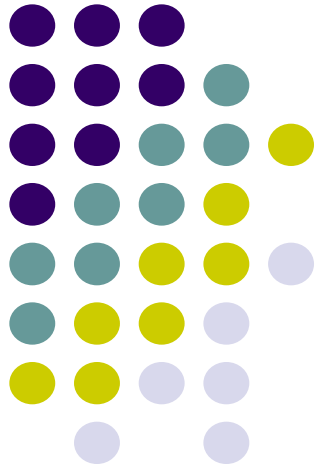
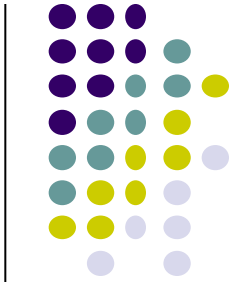
IP-Internet Protocol Addresses

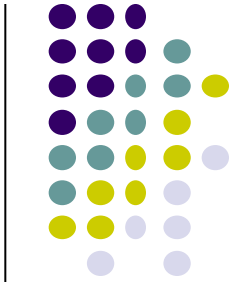


Addresses for the Virtual Internet



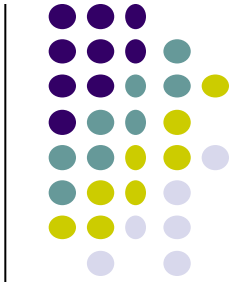
- The goal of internetworking is to provide a seamless communication system
- Internet protocol software must hide the details of physical networks and offer facilities of a large network.
- The virtual internet operates much like any network.
- Internet allows computers to send and receive packets of information.

Internet and a physical network



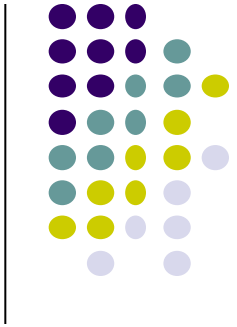
- An internet is an abstraction imagined by its designers and created by software.
- The designers are free to choose addresses, packet format and delivery techniques.
- All of them are independent of the details of the physical hardware.

Addressing



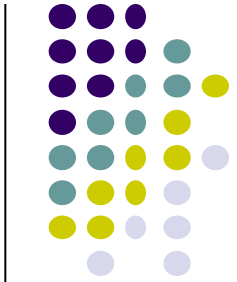
- Addressing is a critical component of the internet abstraction.
- All host computers must use a uniform addressing scheme, each address must be unique.
- Physical network addresses do not suffice because an internet can include multiple network technologies and each defines its own address format in different sizes.
- To guarantee uniform addressing for all hosts, protocol software defines an addressing scheme.
- The addressing scheme is an abstraction created by software.

Addressing (2)



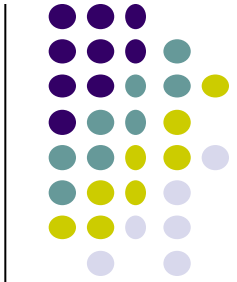
- Protocol addresses are used as destinations for the virtual internet analogous to the way hardware addresses used as destination on a physical network.
- The sender places the destination's protocol address in the packet, then passes the packet to protocol software for delivery.
- The software uses the destination protocol address when it forwards the packet across the internet to the destination computer.

Benefits of uniform addressing



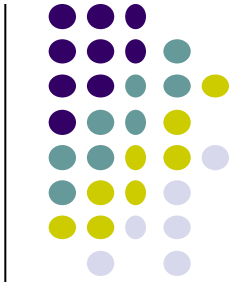
- Uniform addressing helps to create the illusion of a large, seamless network.
- It hides the details of the underlying physical network addresses.
- Two application programs can communicate without knowing other hardware address.
- Many layers of protocol software use protocol addresses.

Summary



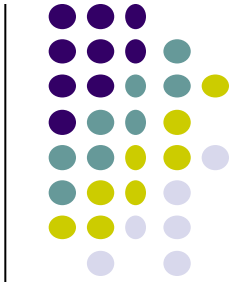
- To provide uniform addressing in an internet, protocol software defines an abstract addressing scheme that assigns each host a unique address.
- Users, application programs and higher layers of protocol software use the abstract protocol addresses to communicate.

