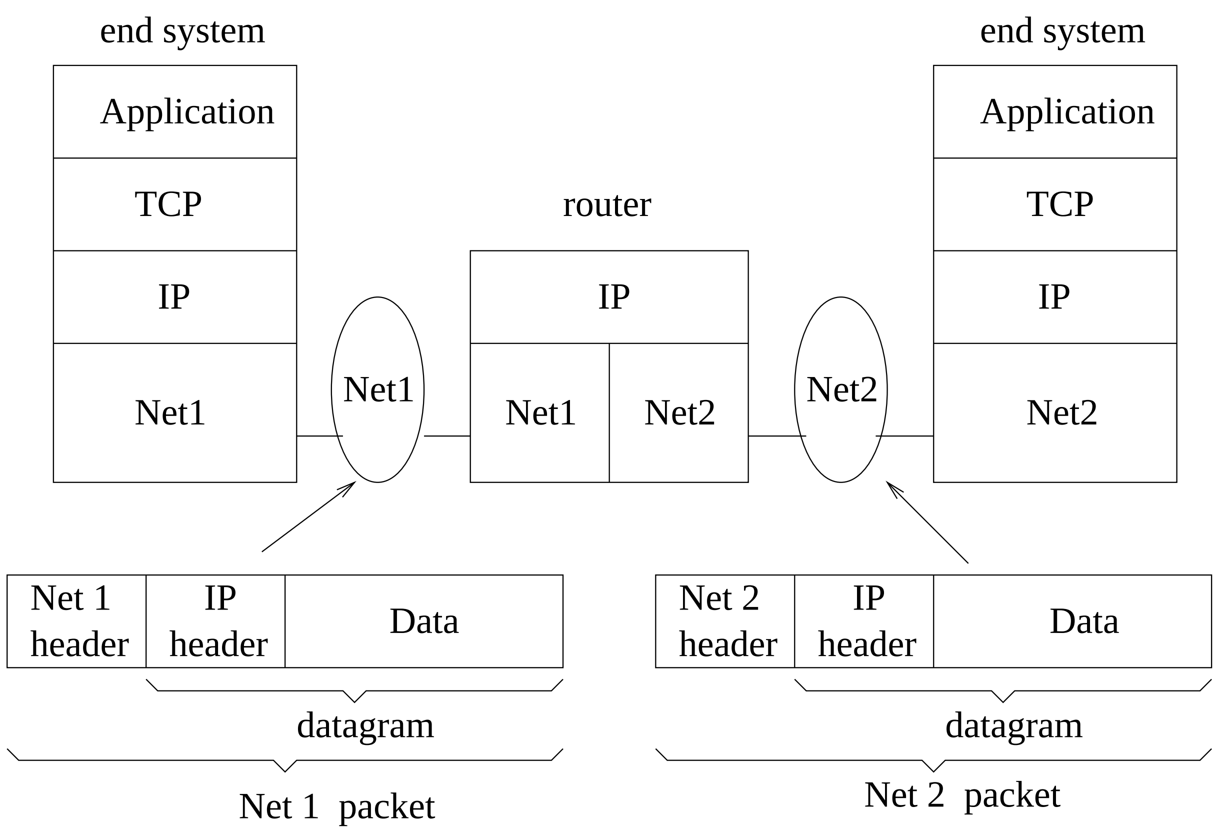
Internet Protocol (IP)

I) IP Basics

1. IP Architecture

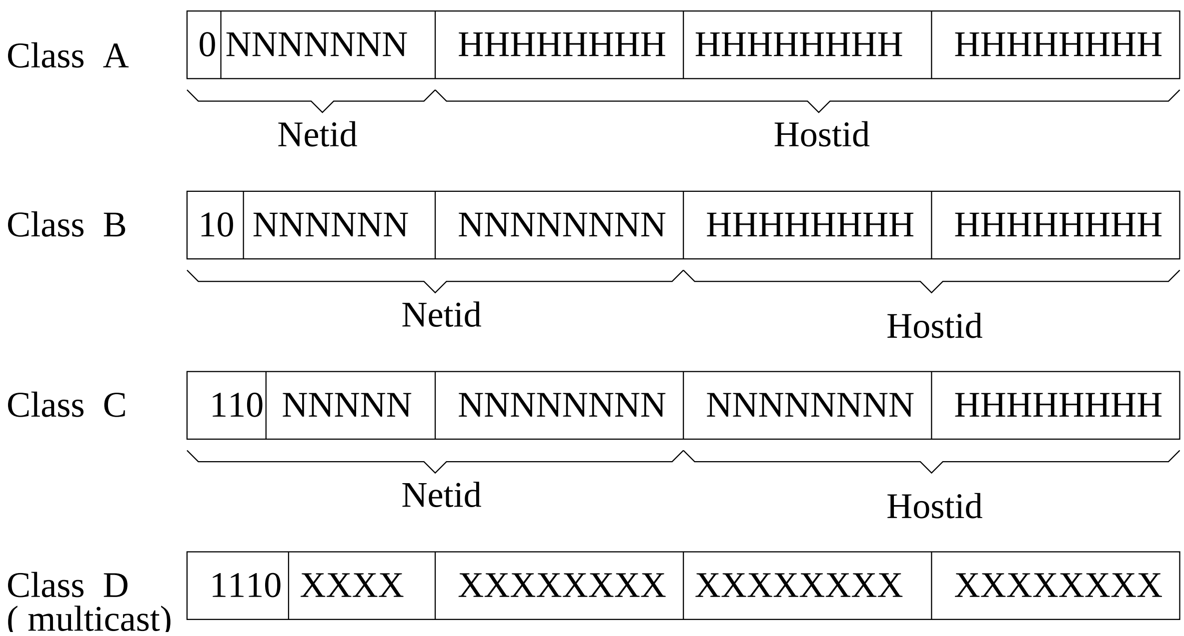
- Internetworking protocol used by Internet.



- Datagram Service.
- Routing inside a network is based on the physical address in the packet header.
- Internet routing is based on the network id in the IP header.

