Network Architecture

Chapter 1

Application programs
Process-to-process channels
Host-to-host connectivity
Hardware

Example of a layered network system

1

Network Architecture

Chapter 1

Application programs	
Request/reply channel	Message stream channel
Host-to-host connectivity	
Hardware	

Layered system with alternative abstractions available at a given layer

2

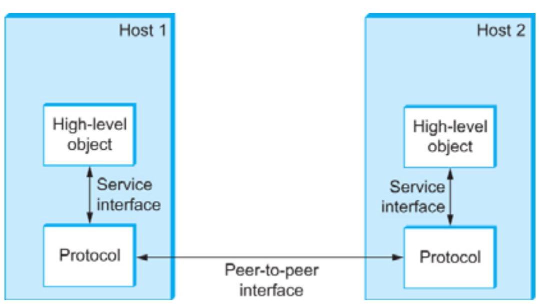
Protocols

Chapter 1

- Protocol defines the interfaces between the layers in the same system and with the layers of peer system
- Building blocks of a network architecture
- Each protocol object has two different interfaces
  - service interface: operations on this protocol
  - peer-to-peer interface: messages exchanged with peer
- Term “protocol” is overloaded
  - specification of peer-to-peer interface
  - module that implements this interface

Interfaces

Chapter 1



Service and Peer Interfaces

Protocols

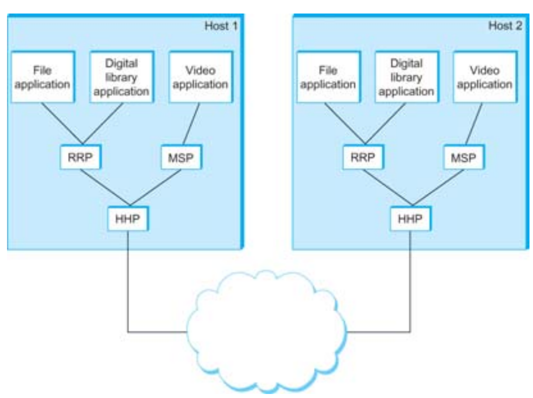
Chapter 1

- Protocol Specification: prose, pseudo-code, state transition diagram
- Interoperable: when two or more protocols that implement the specification accurately
- IETF: Internet Engineering Task Force

MK MORGAN KAUFMANN 5

Protocol Graph

Chapter 1

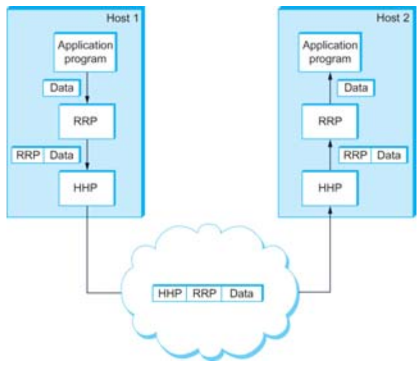


Example of a protocol graph
nodes are the protocols and links the “depends-on” relation

MK MORGAN KAUFMANN 6

Encapsulation

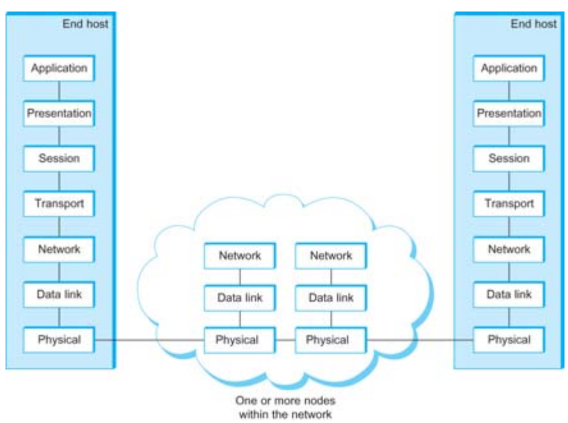
Chapter 1



High-level messages are encapsulated inside of low-level messages

OSI Architecture

Chapter 1



The OSI 7-layer Model
OSI – Open Systems Interconnection

Description of Layers

Chapter 1

- Physical Layer
  - Handles the transmission of raw bits over a communication link
- Data Link Layer
  - Collects a stream of bits into a larger aggregate called a *frame*
  - Network adaptor along with device driver in OS implement the protocol in this layer
  - Frames are actually delivered to hosts
- Network Layer
  - Handles routing among nodes within a packet-switched network
  - Unit of data exchanged between nodes in this layer is called a *packet*

