Internet Addresses

COMP476
Networked Computer Systems

Goals

- Understand the details on Internet Addresses
- Be able to describe all of the transmissions necessary to send data over the Internet.

Network Identifiers

Computers on the Internet are referred to as hosts. Each host as at least three identifiers:

- **Internet name** for humans to use (i.e. garfield.ncat.edu)
- **Internet address**, a 32 bit binary number written in decimal as four bytes (i.e.152.8.240.16)
- **hardware address**, such as an Ethernet address (i.e. 00-e0-63-03-76-c0 for garfield)

Internet Names

- Hierarchical starting from the right
  `host.subnet.organization.type`
- Rightmost identifies the type or organization or country
  - edu, com, mil, org, net
  - us, ca, de, uk

Internet Addresses

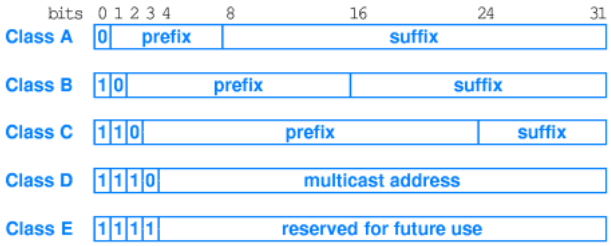
- Internet Addresses map to Internet Names.
- An Internet Address is composed of two parts, a netid (or prefix) and a hostid (or suffix).
- The hostid identifies the particular host on a network.
- The netid identifies the network where the host is connected.
- A computer physically connected to two networks needs two Internet addresses.

Internet Address Classes

class				
A	NetID	hostID	hostID	hostID
B	NetID	NetID	hostID	hostID
C	NetID	NetID	NetID	hostID

IP Addressing Classes

- The five classes of IP addresses in the classful scheme. The address assigned to a host is either class *A*, *B*, or *C*; the *prefix* identifies a network, and the suffix is unique to a host on that network.



Compute the Address Class

First Four Bits Of Address	Table Index (in decimal)	Class of Address
0000	0	A
0001	1	A
0010	2	A
0011	3	A
0100	4	A
0101	5	A
0110	6	A
0111	7	A
1000	8	B
1001	9	B
1010	10	B
1011	11	B
1100	12	C
1101	13	C
1110	14	D
1111	15	E

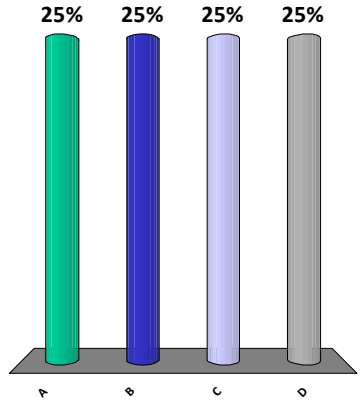
Range of Values

First Byte	Address Class
0 - 127	A
128 - 191	B
192 - 223	C

The range of decimal values found in the first octet of each address class.

What class is address 152.8.110.47?

1. A
2. B
3. C
4. D



Assigning Addresses

- Domain names and netids are assigned by the *Internet Corporation for Assigned Names and Numbers (ICANN)* **`www.icann.org`**
- Local network administrators assign hostid numbers to computers
- All IP addresses must be unique
- The domain's DNS is required to know the IP addresses for all computers in the domain

Binary to Decimal Conversion

- Binary values appear in IP packets in *Big Endian* style (most significant byte first).

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

Examples of 32-bit binary numbers and their equivalent in dotted decimal notation. Each octet is written in decimal with periods (dots) used to separate octets.

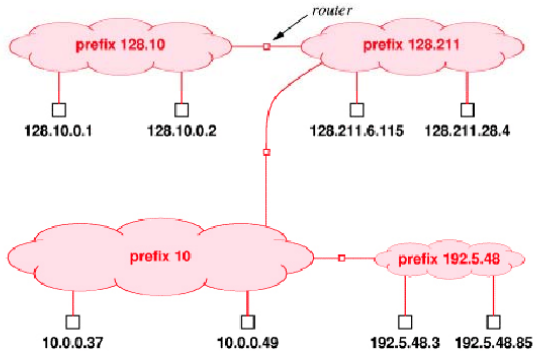
Address Mask

- A address mask is a 32 bit integer that is logically ANDed with an Internet address to separate the hostID.

