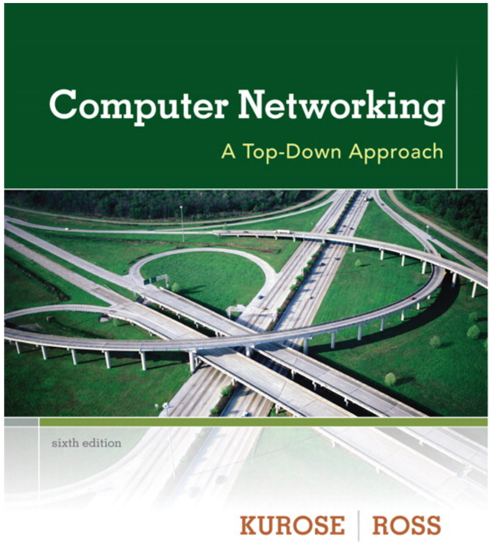
Chapter 5
Link Layer



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Thanks and enjoy! JFK/KWR

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Chapter 5: Link layer

our goals:

- understand principles behind link layer services:
  - error detection, correction
  - sharing a broadcast channel: multiple access
  - link layer addressing
  - local area networks: Ethernet, VLANs
- instantiation, implementation of various link layer technologies

Link layer services

- *framing:*

Almost all link-layer protocols encapsulate each network-layer datagram within a link-layer frame before transmission over the link. A frame consists of a data field, in which the network-layer datagram is inserted, and a number of header fields.

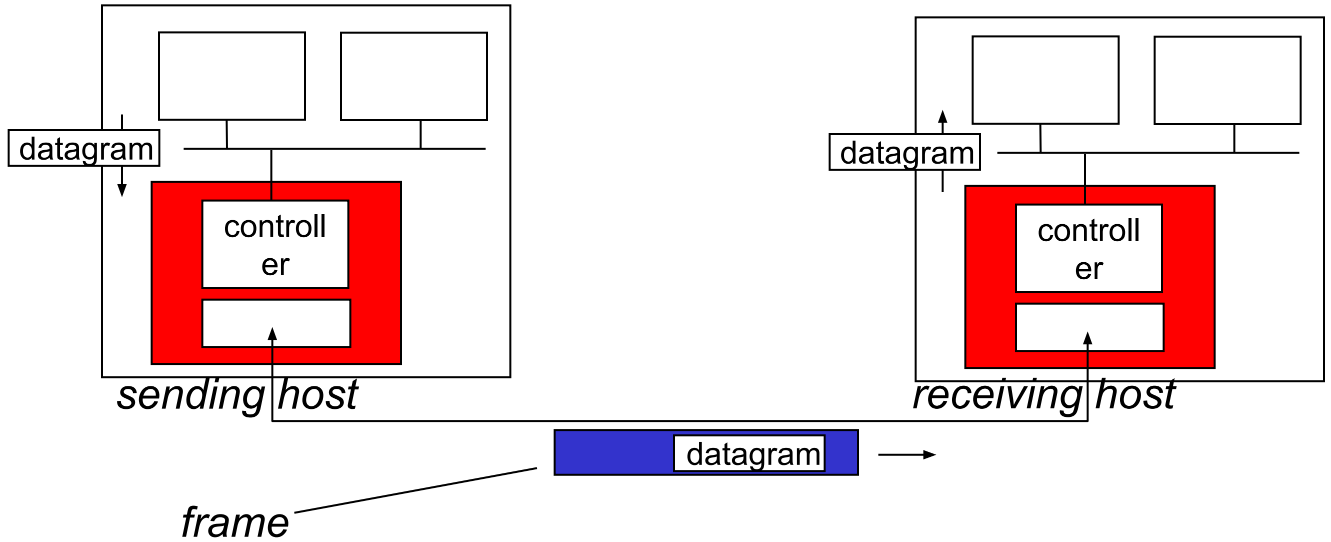
- *reliable delivery between adjacent nodes*

When a link-layer protocol provides reliable delivery service, it guarantees to move each network-layer datagram across the link without error.