IP Addressing Scheme



- Addressing is specified by the Internet Protocol.
- Each host is assigned a unique 32 bit number.
- This number is known as that host's Internet Protocol Address.
- It is commonly abbreviated as IP address or Internet address.
- To transmit information on the internet, each packet should include IP address.
- An internet address is an 32-bit binary number assigned to a host and used for all communication with the host.

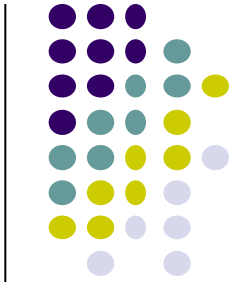
IP Address Hierarchy



- Each IP address has two parts:
  - Prefix
  - Suffix

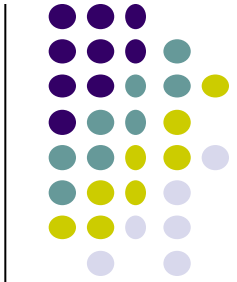
  the two-level hierarchy is designed to make routing efficient.
- **Prefix** identifies the physical network to which the computer is attached.
- **Suffix** identifies an individual computer on the network.
- Each physical network on the internet has its own **network number** and each network number is **unique**.
- Suffixes may be same on different networks.

IP Address Hierarchy (2)



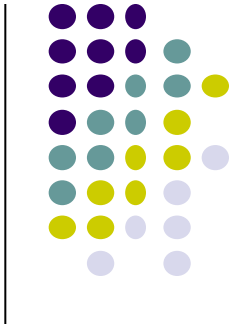
- IP address hierarchy guarantees two important properties:
  - Each computer is assigned a unique address.
  - Although network number assignments must be coordinated globally, suffixes can be assigned locally without global coordination.
- Prefix and suffix are assigned to ensure uniqueness, so first property is guaranteed.

IP Address Classes



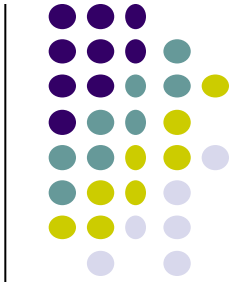
- The designers of IP had to determine how many bits to place in each part.
- The prefix need sufficient bits to allow a unique network number to be assigned to each physical network in an internet.
- The suffix needs sufficient bits to permit each computer attached to the network to be assigned a unique suffix.

IP Address Classes (2)



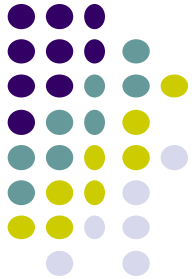
- Choosing a large prefix accommodates many networks, but limits the size of the network.
- Choosing a large suffix accommodates many hosts on a networks, but limits the total number of networks.
- A single internet can contain large and small networks.
- The designers chose an addressing scheme that can accommodate a combination of large and small networks.

