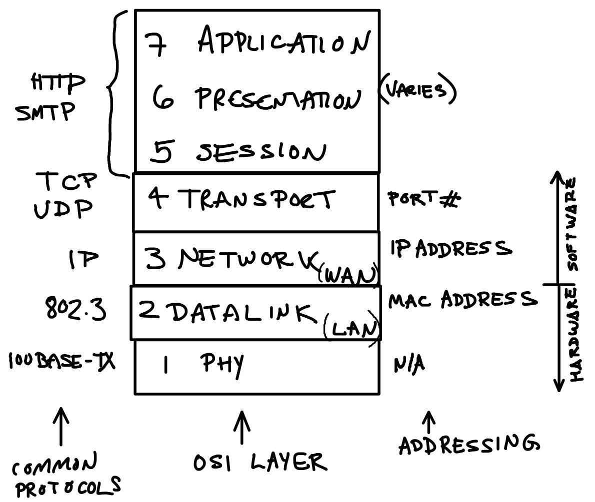
Protocol Layering, Encapsulation and Standards Organizations

This lecture describes the purpose of communication protocol layering, the OSI 7-layer model and gives some common examples. Some of the organizations that write protocol specifications are also described.
After this lecture you should be able to: explain the advantage of protocol layering and give one or more examples of protocols used at each of the OSI layers.

OSI Protocol Layers

The Open Systems Interconnect model for data networks is an attempt to divide the functions that are performed by typical data communication networks into protocol layers. The OSI model defines 7 layers as shown below:



The layers of the OSI model are:

Physical Layer is the lowest layer (layer 1) of the OSI model. It defines physical features such as connectors, voltages, currents, waveforms, frequencies, modulation formats, line codes, etc. Common examples include 100BASE-TX Ethernet LANs, 802.11 WLANs, and DOCSIS cable modems. This layer is always implemented in hardware.

Data Link Layer is layer 2 of the OSI model. It is often considered to include two sub-layers, the Logical Link Control (LLC) layer and the Medium Access Control (MAC) layer. The LLC layer is responsible for transferring frames between devices on the local network. This includes addressing, error detection and flow control. The MAC is responsible for coordinating access to a shared medium, for example using CSMA/CD. The most common example is IEEE 802.3 Ethernet. Except at the lowest data rates (e.g. telephone modems) this layer is implemented in hardware. Addressing in the Data Link Layer is typically done using IEEE 802 globally unique "MAC" addresses.

Network Layer is layer 3 and is responsible for routing message between local area networks. Layer 3 networks typically consist of point-to-point links between routers. The addressing structure is usually hierarchical to assist with routing. By far most popular example is the Internet Protocol or "IP". This and higher layers are typically implemented in software. Layers 3 and 4 are typically provided by libraries such as the BSD "socket" libraries. IP addressing is done using IPv4 or IPv6 addresses, usually with a mapping from domain names to IP addresses.

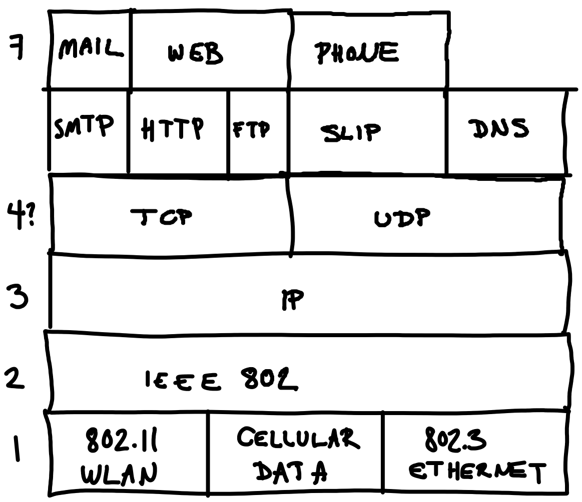
Transport Layer This layer handles retransmissions, flow control, fragmentation (breaking up large frames into smaller ones). There are two common transport layers built on top of IP: TCP and UDP. Both of these make use of 16-bit "port" numbers that allow addressing of transport streams between two hosts.

