# Networks and Data Communications

**Sections 12.0-12.**

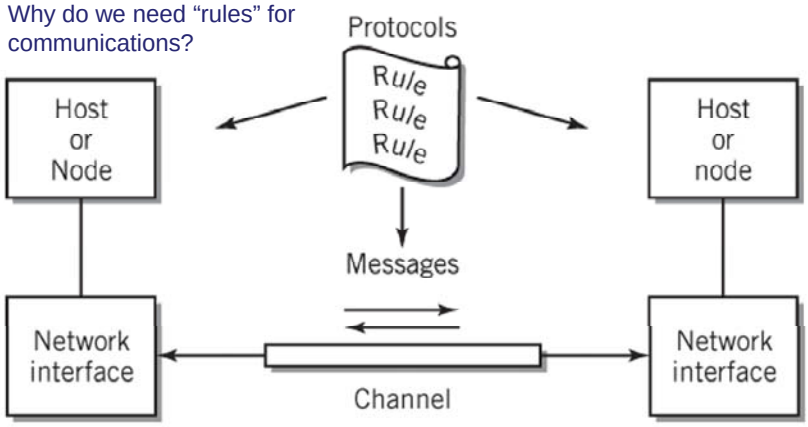
# Data Communications

A simple view

- data - messages to be shared between sender and receiver
- communications channel that can capably and reliably transport messages
- Protocols establish accurate and appropriate meaning to the messages that are understood by both senders and receivers
- Physical connection that is independent of the messaging
  - message sharing “connection” between applications at the sender and the receiver
  - physical connection with signaling that represents the messages being transported
- Examples
  - POTS - plain old telephone service
  - Web servers and Web browsers

# Communication Channel

Why do we need "rules" for communications?

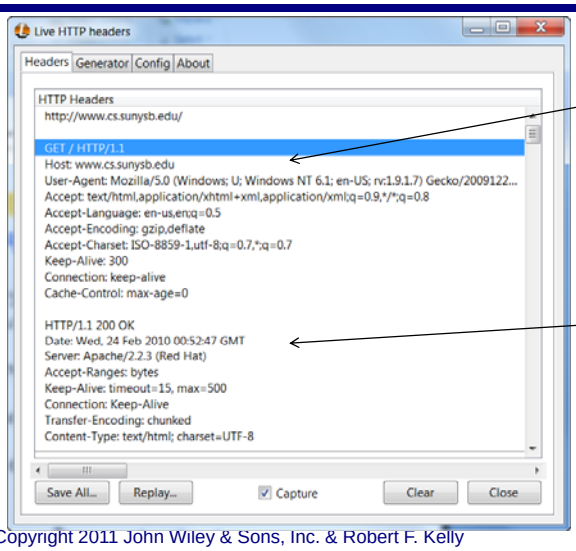



What "rules" do you have in your ordinary phone conversations?





# Example - HTTP




request

response

# Messages

- Communication between cooperating applications at each end node
- Can take many forms such as data, a program, a file, or multimedia
- Represented digitally
- Data is described as a byte stream because communications are predominantly serial
- varying message length (e.g., text messages and NetFlix video download)




# Packets

- Used to solve problems (for long messages) of channel availability and utilization
- A group of related packets make up a single message
- Consist of data encapsulated by the packet header which contains information about the packet
- Equivalent to an envelope that contains pages of data

# Packet Header

- Also known as the preamble
- Contains
  - Description of the packet
  - Destination address of receiver
  - Source address of sender
  - Information about the data being sent




