

Data Link Layer Overview

First of four classes on the data link layer

1/23/2013 CSC 257/457 - Spring 2013 1

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

application

transport

network

link

physical

1/23/2013 CSC 257/457 - Spring 2013 2

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.

1/23/2013 CSC 257/457 - Spring 2013 3

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

1/23/2013 CSC 257/457 - Spring 2013 4

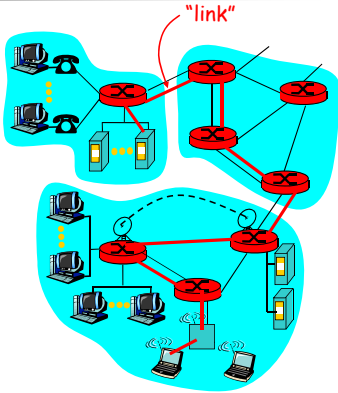
More Link Layer Functions

- **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

1/23/2013 CSC 257/457 - Spring 2013 5

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
 -



1/23/2013 CSC 257/457 - Spring 2013 6

Outline

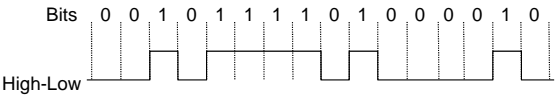
- Introduction and functions of the data link layer
- **Encoding**
- Framing
- Error detection and correction

1/23/2013 CSC 257/457 - Spring 2013 7

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 1 0 1 0 0 0 0 1 0



High-Low

1/23/2013 CSC 257/457 - Spring 2013 8

Problem with Consecutive 1s or 0s

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

Bits 0 0 1 0 1 1 1 1 0 1 0 0 0 0 1 0

High-Low

Clock

1/23/2013 CSC 257/457 - Spring 2013 9

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

Bits 0 0 1 0 1 1 1 1 0 1 0 0 0 0 1 0

High-Low

Transition

1/23/2013 CSC 257/457 - Spring 2013 10

Manchester Encoding

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

Bits 0 0 1 0 1 1 1 1 0 1 0 0 0 0 1 0

High-Low

Transition

Manchester

1/23/2013 CSC 257/457 - Spring 2013 11

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%

1/23/2013 CSC 257/457 - Spring 2013 12

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

1/23/2013 CSC 257/457 - Spring 2013 13

Where each frame begins and ends?

- Sentinel-based framing
 - delineate frame with special begin/end patterns
 - e.g.,

Beginning sequence	Header	Body	EDC	Ending sequence
8	16		16	8
- 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

1/23/2013 CSC 257/457 - Spring 2013 14

Where each frame begins and ends?

- Counter-based framing
 - include payload length in header

1/23/2013 CSC 257/457 - Spring 2013 15

Outline

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

1/23/2013 CSC 257/457 - Spring 2013 16

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

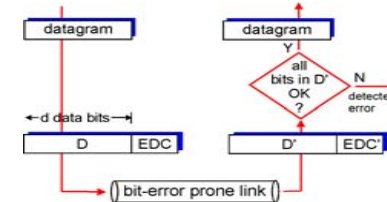
1's complement addition – carryout from the most-significant bit adds to the least-significant bit: $1010 + 1100 = 0111$

1/23/2013

CSC 257/457 - Spring 2013

21

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

1/23/2013

CSC 257/457 - Spring 2013

22

Disclaimer

- Parts of the lecture slides contain original work of James Kurose, Larry Peterson, and Keith Ross. The slides are intended for the sole purpose of instruction of computer networks at the University of Rochester. All copyrighted materials belong to their original owner(s).

1/23/2013

CSC 257/457 - Spring 2013

23