CS 425: Computer Networks **Jan-Apr 2020**

Lecture 4: Computer Networks – January 14, 2020

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4.1 Reference models

4.1.1 OSI 7 layer reference model(1984)

The model is called the ISO OSI (Open Systems Interconnection) Reference Model because it deals with connecting open systemsthat is, systems that are open for communication with other systems.

The OSI model has seven layers. The principles that were applied to arrive at the seven layers can be briefly summarized as follows:

- A layer should be created where a different abstraction is needed.
- Each layer should perform a well-defined function.
- The function of each layer should be chosen with an eye toward defining internationally standardized protocols.

Layer	**Functions**
Application	Provide functionalities to user
Presentation	Converts different representations
Session	Manages task dialogs
Transport	End to End delivery
Network	Routing
Data Link	Single Link reliability
Physical	Bits

Table 4.1: The OSI reference model

The OSI reference model did not gain much popularity, primarily because-

1. 7 layers make the model bulky.
2. TCP/IP Model was already existing and highly popular, even today

4.1.2 TCP/IP reference model(1974)

- It was first described by Cerf and Kahn in 1974.

- In comparison to OSI reference model, it does not have Presentation, Session and Physical as separate layers.
- The TCP/IP model supports only one mode in the network layer (connectionless) but both in the transport layer, giving the users a choice. This is different in comparison to the OSI model which supports both connectionless and connection-oriented communication in the network layer, but only connection-oriented communication in the transport layer, where it counts (because the transport service is visible to the users).

OSI	**TCP/IP**
Application	Application
Presentation	
Session	
Transport	Transport
Network	Network
Data Link	Link
Physical	

Table 4.2: Comparison of OSI and TCP/IP Referene model

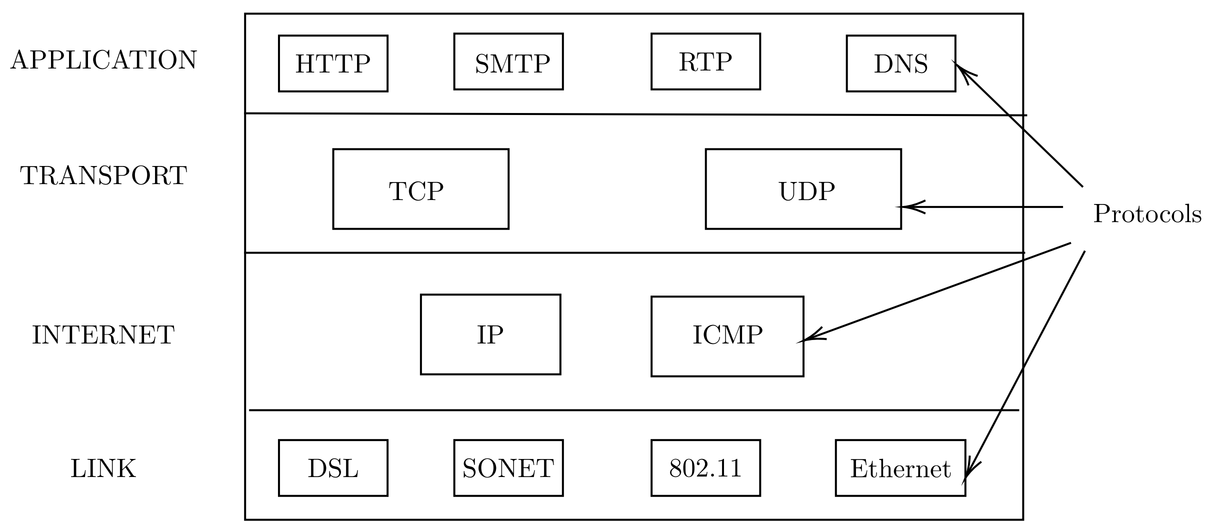


Figure 4.1: TCP/IP model with some protocols

TCP/IP model is a narrow waist architecture, with one universal protocol in the middle (IP), widening to support many transport and application protocols above it (e.g., TCP, UDP, RTP, SMTP, HTTP) and able to run on top of many network technologies below (e.g., Ethernet, WiFi, SONET). This is why IP is called the "thin waist" of the Internet.