Classful IP addressing



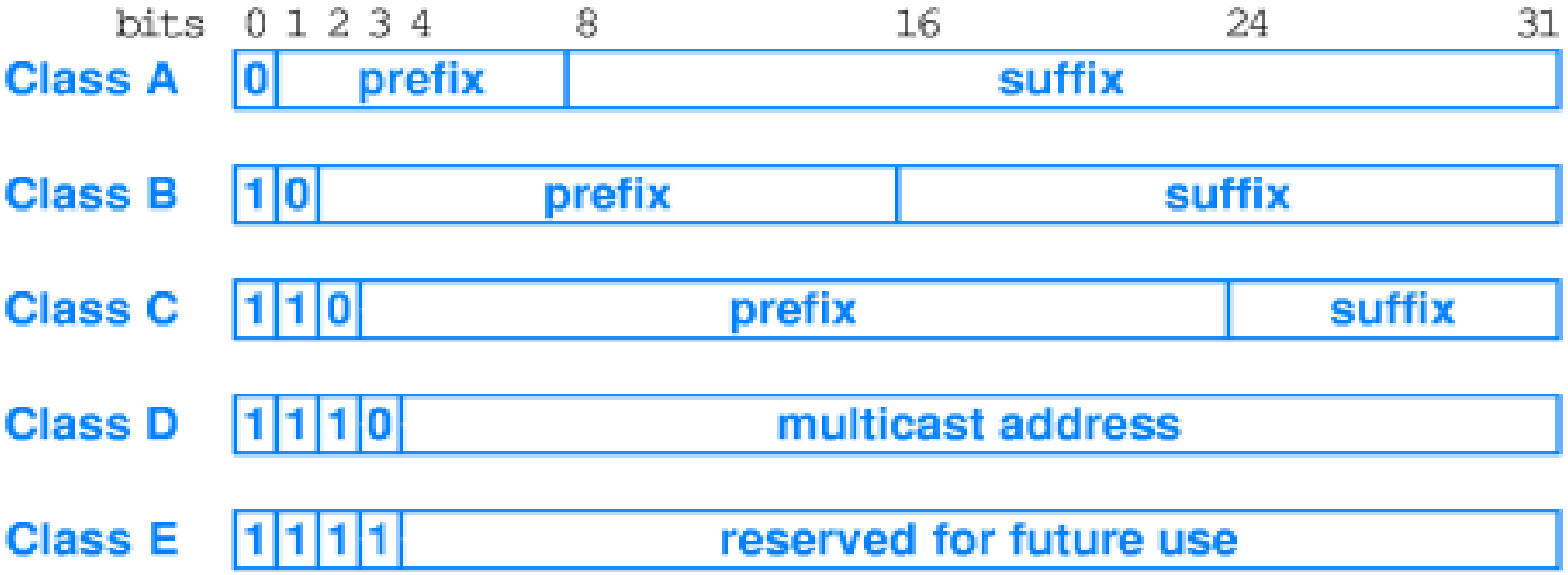
- The original scheme, known as *Classful IP addressing*, divides the IP address space into three primary *classes*.
- Each class has a different size prefix and suffix.

Defining IP Address classes

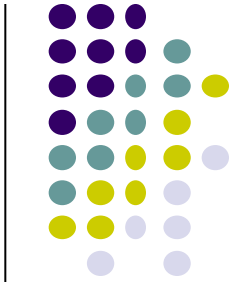


- The first four bits of an address
  - determine the class to which the address belongs.
  - specify how the reminder of the address is divided into prefix and suffix.

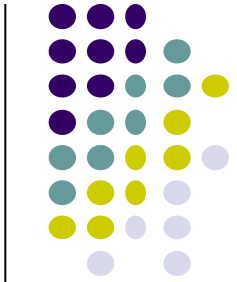
IP classes


bits 0 1 2 3 4 8 16 24 31
Class A
0
prefix
suffix
Class B
1 0
prefix
suffix
Class C
1 1 0
prefix
suffix
Class D
1 1 1 0
multicast address
Class E
1 1 1 1
reserved for future use

IP classes (2)



- Classes A, B, and C are primary classes.
- They are used for host addresses.
- Class D is used for multicasting
- To use multicasting, a set of computers must aggree to share a multicast address.
- The class of an address determines the boundary between the network prefix and host suffix, e.g. class A places the boundary between the first and second octets.



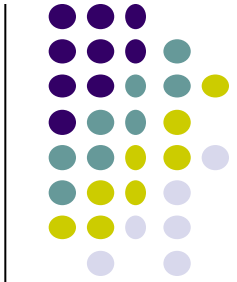
- Broadcast ID: Used to send messages to all hosts in a network.
- Subnet Mask: Used to define the network and devide it in sub networks.
- Gateway: Used for transition from a network to another.

Computing the IP address class

- Knowing the first 4 bits is enough to find the IP address class.
- Classful IP addresses are *self identifying*, because the class of the address can be computed from the address itself.

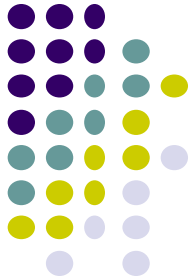
First Four Bits Of Address	Table Index (in decimal)	Class of Address
0000	0	A
0001	1	A
0010	2	A
0011	3	A
0100	4	A
0101	5	A
0110	6	A
0111	7	A
1000	8	B
1001	9	B
1010	10	B
1011	11	B
1100	12	C
1101	13	C
1110	14	D
1111	15	E

Dotted Decimal Notation (DDN)



