CS 4/55231
Internet Engineering

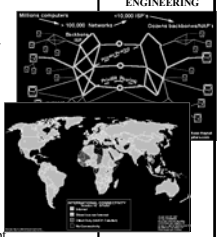
Kent State University
Dept. of Computer Science

LECT-6

INTERNET SYSTEM

Large Scale Networking

- No Single Technology can Adequately Serve Every One's Need.
  - Each LAN/ WAN has specific Performance, Quality of Service, Advantages.
  - Again WAN/ LAN Technologies are not interoperable
    - Packet Format & Size
    - Addressing Format
    - Overall how actions are coordinated.
- Autonomy:
  - Single Administrative Domain
  - Multiple Administrative Domains.
  - No one can be forced to give away their mode and adopt an universal LAN/ WAN technology.



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Internet Protocol

- Objective: Universal Service.
- Can we have one single network technology serving all?
- Why networks cannot communicate?
  - What are the two main sources of incompatibilty?
- What is **internet** and **Internet**?

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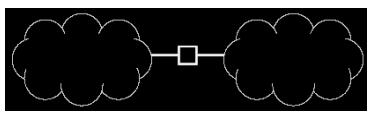
The Main Hardware Component

- Routers:
  - like bridge connects two network.
  - Performs filtered frame forwarding.
  - But, also understands packet format.
  - Two sides can be two technologies.



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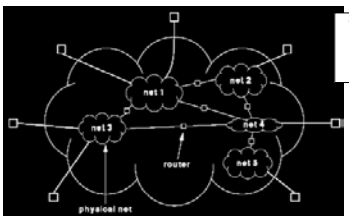
Internet Architecture



Why Routers are Bridge like, but not Switch like?

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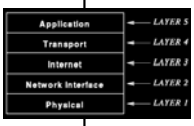
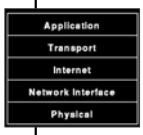
Protocols for Internetworking

- A number of attempts were made to make internetworking possible. However, the most successful one is the protocol suit known as TCP/IP. Its development begun in the 1970s by DARPA.
- Now Internet connects more than 80 million computers across more than 107 countries.



- IP- Internet Protocol
  - Global Addressing Scheme
  - Virtual Datagram
  - Datagram Forwarding
  - Fragmentation & Reassembly
- TCP- Transmission Control Protocol
  - Connection startup & shutdown
  - Reliability: ordering, missing data handling

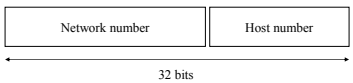


IP Addressing Scheme

- To achieve an illusion of single network, all computers, despite their differences in physical technology, should have a uniform addressing scheme.
- This is done as a software address.
- In this abstraction, each host in internet is assigned an unique 32 bit address called IP address.

IP Addressing Format

IP address
=
Network number + host number



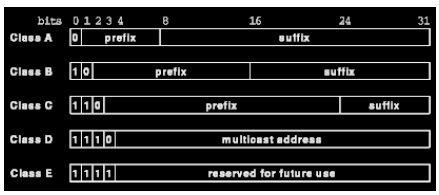
If n bits are for network than how many networks can be there?

How many hosts can be in those networks?

The hierarchy allows host addresses to be assigned independently.
What is the right allocation for bits for each part?

IP Addressing Classes

- IP divides the addresses into 5 classes to accommodate networks of varying sizes.



Network Sizes

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

Special Addresses

- Network Address (n.n.n.0, n.0.0.0, etc)
  - Never appears as the destination in an IP packet.
- Direct Broadcast (n.n.n.255, n.n.255.255, etc.)
  - All computer in the logical network.
- Limited Broadcast (255.255.255.255)
  - All computers in physical network
- This computer (0.0.0.0)
  - used during booting.
- Loopback (127.any)
  - used for testing.

Prefix	Suffix	Type Of Address	Purpose
all-0s	all-0s	this computer	used during bootstrap
network	all-0s	network	identifies a network
network	all-1s	directed broadcast	broadcast on specified net
all-1s	all-1s	limited broadcast	broadcast on local net
127	any	loopback	testing

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Address Management

- ICANN/ IANA/ authorized registries now assign network numbers or blocks of network numbers to ISPs.
- Big ISPs further distribute the network numbers to smaller ISPs connected to them.
- Network administrators assigns the host numbers to individual computers.