Class	Network Mask
A	255.0.0.0
B	255.255.0.0
C	255.255.255.0

```
  10011000.00001000.11111011.00101001
AND 11111111.11111111.00000000.00000000
  10011000.00001000.00000000.00000000
```

IP Assignment Address Example



All hosts connected to a network have the same Internet address prefix.

Special IP addresses

- all 1's broadcast on the local network
- all 0's this host
- hostid = all 0's the network (not a host)
- hostid = all 1's broadcast on given network
- netid = all 0's this network
- netid = 127 loop back (never appears on net)

Moving Computers

- Because the Internet address encodes the network to which the computer is connected, moving a computer to a different network requires giving it a new address.
- This has a big impact on mobile computing.

Mapping Between Addresses

- Humans use Internet Names. The hardware uses the MAC addresses.
- Internet Names are converted to Internet Addresses by a Domain Name Server (DNS)
- Internet Addresses are converted to MAC addresses by using the Address Resolution Protocol (ARP).

Domain Name Servers

- Domain Name Servers (DNS) map Internet Names to Internet Addresses.
- A DNS maintains a distributed database of names and addresses.
- Computers can send a request to a DNS to get the IP address of a computer.
- Hosts and DNS cache addresses they have found.

MAC Addresses

- The actual network hardware must use the MAC or physical addresses.
- An Ethernet interface knows nothing of Internet addresses.
- To send a frame to another computer on the **same** network, you must know it's MAC address (or broadcast).
- Each network type uses different addresses.

Address Resolution Protocol (ARP)

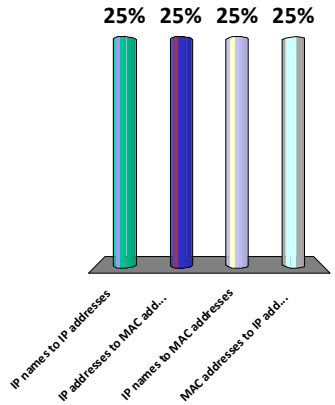
- Used by a computer to find the MAC or physical address of another computer on the **same** network.
- To find a MAC address, ARP broadcasts a request containing the desired IP address to all computers on its local network.
- All computers receive the ARP request and compare the requested address to theirs.
- Only if the address matches, does the computer send a response back to the source.

IP Routing

- If a host has the IP name of the destination but does not know the IP address, it must send a request to the DNS.
- If a host does not know the MAC address of a destination computer on it's local network, it must use ARP to find the address.

ARP converts

1. IP names to IP addresses
2. IP addresses to MAC addresses
3. IP names to MAC addresses
4. MAC addresses to IP addresses



Local Routing Decision

- When sending an IP datagram, the source computer must decide if it can send the packet directly to the destination on the local network or if it must send the packet to a router or gateway.
- Each host must be aware of the address of its local DNS and default gateway.

Local Destinations

- If the NetID of the destination's IP address is the same as the NetID of the source's IP address, then the destination is in the same Internet domain.
- The frame can be sent directly to the destination.
- ARP may be needed to find the destination's MAC address.

Global Destinations

- If the NetID of the destination's IP address is different from the NetID of the source's IP address, then the destination is in another Internet domain.
- The frame must be sent to a gateway.
- ARP may be needed to find the gateway's MAC address.
- The IP destination address will be the IP address of the final destination.

IP Routing Procedure

Assume computer **A** wants to send one frame to computer **B**

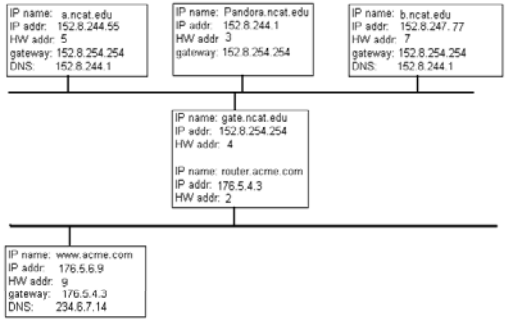
1. **A** sends a DNS request to the local Domain Name Server asking for the IP address of **B**.
2. The DNS sends the IP address of **B** to **A**.
3. The netid portion of **B**'s IP address is extracted by ANDing **B**'s IP address with the subnet mask of **A**