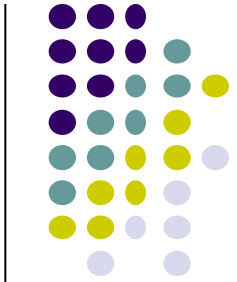
- Binary notation is not easy to be understood.
- IP addresses can be defined in decimal values.
- It is called “Dotted Decimal Notation”
- Dotted Decimal Notation is a syntactic form that IP software uses to express 32-bit binary values when interacting with humans.
- Dotted decimal represents each octet in decimal and uses a dot to separate octets.
- Dotted decimal addresses range from 0.0.0.0 to 255.255.255.255

Dotted Decimal Notation (2)



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

Classes and DDN



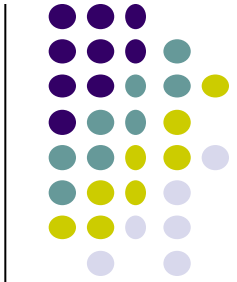
- An IP address class must be recognized from the decimal value of the first octet.

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

Classes of IP Addresses

Class	From	To
A	0.0.0.0	127.255.255.255
B	128.0.0.0	191.255.255.255
C	192.0.0.0	223.255.255.255
D	224.0.0.0	239.255.255.255
E	240.0.0.0	255.255.255.255

IPv4 Address Model



- IP addresses
  - Decimal-dot notation
  - Host in class A network
    - 56.0.78.100 www.usps.gov
  - Host in class B network
    - 128.174.252.1 www.cs.uiuc.edu
  - Host in class C network
    - 198.182.196.56 www.linux.org

IPv4 Address Model

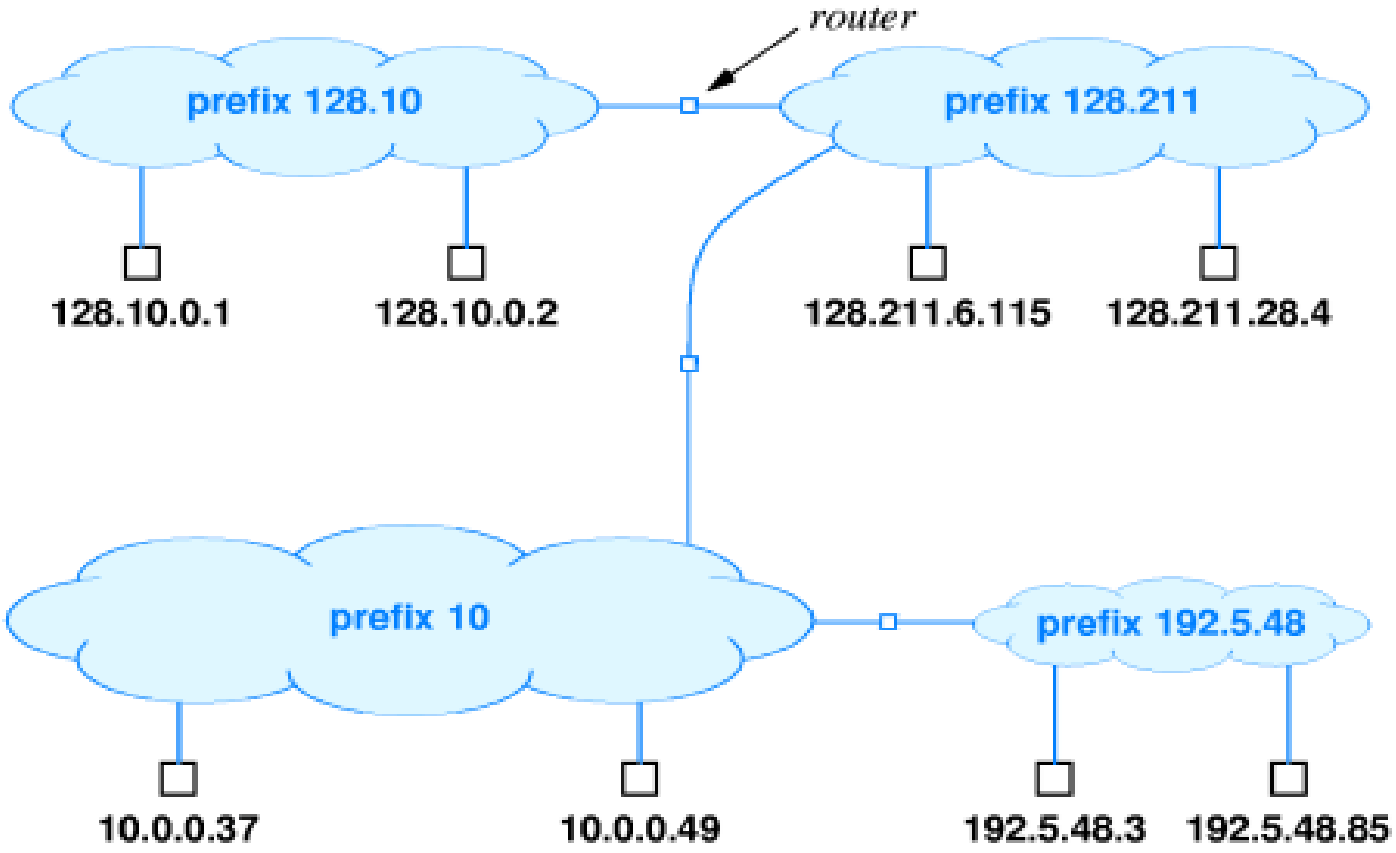
Class	Network ID	Host ID	# of Addresses	# of Networks
A	0 + 7 bit	24 bit	2^{24}-2	126
B	10 + 14 bit	16 bit	65,536 - 2	2^{14}
C	110 + 21 bit	8 bit	256 - 2	2^{21}
D	1110 + Multicast Address		IP Multicast	
E	Future Use			