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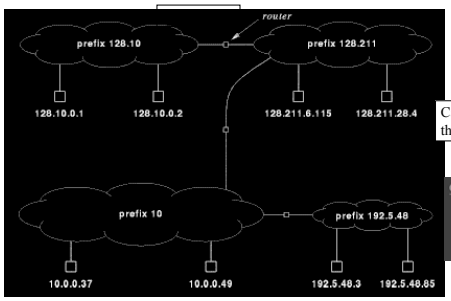
An Example Private TCP/IP Network



Can you determine the network classes?

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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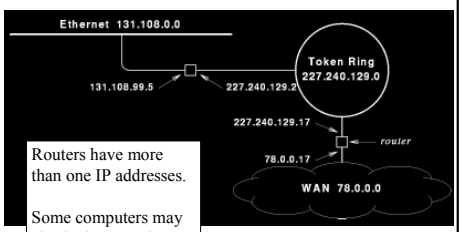
Router Addresses



Routers have more than one IP addresses.

Some computers may also be in more than one networks.

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IP Packets

- Physical Networks differ in the format, size, transmission mechanism of packets. If applications have to be aware of these diversities than application developed for one physical network technology will not work for other.
- IP therefore creates a definition of virtual packets which all applications can use. IP software takes the responsibility of adapting to specific underlying network technology.
- IP packets are virtual. They never travel across a network intact.
- IP offers communication mechanism for both connectionless and connection-based services.

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IP Datagram

- IP packets are called IP datagram.

- IP datagrams can be of variable size 1-64K octates.
- IP datagram header contains information to route the packet across internet.
- IP datagrams are encapsulated in frames before they are transmitted over any Network.

The address that appears in datagram header is different from the address that appears in frame header.

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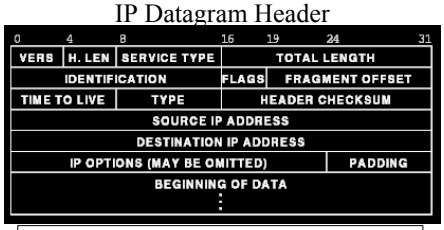
IP Datagram Header



VARS=IP version, H.LEN=how many 32 bit segments in header
SEVICE TYPE= min delay or max capacity path?
TOTAL LENGTH= HEADER+DATA octates.
TIME TO LIVE=maximum allowable hops (0-255)
HEADER CHECKSUM= 1's complement sum
OPTIONS=optional, without it LEN=H.LEN=5,
PADDING=0's to meet 32 bit boundary

IP does not take responsibility of: duplication, out-of-order, corrupt data or lost datagram problems.

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- IP- Internet Protocol
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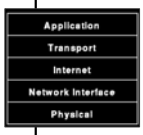
  - Datagram Forwarding
  - Fragmentation & Reassembly
- TCP- Transmission Control Protocol
  - Connection startup & shutdown
  - Reliability: ordering, missing data handling



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How Data is Forwarded?

- To create an illusion of large uniform network software works with IP addresses. It puts data into packet and specifies the IP address of the destination.
- TCP/IP software in each host (or router) looks into the destination address and decides the next-hop. This next hop is also IP address.
- Unfortunately, IP addresses are virtual and cannot be used to reach the next-hop across a physical network.
- A frame sent across a physical network must have a physical address.

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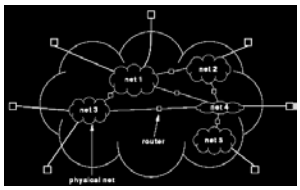
IP Datagram Forwarding: Concept

- **Q1: How to travel through the network to the destination? What is the best path? Immediate question, who is the next IP Hop router?**
- **Q2: How to get to the next HOP? What is the LAN address of next Hop router?**



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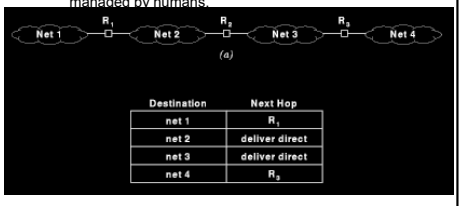
Q1: How IP Datagram Routing

- Each router sends forwards it to next router. They maintain a simple table which can also be managed by humans.



