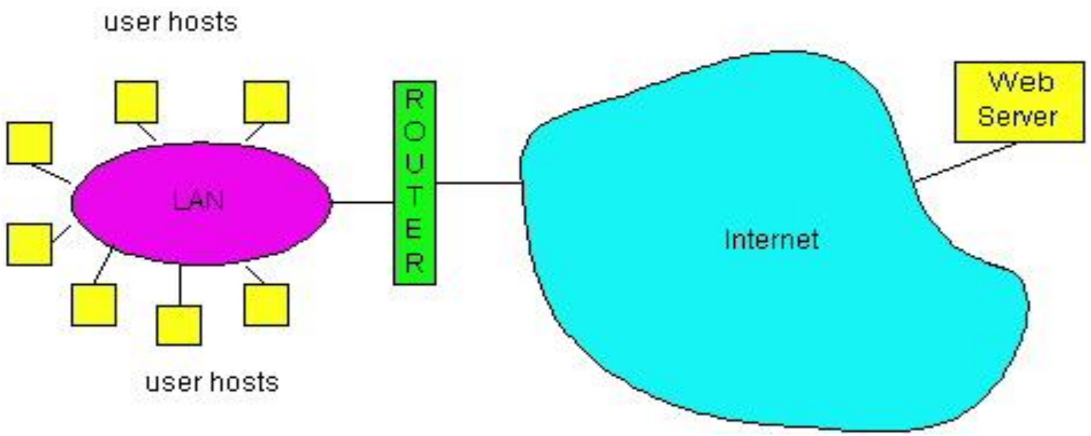


shared RF (satellite)

humans at a cocktail party (shared air, acoustical)

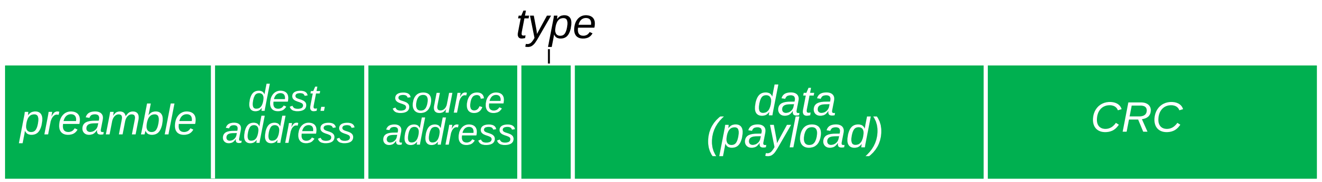
LAN: Issues & Technologies

- Issues:
  - addressing: physical (or MAC) addresses
  - media access control (MAC) for broadcast LANs
  - expanding LANs: connecting multiple LAN segments
- Various commonly used LAN technologies
  - Ethernet
  - 802.11(WiFi)
  - PPP



Ethernet Frame Structure

sending adapter encapsulates IP datagram (or other network layer protocol packet) in Ethernet frame



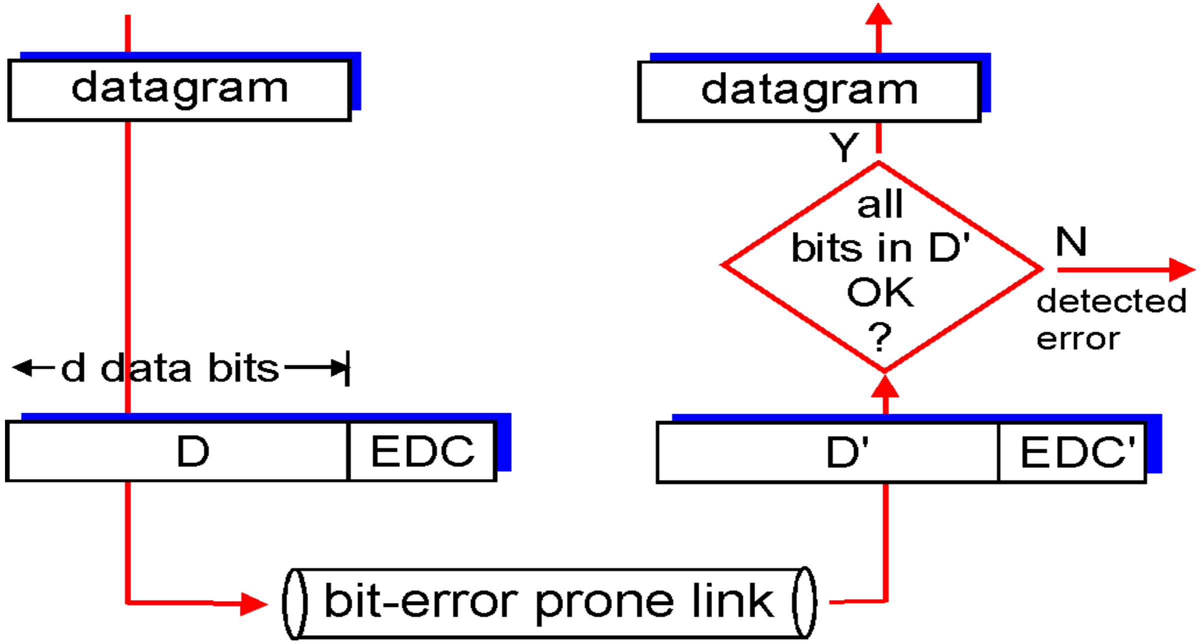
preamble:

- 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
- used to synchronize receiver, sender clock rates

Error Detection

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

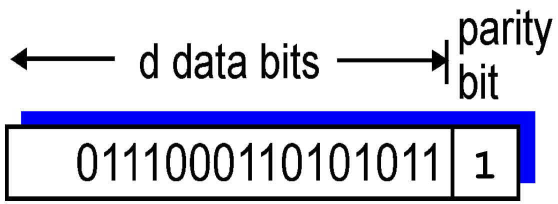
- Error detection not 100% reliable!
  - protocol may miss some errors, but rarely
  - larger EDC field yields better detection and correction



Parity Checking

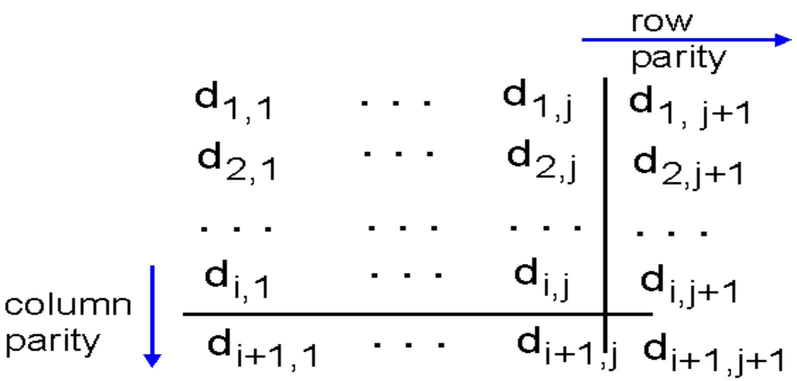
Single Bit Parity:

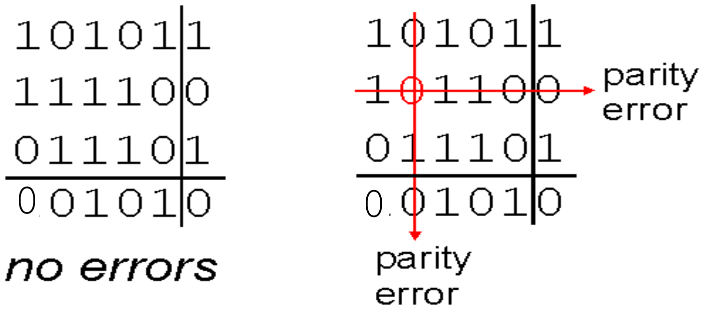
Detect single bit errors



Two Dimensional Bit Parity:

Detect *and correct* single bit errors





no errors

correctable single bit error

Internet Checksum (Review)

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

Sender:

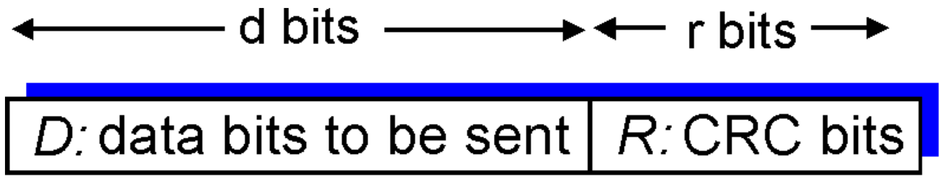
- treat segment contents as sequence of 16-bit integers
- checksum: addition (1's complement sum) of segment contents
- sender puts checksum value into UDP checksum field

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 ….*

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 (Ethernet, 802.11 WiFi, ATM)



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

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