Division of the Address Space

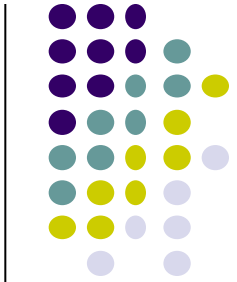
- Addresses can not be divided equally.
- Internet Assigned Number Authority is the central coordinator organization.
- IANA ensures that, each network prefix is unique throughout the internet.

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

An example


router
prefix 128.10
prefix 128.211
128.10.0.1
128.10.0.2
128.211.6.115
128.211.28.4
prefix 10
prefix 192.5.48
10.0.0.37
10.0.0.49
192.5.48.3
192.5.48.85

Subnet and Classless Addressing

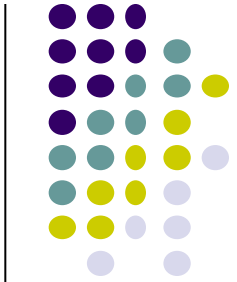


- Since all networks had to choose one of three possible sizes, many addresses were unused.
- Two new mechanisms were invented to overcome the limitations.
- Subnet addressing and Classless addressing
- These mechanisms allow the division between prefix and suffix to occur on an arbitrary bit boundary.

Problems

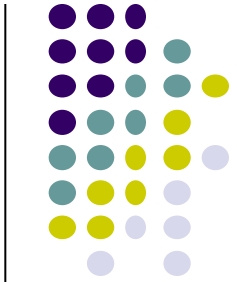
- Too few network addresses for large networks
  - Class A and Class B addresses are gone
- Two-layer hierarchy is not appropriate for large networks with Class A and Class B addresses.
  - Subnetting
- Inflexible.
- Exploding Routing Tables: Routing on the backbone Internet needs to have an entry for each network address. In 1993, the size of the routing tables started to outgrow the capacity of routers.
- The Internet is going to outgrow the 32-bit addresses
  - IP Version 6

Advantages of Subnetting



- Improves efficiency of IP addresses by not consuming an entire Class B or Class C address for each physical network
- Reduces router complexity. Since external routers do not know about subnetting, the complexity of routing tables at external routers is reduced.
- With subnetting, IP addresses use a 3-layer hierarchy:
  - Network
  - Subnet
  - Host