4. If the netid of the sender and receiver are the same, then the destination is on the same network. **A** can send the packet directly to **B**.
5. If the netids are different, **A** must send the packet to the gateway.
6. The gateway will forward the packet to another gateway that is closer to the destination's domain.
7. The gateway at the destination's domain will send the frame to **B**

IP Routing Example

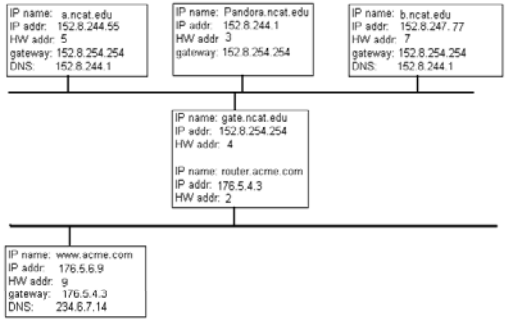
- Assume that all computers were just powered on and have no additional information other than their IP configuration.
- **`a.ncat.edu`** wants to send one packet to **`b.ncat.edu`**

ARP Request to Find the HW address of the DNS



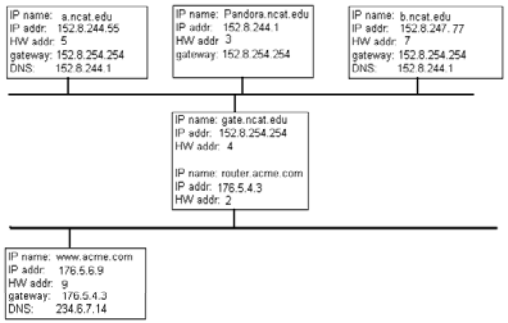
Source HW addr	Dest HW addr	Source IP addr	Desired IP addr
5	broadcast	152.8.244.55	152.8.244.1

ARP Reply from DNS to A



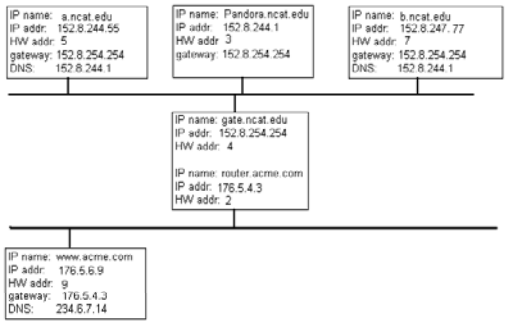
Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
3	5	152.8.244.1	152.8.244.55

Send request for b.ncat.edu's IP address to DNS



Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
5	3	152.8.244.55	152.8.244.1

DNS sends b.ncat.edu's IP address to A

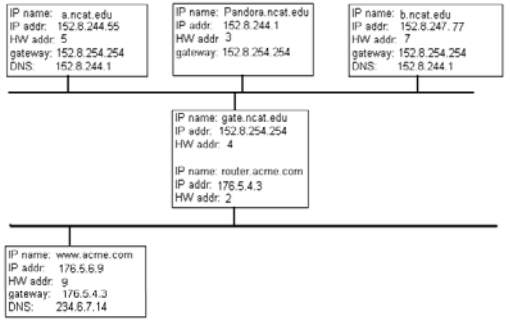


Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
3	5	152.8.244.1	152.8.244.55

Local or Global Decision

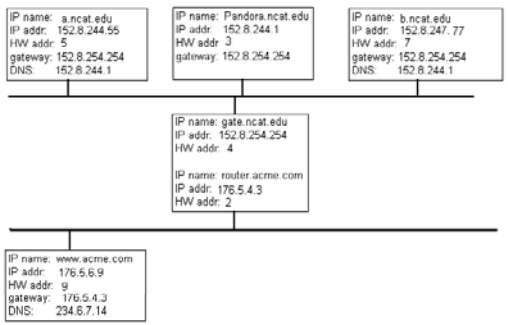
- The NetID of the destination is **`152.8`**
- The NetID of the source is **`152.8`**
- Since the NetIDs are the same, the destination must be in the same domain. The packet can be sent directly to the destination.

