

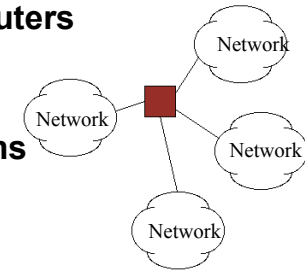
Internetworking

- *Internetworking* is a scheme for interconnecting multiple networks of dissimilar technologies
- System of interconnected networks is called an *internetwork* or an *internet*

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Internet architecture

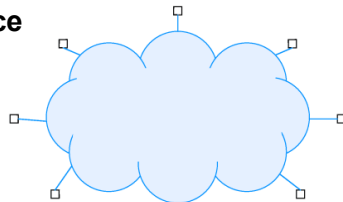
- An internetwork is composed of arbitrarily many networks interconnected by routers
- Routers can have more than two interfaces which forms a web layout



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A virtual network

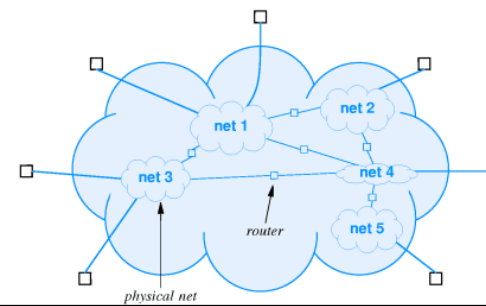
- Internetworking software builds a single, seamless *virtual network* out of multiple physical networks
 - ❖ Universal addressing scheme
 - ❖ Universal service



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A virtual network

- All details of physical networks hidden from users and application programs



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Communication Protocol



- A common language computers use to exchange messages.
 - ❖ Specifying exact format and meaning of each message
 - ❖ Sending and receiving

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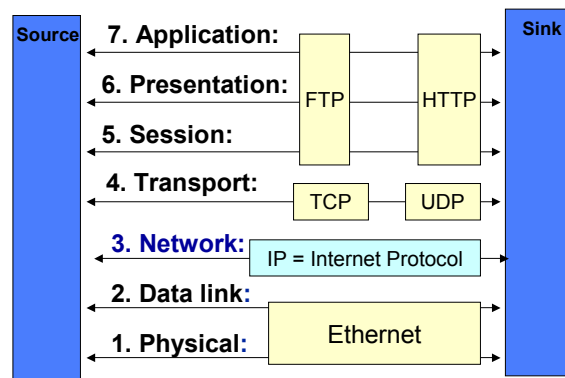
Protocol for internetworking

- The *TCP/IP Internet Protocols* are the mostly widely used internetworking protocol suite
- First internetworking protocol suite; ARPA
- Vendor and platform independent
- Used in the *Internet* - 20 million computers in 82 countries (1999)

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OSI Model

(Open Systems Interconnection)



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Basic Functionality: Internet Protocol (IP)



- IP defines computer communication details.
 - ❖ Specifying how packets are formed
 - ❖ Specifying how routers forward each packet
- Computers connecting to the Internet must follow the IP rules.
- Computers need IP software before using the Internet.

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Internet Packets Are Called Datagrams

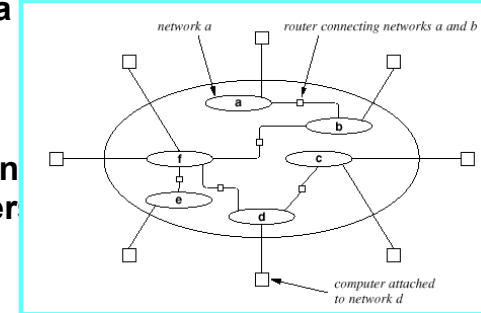
- IP Datagrams are packets that follow the IP specifications.
- Traveling across the Internet independent of sender
- Any computer can send IP datagrams to any other computer



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The Reality Of Internal Structure