# Advantages of Packets

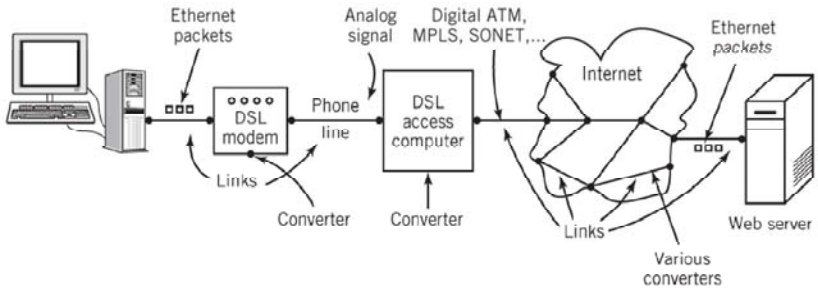
- Simplifies operations and increases communications efficiency
- Reasonable unit for routing of data
- Alternative to dedicating a channel for the entire length of the message
- Packets from several sources can share a single channel
- Each sender/receiver pair appears to have a channel to itself
- Simplifies synchronization of the sending and receiving systems by providing clear start and stop points

# Channel Characteristics (1)

- Communication channel
  - The path for the message between two communicating nodes
  - May include intermediate nodes that forward packets to the next node
  - Interfaces at each end of the connection may be different
- Links
  - A segment of a communication channel
- Bandwidth
  - Bit rate of overall channel derived from link bit rates
- Medium
  - Guided – communications limited to a specific path (e.g., cable)
  - Unguided – communications not limited to a specific path (e.g., wireless)




# A Multi-Link Channel



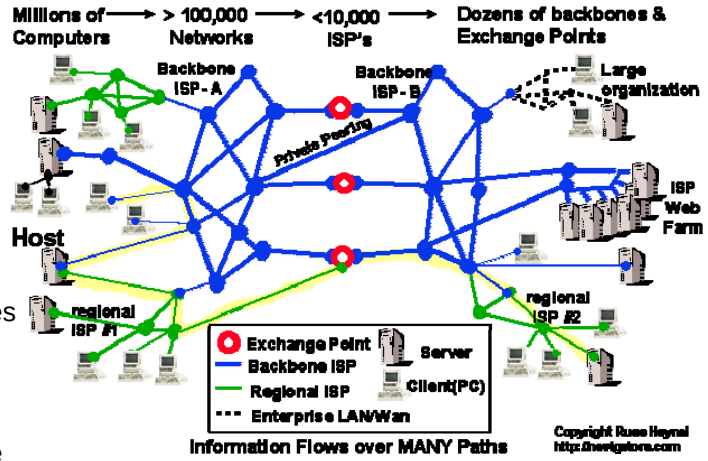
# Channel Characteristics (2)

- Data transmission directionality
  - Simplex – messages are carried only in one direction
  - Half-duplex – messages are carried in both directions but only one direction at a time
  - Full duplex – messages are simultaneously carried in both directions
- Number of connections
  - Point-to-point
  - Multipoint
- Digital vs. Analog
- End node interfaces
  - Wired or wireless Ethernet
  - Bluetooth, WiMax, DSL or cable link, modem, etc.