ARP Request to Find the HW address of B



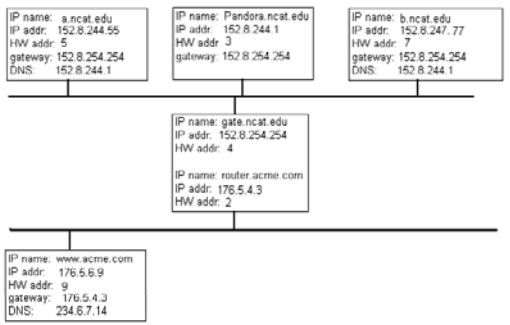
Source HW addr	Dest HW addr	Source IP addr	Desired IP addr
5	broadcast	152.8.244.55	152.8.247.77

ARP Reply from B to A



Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
7	5	152.8.247.77	152.8.244.55

A sends the datagram to B

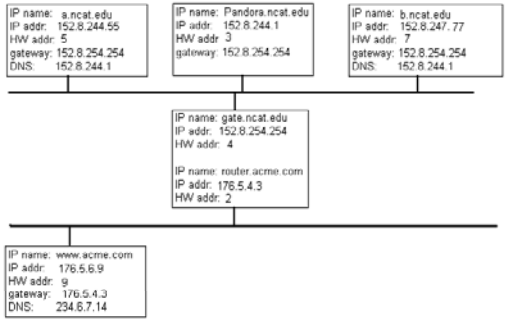


Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
5	7	152.8.244.55	152.8.247.77

Follow-on Example

- Assume all of the traffic from the previous example has just occurred. Information learned by these exchanges has been cached.
- **`a.ncat.edu`** wants to send another packet to **`b.ncat.edu`**

A sends the datagram to B

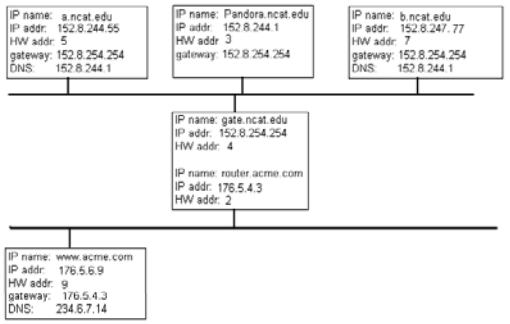


Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
5	7	152.8.244.55	152.8.247.77

Another IP Routing Example

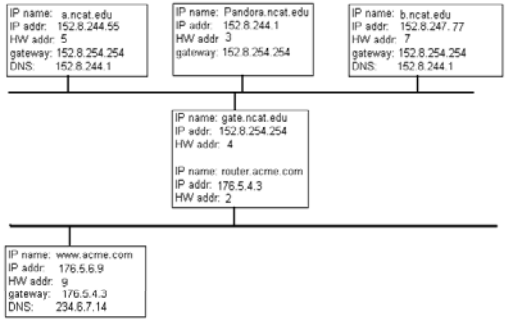
- Assume that all computers were just powered on and have no additional information other than their IP configuration.
- **`a.ncat.edu`** wants to send one packet to **`www.acme.com`**

ARP Request to Find the HW address of the DNS



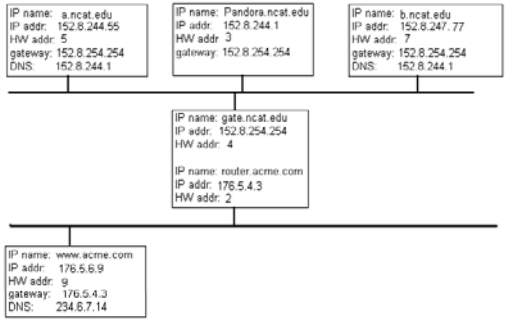
Source HW addr	Dest HW addr	Source IP addr	Desired IP addr
5	broadcast	152.8.244.55	152.8.244.1

ARP Reply from DNS to A



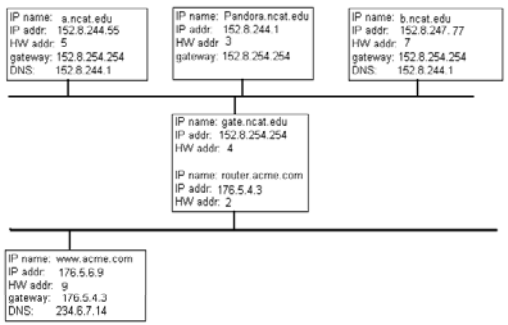
Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
3	5	152.8.244.1	152.8.244.55