2. Address Structure

- Address field is 32-bit long.
- The address consists of a network id and host id.
- The network id is used by routers for datagram routing.
- Division of the address space



Address class	Bits in prefix	Max. number of networks	Bits in suffix	Max number of hosts
A	7	128	24	16,777,216
B	14	16,384	16	65,536
C	24	2097152	8	256

- Summary of special IP addresses

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
1110	address	multicast	multicast to a group of hosts
127	any	loopback	testing

- Address for private networks

Class	Netids	total
A	10.0.0	1
B	172.16 to 172.31	16
C	192.68.0 to 192.68.255	256

3. <u>Network Mask</u>

- For classless routing
- Indicates the Netid portion of the address

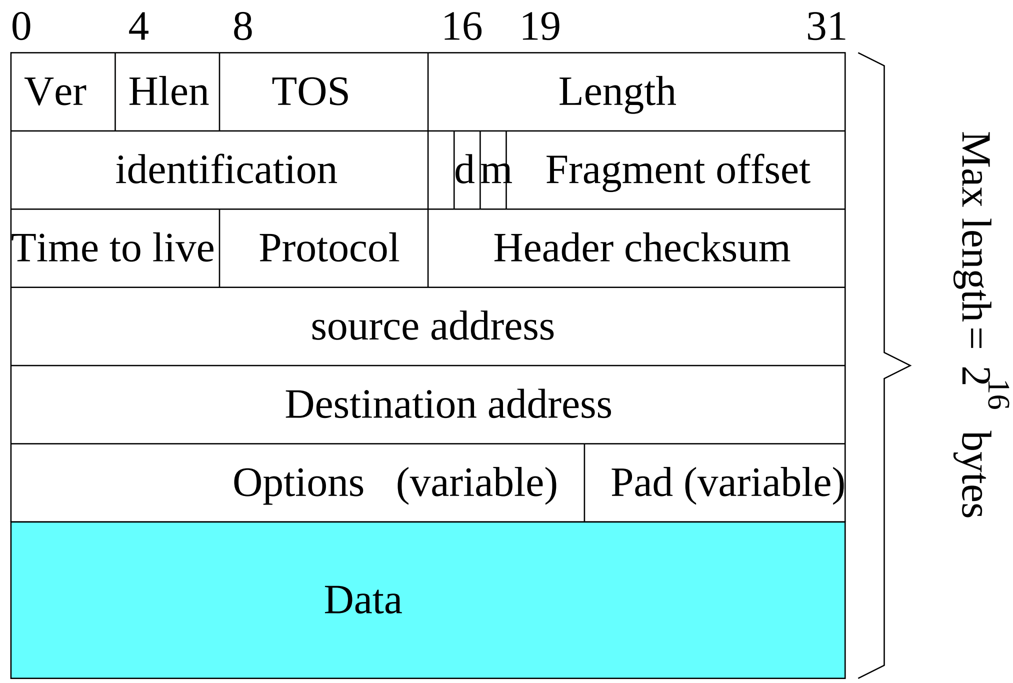
Mask	1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1	1 1 1 1 0 0 0 0	0 0 0 0 0 0 0 0
IP address	XXXXXXXX	XXXXXXXX	XXXX XXXX	XXXXXXXX

Netid Hostid

- Uses the "AND" operation to extract the Netid

dotted decimal	255 .	255 .	240 .	0
Mask	1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1	1 1 1 1 0 0 0 0	0 0 0 0 0 0 0 0
	151 .	10 .	40 .	7
IP address	1 0 0 1 0 1 1 1	0 0 0 0 1 0 1 0	0 0 1 0 1 0 0 0	0 0 0 0 0 1 1 1
	151 .	10 .	32 .	0
Netid	1 0 0 1 0 1 1 1	0 0 0 0 1 0 1 0	0 0 1 0 0 0 0 0	0 0 0 0 0 0 0 0

4. Datagram Structure



- Ver = Version number (4 or 6).
- TOS = Type of Service.
- Length = Total length of the datagram.
- Identification, d and m bits, and Fragment offset: For fragmentation.
- Time to Live = number of hops.
- protocol: TCP, UDP, ICMP, ... ,etc.
- Options: Souce routing, routing record, etc...

5. Fragmentation and Reassembly

- Fragmentation is required in order to transport a large datagram across a network that supports a small datagram size.
- Reassembly is done at the destination.
- Fragmentation information is carried at the datagram header.
- Example: An datagram of 1000 octets is to be transmitted over a network which supports a maximum packet size of 256 octets. Assuming the header in each IP datagram requires 20 octets, derive the number of datagrams (fragments) required and the contents of the following fields in each datagram header:
  - identification,
  - total length,
  - fragment offset,
  - more fragments flag.

  Maximum usable data per datagram = 256 - 20 = 236 octets.

  Use, say, $29 \times 8 = 232$ octets

  Hence five datagrams will be required, four with 232 octets of user data and one with 72 octets

  The field are as follows:

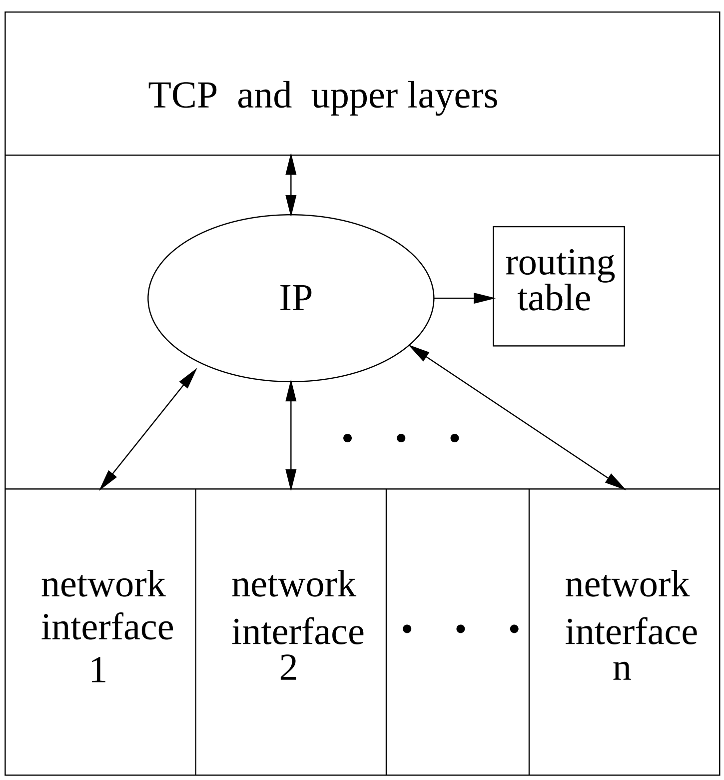
identification	20(say)	20	20	20	20
total length	252	252	252	252	92
fragment offset	0	29	58	87	116
more fragments flag	1	1	1	1	0

