Introduction to Networks & Distributed Computing
CECS 327

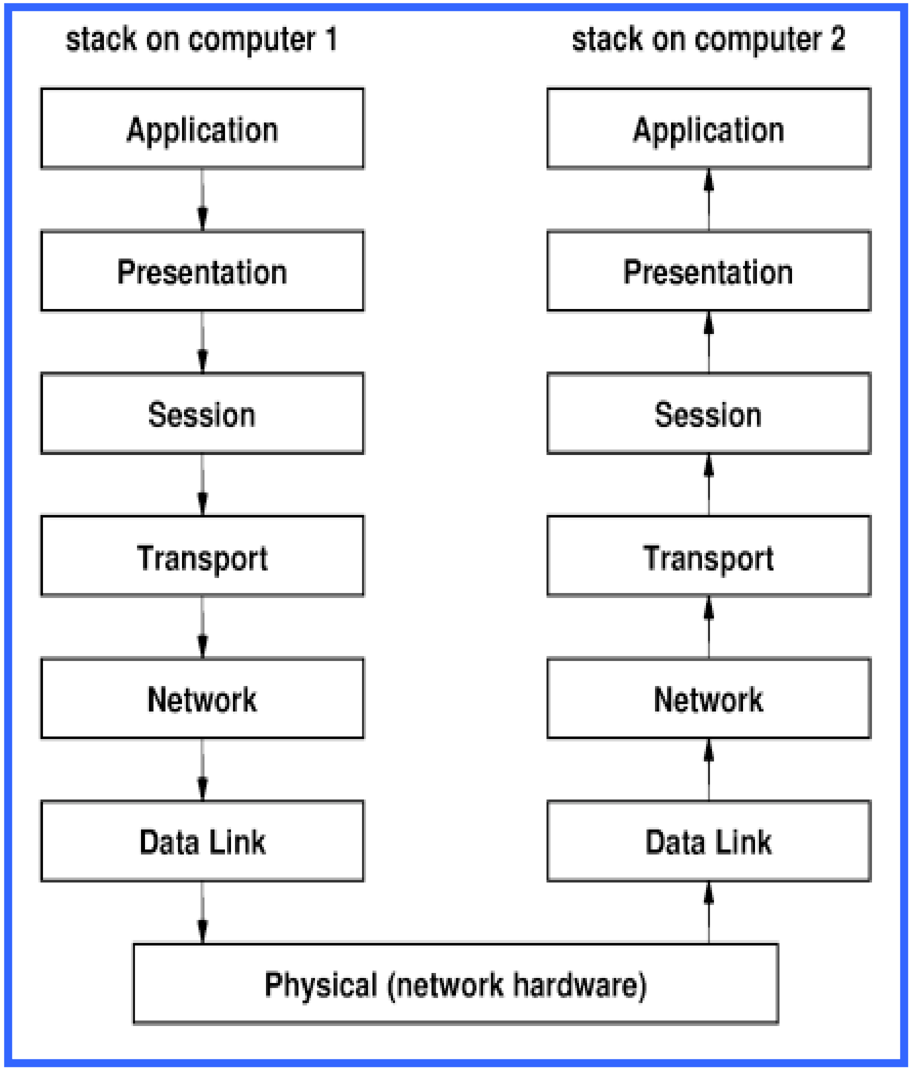
Protocol Suites and Layering Models

The Layering Model

Protocol software follows the layering model, with:

- One software module per layer
- Modules that work together
- Incoming or outgoing data passing from one module to another

