Chapter 1
Communication Networks and Services

What is a communication network?

- A communication network is a set of equipment (hardware & software) and facilities that provide the basic communication service
- A communication service enables the exchange of information between users at different locations.
- Communication services & applications are everywhere.

Network Architecture Evolution

- Telegraph Networks
  - Message switching & digital transmission
- Telephone Networks
  - Circuit Switching
  - Analog transmission → digital transmission
  - Mobile communications
- Internet
  - Packet switching & computer applications
- Next-Generation Internet
  - Multiservice packet switching network

Circuit Switching

- Three phases
  - Establish
  - Transfer
  - Disconnect
- Dedicated communication path between two stations

Packet Switching

- Data transmitted in packets
  - Longer messages split into small packets
  - Each packet contains a portion of user data plus some control info (e.g. addressing info)
- Packets are received, stored and past on to the next node
  - Store and forward
- Different paths can be used to get packets to their destination.

Circuit vs Packet Switching

- Circuit Switching
  - Network is used for the entire duration of the call. Inefficient.
  - Routing is done at call setup. Relatively easy
  - Suited for voice traffic
- Packet Switching
  - Network is used on demand. Efficient.
  - Routing is difficult.
  - Suited for data traffic

Chapter 2
Applications and Layered Architectures

Layers, Services & Protocols

- The overall communications process between two or more machines connected across one or more networks is very complex
- ***Layering*** partitions related communications functions into groups that are manageable
- Each layer provides a ***service*** to the layer above
- Each layer operates according to a ***protocol***

Protocols

- A *protocol* is a set of rules that governs how two or more communicating entities in a layer are to interact
- *Messages* that can be sent and received
- *Actions* that are to be taken when a certain event occurs, e.g. sending or receiving messages, expiry of timers
- **The purpose of a protocol is to provide a service to the layer above**

Layers

- A set of related communication functions that can be managed and grouped together
- Application Layer: communications functions that are used by application programs
  - HTTP, DNS, SMTP (email)
- Transport Layer: end-to-end communications between two processes in two machines
  - TCP, User Datagram Protocol (UDP)
- Network Layer: node-to-node communications between two machines
  - Internet Protocol (IP)

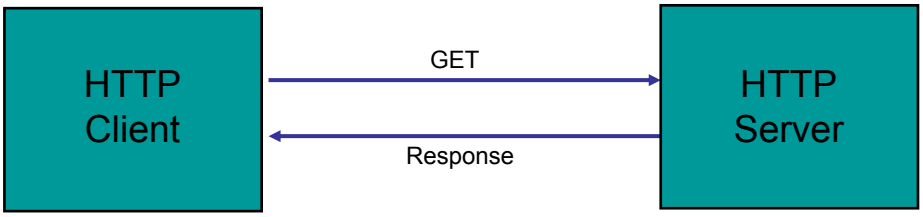
Why Layering?

- Layering simplifies design, implementation, and testing by partitioning overall communications process into parts
- Protocol in each layer can be designed separately from those in other layers
- Layering provides flexibility for modifying and evolving protocols and services without having to change layers below
- Monolithic non-layered architectures are costly, inflexible, and soon obsolete

Example: HTTP

- HTTP is an application layer protocol
- Retrieves documents on behalf of a browser application program
- HTTP specifies fields in request messages and response messages
  - Request types; Response codes
  - Content type, options, cookies, …
- HTTP specifies actions to be taken upon receipt of certain messages

HTTP Protocol



- HTTP assumes messages can be exchanged directly between HTTP client and HTTP server
- In fact, HTTP client and server are processes running in two different machines across the Internet
- HTTP uses the reliable stream transfer service provided by TCP

Example: TCP

- TCP is a transport layer protocol
- Provides *reliable byte stream service* between two processes in two computers across the Internet
- TCP is *connection-oriented*: the sender and receiver must first establish an association and set initial sequence numbers before data is transferred
- Connection ID is specified uniquely by

(send port #, send IP address, receive port #, receiver IP address)

Example: DNS Protocol

- DNS protocol is an application layer protocol
- DNS is a distributed database that resides in multiple machines in the Internet
- DNS protocol allows queries of different types
  - Name-to-address or Address-to-name
  - Mail exchange
- DNS usually involves short messages and so uses service provided by UDP
- Well-known port 53