4.1.3 Network Standardisation

- Many network vendors and suppliers exist, each with its own ideas of how things should be done.
- Without coordination, there would be complete chaos, and users would get nothing done.

- Several standard bodies are present to design the protocols.
- Protocols are just guidelines , i.e, they are non-binding.

Organisation	**Protocols**	**Examples**
ITU	Telecommunication	ADSL, MP4, etc.
IEEE	Physical and Link Layer communication protocols	Ethernet, 802.11,etc.
IETF	Internet	HTTP, DNS, RFCs, etc.

Table 4.3: Organisations and the protocols designed by them

4.1.4 Layering used in this course

- The model has five layers, running from the physical layer up through the link, network and transport layers to the application layer.
- The physical layer specifies how to transmit bits across different kinds of media as electrical (or other analog) signals.
- The link layer is concerned with how to send finite-length messages between directly connected computers with specified levels of reliability.
- The network layer deals with how to combine multiple links into networks, and networks of networks, into internetworks so that we can send packets between distant computers.
- The transport layer strengthens the delivery guarantees of the Network layer, usually with increased reliability, and provide delivery abstractions, such as a reliable byte stream, that match the needs of different applications.
- The application layer contains programs that make use of the network.

Layer	**Units of Data**
Application	Original message
Transport	Segment
Network	Packet
Link	Frames
Physical	Bits

Table 4.4: Units of data in various layers used in this course

4.1.5 Layer based names of devices

We have different names for devices, depending on the layers between which the device is operating.

4.1.5.1 Repeators/Hubs

It is the simplest device that provides only physical layer connectivity. In these types of devices, the medium on both the physical layer should be the same. If it is on wired other part has to be on wired.

Figure 4.2: Repeators/hubs

4.1.5.2 Switch/Bridge

It uses the headers in the link layers to find if we have received the correct packet or not and do certain operations. After verifying it is a valid packet, it sends it to the other part of the physical layer.
Here, one type of physical layer could be different from other types of the physical layer. E.g., It may receive a packet from a wireless, and on the other side, we may have a wired link.

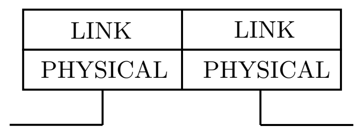


Figure 4.3: Switch/Bridge

4.1.5.3 Router

This device can look into the packet to the network layer. It is responsible for deciding which path this network should take. After the packet has been correctly received, it is also deciding , which physical port we should send that message (in case of multiple physical ports) and appropriately decides its header and other network specifications.

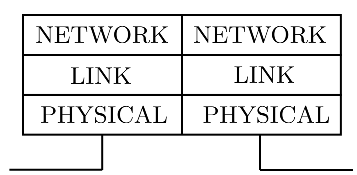


Figure 4.4: Router

4.1.5.4 Proxy/Middlebox

This hybrid device does not fall into any of the above categories. It goes into much deeper layers of the protocol stack. Depending on which type of middleboxes you are looking at, it may look at all the layers starting from the physical layer to the application layer. It can look at all the different kinds of details that are available with the message. It can look at the application and see if the application is most suited for this particular type of lower-level technologies. We will study at one such type of device called NAT - Network Address Translation.

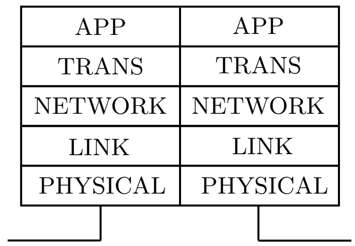


Figure 4.5: Proxy/Middlebox

4.1.6 Summary

- Read and understand layering diagrams.
- Protocols and their uses in each layer.

4.2 Physical Layer

- Deals with how the signals are sent on a physical medium, e.g. Copper wire, optical fiber and wireless(Ether).
- Carry analog signals - messages sent via voltage, frequency information.
- Bits are encoded into the analog signals for transmission, and the digital signal is recovered on the other side of the physical medium.