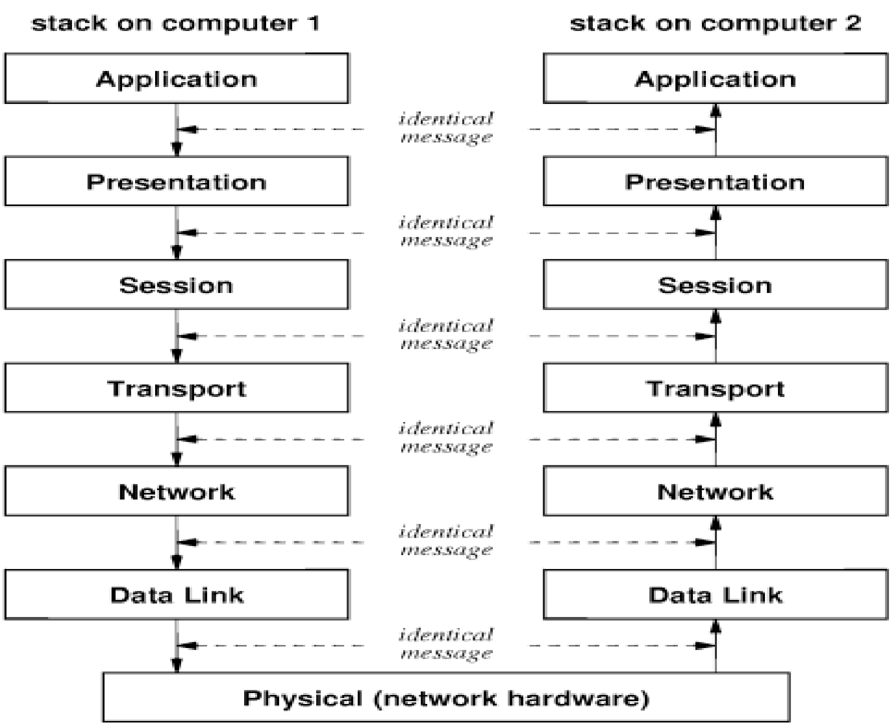
The entire set of protocol layers (or modules) is known as a ***stack***.



Protocol Suites and Layering Models

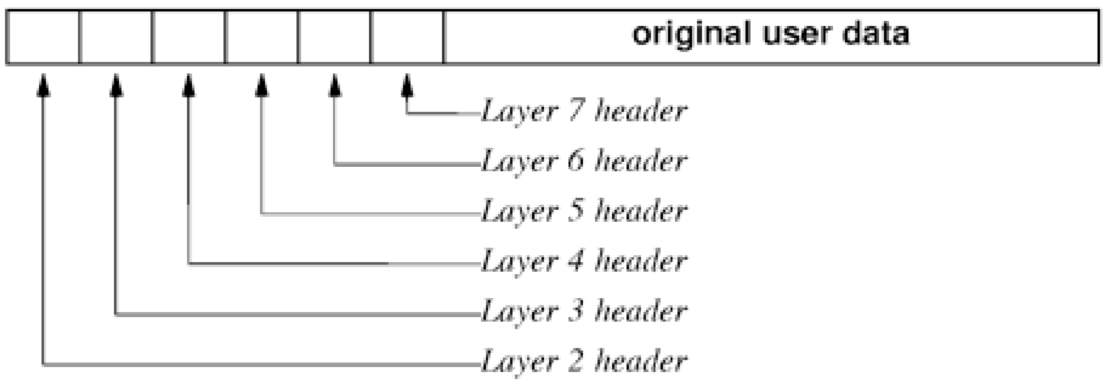
Layering Principle

Software implementing layer N at the destination receives exactly the message sent by software implementing layer N at the source. --Comer



Protocol Suites and Layering Models

- **Layers and Packet Headers**



Each layer:

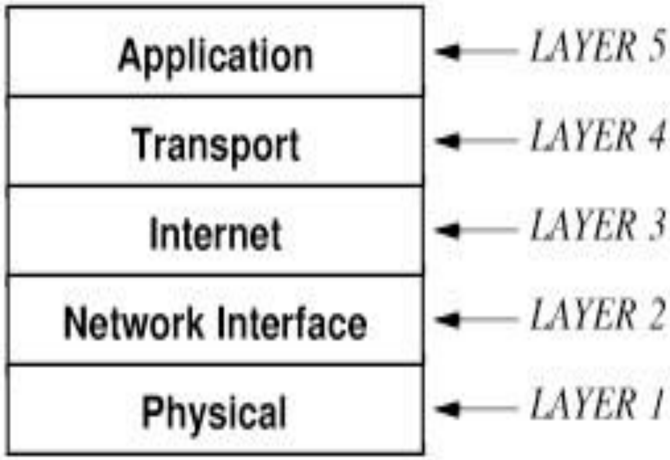
- Prepends a header to the outgoing packet
- Removes a header from the incoming packet