Example: UDP

- UDP is a transport layer protocol
- Provides *best-effort datagram service* between two processes in two computers across the Internet
- Port numbers distinguish various processes in the same machine
- UDP is *connectionless*
- Datagram is sent immediately
- Quick, simple, but not reliable

Layers, Services & Protocols

- Layers: related communications functions
  - Application Layer: HTTP, DNS
  - Transport Layer: TCP, UDP
  - Network Layer: IP
- Services: a protocol provides a communications service to the layer above
  - TCP provides connection-oriented reliable byte transfer service
  - UDP provides best-effort datagram service
- Each layer builds on services of lower layers
  - HTTP builds on top of TCP
  - DNS builds on top of UDP
  - TCP and UDP build on top of IP

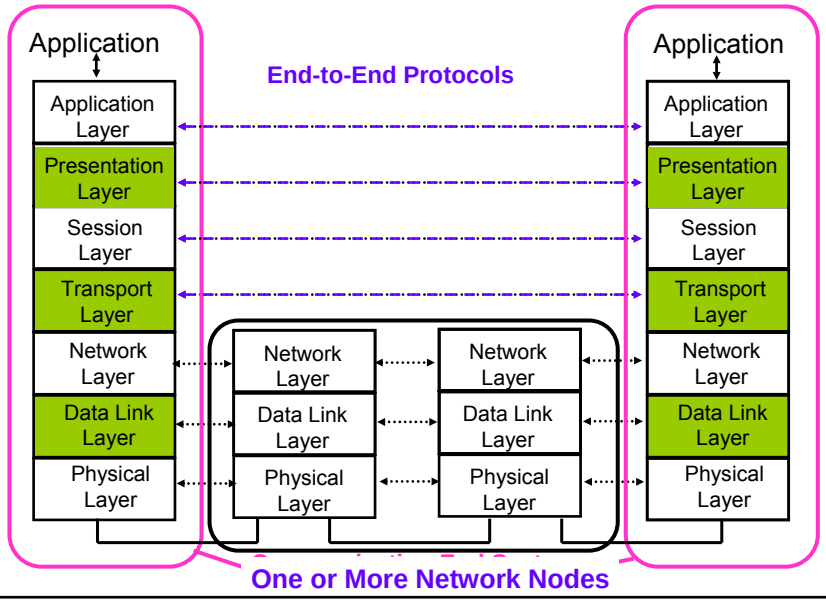
OSI Reference Model

- By the 1970s every computer vendor had developed its own proprietary layered network architecture
- Problem: computers from different vendors could not be networked together
- Open Systems Interconnection (OSI) was an international effort by the International Organization for Standardization (ISO) to enable multivendor computer interconnection

OSI Reference Model

- Describes a seven-layer abstract reference model for a network architecture
- Purpose of the reference model was to provide a framework for the development of protocols
- OSI also provided a unified view of layers, protocols, and services which is still in use in the development of new protocols
- Detailed standards were developed for each layer, but most of these are not in use
- TCP/IP protocols preempted deployment of OSI protocols

7-Layer OSI Reference Model

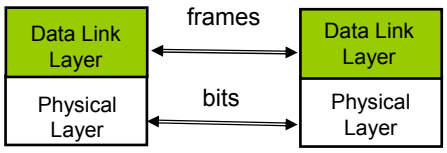


Physical Layer

- Transfers bits across link
- Definition & specification of the physical aspects of a communications link
  - Mechanical: cable, plugs, pins...
  - Electrical/optical: modulation, signal strength, voltage levels, bit times, …
  - functional/procedural: how to activate, maintain, and deactivate physical links…

Data Link Layer

- Transfers *frames* across *direct* connections
- Groups bits into frames
- Detection of bit errors; Retransmission of frames
- Activation, maintenance, & deactivation of data link connections
- Medium access control for local area networks
- Flow control