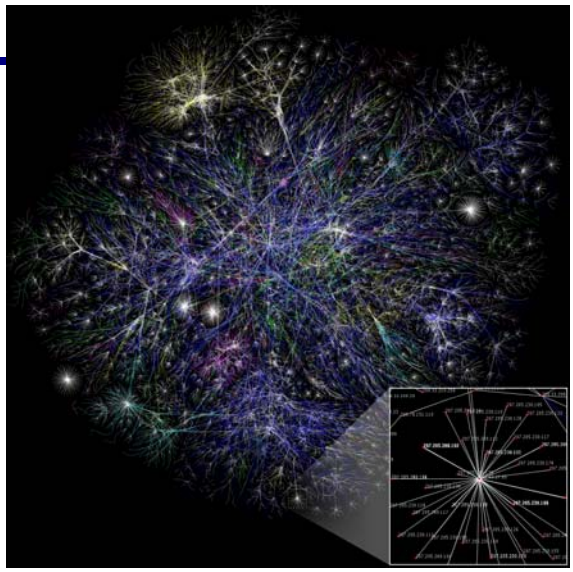



# Internet Physical Layer

- Multiple backbones
- Multiple ISPs
- Multiple exchange points



# Internet



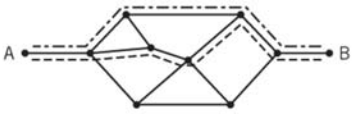



# Packet Routing

- Circuit switching (e.g., old telephony)
  - Dedicated channel between source and destination for duration of connection
- Virtual circuit
  - A channel path that is used to send packets between two end nodes
  - Intermediate nodes may be shared with other channel paths
- Packet switching (e.g., TCP/IP)
  - Each packet is routed from node to node independently based on various criteria

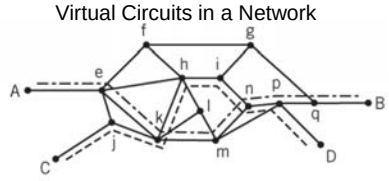
# Packet Routing

End-to-end channel with many possible paths through intermediate nodes



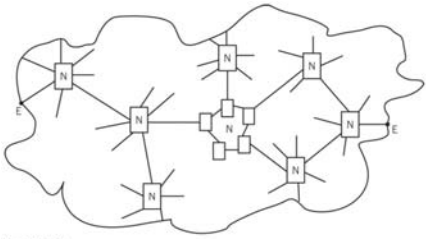

Path 1 –·–·–
Path 2 – – – –

Virtual Circuits in a Network




A-B Path –·–·– (AekmnpqB)
C-D Path – – – – (CjkhinpD)

Connecting End Points through Links and Networks




N = Network
E = Endpoint

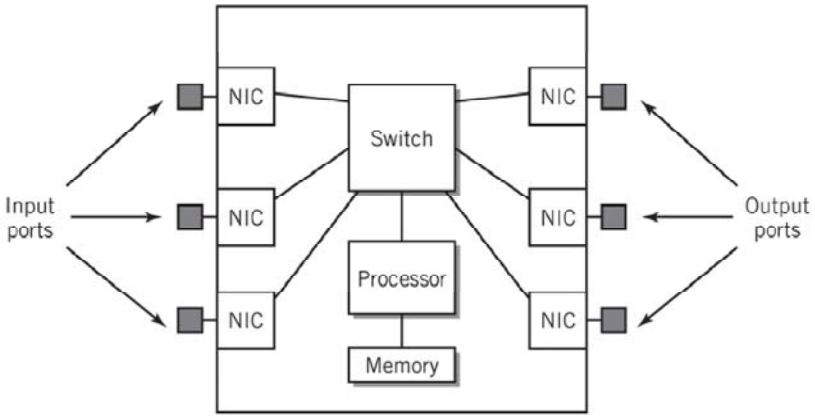




# Packet Routing

- Routers
  - Specialized devices used to interconnect network and pass packets from one network to another
  - Operation (see following slide)
    - When packet arrives at input port
    - Processor decides where packet is to be directed
    - A switch is set to direct the packet to the correct output port
- Gateways (Falling out of use)
  - Same as routers but connect dissimilar networks together
  - Convert packet headers for the dissimilar networks