The lower three layers are implemented on all network nodes

MK MORGAN KAUFMANN 9

Description of Layers

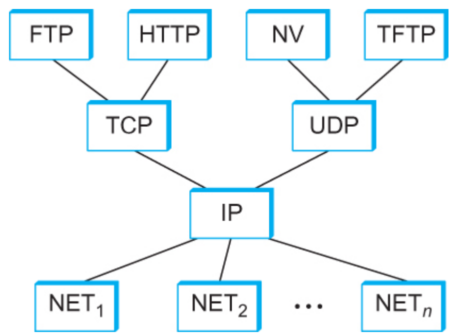
Chapter 1

- Transport Layer
  - Implements a process-to-process channel
  - Unit of data exchanges in this layer is called a *message*
- Session Layer
  - Provides a name space that is used to tie together the potentially different transport streams that are part of a single application
- Presentation Layer
  - Concerned about the format of data exchanged between peers
- Application Layer
  - Standardize common type of exchanges

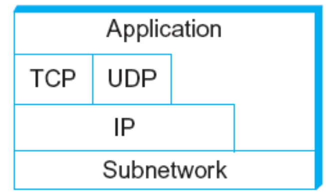
The transport layer and the higher layers typically run only on end-hosts and not on the intermediate switches and routers

MK MORGAN KAUFMANN 10

Internet Architecture (TCP/IP)



Internet Protocol Graph



Alternative view of the Internet architecture. The "Network" layer shown here is sometimes referred to as the "sub-network" or "link" layer.

Internet Architecture

- Defined by IETF
- Three main features
  - Does not imply strict layering. The application is free to bypass the defined transport layers and to directly use IP or other underlying networks
  - An hour-glass shape – wide at the top, narrow in the middle and wide at the bottom. IP serves as the focal point for the architecture
  - In order for a new protocol to be officially included in the architecture, there needs to be both a protocol specification and at least one (and preferably two) representative implementations of the specification

Application Programming Interface

Chapter 1

- Interface exported by the network
- Since most network protocols are implemented (those in the high protocol stack) in software and nearly all computer systems implement their network protocols as part of the operating system, when we refer to the interface "*exported by the network*", we are generally referring to the interface that the OS provides to its networking subsystem
- The interface is called the network Application Programming Interface (API)

MK MORGAN KAUFMANN 13

Application Programming Interface (Sockets)

Chapter 1

- Socket Interface was originally provided by the Berkeley distribution of Unix
  - Now supported in virtually all operating systems
- Each protocol provides a certain set of *services*, and the API provides a syntax by which those services can be invoked in this particular OS

MK MORGAN KAUFMANN 14

Performance

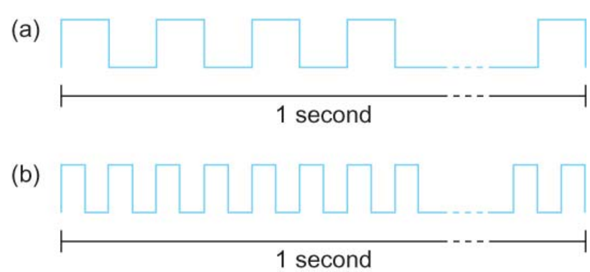
Chapter 1

- Bandwidth
  - Width of the frequency band
  - Number of bits per second that can be transmitted over a communication link
- 1 Mbps: 1 x 10^6 bits/second
- 1 x 10^{-6} seconds to transmit each bit or imagine that a timeline, now each bit occupies 1 micro second space.
- On a 2 Mbps link the width is 0.5 micro second.
- Smaller the width more will be transmitted per unit time.

