Data Link Layer Overview

First of four classes on the data link layer

Internet Architecture

Bottom-up:
- **Physical**: electromagnetic signals “on the wire”
- **Link**: data transfer between neighboring network elements
- **Network**: host-host multi-hop connectivity
  - routing, addressing
- **Transport**: host-host data transport
  - reliable data transport, congestion control, flow control
- **Application**: anything you want to do on computer networks

Link Layer: Introduction

Some terminology:
- nodes in the network edge are hosts; nodes in the network core are routers
- communication channels that connect adjacent nodes along communication path are links
  - LANs, modem links, satellite links, wireless radio links

Data link layer has responsibility of transferring data from one node to adjacent node over a link.

Link Layer Functions

- **Encoding**
  - encode binary data to/from electromagnetic signals
- **Framing**
  - encapsulate data into frame, adding header, trailer
  - ‘physical addresses’ used in frame headers to identify source, dest (different from IP address!)
- **Link access control**
  - coordinate access for shared link
- **Flow control**
  - pacing between sending and receiving nodes such that the sender does not overwhelm the receiver
More Link Layer Functions

- Error detection
  - errors caused by signal attenuation, electromagnetic noise.
  - receiver detects presence of errors:
    - drops frame or signals sender for retransmission
- Error correction
  - receiver identifies and corrects error(s) without resorting to retransmission
- Reliable delivery over the link
  - typically mean no data loss and/or in-order delivery

Variety of Link Types

- Data transfer over different links:
  - e.g., first link (local-area cable)
  - intermediate links (long-haul fiber)
  - last link (wireless)
- Different links may demand different functions
  - encoding
  - link access control
  - reliable delivery
  - ...

Outline

- Introduction and functions of the data link layer
  - Encoding
  - Framing
  - Error detection and correction

Encoding

- Signals propagate over a physical medium
  - modulate electromagnetic waves
    - e.g., vary power
- Encode binary data onto signals
  - e.g., positive voltage as 1 and negative voltage as 0
  - Also known as Non-Return to Zero (NRZ)

Bits: 0 0 1 0 1 1 1 0 1 0 0 0 1 0
High-Low
Problem with Consecutive 1s or 0s

- Clock synchronization
  - both the sender and the receiver maintains a clock
  - clock synchronized at signal change

An Alternative Encoding

- Transition encoding
  - make a transition from current signal to encode a one; stay at current signal to encode a zero
  - only solves the problem of consecutive ones

Manchester Encoding

- Manchester
  - encode 0 into low-to-high transition; encode 1 into high-to-low transition.
  - only 50% efficient.

4B/5B Encoding

- every 4 bits of data encoded in a 5-bit code
  - since there are more 5-bit codes than 4-bit data; some codes are not used; we can design a mapping/encoding such that no data is encoded into 5-bit code with more than one leading 0 or more than two trailing 0s
  - thus, never get more than three consecutive 0s
  - resulting 5-bit codes are transmitted using the transition encoding
  - efficiency?
    - 80%
Outline

- Introduction and functions of the data link layer
- Encoding
- Framing
  - break sequence of bits into frames, add protocol headers/trailers
- Error detection and correction

Where each frame begins and ends?

- Sentinel-based framing
  - delineate frame with special begin/end patterns
    - e.g.,
      - problem: end pattern appears in the payload
        - solution: bit stuffing
          - for pattern 01111110:
            - Sender – insert 0 after five consecutive 1s
            - Receiver – delete 0 that follows five consecutive 1s
          - similar to escape characters in program languages

- Counter-based framing
  - include payload length in header

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**Error Detection and Correction**

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

**Parity Checking**

**Two Dimensional Bit Parity:**

**Single Bit Parity:**

Detect single bit errors

- d data bits

- parity bit

0111001101010111 1

Non-zero remainder: error detected!

Correctable single bit error

**Cyclic Redundancy Check**

- view data bits, D, as a binary number
- constant r+1 bit pattern (generator), G

**Sender:**

- for each D: choose r CRC bits, R, such that <D,R> exactly divisible by G

**Receiver:**

- divides <D',R'> by G. Non-zero remainder: error detected!
- can detect all burst errors fewer than r+1 bits

**CRC Example**

There is no carries and borrows in modulo-2 arithmetic. Addition, subtraction, and bit-wise XOR are all identical.

**Wont:**

\[ D \cdot 2^r + R = nG \]

**equivalent to (modulo-2):**

\[ D \cdot 2^r \equiv nG + R \]

**equivalent to:**

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

Note: used at network/transport layers (IP, TCP/UDP).

**Sender:**
- treat data as sequence of 16-bit integers
- add using 16-bit 1’s complement arithmetic; take 1’s complement of the result as the checksum
- sender puts checksum value into TCP/UDP checksum field

**Receiver:**
- compute checksum of received segment
- check if computed checksum equals checksum field value:
  - NO - error detected
  - YES - no error detected

1’s complement addition – carryout from the most-significant bit adds to the least-significant bit: 1010 + 1100 = 0111

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**Error Detection Reliability**

Error detection is not 100% reliable!
⇒ It is possible for corrupted D’ to match EDC’
- what is the chance that a random error escapes detection?
- larger EDC field yields better detection and correction

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