II) **Datagram Forwarding**

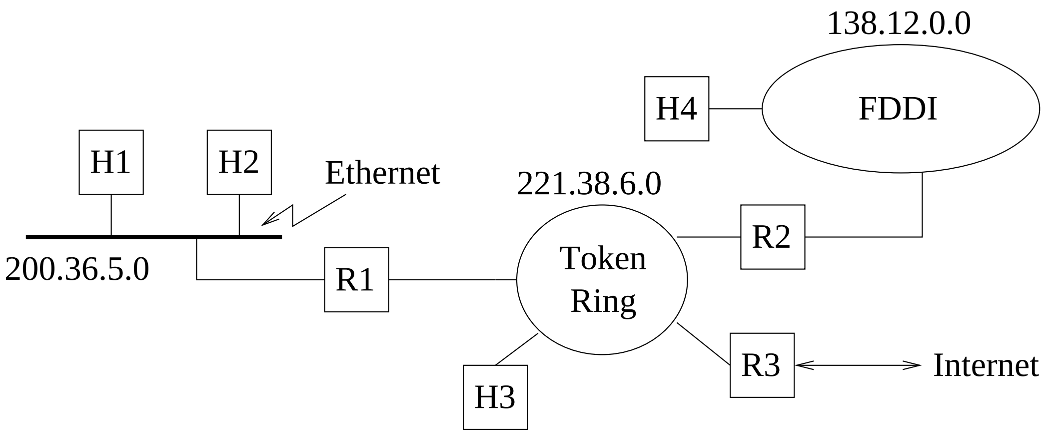
1. Basic Forwarding algorithm

   - The algorithm

     DES = Network ID of the destination.
     if (DES = NetworkID of one of my interfaces) then
         deliver packet to destination over that interface
     else
         if (DES is in my forwarding table) then
             deliver packet to NextHop router
         else
             deliver packet to default router



- Example



Routing table of H1:

Network ID	Next Hop (NH)	interface (IF)
200.36.5.0	-	E0
default	R1	E0
local host	-	lo0

Routing Tables of Routers 1 and 2:

R1

NetworkID	NH	IF
200.36.5.0	-	E0
221.38.6.0	-	TR0
138.12.0.0	R2	TR0
default route	R3	TR0

R2

NetworkID	NH	IF
200.36.5.0	R1	TR0
221.38.6.0	-	TR0
138.12.0.0	-	FDDI0
default route	R3	TR0

2. <u>Subnetting</u>

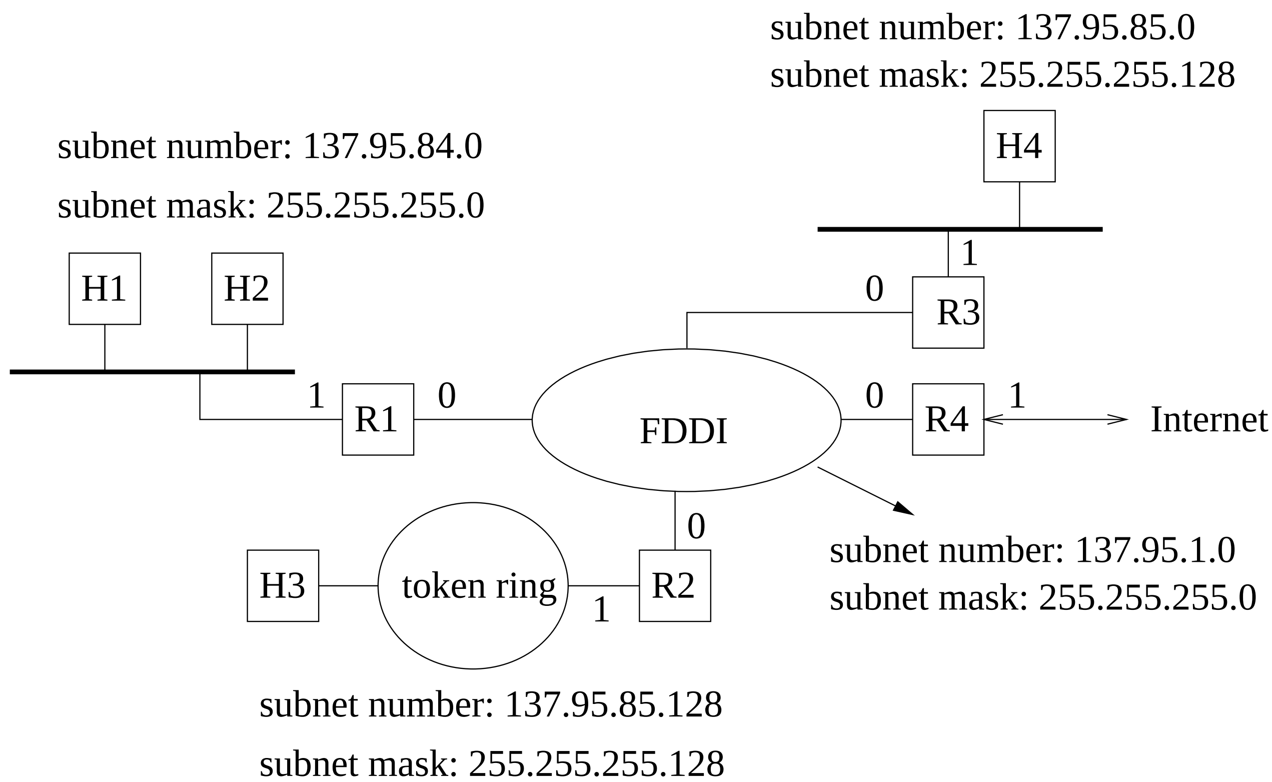
- One IP address for several physical networks (subnets).
- Introduce one more level of hierarchy into the IP addressing.
- The subnet number of a subnet can be obtained by using subnet mask.