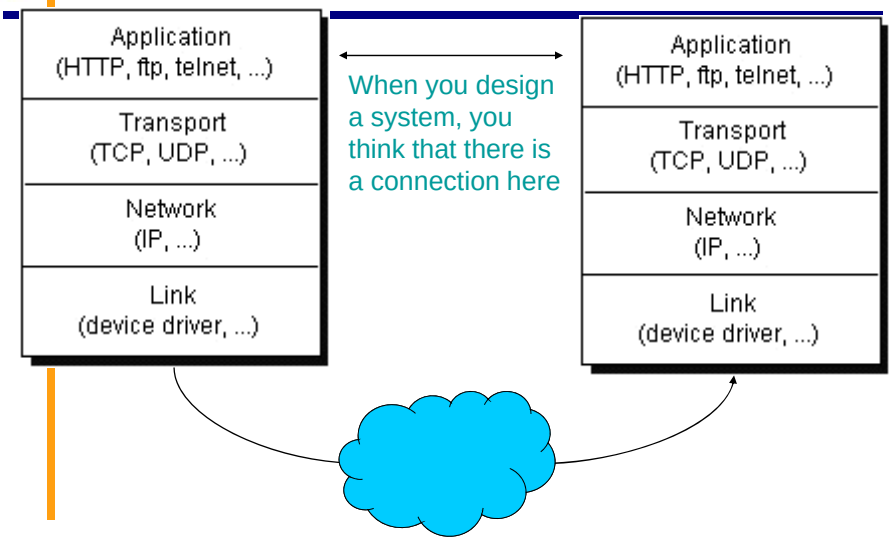
# Router Block Diagram




Issues: speed of switch, security QoS




# Internet Protocol Stacks



# Network Overview

- Communication Models
  - TCP/IP
  - OSI – theoretical model
- Addressing
- Network Topology
- Types of Networks
  - Local Area Networks
  - Backbone Networks
  - Metropolitan Area Networks
  - Wide Area Networks
  - Internet Backbones and the Internet
  - Piconets
- Standards




# Communication Model

- Implemented as a hierarchical protocol stack
- Each layer of the stack at the sender node contributes information that is used by the corresponding peer layer at the receiver node
- Different protocols for the different aspects of communication
- Separating tasks and including well defined interfaces between the tasks
  - Adds flexibility
  - Simplifies design of protocols
  - Permits modification or substitution of protocols without affecting unrelated tasks
  - Permits a system to select only the protocols needed for a particular application

# TCP/IP

- Transmission Control Protocol/Internet Protocol
- Based on five protocol layers, although layers 1 and 2 are not actually specified in the standard. However, the TCP/IP model recognizes the existence of these layers as a necessity.
- The TCP/IP protocol suite encompasses an integrated suite of numerous protocols that work together and guide all aspects of communication.

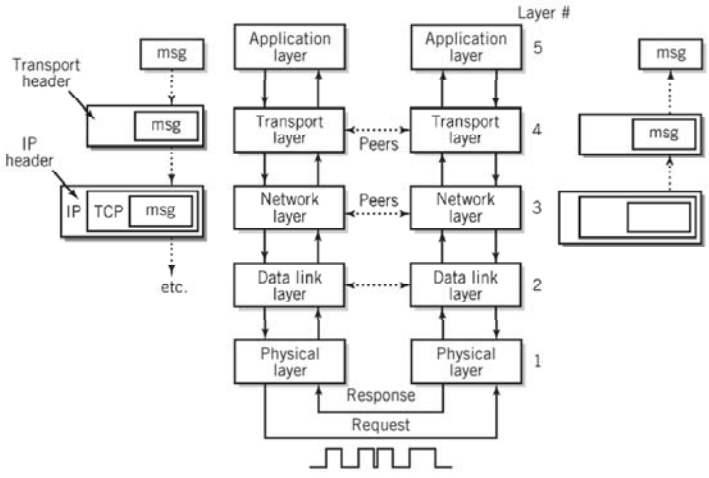
| | | | | | |
|---|---|---|---|---|---|
| Layer 5 | Application layer | HTTP SMTP | FTP SSH | DNS POP3 | ... |
| Layer 4 | Transport layer | TCP | UDP | SCTP | |
| Layer 3 | Network layer | IP | ICMP DHCP | ARP | |
| Layer 2 | Data link layer | Depends on underlying network | | | |
| Layer 1 | Physical layer | Depends on underlying network | | | |

Actual layers are not that important as layers are combined in some cases





# Operation of TCP/IP Model



# Application Layer (Layer 5)

- Layer where message is created
- Includes any application that provides software that can communicate with the network layer
- Sockets
  - Originated with BSD UNIX
  - Provide the interface between the application layer and transport layer
  - Used by applications to initiate connections and to send messages through the network
  - A means for adding new protocols and keeping the network facilities current in their offerings
  - Example: SCSI over IP