- The Internet contains a complex physical structure transparent to the user



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Computer Internet Address

- Each computer attached to the Internet must be assigned a unique IP address.
- Can't use hardware addresses because Address format must be independent of any particular hardware address format
- Sending host puts destination internet address in packet
- Routers examine destination address and forward packet on to the destination

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IP Address Syntax

- IP address is four bytes or 32 bits
- Unique across entire Internet
- Usually described with each byte represented with a decimal number between 0 and 255

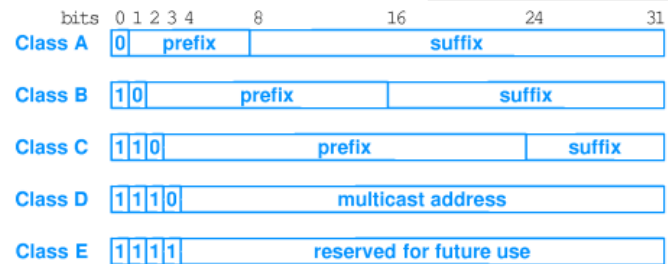
32-bit Binary Number				Equivalent Dotted Decimal
10000001	00110100	00000110	00000000	129 . 52 . 6 . 0
11000000	00000101	00110000	00000011	192 . 5 . 48 . 3
00001010	00000010	00000000	00100101	10 . 2 . 0 . 37
10000000	00001010	00000010	00000011	128 . 10 . 2 . 3
10000000	10000000	11111111	00000000	128 . 128 . 255 . 0

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Address Classes

- Prefix = Network ID
- Suffix = Host ID (Subnet)

Class	Range of Values
A	0 through 127
B	128 through 191
C	192 through 223
D	224 through 239
E	240 through 255



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Networks and hosts in classes

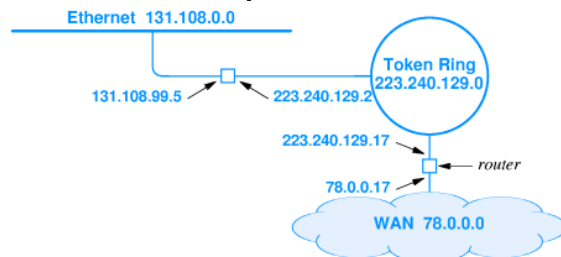
- Classing scheme does not yield equal number of networks in each class
- Class A:
 - ❖ First bit must be 0
 - ❖ 7 remaining bits identify Class A net
 - ❖ 2^7 (= 128) possible class A nets

Address Class	Bits In Prefix	Maximum Number of Networks	Bits In Suffix	Maximum Number Of Hosts Per Network
A	7	128	24	16777216
B	14	16384	16	65536
C	21	2097152	8	256

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Routers and IP addressing

- IP address dependent on network address
- Routers - connected to two or more networks
- IP address specifies an *interface*, or network attachment point, *not* a computer
- Router has multiple IP addresses



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Forwarding, destination address and next-hop

- *Destination address* in IP datagram is always ultimate destination
- Router looks up *next-hop address* and forwards datagram
- *Network layer* (OSI-3) has two parameters:
 - ❖ IP datagram
 - ❖ Next-hop address
- Next-hop address *never* appears in IP datagram, Routers performs this function

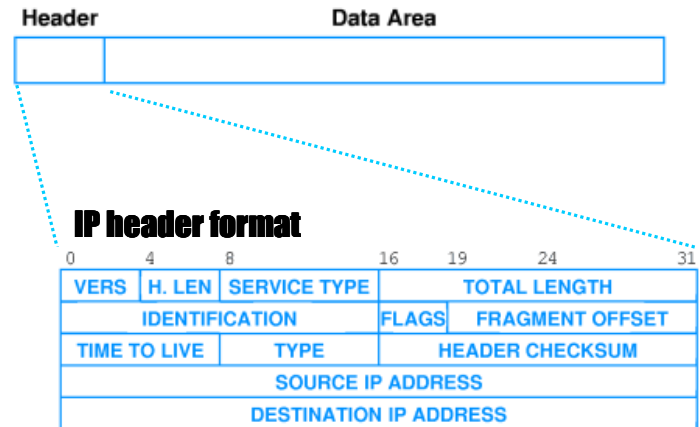
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IP = Best-effort delivery