  IP address: 137.95.84.139
  subnet mask: 255.255.255.0
  subnet number = IP address .AND. subnet mask
  = 137.95.84.0

- Subnet forwarding algorithm

```
DES = Destination IP address
For each forwarding table entry
    DES1 = subnet mask & DES
    if ( DES1 = subnet number)
        if NextHop is an interface
          deliver datagram directly to that interface
        else
          deliver datagram to NextHop router
```

- Example



hosts	IP addresses
H1	137.95.84.1
H2	137.95.84.2
H3	137.95.85.130
H4	137.95.85.1

routers	interface 0	interface 1
R1	137.95.1.1	137.95.84.3
R2	137.95.1.2	137.95.85.131
R3	137.95.1.3	137.95.85.2
R4	137.95.1.4	-

Routing Table of Router 1

NetID	NetMask	NextHop	interface
137.95.84.0	255.255.255.0	-	interface 1
137.95.1.0	255.255.255.0	-	interface 0
137.95.85.128	255.255.255.128	R2	interface 0
137.95.85.0	255.255.255.128	R3	interface 0

Routing table of Router 2

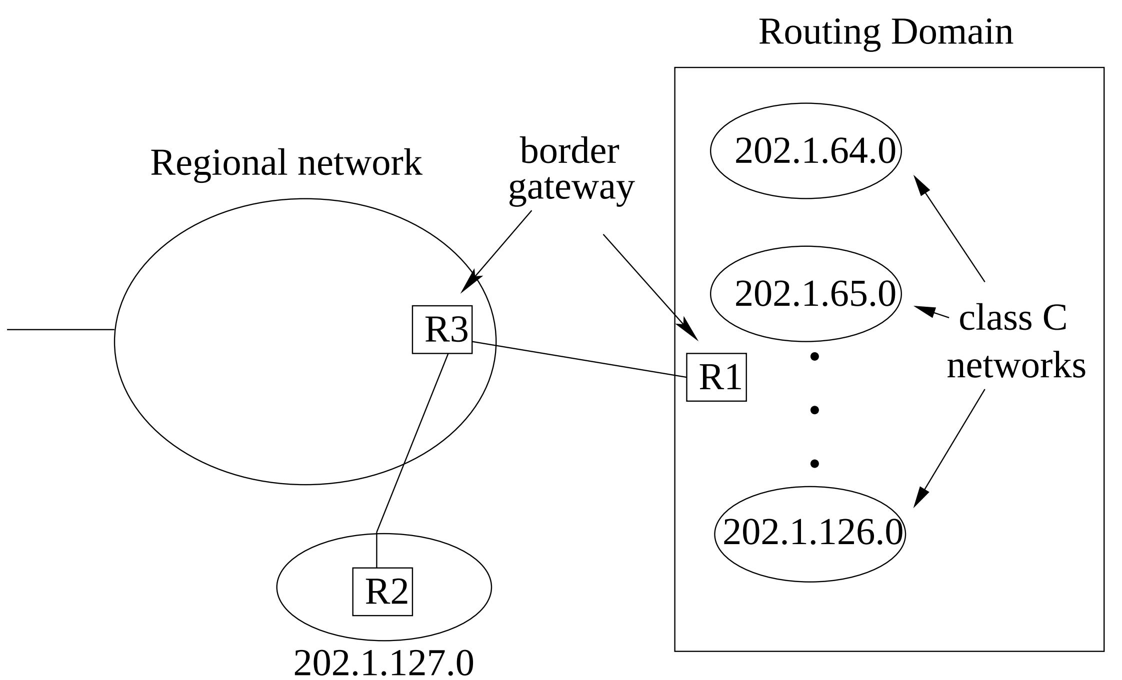
NetID	NetMask	NextHop	interface
137.95.84.0	255.255.255.0	R1	interface 0
137.95.1.0	255.255.255.0	-	interface 0
137.95.85.128	255.255.255.128	-	interface 1
137.95.85.0	255.255.255.128	R3	interface 0

Routing table of Router 3

NetID	NetMask	NextHop	interface
137.95.84.0	255.255.255.0	R1	interface 0
137.95.1.0	255.255.255.0	-	interface 0
137.95.85.128	255.255.255.128	R2	interface 0
137.95.85.0	255.255.255.128	-	interface 1

3. Classless InterDomain Routing (CIDR)

- Grouping of number of class C addresses to form a single aggregated network address.
- The aggregated address is identified by using network masking.
- Example:



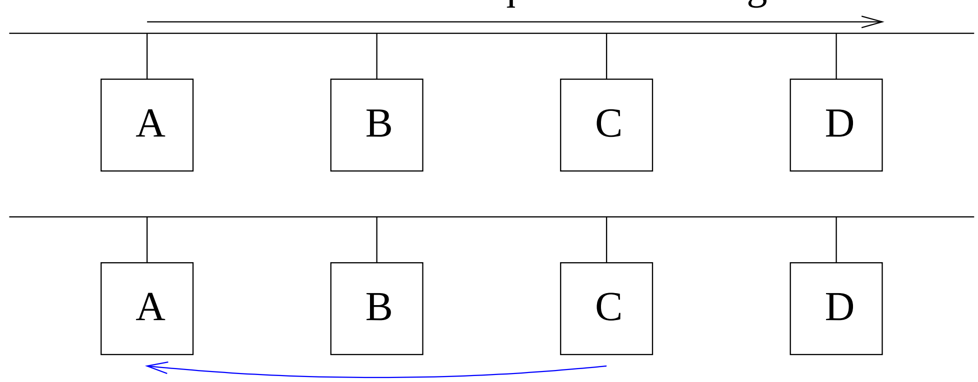
advertises path to
an aggregated network with
network number: 11001010 00000001 01
mask: 255.255.192.0

III) IP Routing

1. Address Binding

- Address resolution protocol (ARP)
  - To bind the IP address to the physical address.