# Transport Layer (Layer 4)

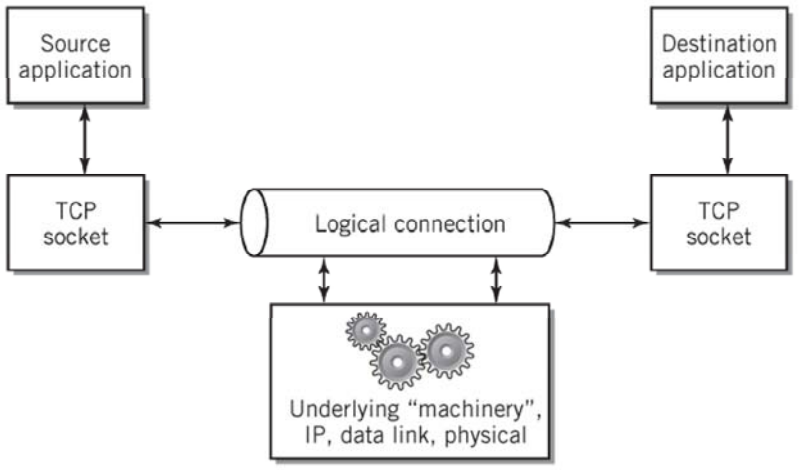
- Provides services that support reliable end-to-end communications
- Generates the final address of the destination
- Responsible for all end-to-end communication facilities
- Packetization of the message, breaking up of the message into packets of reasonable size takes place at this level
- Three different protocols
  - TCP
  - UDP
  - SCTP

# Transport Layer Protocols

- TCP (Transmission Control Protocol)
  - Reliable delivery service
  - Sending and receiving TCP each create a socket
  - Control packets are used to create a full duplex connection between the sockets
  - A single TCP service can create multiple connections that operate simultaneously by creating additional sockets as needed
  - Routing is the responsibility of the network layer (layer 3)
- UDP (User Datagram Protocol)
  - Unreliable, connectionless service
  - No acknowledgment of receipt by receiving node
  - Example: streaming video
- SCTP (Stream Control Transmission Protocol)
  - Similar to TCP but with improved fault tolerance and ability to transport multiple messages through the same connection




# Logical Connection View of TCP



# Network Layer (Layer 3)

- The TCP/IP network layer is also called the internetworking layer or the IP layer
- Responsible for the addressing and routing of packets to their proper and final destination
- Unreliable, connectionless, packet switching service
- Does not guarantee delivery nor check for errors
- Routers and gateways are sometimes referred to as level 3 switches to indicate the level at which routing takes place

TCP provides the reliability




# Network Layer (cont.)

- Communications within a local network:
  - No routing is required because nodes are directly addressable
  - Physical addresses for corresponding IP addresses are looked up in a table
  - IP appends a header with the physical address and passes the datagram to the data link layer (layer 2)
- Communications sent outside of the local network
  - At each intermediate node, the network layer removes the current node address and determines the next node address
  - The new address is added to the packet and passed to the data link layer (layer 2)