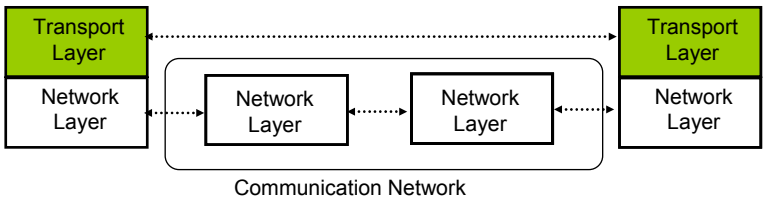


Network Layer

- Transfers *packets* across multiple links and/or multiple networks
- Addressing must scale to large networks
- Nodes *jointly* execute routing algorithm to determine paths across the network
- Forwarding transfers packet across a node
- Congestion control to deal with traffic surges
- Connection setup, maintenance, and teardown when connection-based

Transport Layer

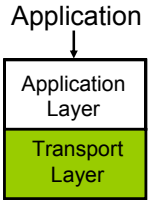
- Transfers data end-to-end from process in a machine to process in another machine
- Reliable stream transfer or quick-and-simple single-block transfer
- Port numbers enable multiplexing
- Message segmentation and reassembly
- Connection setup, maintenance, and release



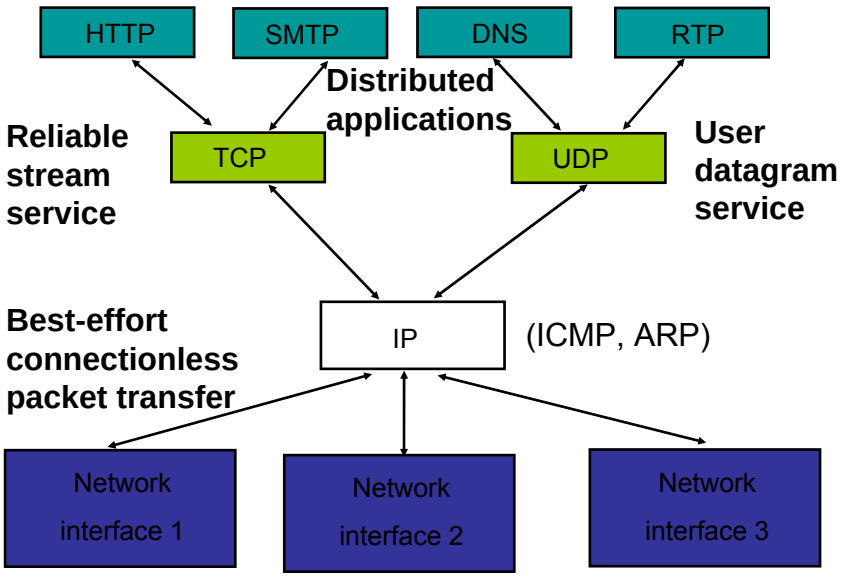
Application & Upper Layers

- Application Layer: Provides services that are frequently required by applications: DNS, web acess, file transfer, email…
- Presentation Layer: machine-independent representation of data…
- Session Layer: dialog management, recovery from errors, …

Incorporated into Application Layer

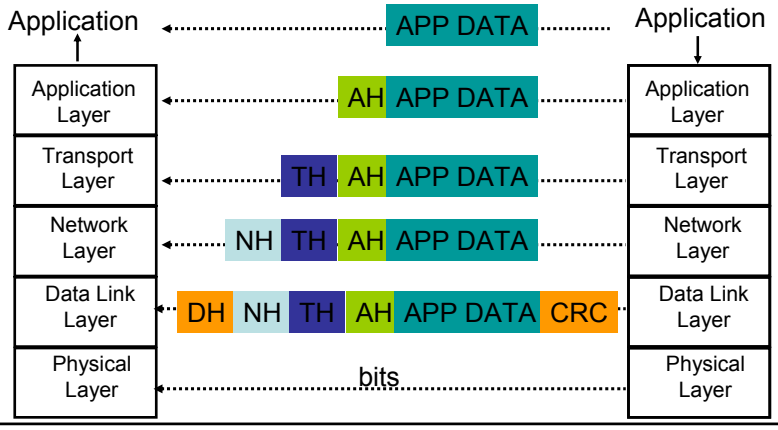


TCP/IP Protocol Suite



Headers & Trailers

- Each protocol uses a header that carries addresses, sequence numbers, flag bits, length indicators, etc…
- CRC check bits may be appended for error detection