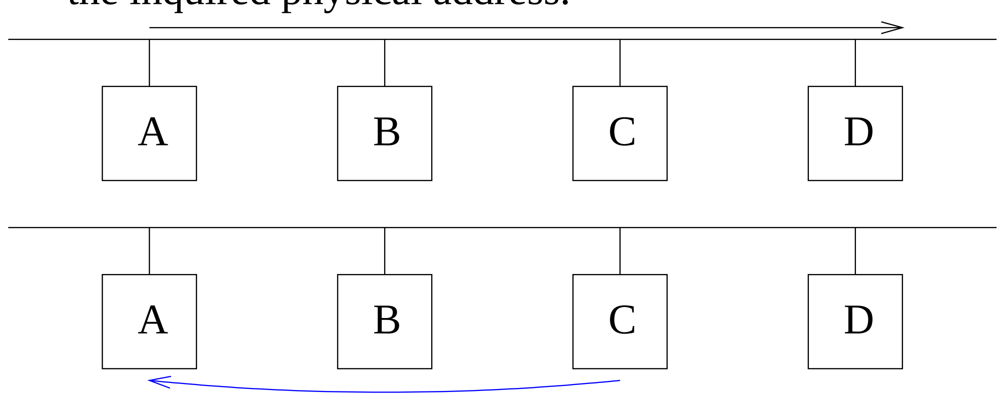
Host A broadcasts an ARP request containing IP address of C



Host C responds with an ARP reply that contains the physical address

- BOOTstrap Protocol (BOOTP)
  - Use by workstation to find bootstrap information.

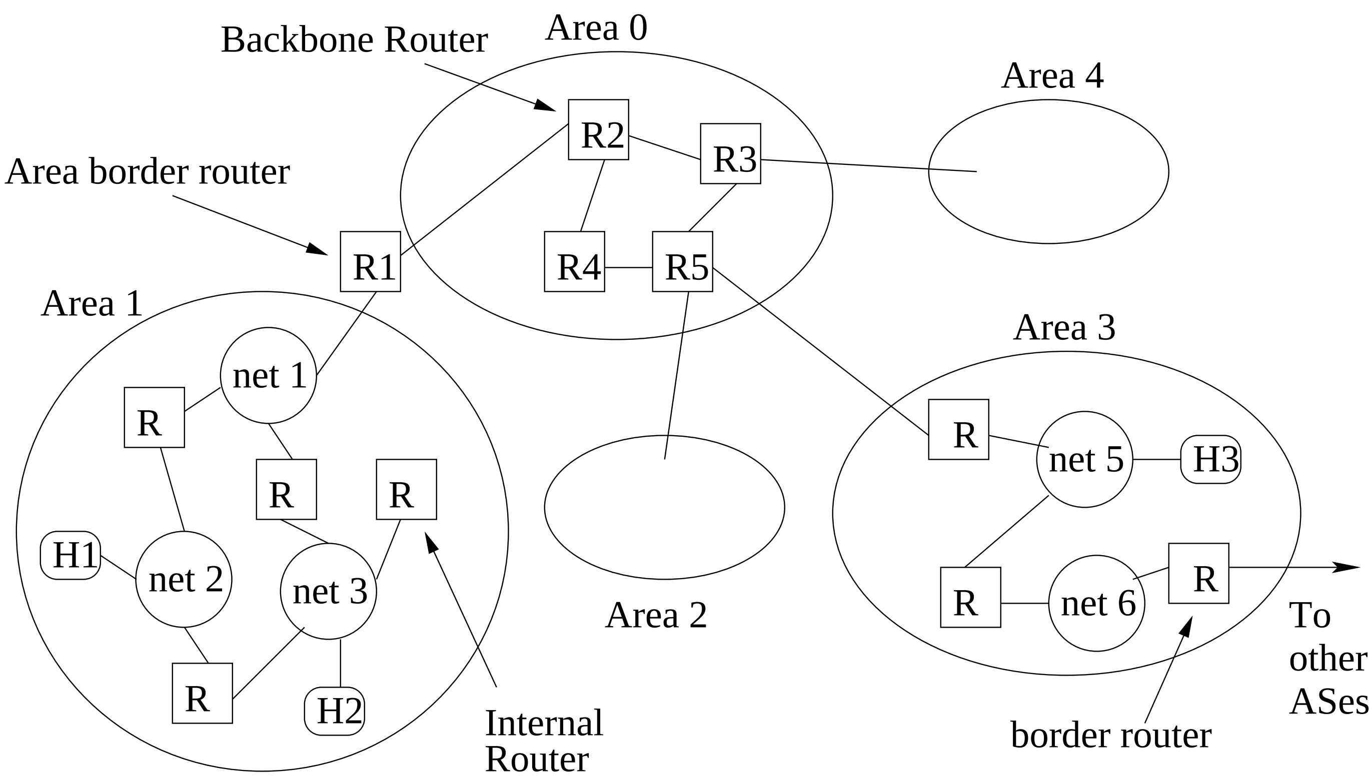
Host A broadcasts a BOOTP request containing
the inquired physical address.



A server station responds with an BOOTP reply

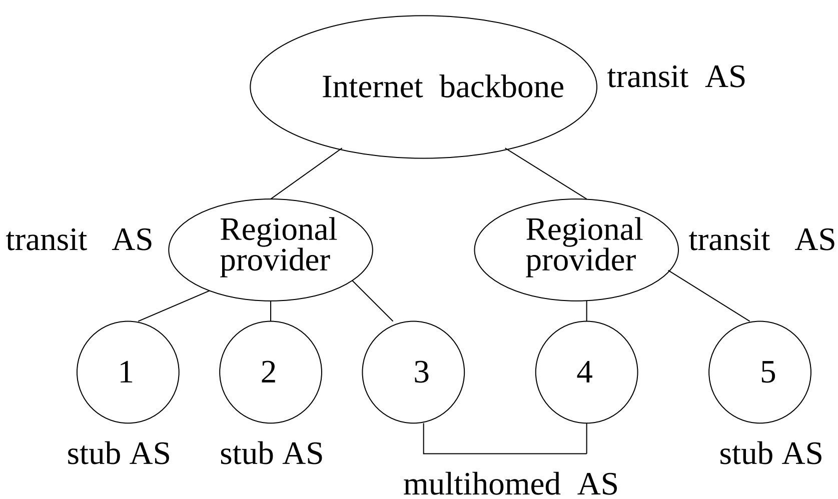
2. Routing Within An Autonomous System (AS)

- AS is an internet under one administration – using the same routing algorithm.
- Major issue: selection and maintenance of the best path among networks.
- Routing algorithms:
  - Routing Information Protocol (RIP): Distance-Vector algorithm.
  - Open Shortest Path First (OSPF): Link-state routing.
  - An AS can be further divided into area - hierarchical routing.



