Lecture 2:
Links and Signaling

CSE 123: Computer Networks
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DISCUSSION @3pm Friday
Our Problem

- Communications is complicated
  - Modulation and encoding bits
  - Splitting sequences of bits into packets
  - Fixing errors
  - Controlling access to network
  - Routing
  - Recovering from lost messages
  - Etc....

- Really hard to think about all of this and get it right
- Not all applications need all of it
- How to achieve interoperability?
Layering: A Modular Approach

- **Sub-divide the problem**
  - Each layer relies on services from layer below
  - Each layer exports services to layer above

- **Interface between layers defines interaction**
  - Hides implementation details (encapsulation)
  - Layers can change without disturbing other layers (modularity)

- **Interface among peers in a layer is a protocol**
  - If peers speak same protocol, they can interoperate
Key Design Decision

- How do you divide functionality across the layers?

- **End-to-end argument [Saltzer84]**
  - Functionality should be implemented at a lower layer iff it can be **correctly** and **completely** implemented there.
  - Incomplete versions of a function can be used as a performance enhancement, but not for correctness.

- Early, and still relevant, example:
  - ARPAnet provided reliable link transfers between switches.
  - Was this enough for reliable communication?
  - No, packets could still get corrupted on host-switch link, or inside of the switches.
  - Hence, still need reliability at higher layers.
Protocol Standardization

- Communicating hosts speaking the same protocol
  - Standardization to enable multiple implementations
  - Or, the same folks have to write all the software

- Internet Engineering Task Force
  - Based on working groups that focus on specific issues
  - Produces “Request For Comments” (RFCs)
    » Rough consensus and running code
    » After enough time passes, promoted to Internet Standards

- Other standards bodies exist
  - ISO, ITU, IEEE, etc.
TCP/IP Protocol Stack

Application Layer
- HTTP

Transport Layer
- TCP

Network Layer
- IP
- Ethernet interface
- SONET interface

Link Layer
- Ethernet interface
- SONET interface
Encapsulation via Headers

- **Typical Web packet**
  
  ![Diagram of a typical Web packet with headers and payload](image)

- **Notice that layers add overhead**
  - Space (headers), effective bandwidth
  - Time (processing headers, “peeling the onion”), latency
Internet Protocol Suite

The Hourglass Model

Applications
Transport
Data Link
Physical

"Thin Waist"

NET_1
NET_2
... 
NET_n

IP
TCP
UDP

FTP
HTTP
NV
TFTP
Later: Phy/(MAC)Link layer

- Signal encoding
  - Encode binary data from source node into signals that physical links carry
  - Signal is decoded back into binary data at receiving node
  - Work performed by network adapter at sender and receiver

- Media access
  - Arbitrate which nodes can send frames at any point in time
  - Not always necessary; e.g. point-to-point duplex links
For now: (Data) Link Layer

- **Framing**
  - Break stream of bits up into discrete chunks

- **Error handling**
  - Detect and/or correct errors in received frames

- **Multiplexing**
  - Determine appropriate destination for a given frame
  - Also not always required; again, point-to-point
Today’s Focus: Framing

- Break down a stream of bits into smaller, digestible chunks called **frames**

- Allows the link to be shared
  - Multiple senders and/or receivers can **time multiplex** the link
  - Each frame can be separately addressed

- Provides manageable unit for error handling
  - Easy to determine whether something went wrong
  - And perhaps even to fix it if desired
What’s a Frame?

- Wraps payload up with some additional information
  - Header usually contains addressing information
  - Maybe includes a trailer (w/checksum—next lecture)
- Basic unit of reception
  - Link either delivers entire frame payload, or none of it
  - Typically some maximum transmission unit (MTU)
- Some link layers require absence of frames as well
  - I.e., minimum gaps between frames
Identifying Frames

- First task is to delineate frames
  - Receiver needs to know when a frame starts and ends
  - Otherwise, errors from misinterpretation of data stream

- Several different alternatives
  - Fixed length (bits) frames
  - Explicitly delimited frames
    » Length-based framing
    » Sentinel-based framing
  - Fixed duration (seconds) frames
Fixed-Length Frames

- Easy to manage for receiver
  - Well understood buffering requirements

- Introduces inefficiencies for variable length payloads
  - May waste space (padding) for small payloads
  - Larger payloads need to be fragmented across many frames
  - Very common inside switches

- Requires explicit design tradeoff
  - ATM uses 53-byte frames (cells)
To avoid overhead, we’d like variable length frames
  ● Each frame declares how long it is
  ● E.g. DECNet DDCMP

What’s the issue with explicit length field?
  ● Must correctly read the length field (bad if corrupted)
    » Need to decode while receiving
  ● Still need to identify the beginning…
Sentinel-based Framing

- Allow for variable length frames
- Idea: mark start/end of frame with special “marker”
  - Byte pattern, bit pattern, signal pattern
- But… must make sure marker doesn’t appear in data

- Two solutions
  - Special non-data physical-layer symbol
    » Impact on efficiency (can’t use symbol for data) of code
  - Stuffing
    » Dynamically remove marker bit patterns from data stream
    » Receiver “unstuffs” data stream to reconstruct original data
Stuffing

- Insert bytes/bits into data stream to make sure that sentinel (flag) does not appear in payload
Bit-level Stuffing

- Avoid sentinel bit pattern in payload data
  - Commonly, sentinel is bit pattern 01111110 (0x7E)
  - Invented for SDLC/HDLC, now standard pattern
- Sender: any time five ones appear in outgoing data, insert a zero, resulting in 0111110

- Receiver: any time five ones appear, removes next zero
  - If there is no zero, there will either be six ones (sentinel) or
  - It declares an error condition!
  - Note bit pattern that cannot appear is 0111111 (0x7F)
- What’s the worst case for efficiency?

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Byte Stuffing

- Same as bit stuffing, except at byte (character) level
  - Generally have two different flags, STX and ETX
  - Found in PPP, DDCMP, BISYNC, etc.
- Need to stuff if either appears in the payload
  - Prefix with another special character, DLE (data-link escape)
  - New problem: what if DLE appears in payload?
- Stuff DLE with DLE!
  - Could be as bad as 50% efficient to send all DLEs
For Next Class

- Read 2.4

- Make sure you’ve sent us your GitHub Id
  
  https://docs.google.com/forms/d/e/1FAIpQLSdGe_iq9EfI3u_YJl1opEZIv
  iwhwXs60LyVESIhLiHgAhC3Ng/viewform

- Take a look at Project 1