15

Bandwidth

Chapter 1



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).

16

Performance

Chapter 1

- Latency = Propagation + transmit + queue
- Propagation = distance/speed of light*
- Transmit = size/bandwidth

- One bit transmission => propagation is important
- Large bytes transmission => bandwidth is important

- *Unless the speed of transmission is otherwise specified, the speed of light is 3×10^8 meter/second.

MK 17

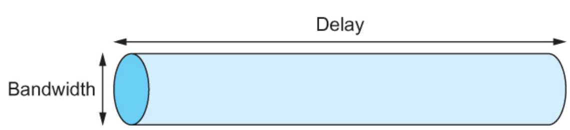
Delay X Bandwidth

Chapter 1

- We think of the channel between a pair of processes as a hollow pipe
  - Latency (delay) - length of the pipe and
  - Bandwidth (transmission rate) - the width of the pipe
- Delay of 50 ms and bandwidth of 45 Mbps

⇒ 50×10^{-3} seconds x 45×10^6 bits/second

⇒ 2.25×10^6 bits = 281.25×10^3 Bytes = 274.66 KB data.



Network as a pipe

MK 18

Delay X Bandwidth

Chapter 1

- Relative importance of bandwidth and latency depends on application
  - For large file transfer, bandwidth is critical
  - For small messages (HTTP, NFS, etc.), latency is critical
  - Variance in latency (jitter) can also affect some applications (*e.g.*, audio/video conferencing)

MK MORGAN KAUFMANN 19

Delay X Bandwidth

Chapter 1

  - How many bits the sender must transmit before the first bit arrives at the receiver if the sender keeps the pipe full
  - Takes another one-way latency to receive a response from the receiver
  - If the sender does not fill the pipe—send a whole delay × bandwidth product's worth of data before it stops to wait for a signal—the sender will not fully utilize the network

MK MORGAN KAUFMANN 20

Delay X Bandwidth

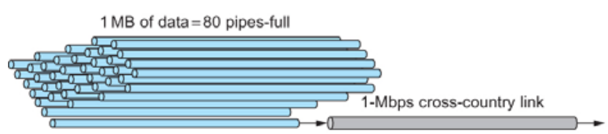
Chapter 1

- **Infinite bandwidth**
  - RTT dominates
  - Throughput = TransferSize / TransferTime
  - TransferTime = RTT + 1/Bandwidth x TransferSize
- **Its all relative**
  - 1-MB file to 1-Gbps link looks like a 1-KB packet to 1-Mbps link
- **1 cross country RTT is approximately 100 milli-seconds**

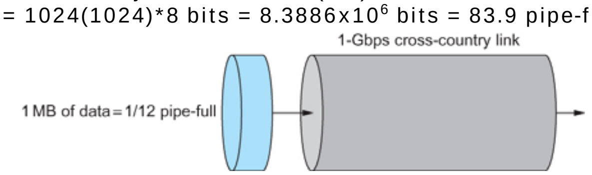
21

Relationship between bandwidth and latency

Chapter 1



1 pipe-full = Delay X BW = $1x10^6$ (0.1) = 100,000 bits
1 MB = 1024(1024)*8 bits = $8.3886x10^6$ bits = 83.9 pipe-fulls



1 pipe-full = Delay X BW = $1x10^9$ (0.1) = $1x10^8$ bits
1 MB = 1024(1024)/8 bits = $8.3886x10^6$ bits = 0.0839 pipe-fulls

A 1-MB file would fill the 1-Mbps link 80 times,
but only fill the 1-Gbps link 1/12 of one time

22

Summary

Chapter 1

- We have identified what we expect from a computer network
- We have defined a layered architecture for computer network that will serve as a blueprint for our design
- We have discussed the socket interface which will be used by applications for invoking the services of the network subsystem
- We have discussed two performance metrics using which we can analyze the performance of computer networks

23