Request for www.acme.com's IP address to DNS



Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
5	3	152.8.244.55	152.8.244.1

DNS sends www.acme.com's IP address to A

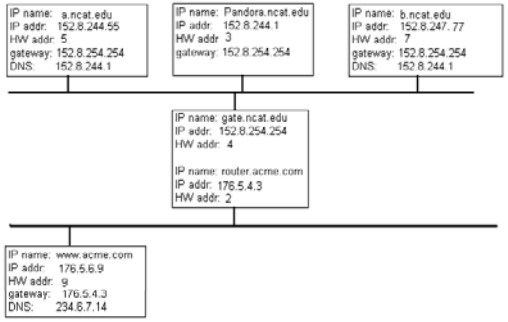


Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
3	5	152.8.244.1	152.8.244.55

Local or Global Decision

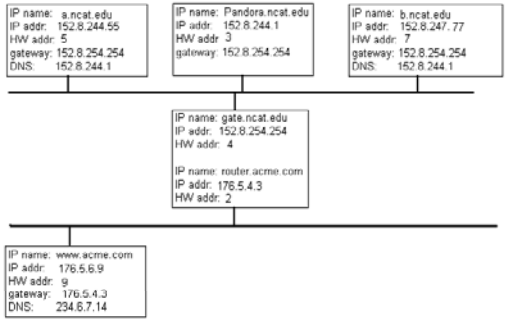
- The netid of the destination is **`176.5`**
- The netid of the source is **`152.8`**
- Since they are different, the frame must be sent to the gateway using the gateway's hardware address.

ARP Request for the HW address of the gateway



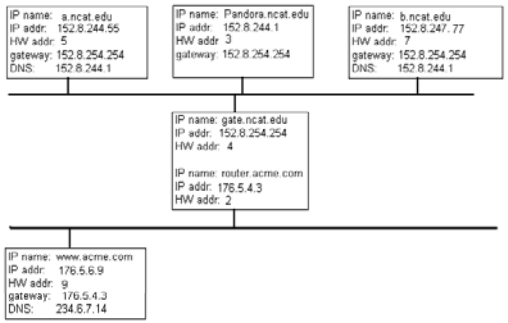
Source HW addr	Dest HW addr	Source IP addr	Desired IP addr
5	broadcast	152.8.244.55	152.8.254.254

ARP reply from Gateway to A



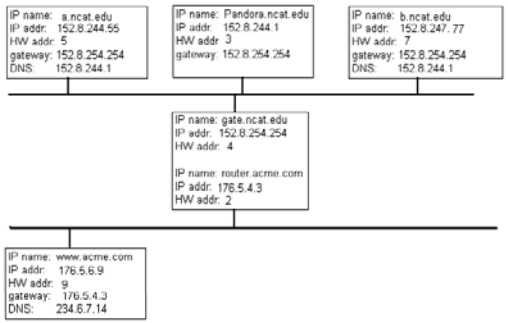
Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
4	5	152.8.254.254	152.8.244.55

A sends data packet to Gateway



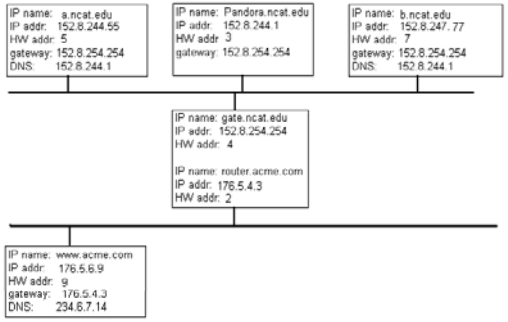
Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
5	4	152.8.244.55	**176.5.6.9**

Gateway broadcasts ARP request for WWW's IP addr



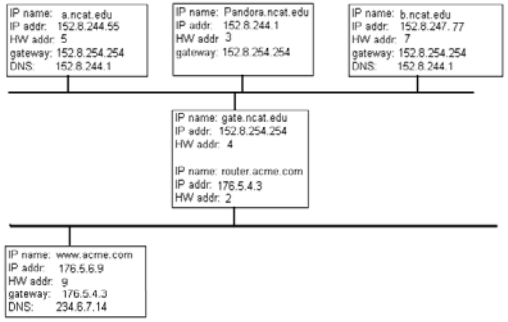
Source HW addr	Dest HW addr	Source IP addr	Desired IP addr
2	broadcast	176.5.4.3	176.5.6.9