Session, Presentation, Application The distinctions between these three highest layers are not widely observed since they are all typically implemented by the same software. Examples include Web browsers (HTTP) and e-mail (SMTP).

Protocol Layering

Data communication protocols are designed in "layers." Each layer is responsible for providing specific services (error checking, routing, retransmission, etc). This allows protocols at one layer to interoperate with different protocols at other layers. For example, a web browser can access the internet through a WLAN or an ADSL connection or wired Ethernet connection. It is not necessary to re-write the browser to operate over each new physical layer because the browser is designed to interact only with the layer immediately below it (the network layer). The concept is similar to API layering.

The following diagram shows how some common protocols are layered. A layer passes data down to layers below it and thus uses the services provided by those lower layers.



This is a somewhat simplified view because layering violations are sometimes necessary to improve overall simplicity, for efficiency or for management purposes.

Certain functions,such as error control, may be performed at multiple layers. For example, a WLAN may included it's own ARQ protocol because errors happen more often on wireless networks. If retransmission were only done by higher layers the delay might become excessive.

Protocol Encapsulation

At the sending end, data travels "down" the layers of the protocol stack and then travels "up" the layers at the receiving end.

On the way down each layer adds on a header that carries the information required by that layer. On the way back up the stack each layer removes that layer's header.

An example of a fully encapsulated web page as would be seen on the PHY layer is shown above. The HTTP layer added the HTTP header, the TCP layer added a TCP header, etc.

Exercise 1: What header(s) would be present in a frame being passed from the IP to the 802 layer? What about a frame being passed in the other direction?

Standards Organizations

There are various organizations that manage and publish telecommunications interoperability specifications. Among the more important ones are:

ITU The International Telecommunication Union is an agency of the UN that deals with telecommunications standards that require international coordination. This includes radio frequency allocations and international telephony standards. The ITU is divided up into ITU-R for radio communications and ITU-T for wired communications. The ITU publishes various series of standards. Each series begins with a different letter. For example, G (speech coders such as G.729), T (telephony standards such as T.4 fax), V (voice-band modems such as V.34).

IEEE The Institute of Electrical and Electronic Engineers is a professional society that sponsors the development of telecommunications standards. These include the 802 series of specifications that includes 802.3 LAN, 802.11 WLAN and 802.15 WPAN.

ETSI The European Telecommunications Standards Institute is a Europe-based telecommunications standards organization. ETSI has published some 2G (GSM) and 3G (WCDMA) cellular standards.

There are also many industry-sponsored organizations that promote a particular standard and provide conformance-testing services. Example include the WiFi Alliance that test for conformance with a subset of the IEEE 802.11 standard and if the product passes, allows the use of a "WiFi" logo with the product. Similar groups exist for many other telecom standards.

Standards development is primarily driven by telecommunications manufacturers. The companies that participated in the development of a standard often form a "patent pool" that allows these manufacturers to use each others patents without paying licensing fees. This is an important incentive for companies to participate in standards development and to have their intellectual property (IP) included in a standard.

Since many standards organizations will only approve one standard for each application (e.g. one WLAN standard), manufacturers with competing ideas sometimes go to other standards organizations to have their standard formalized. This is one reason for the proliferation of standards organizations with overlapping coverage.

In general, the success of any standard is determined by manufacturer and customer acceptance rather than by government mandate. In fact, the large majority of standards are never widely implemented.

Some people distinguish between a "standard" (something most people agree to) and a "specification" (a document specifying requirements) but in popular use the two words are used interchangeably.

Regulatory Agencies

Closely related to standards organizations are the organizations that have authority to regulate telecommunication devices and services to ensure public safety and efficient use of public resources.

These government bodies can define technical requirements such as RF frequencies and transmit powers. They also test for compliance and license service providers. They may also mandate technical standards to enhance competition.

IC Industry Canada is resposible for technical aspects of telecommunications regulations in Canada.

FCC the Federal Communications Commission regulates telecommunications in the US.

The EC and other countries have their own regulatory agencies although smaller countries tend to adopt regulations similar to those in larger markets.