3. Routing Among ASes

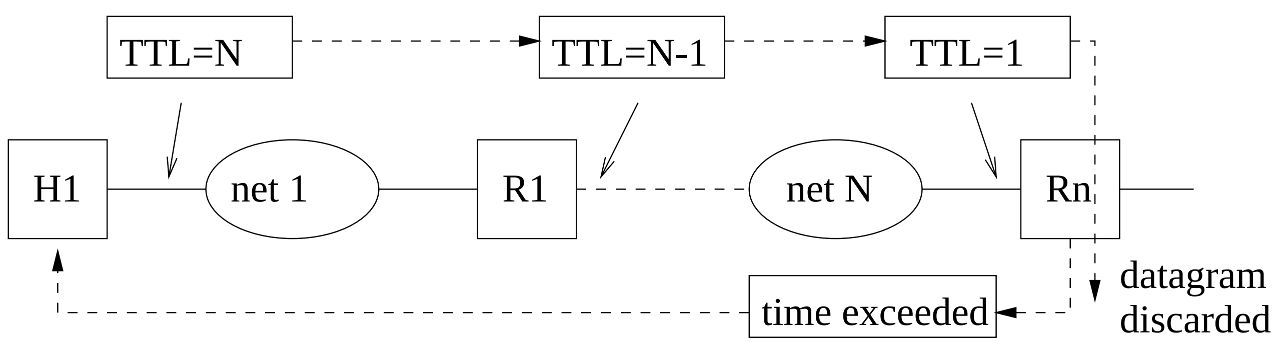
- The main concern is the maintenance and enforcement of policies that govern the willingness of an AS to:
  (a) act as a transit domain for traffic originating from and destined for other ASes;
  (b) receive information from sources outside the AS and deliver them to destinations within the AS,
  (c) forward information from within the AS to destinations outside the AS.
- Three types of ASes:
  - Stab AS – an AS that has single connection to one other AS and only carry local traffic.
  - Multihomed AS – an AS that has connection to multiple ASes but that refuses to carry transit traffic.
  - Transit AS – an AS that is designed to carry both transit and local traffic.



IV) Related Protocols

1. Internet Control Message Protocol (ICMP)

   - For network management.
   - Provides an elaborate mechanism for reporting errors in IP datagram processing at hosts and gateways.
   - ICMP Messages:
     - Source Quench: for congestion control.
     - Echo Request/Reply: to test reachability.
     - Timestamp Request/Reply: Echo Request/Reply with timestamp.
     - Time Exceeded:

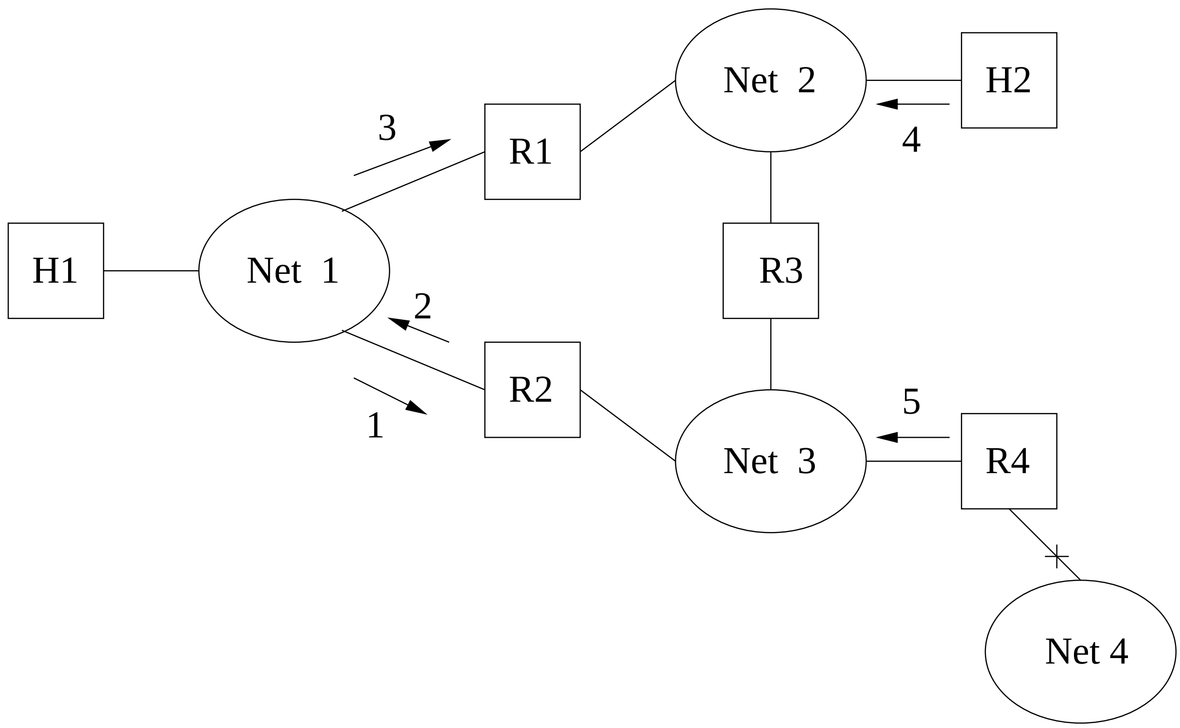


– ICMP Redirect:

(1) H1 sends a datagram to H2 using the default router R2.

(2) R2 sends an ICMP redirect message back to H1.

(3) Subsequent datagrams are sent through R1.