ARP reply sending www IP address to gateway



Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
9	2	176.5.6.9	176.5.4.3

Gateway sends the data to www.acme.com



Source HW addr	Dest HW addr	Source IP addr	Dest IP addr
2	9	**152.8.244.55**	1176.5.6.9

Number of Computers

Class	Netid bits	Max Networks	Hostid bits	Max hosts	Number of addresses
A	7	126	24	16,777,214	2,113,928,964
B	14	16,382	16	65534	1,073,577,988
C	21	2,097,150	8	254	532,676,100
					3,720,183,052

There are about 6,825,894,115 people in the world today

Classless IP Addresses

- The mechanism that divides IP addresses into three classes was found to be wasteful
- Many domains have address spaces they are not going to fill
- If a network is only going to have 12 computers, the hostid only needs to have 4 bits

CIDR

- Classless Inter-Domain Routing (CIDR) is an addressing scheme that allows specifying how many bits should be used for the netid
- Addresses are written in the form

  `ddd.ddd.ddd.ddd/m`
- Where m is a decimal number specifying how bits are to be used for the netid

A list of address masks in CIDR notation and in dotted decimal

Length (CIDR)	Address Mask	Notes
/0	0 . 0 . 0 . 0	All 0s (equivalent to no mask)
/1	128 . 0 . 0 . 0	
/2	192 . 0 . 0 . 0	
/3	224 . 0 . 0 . 0	
/4	240 . 0 . 0 . 0	
/5	248 . 0 . 0 . 0	
/6	252 . 0 . 0 . 0	
/7	254 . 0 . 0 . 0	
/8	255 . 0 . 0 . 0	Original Class A mask
/9	255 . 128 . 0 . 0	
/10	255 . 192 . 0 . 0	
/11	255 . 224 . 0 . 0	
/12	255 . 240 . 0 . 0	
/13	255 . 248 . 0 . 0	
/14	255 . 252 . 0 . 0	
/15	255 . 254 . 0 . 0	
/16	255 . 255 . 0 . 0	Original Class B mask
/17	255 . 255 . 128 . 0	
/18	255 . 255 . 192 . 0	
/19	255 . 255 . 224 . 0	
/20	255 . 255 . 240 . 0	
/21	255 . 255 . 248 . 0	
/22	255 . 255 . 252 . 0	
/23	255 . 255 . 254 . 0	
/24	255 . 255 . 255 . 0	Original Class C mask
/25	255 . 255 . 255 . 128	
/26	255 . 255 . 255 . 192	
/27	255 . 255 . 255 . 224	
/28	255 . 255 . 255 . 240	
/29	255 . 255 . 255 . 248	
/30	255 . 255 . 255 . 252	
/31	255 . 255 . 255 . 254	
/32	255 . 255 . 255 . 255	All 1s (host specific mask)

CIDR Host Address Example

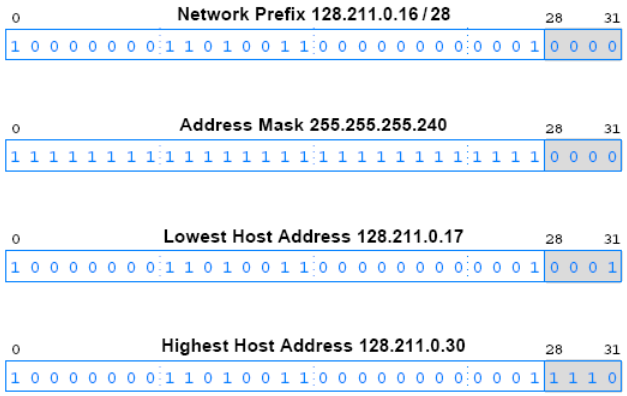


Figure 21.6 Illustration of CIDR addressing for an example / 28 prefix.

aaa.aaa.aaa.aaa/8 is class

1. A
2. B
3. C
4. D