- IP provides service equivalent to LAN
- Does *not* guarantee to prevent
 - ❖ Duplicate datagrams
 - ❖ Delayed or out-of-order delivery
 - ❖ Corruption of data
 - ❖ Datagram loss
- *Reliable delivery* provided by *transport layer* (OSI-4) using TCP

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IP datagram format



Datagram transmission using hardware frames

- IP
 - ❖ Constructs datagram
 - ❖ Determines next hop
 - ❖ Hands to network interface
- Network interface
 - ❖ Binds next hop address to hardware address
 - ❖ Hardware frame is not a IP datagram
 - ❖ Encapsulation required



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Encapsulation across multiple hops

- Each router in the path from the source to the destination:
 - ❖ *Unencapsulates* incoming datagram from frame
 - ❖ Processes datagram - determines next hop
 - ❖ *Encapsulates* datagram in outgoing frame
- Datagram may be encapsulated in different hardware format at each hop
- Animation available:
 - http://www.islandman.org/umuc/ifsm450/ANIM17_1.HTM

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MTU

- Every hardware technology specification includes the definition of the maximum size of the frame data area
- Called the *maximum transmission unit (MTU)*
- Any datagram encapsulated in a hardware frame must be smaller than the MTU for that hardware

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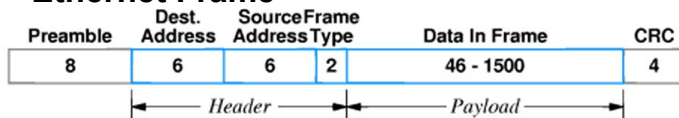
MTU and datagram transmission

- IP datagrams can be larger than most hardware MTUs
 - ❖ IP: 65,000 bytes
 - ❖ Ethernet: 1500 bytes
 - ❖ Token ring: 2048 or 4096 bytes
- Source can simply limit IP datagram size to smallest MTU of *any* network
- IP can also use *Fragmentation*
 - ❖ Datagrams can be split into pieces to fit in network with small MTU

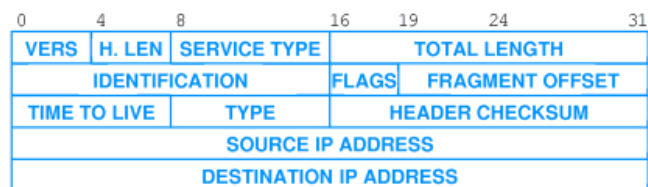
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Ethernet vs. IP Frames

■ Ethernet Frame



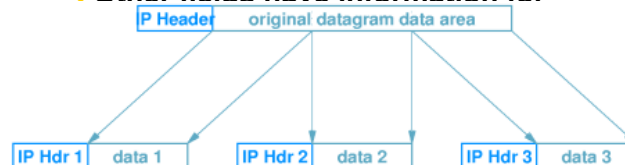
■ IP Frame



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Fragmentation

- Each fragment is an independent datagram
 - ❖ Includes all header fields
 - ❖ Bit in header indicates datagram is a fragment
 - ❖ Other fields have information for



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The future of IP

- **Current version of IP - version 4 - is 20 years old**
- **Address space**
 - ❖ **32 bit address space allows several million networks**
 - ❖ **But...most are Class C and too small for many organizations (2M Networks x 256 Computers)**
 - ❖ **Class B network addresses already almost exhausted (16K Networks x 64K Computers)**

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New IPv6 features

- **Address size - IPv6 addresses are 128bits**
- **Header format - entirely different**
- **Extension headers - Additional information stored in optional extension headers, followed by data**
- **Support for audio and video - flow labels and quality of service allow audio and video applications to establish appropriate connections**

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