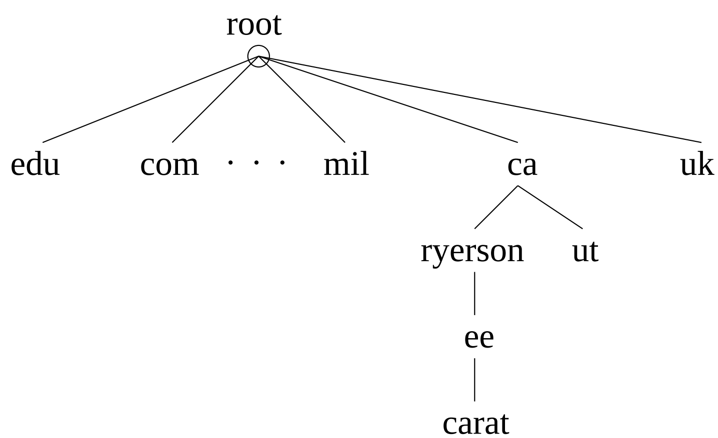
– Destination Unreachable:

(4) H2 sends a datagram to Net 4.

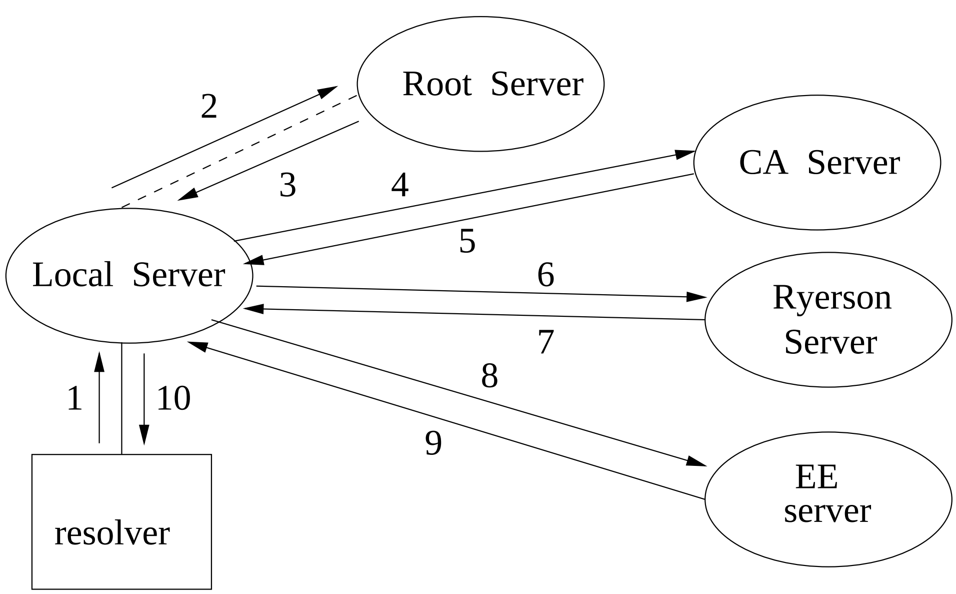
(5) R4 sends back a Destination-Unreachable message.

2. Domain-Name System (DNS)

- To map a host name to its IP address.
- Domain-name hierarchy:

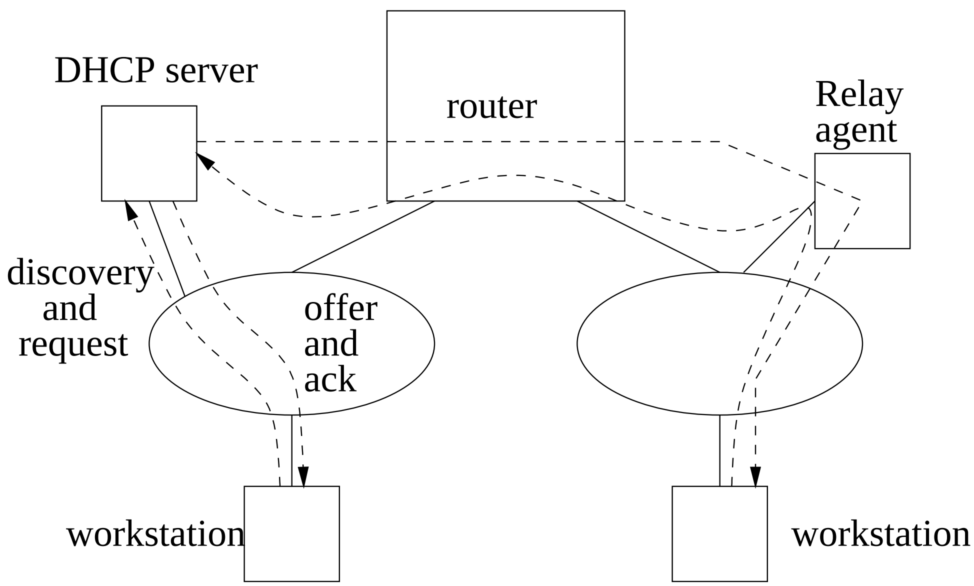


- DNS is implemented as two distinct components:
  - DNS servers
  - Name resolvers
- Name resolution (carat.ee.ryerson.ca):



3. Dynamic Host Configuration Protocol (DHCP)

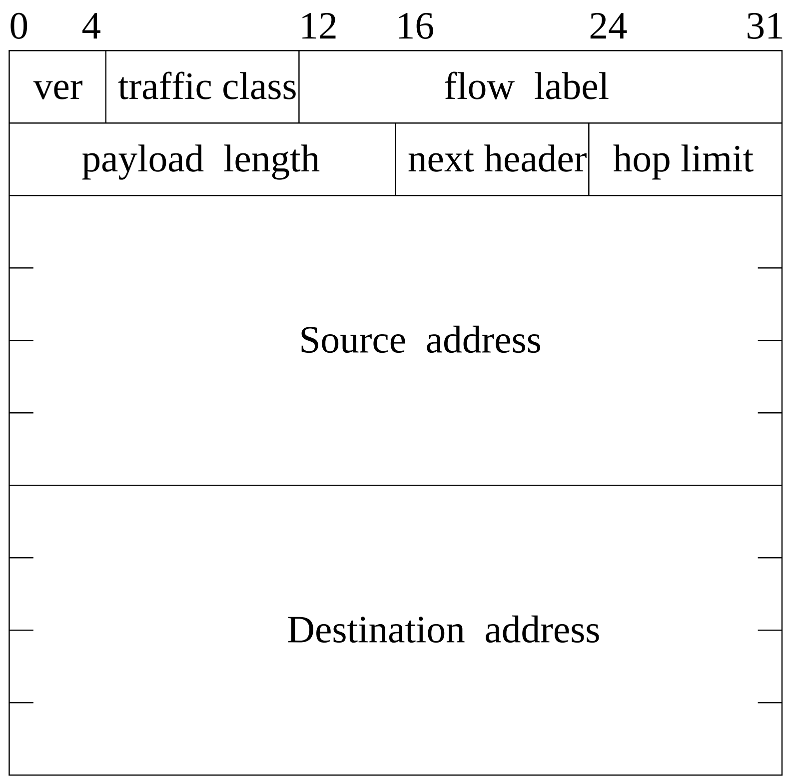
- Automated Configuration.
- Based on BOOTP
- DHCP can dynamically assign IP addresses to workstations.
- A workstation can only lease an IP address for a limited duration.
- The workstation may extend the lease through the DHCP transaction with the server.