Link layer services (more)

- *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

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

Link layer, LANs: outline

5.1 introduction, services

5.2 error detection, correction

5.3 multiple access protocols

5.4 LANs
- addressing, ARP
- Ethernet
- switches
- VLANS

5.5 link virtualization: MPLS

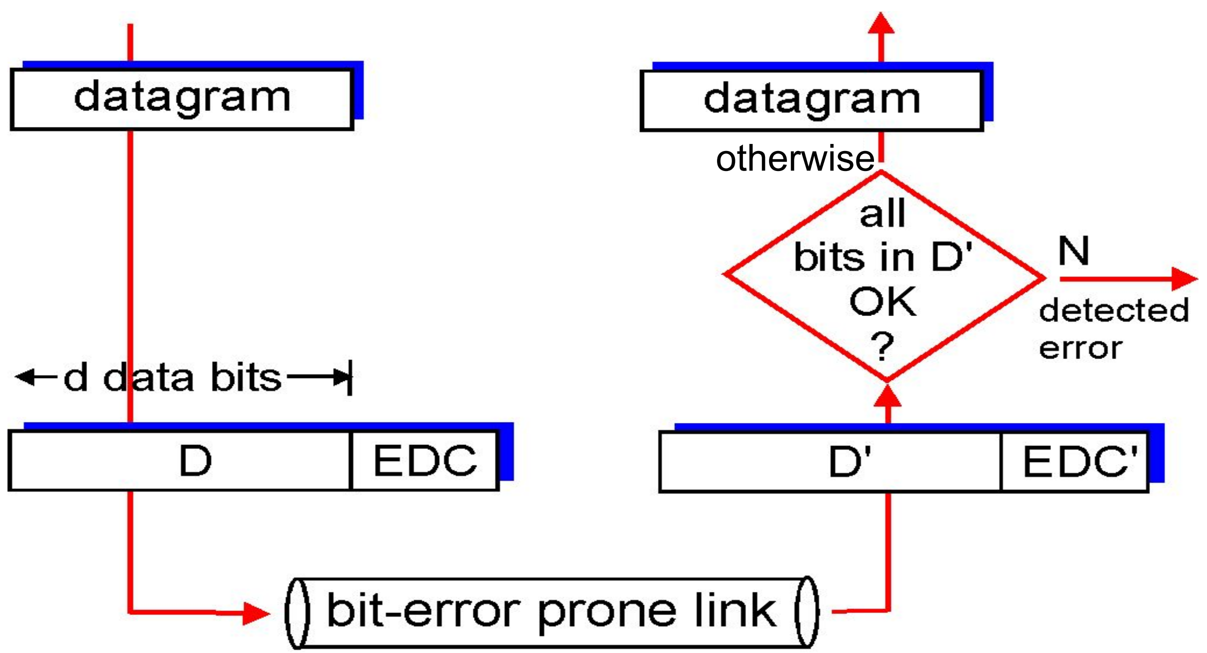
5.6 data center networking

5.7 a day in the life of a web request

Error detection

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

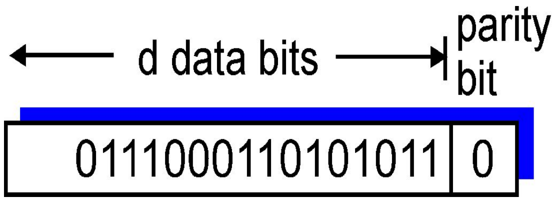
- Error detection not 100% reliable!
  - protocol may miss some errors, but rarely
  - larger EDC field yields better detection and correction



Parity checking

single bit parity:

- *d*etect single bit errors



two-dimensional bit parity:

- detect and correct single bit errors

Internet checksum (review)

goal: detect "errors" (e.g., flipped bits) in transmitted packet (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?*

Cyclic redundancy check

Q): Given $G(x) = 10110111$ & $P(x) = 110011$

Determine BCS.