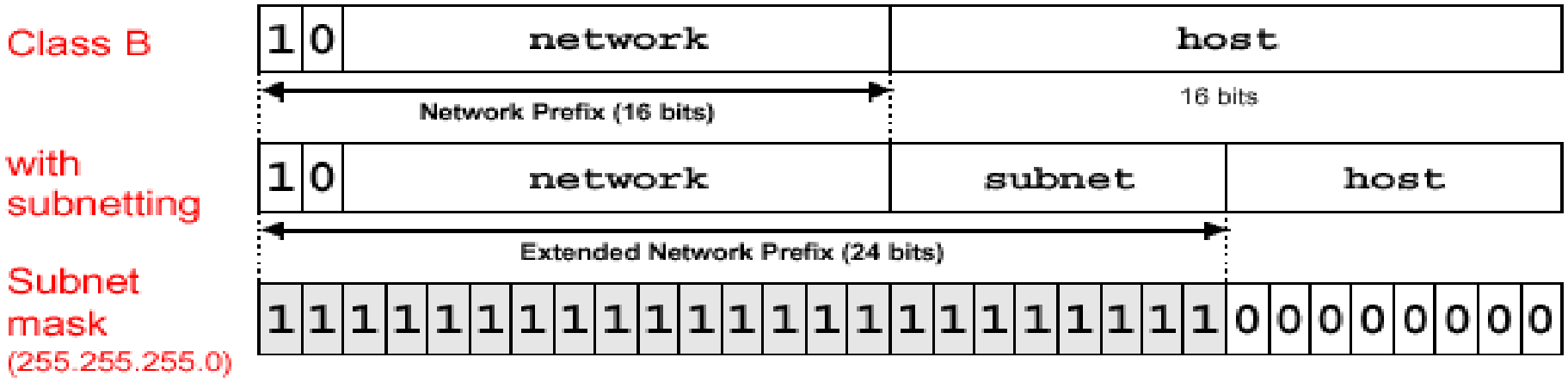
Address Masks



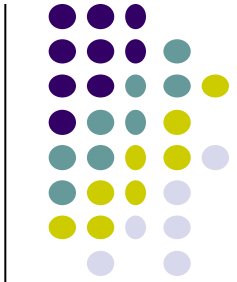
- An additional information is required to specify the exact boundary between the network prefix and the host suffix.
- Tables inside hosts and routers must keep two pieces of information with each address:
  - The 32 bit address
  - The additional 32-bit value that specifies the boundary between the network prefix and suffix.
  - This additional information is known as “Address Mask” or “Network Mask”.

Subnetting

- Part of the host number (suffix) can be used to identify a (sub) network
  - IP address space has a 3-level hierarchy
  - Hosts and routers need to know the subnet mask (address mask)
- Subnetting with mask 255.255.255.0 is quite common.

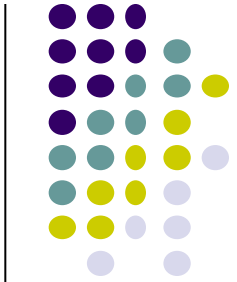


Finding the Network



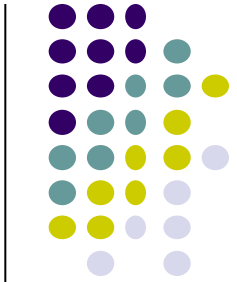
- A router is given a destination address (D), and a pair (Address, Mask)
- A== (D & M) (Logical “and” operation)
- The router uses the mask with a “logical and” operation to set the host bits of address D to zero, then compares the result with the network prefix A.

An example (Network Address)