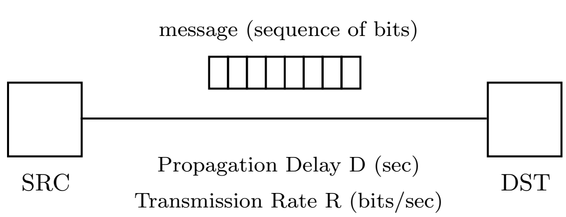
It is different from other layers such that the communication of other layers in the two protocol stack is virtual, there is no physical connection (e.g., Network layers do not talk to each other). But the physical layer physically transmits bits to the receiver. So it can be called the real layer.

4.2.1 Topics in Physical layer

- Properties of the media: Wires, Fiber optics, Wireless.
- Simple signal propagation: Bandwidth, Attenuation and Noise.
- Modulation: Represent bits in analog signal.
- Fundamental Limits: Nyquist, Shannon

4.2.2 Simple Signal Propagation

4.2.2.1 Message Latency



Transmission Rate (also called bandwidth or capacity or maximum data rate) depends on the type of the link (that is, ethernet, wireless etc) and the SRC device. It is basically the rate at which data is pushed from SRC into the link.

Latency is the time taken to send a message over a link. Consider a message of size M bits, the transmission rate of the link as R bits/sec and the propagation delay over the link as D seconds. Then Latency consists of two components:

1. **Transmission Delay**: Time taken to create and put a message on the link. Transmission delays are typically of the order of microseconds to milliseconds in practice. It is given by $\frac{M}{R}$.

2. **Propagation Delay**: It is the time taken for a signal to traverse the link end-to-end. The signal propagates at the propagation speed of the link. The propagation speed depends on the physical medium of the link (that is, fiber optics, twisted-pair, copper wire, etc) and is of the range of $2 \cdot 10^8$ meters/sec to $3 \cdot 10^8$ meters/sec. Propagation Delay written in terms of the link properties is, $\frac{\text{length of wire}}{\text{speed of signal in the link}} = D$.

The difference between transmission delay and propagation delay is subtle but important. Transmission delay is the amount of time required for the SRC device to push out the message packet. It is a function of the packets length and the transmission rate of the link, but has nothing to do with the distance between the SRC and DST devices. The propagation delay, on the other hand, is the time it takes a bit to propagate from SRC to DST. It is a function of the distance between the two devices, but has nothing to do with the packets length or the transmission rate of the link.

For representing higher orders of bits, let's introduce some concise notational units. Note that 'B' is used for bytes while 'b' is used for bits, with the relationship 1 Byte = 8 bits.

- Powers of 10 - Usually used for rates, e.g. 1Mbps = 10^6 bits/sec.

- Powers of 2 - Usually used for storage, e.g. 1KB = 2^{10} bytes.

Example 1: Dial-up connection, D = 3ms, R = 56Kbps, M = 28KB

Transmission Time = $\frac{M}{R}$ = 4.096s.
Propagation Delay = D = 3ms.

Example 2: Broadband Connection, D = 3ms, R = 100Mbps, M = 28KB

Transmission Time = $\frac{M}{R}$ = 2.29ms.
Propagation Delay = D = 3ms.

Data-in-Flight is the total data contained in the wire/fiber at any point of time. It is given by the product, Delay-Bandwidth Product = $D \times R$ (physical limit of a material)