V) **IPv6**

1. Header Format

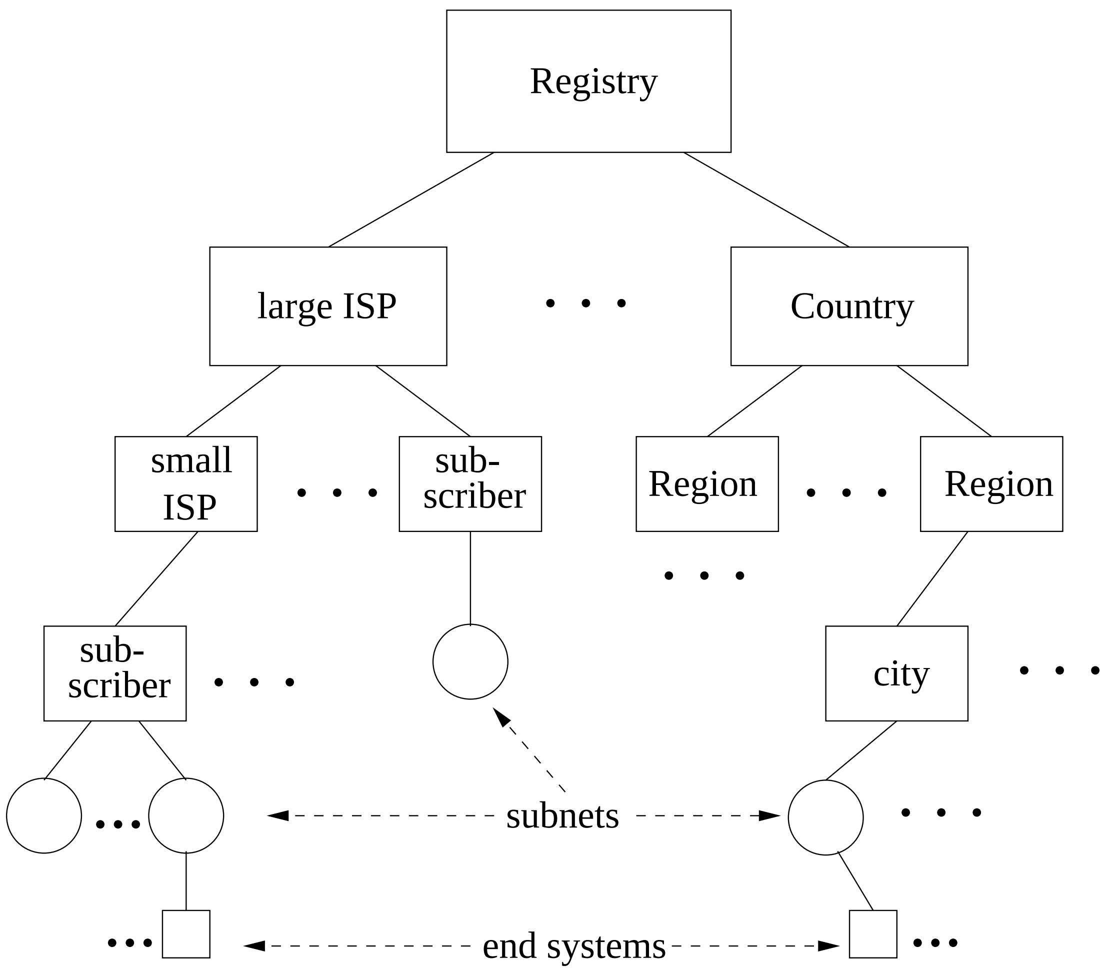
- Header Format:



- Address length is 128 bits.
- Simplification of the header. Use the extension headers to carry the options.
- Support QOS.

2. Address Space

- Hierarchical address space.

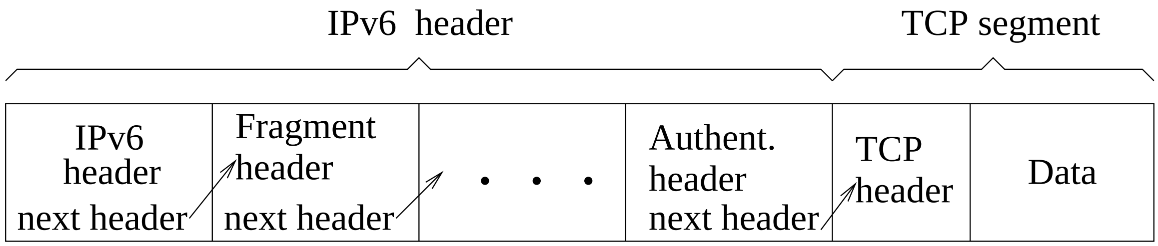


	5 bits	n bits	m bits		
010 or 100	Registry	ISP or Country	subscriber or Region	. . .	interface ID

128 bits

- Link-local address.
- Site-local address.

3. extension header



- Hop-by-hop options header
  - Examined by all the routers along the path.
  - Used to transmit management information.
- Destination options header -1
- Source routing header
- Fragmentation header
  - Only the source can fragment the datagram.
  - The source must first find out the Maximum transmission unit along the path.
- Authentication header
- IPv6 encryption header
- Destination options header-2