- R2's routing table

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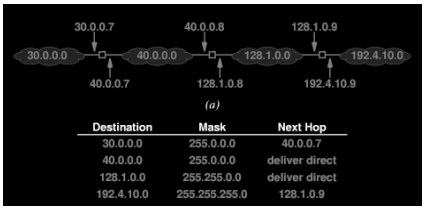
IP Datagram Routing: Example

- The IP tables are a little complicated. It uses Masks.



- R2's routing table

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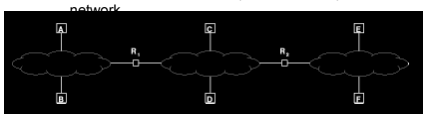
Q2: Address Resolution

- Translation from IP address to hosts physical address is known as address resolution.
- Address resolution is always local to a physical network.



A to B: Protocol Software resolves B's address.
A to D: Protocol Software on A determines R1 is the next hop's IP address. A resolves R1's address. Protocol Software on R2 resolves D's address.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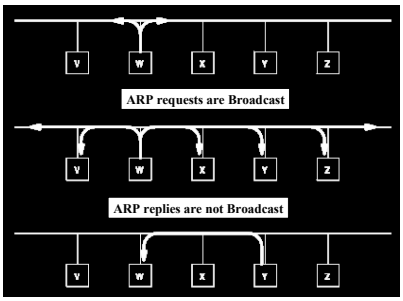
ARP Protocol

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ARP Message Format

- ARP protocol is general and can handle any-to-any translation.

1 FOR ETHERNET

0	8	16	24	31
HARDWARE ADDRESS TYPE		PROTOCOL ADDRESS TYPE		
HADDR LEN	PADDR LEN	OPERATION		
SENDER HADDR (first 4 octets)				
SENDER HADDR (last 2 octets)		SENDER PADDR (first 2 octets)		
SENDER PADDR (last 2 octets)		TARGET HADDR (first 2 octets)		
TARGET HADDR (last 4 octets)				
TARGET PADDR (all 4 octets)				

x0800 FOR IP

1 for REQ
2 for RES

TCP/IP to Ethernet ARP message format


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ARP Message on Ethernet Frame

- Preamble 64 (8 octates) '10101010..' synchronizes hardware.

Preamble	Dest. Address	Source Address	Frame Type	Data In Frame	CRC
8	6	6	2	46 - 1500	4
		Header			

- 48 bits static destination and source address.
- 16 bit frame type describe content forms.
  - 0800 IP Version 4
  - **806 Internet ARP**
- 46-1500 byte data.
- 32 bit CRC.


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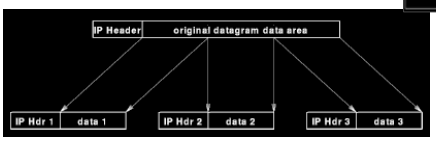
Fragmentation & Reassembly

- Datagrams are fragmented into multiple segments, if it faces a Network with MTU smaller than the datagram size.
- Each fragment has the same format as the datagram, except a bit flag which indicates that it is a fragment, not the entire datagram.
- FRAGMENTOFFSET field indicates where in the orginal datagram the fragment data belongs.

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Flashback: Subnetting

Subnetting & Masks

- IP address is depleting faster than expected:
  - All network, even one with 2 hosts, need at least class C address.
  - A network with 256 hosts need class B address.
- Also, the more there is networks, the bigger the routing table gets.
- Solution is *subnetting*.
  - A network can be divided into subnets.
  - Outside routers still view them as one large network.
  - Only, the local routers see them as separate networks.

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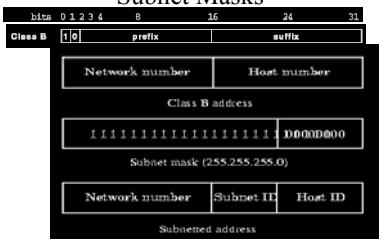
Subnet Masks



•Now in each routing table both the network number and the mask is stored.
•An AND operation is performed before looking up for the next hop.
•For distant networks, the mask is of type A, B, or C. But for local network, the mask is longer.