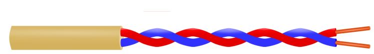
Example 3: R = 4Mbps, D = 50ms

Data-in-Flight = $D \times R$ = 25KB

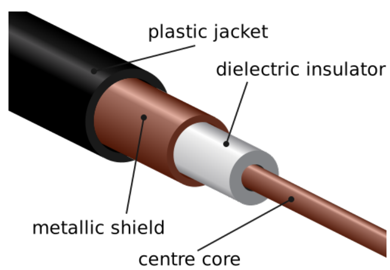
4.2.3 Transmission Media

4.2.3.1 Guided Media

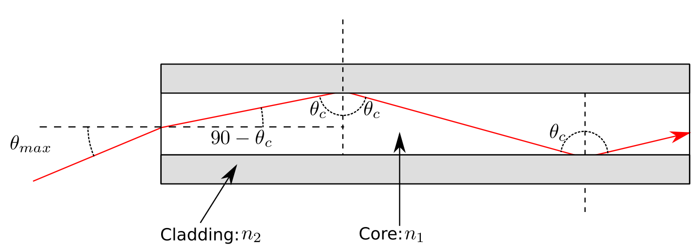
1. **Twisted pair**: Twisted pair consists of two insulated copper wires, typically 1mm thick. The wires are twisted together in a helical form the purpose of twisting is to reduce cross talk interference between several pairs. It is cheap but is susceptible to noise and electromagnetic interference and attenuation is large.
   The most common application of twisted pair is the telephone system.



2. **Coaxial cable**: Coaxial cable consists of an inner conductor and an outer conductor which are separated by an insulator. The inner conductor is usually copper. The outer conductor is covered by a plastic jacket. It is named coaxial because the two conductors are coaxial.
   The most application of coaxial cable is cable T.V.
   The coaxial cable has high bandwidth, attenuation is less.



3. **Optical Fiber** An optical fiber is a thin, flexible medium that conducts pulses of light, with each pulse representing a bit. A single optical fiber can support tremendous bit rates, up to tens or even hundreds of gigabits per second.
   It uses the principle of total internal reflection to transfer data over optical fibers.
   Disadvantage of optical fiber is that end points are fairly expensive(eg. switches).



4.2.3.2 Wireless Medium

The flexibility to connect to devices without physically connecting them makes wireless medium convenient. A challenge with wireless medium is that signals are broadcasted. So, signals may interfere with each other. Different methods to deal with this problem are discussed in the next section.

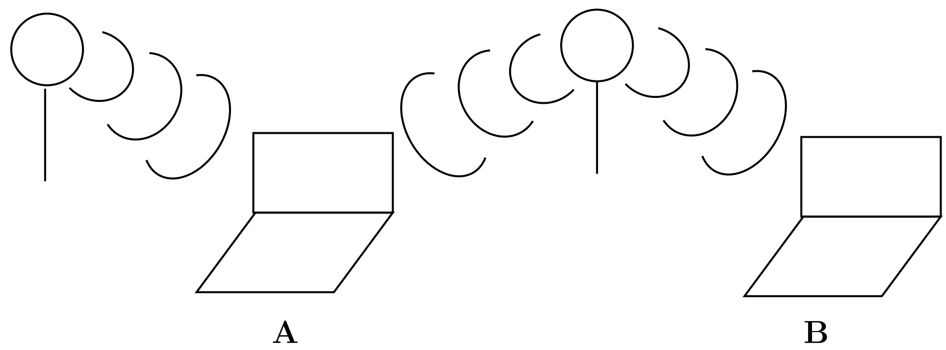


Figure 4.6: Wireless medium

4.2.4 Multiplexing

Multiplexing is a technique by which different analog and digital streams of transmission can be simultaneously processed over a shared link. Multiplexing divides the high capacity medium into low capacity logical medium which is then shared by different streams.

1. **Time Division Multiplexing (TDM)**: In this, users take turns (in a round-robin fashion), each one periodically getting the entire bandwidth for a little burst of time.
   TDM is used widely as part of the telephone and cellular networks.
2. **Frequency Division Multiplexing (FDM)**: It takes advantage of passband transmission to share a channel. It divides the spectrum into frequency bands, with each user having exclusive possession of some band in which to send their signal.
   AM radio broadcasting illustrates a use of FDM.
3. **Code Division Multiplexing(CDM)/Multiple Access (CDMA)**:In this, a unique "code" is assigned to each user. i.e., code set partitioning.
   - All users share same frequency, but each user has own "chipping" sequence (i.e., code) to encode data
   - Allows multiple users to "coexist" and transmit simultaneously with minimal interference (if codes are "orthogonal")
   - For Encoding: encoded signal= (original data) $\times$ (chipping sequence)
   - For Decoding: Take the inner-product of encoded signal and chipping sequence
   - Example of orthogonal codes are [1,1,1,1], [1,-1,1,-1], [1,1,-1,-1] and [1,-1,-1,1].