This process is known as *data encapsulation.*

Protocol Suites and Layering Models

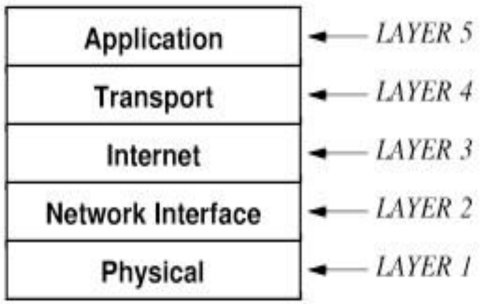
TCP/IP Layering

Notwithstanding the push by researchers to adopt the OSI model, it became clear that TCP/IP was technically more flexible and superior. TCP/IP is the primary protocol stack used today.



Protocol Suites and Layering Models

TCP/IP Layers

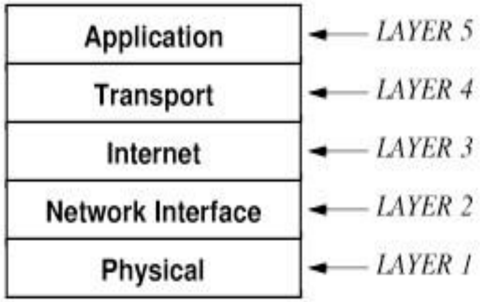


- Layer 1: Physical
  - Basic network hardware
  - Similar to OSI Layer 1
- Layer 2: Network Interface
  - MAC frame format
  - MAC addressing
  - Interface between computer and the network (i.e., the NIC)
  - Similar to OSI Layer 2
- Layer 3: Internet (IP)
  - Format of packets
  - Mechanisms for forwarding packets
  - Unit of data exchanged between nodes in this layer is called a *datagram*
  - Not in the OSI Model

Protocol Suites and Layering Models

- Layer 4: Transport (TCP/UDP)
  - Specifies how to provide reliable transfer from one application on one computer to an application on another
  - Similar to OSI Layer 4
  - Unit of data exchanges in this layer is called a *segment*

- Layer 5: Application
  - Everything else (i.e., how one application uses the Internet)
  - Similar to OSI Layer 6 and 7
  - Unit of data exchanges in this layer is called a *message*



Performance

- Bandwidth
- Latency or delay

Performance - Bandwidth

- Networks need high performance (or high performance per unit cost).

- The old computer adage, “Get it right and then make it fast,” may not apply. Networks must be designed at the outset for speed.

Bandwidth Definition

- ***Bandwidth*** is the measure of the capacity of a transmission system. It is the range (or band) of frequencies used on the transmission medium. Bandwidth is typically measured in Hertz.

- ***Bandwidth*** is the maximum number of bits that can be transmitted in a certain amount of time over a particular medium. This is the data transfer rate or transmission rate of the system.

We use definition 2 in computer networks.

Performance - Bandwidth

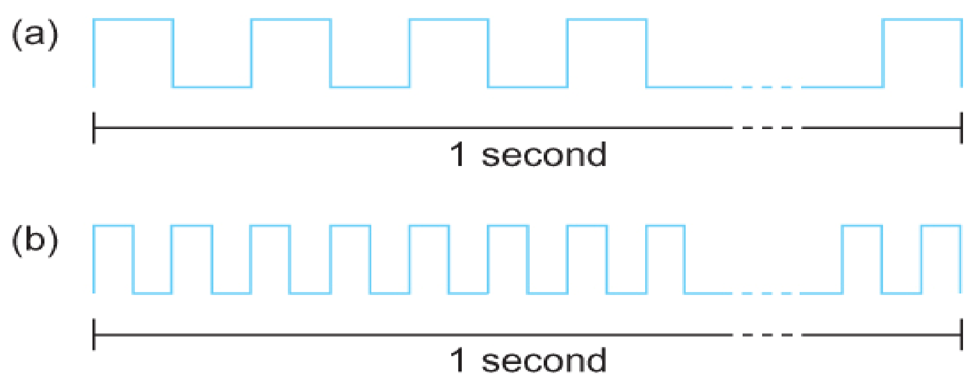
Bits transmitted at a particular bandwidth can be regarded as having some width:

a) bits transmitted at 1Mbps (each bit 1 μs wide);

b) bits transmitted at 2Mbps (each bit 0.5 μs wide).