# Data Link Layer (Layer 2)

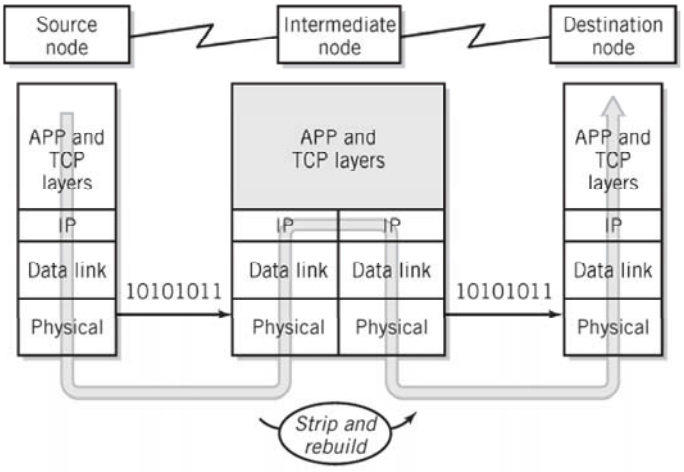
- Responsible for the reliable transmission and delivery of packets between two adjacent nodes
- Packets at this layer are called ***frames***
- Often divided into the following two sublayers:
  - Software logical link control sublayer
    - Error correction, flow control, retransmission, packet reconstruction and IP datagram/frame conversions
    - Numbers frames and reorders received frames to recreate the original message
    - Rarely used
  - Hardware medium-access control sublayer
    - Defines procedures for access the channel and detecting errors
    - Responsible for services such as data encoding, collision handling, synchronization, and multiplexing




# Physical Layer (Layer 1)

- Layer at which communication actually takes place consisting of a bare stream of bits
- Primarily implemented in hardware by a network interface controller (NIC)
- Physical access protocol includes
  - Definition of the medium
  - Signaling method, signal parameters, carrier frequencies, lengths of pulses, synchronization and timing issues
  - Method used to physically connect the computer to the medium

# Passing a Message Through an Intermediate Node







# TCP/IP Addressing (1)

- User friendly addresses
  - URL – www.youtube.com
  - Email – somebody@yahoo.com
  - Printer name on the network
- Domain name
  - Standard global domain name system provides global scope for user friendly addresses
  - Hierarchical system for name creation and registration
  - Tools for locating and identifying specific names

# TCP/IP Addressing (2)

- Port Addresses (port numbers)
  - Transport layer uses to identify the application that is to receive the message
  - 16 bits in length
  - Example: port 80 is commonly used for Web services
  - First 1024 numbers are called well-known ports because they are standard addresses specified for most common applications
  - User defined port numbers are also available to applications
  - For example, the following Web service uses the user-defined port of 8080
    http://www.somewhere.org:8080/hiddenServer/index.html

    By convention, 8080, is a test Web server




# Well-Known Port Addresses

| | | |
|---|---|---|
| ftp | 20 | file transfer |
| ssh | 22 | secure login |
| smtp | 25 | simple mail transfer |
| nicname | 43 | "who is" request |
| finger | 79 | info about system |
| http | 80 | Web |
| kerberos | 88 | encryption |
| pop3 | 110 | post office protocol |
| sqlserv | 118 | SQL services |

# TCP/IP Addressing (3)

- IP addresses
  - Logical addresses
  - IPv4
    - 32-bit addresses arranged as 4 octets, delimited by dots
    - Each octet is written as a decimal number between 0 and 255
    - Example: 208.80.152.2 (Wikipedia's IP address)
  - IPv6
    - Intended to eventually supplant IPv4 to provide additional IP addresses
    - 128-bit addresses arranged as 8 groups of four-digit hexadecimal numbers separated by colons
    - Leading zeros and zero values in one or more consecutive groups may be eliminated
    - Example: 6E:2A20::35C:66C0:0:5500 is the same as 006E:2A20:0000:0000:035C:66C0:0000:550




# TCP/IP Addressing (4)

- Domain name translation
  - Translate a user friendly address into an IP address and port address for the transport layer
  - Utilizes a global domain name directory service
- Address resolution protocol (network layer)
  - Translates IP addresses into physical addresses
- MAC (medium-access control) address
  - Most common type of physical address
  - Every manufactured device that may connect to a network anywhere in the world is supplied with a permanent, unique MAC address
  - Format consists of 48 bits arranged as 6 two-digit hexadecimal numbers separated by colons
  - Example: 00:C0:9F:6C:F9:D0

# Different Addresses Used in a Network