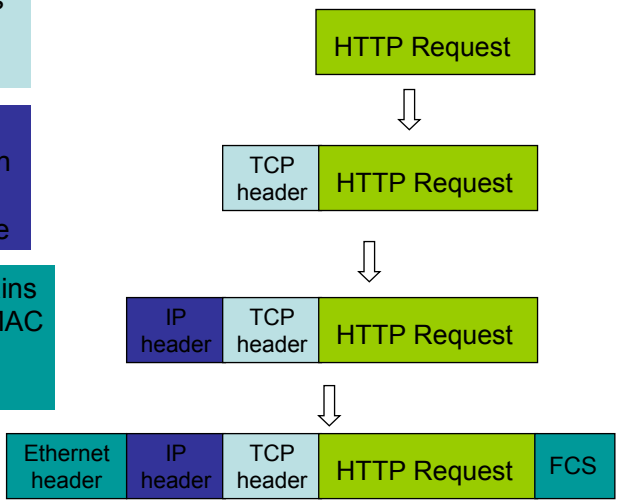


Encapsulation

TCP Header contains source & destination port numbers

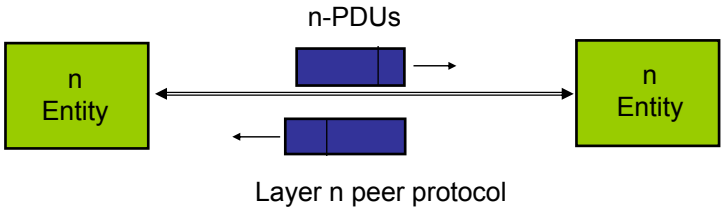
IP Header contains source and destination IP addresses; transport protocol type

Ethernet Header contains source & destination MAC addresses; network protocol type



OSI Unified View

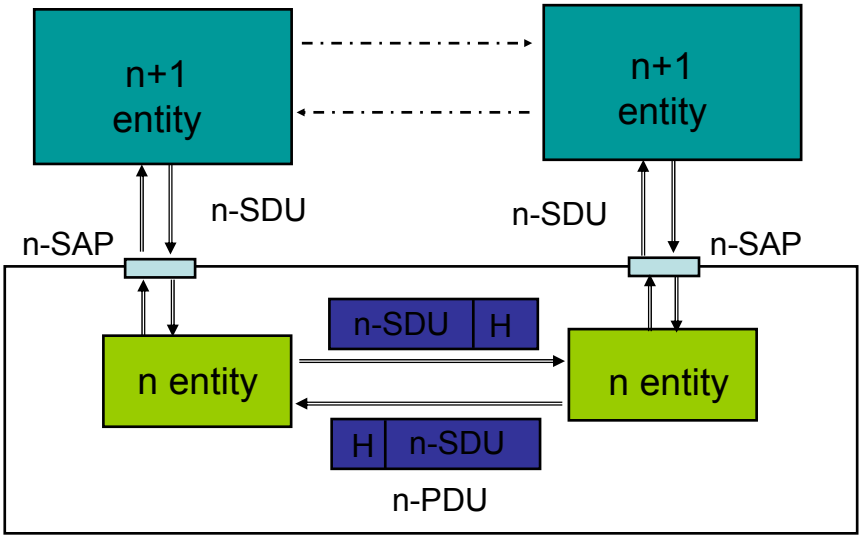
- Layer n in one machine interacts with layer n in another machine to provide a service to layer n +1
- The entities comprising the corresponding layers on different machines are called *peer processes.*
- The machines use a set of rules and conventions called the *layer-n protocol*.
- Layer-n peer processes communicate by exchanging *Protocol Data Units* (PDUs)



OSI Unified View

- Communication between peer processes is virtual and actually indirect
- Layer n+1 transfers information by invoking the services provided by layer n
- Services are available at *Service Access Points (*SAP's)
- Each layer passes data & control information to the layer below it until the physical layer is reached and transfer occurs
- The data passed to the layer below is called a *Service Data Unit* (SDU)
- SDU's are *encapsulated* in PDU's

OSI Unified View



Connectionless & Connection-Oriented Services

- Connection-Oriented
  - Three-phases:
    1. Connection setup between two SAPs to initialize state information
    2. SDU transfer
    3. Connection release
  - E.g. TCP, ATM
- Connectionless
  - Immediate SDU transfer
  - No connection setup
  - E.g. UDP, IP
- Layered services need not be of same type
  - TCP operates over IP
  - IP operates over ATM