Framing, Protocol Layering and Encapsulation

Circuit Switching vs Packet Switching

Networks can be classified as circuit-switched or packet-switched.

The most common example of a circuit-switched network is the phone network. Each time a call is set up the transmission link is dedicated to one pair of users. Circuit switched networks have the shortest propagation delays but can be inefficient if the data source is bursty.

Packet-switched networks group data into frames (also called packets). Each frame contains a header which identifies the destination and possibly other information. These packets can then be transmitted over various links until they reach their destination. Each transmission is done in a "store and forward" method where the complete frame is received and checked before being passed along.

ATM (asynchronous transfer mode) was a compromise between circuit- and packet-switching. ATM used fixed-length frames ("cells") of 48 data bytes and a 5-byte header. The goal was to efficiently carry both delay-sensitive (telephone) and delay-tolerant (internet) data over the same network. However, as data rates increased the low-delay and prioritization features provided by ATM turned out to be unnecessary. ATM has been largely completely replaced by IP store-and-forward networks.

Exercise 1: How long does it take to transmit a 53-byte frame at 1.5 Mb/s? At 1 Gb/s? What is the overall delay if the frame has to be transmitted over 10 hops through a store-and-forward network? How long does it take a signal to propagate over a 6000km path when using a cable with a velocity factor of 0.66?

Frames

A frame typically consists of a header, data and a trailer.

The header contains information about the frame. This can include destination and source addresses, frame length, priority, and many other fields. The header sometimes includes a physical-layer-specific preamble for synchronization.

The data is typically a variable-length field and contains the "payload" data that is being communicated.

The trailer often includes a checksum that allows for detection of errors and may include other fields.

Bit-Oriented Protocols

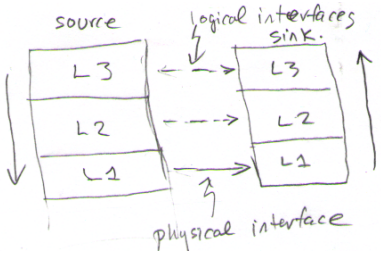
In most protocols a frame is composed of a sequence of bytes. However, there are older protocols (HDLC and SDLC) where the frames were defined in terms of sequences of bits. A special bit sequence (0111 1110) was used to delimit the frame and bit stuffing (stuff a 0 after five 1's) was used to make sure this sequence did not occur within data.

The HDLC protocol was primarily used by low data rate devices. It is still used as part of other protocols (such as fax machines).

Protocol Layering

Communication systems are designed in "layers". Each layer corresponds to communication within a particular type of network. This allows connectivity between higher layers even when lower layers are implemented with different technologies. For example, a web browser works regardless of whether the LAN is wired or wireless.

Data travels up and down the protocol stack within one physical device. Physical communication – between devices – only happens at the lowest layer. Communication between devices at higher layers is through a logical interface (typically a software API).



Conceptually, the lowest layer (Layer 1) transfers data between two physical interfaces (two RS-232 ports, two Ethernet LAN ports, etc).

Above that, Layer 2 is responsible for communication between devices on the same local network. The most common example is the various IEEE 802 LAN protocols. This allows two IEEE 802 LAN devices to communicate as peers even if, for example, one is wired and the other wireless.

The next layer (Layer 3 or "L3") routes data between networks. By far the most common layer 3 protocol is the Internet Protocol (IP) that allows "hosts" on the "internet" to communicate with each other.

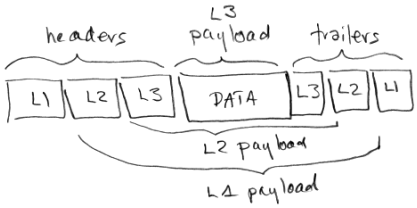
Protocols at even higher layers make sure that data can be exchanged between applications (for example the Hypertext Transfer Protocol (HTTP) used between web browsers and web servers).

This course concentrates on Layer 1. Other courses cover the higher layers.

Encapsulation

Each protocol typically has its own frame format and headers that carry information used by that specific protocol layer.

As data is transmitted between applications passes down the protocol stack (from L3 to L2 to L1), each layer "wraps" the frame received from the layer above with it's own header and trailer. This process is called "encapsulation'. As data makes its way back up the stack these headers and trailers are removed.



For example, a library implementing IP will add an IP header to each frame containing the source and destination IP addresses. This is then passed to an Ethernet interface that adds an Ethernet header containing the Ethernet source and destination addresses and a trailer with a Cyclic Redundancy Check (CRC).