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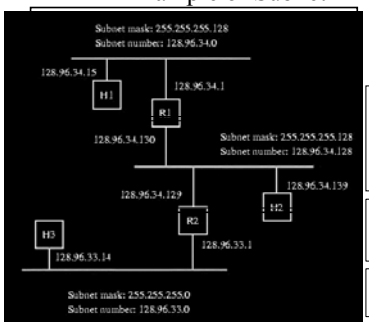
Example of Subnet



•But the administrator of 128.96.34.0 has divided its network into two physical networks 128.96.34.0 and 128.96.34.0 and 128.96.34.128 with mask 255.255.255.128

•Network 128.96.34.0 is class B address and can have about 256x256 hosts in one large network

• H3 in 128.96.33.0 sees everything in 128.96.34.0 as one single network.

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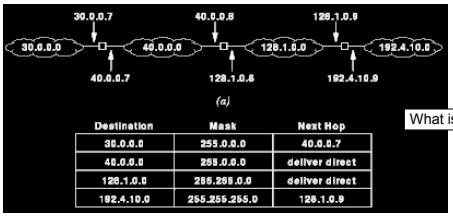
IP Datagram Forwarding: with IP



Destination	Mask	Next Hop
30.0.0.0	255.0.0.0	40.0.0.7
40.0.0.0	255.0.0.0	deliver direct
128.1.0.0	255.255.0.0	deliver direct
192.4.10.0	255.255.255.0	128.1.0.9

What is Bit Mask?

- R2's routing table

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Flashback: Fragmentation & Reassembly

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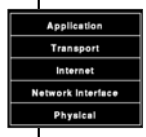

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Encapsulation

- Datagrams have to travel via a physical network. But, a physical network has its own Frame format. A Datagram, therefore must be encapsulated.

- The destination address in the Frame header is the address of the next hop.

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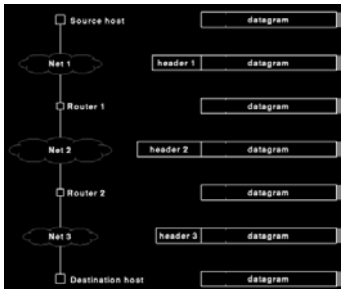
Transmission across Internet



Encapsulation applies to one network at a time. However, in Internet the journey requires series of transmission over many different Networks.

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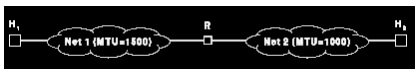
MTU and Datagram Size

- Each Network on its way generally has their own maximum transmission unit size (MTU). How can IP routers can overcome this obstacle?



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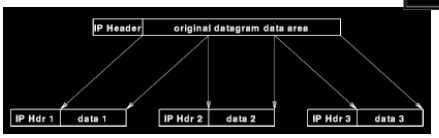

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Reassembly

- Because each fragment has a copy of the original header, and an indication flag that it is a fragment, the original datagram can be reassembled at the end.

IP specifies only the destination should reassemble fragments.

H1 sends 1500B, but it is fragmented by R1. But, R2 does not reassemble them although Net3 MTU is 1500!

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Datagram Identification

- individual fragments can arrive out of order. How IP reassembles out of order fragments?
  - Sender inserts an unique number in INDENTIFICATION field. This with FRAGMENT OFFSET helps in restoring out of order.
- IP does not guarantee delivery and thus fragments can be lost. How IP handles such loss?
  - The same two fields helps in identifying a missing fragment.
  - After receiving the first FRAGMENT, receiver starts a timer. If the entire datagram does not arrive with in a specified time, it discards all fragments.
  - But, it does not notify the sender!

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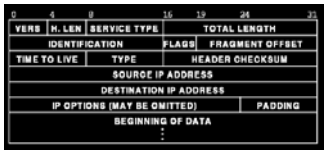
What if a fragment needs to be fragmented again?



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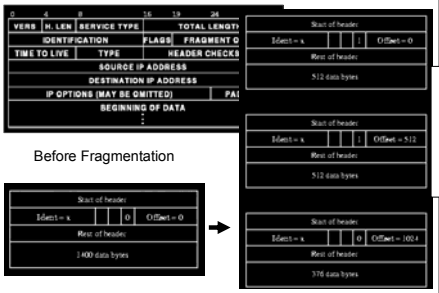
Example of TCP Fragments



Before Fragmentation

Minor detail: Offset field count in units of 8 bytes. Fragmentation have to be performed in units of 8 bytes.

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IP & Reliability

- IP is a best effort mechanism. But provides no guarantee of delivery.
- However, it is not careless!
- ICMP is a mechanism by which network elements can pass information about the source/cause of errors, and also warn each other about potential problem.

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