Note:
1 Mbps: 1 x 10^6 bits/second

- You can also think of each bit on a network as being a pulse of some width.



The more sophisticated the transmission/receiving technology, the narrower each bit can become.

Performance - Throughput

Recall…

- **<u>Defn</u>**: ***Bandwidth*** is the maximum number of bits that can be transmitted in a given amount of time over a particular medium. This is the data transfer rate or transmission rate of the system. Usually, described in bits/sec (or bps).

Consider…

- **<u>Defn</u>**: Network ***<u>throughput</u>*** (or ***<u>effective throughput</u>***) is the measured number of bits that can be transmitted over a particular medium in a given amount of time. Usually, described in bits/sec (or bps).

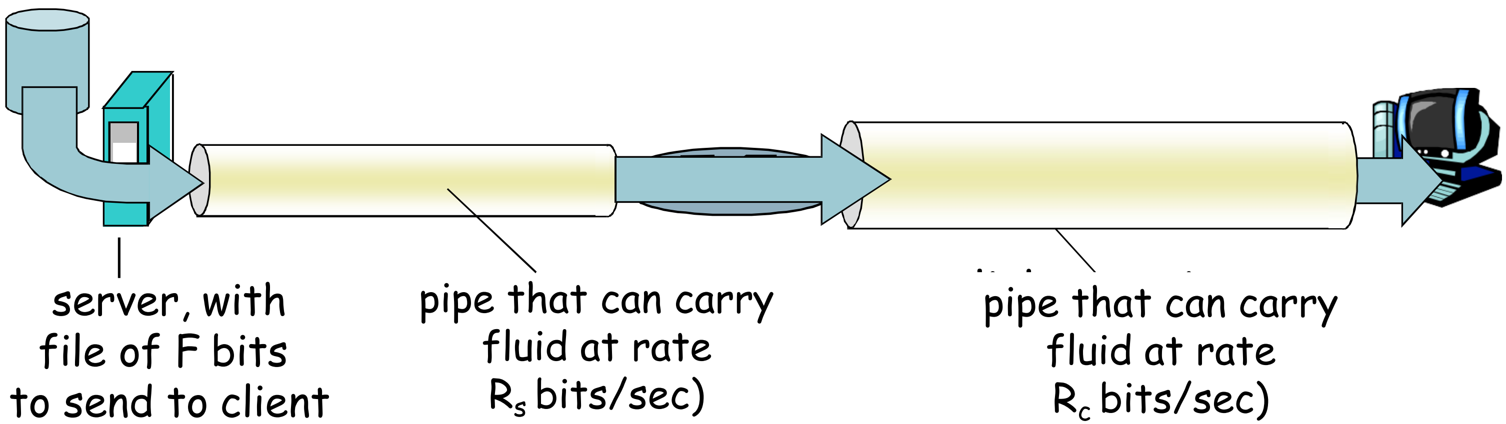
- The throughput is the maximum number of bits/sec an application can expect to receive.

Bandwidth >= Effective Throughput

- For applications, we can describe throughput as the “bandwidth requirements of an application.”

Performance - Throughput

- ***Throughput:*** actual rate (bits/time unit) at which bits transferred between sender/receiver
  - ***instantaneous****:* rate at given point in time
  - ***average****:* rate over longer period of time



Question:
-What is the end-to-end throughput if Rs<Rc?
-In what kind of situation the instantaneous throughput is different from average throughput?

Performance - Latency

Defn: Latency (or **delay** or **end-to-end delay**) is the amount of time is takes for a single bit to propagate from one end of a network to another.