A: Here, Data $G(x) = x^7 + x^5 + x^4 + x^2 + x^1 + x^0$

$$P(x) = x^5 + x^4 + x^1 + x^0$$

Now, while multiplying $G(x)$ with $P(x)$. we shall consider x^5 of $P(x)$.

$$x^5(x^7 + x^5 + x^4 + x^2 + x^1 + x^0) = x^{12} + x^{10} + x^9 + x^7 + x^6 + x^5$$

$$= 1011011100000$$

Now,

```
110011 ) 1011011100000 ( 11010111
         110011
         ------
          111101
          110011
          ------
           111010
           110011
           ------
             100100
             110011
             ------
              101110
              110011
              ------
               111010
               110011
               ------
                01001 = CRC
```

81

Now, CRC will be appended to the data.

$\overbrace{10110111}^{G(x)}\ \overbrace{01001}^{CRC}$

Again we divide it by P(x).

```
110011)10110111 01001 (11010111
       110011
       ------------
        111101
        110011
       ------------
         111010
         110011
       ------------
          100110
          110011
       ------------
           101010
           110011
       ------------
            110011
            110011
       ------------
                 0
```

No remainder. (means no transmission errors)

S: A message 10011 is given. where

$G_1(x) = (1,1,1)$ &

$G_2(x) = (1,0,1)$

Determine codeword design the convolution encoder.

A: $G_1(x)$, $G_2(x)$. and message are converted into

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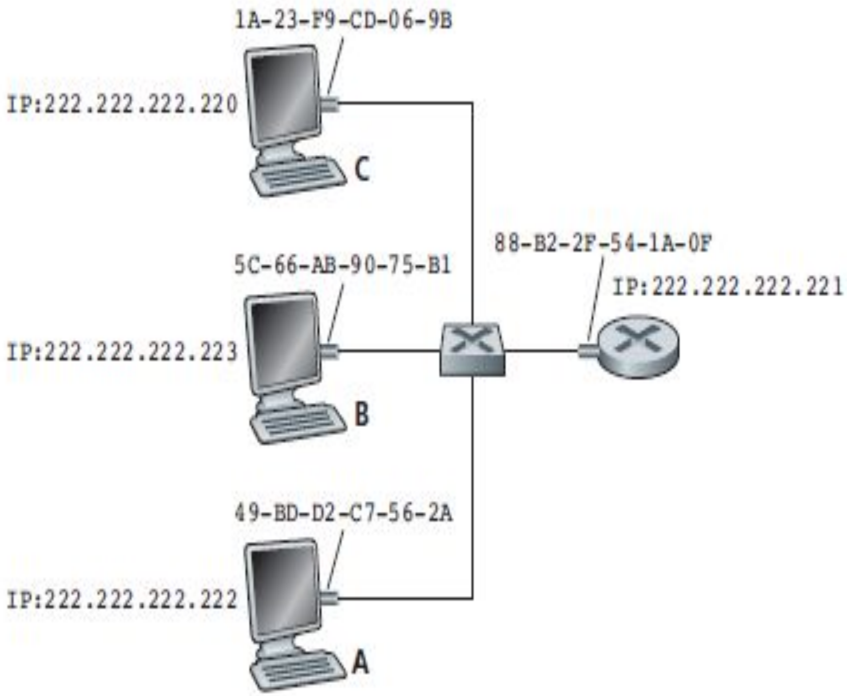
MAC Address

- A link-layer address is variously called a **LAN address**, a **physical address,** or a **MAC address**

Address Resolution Protocol (ARP)

- Because there are both network-layer addresses (for example, Internet IP addresses)and link-layer addresses (that is, MAC addresses), there is a need to translate between them
- Now suppose that the host with IP address 222.222.222.220 wants to send an IP datagram to host 222.222.222.222. To send a datagram, the source must give its adapter not only the IP datagram but also the MAC address for destination 222.222.222.222. The sending adapter will then construct a linklayer frame containing the destination's MAC address and send the frame into the LAN.



IP Address	MAC Address	TTL
222.222.222.221	88-B2-2F-54-1A-0F	13:45:00
222.222.222.223	5C-66-AB-90-75-B1	13:52:00

Switches vs. routers

both are store-and-forward:

- *routers:* network-layer devices (examine network-layer headers)
- *switches:* link-layer devices (examine link-layer headers)

both have forwarding tables:

- *routers:* compute tables using routing algorithms, IP addresses
- *switches:* learn forwarding table using flooding, learning, MAC addresses