Latency is measured in terms of time.

Defn: Round Trip Time (RTT) is the time it takes for a bit to travel from sender to receiver and back again.

There are three components that form the latency:

1. Propagation delay
2. Transmission Time
3. Queuing & Processing Delays

Performance - Latency

1. **Propagation delay**

   We calculate this using the speed-of-light propagation delay:

   - in a vacuum, 3.0 * 10^8 meters/sec
   - in a cable, 2.3 *10^8 meters/sec
   - in fiber, 2.0 * 10^8 meters/sec

   This value is a function of the distances and the speed-of-light delay.

2. **Transmission Time**

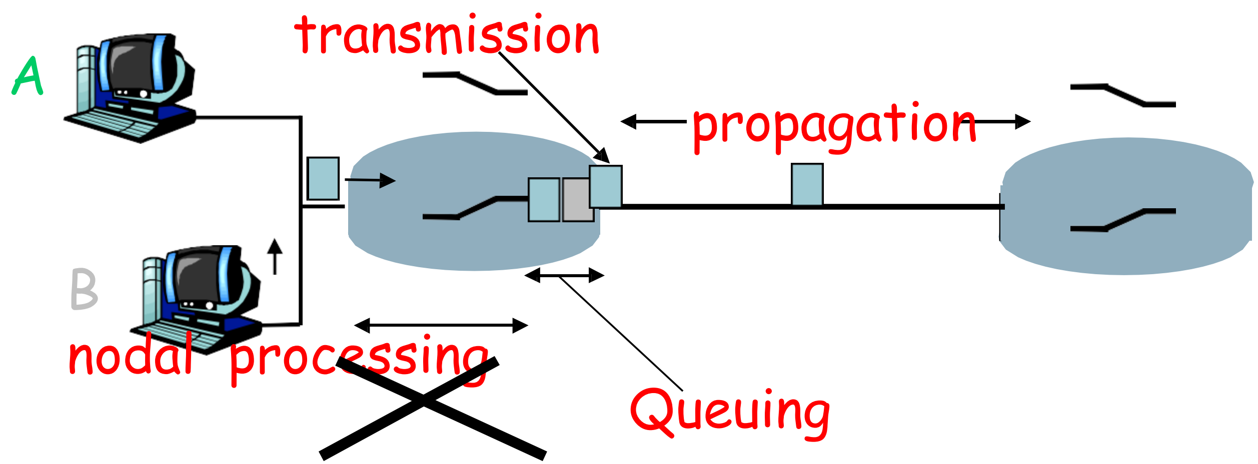
   This is the amount of time it takes to transmit the data onto the transmission media. This value is a function of the bandwidth and the packet size.

3. **Queuing & Processing Delay**

   This is the time the data spends in being processed and waiting for its turn (Queuing) to be transmitted. This value is almost impossible to calculate.

Performance - Latency

Sources of delay



Queuing delay: (also ignore?)

-Time waiting at output link for transmission

-Depends on congestion level of router

Performance - Latency

Latency = Propagation Delay + Transmit Time + Queuing & Processing Delay

= Tp+ Tx+ Tq

Tp (Propagation Delay) = (***Distance across link***)/(***Speed-of-light delay***)

Tx (Transmit Time) = (***Size of data***)/(***Throughput***)

Tq (Queuing & Processing Delay) = *This is hard to measure so a statistically generated value or a constant is used*. (***depends on congestion***)

where

Distance = length of the wire over which the data will travel (usually meters/sec)

Speed-of-light = effective speed of light over the channel

Size = size of the packet (usually bits)

Throughput = #bits/(unit time) at which the packet is transmitted (usually bits/sec)

References

- Distributed Systems: Concepts and Design. George Coulouris, Jean Dollimore, Tim Kindberg and Gordon Blair. Fifth Edition, Pearson, 2012.
- Computer Networks, Fifth Edition: A Systems Approach (The Morgan Kaufmann Series in Networking).
- Computer Networks and Internets (5th Edition)
- Some slides by Dr. Tracy Bradley Maples