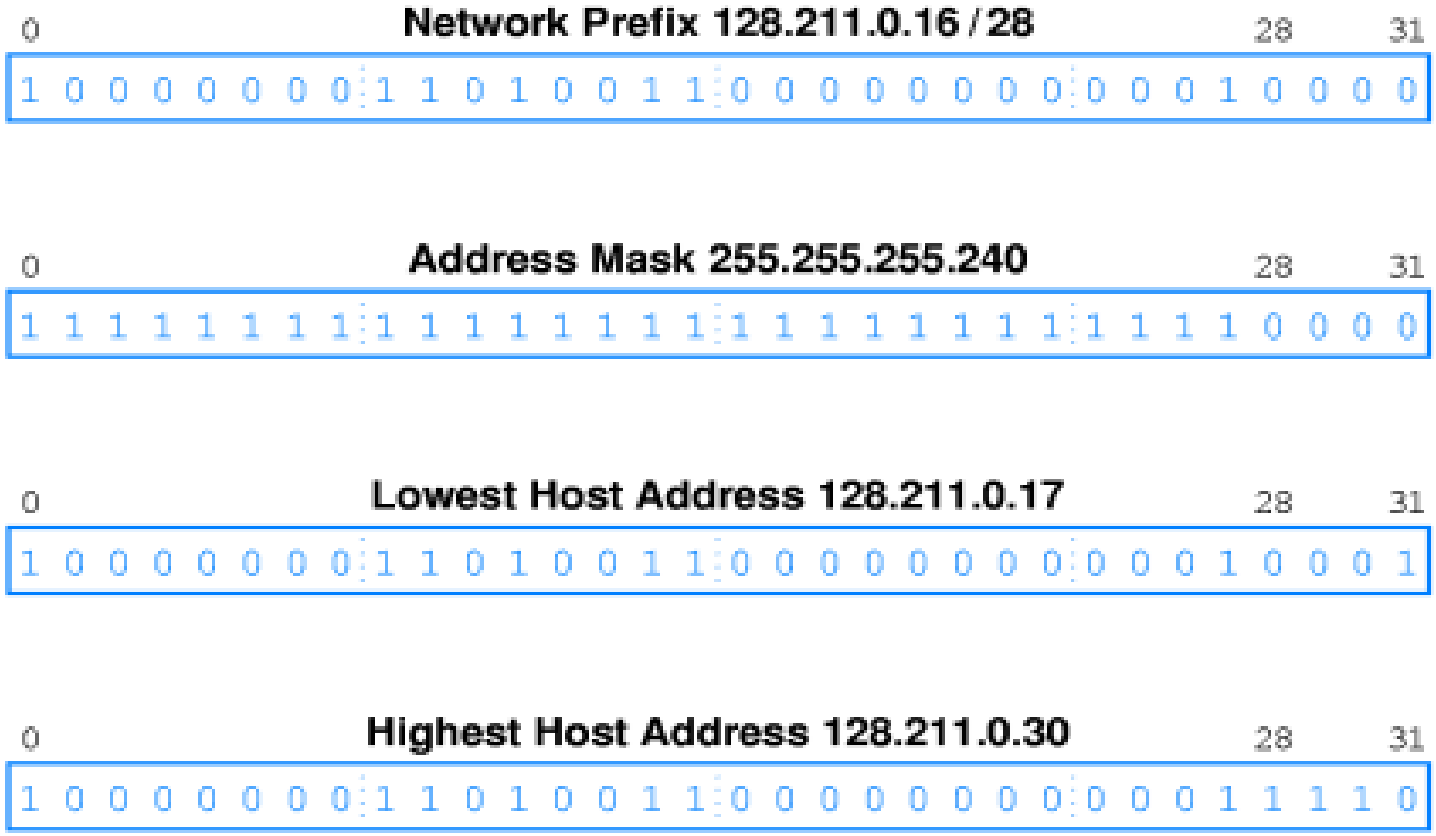
- Network prefix:
  - 10000000 00001010 00000000 00000000
  - 128.10.0.0
- 32 bit mask:
  - 11111111 11111111 00000000 00000000
  - 255.255.0.0
- Destination address:
  - 128.10.2.3
  - 10000000 00001010 00000010 00000011
- After the logical “and” the result is:
  - 10000000 00001010 00000000 00000000
  - 128.10.0.0

CIDR Notation

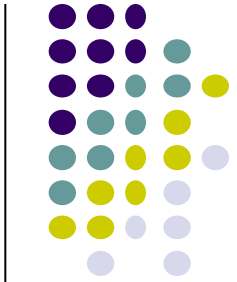


- Classless Inter-Domain Routing
- Modified form of dotted decimal notation
- A network example consists of a 16-bit network prefix and 16-bit host suffix;
  - Network 128.10.0.0
  - Network mask 255.255.0.0
  - In CIDR Notation
    - 128.10.0.0 / 16 == 128.10.0.0 / 255.255.0.0

CIDR Host Addresses

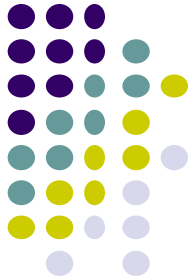


Special IP Addresses



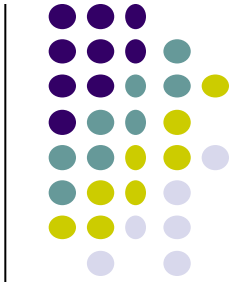
- Network Address
- Directed Broadcast Address
- Limited Broadcast Address
- This Computer Address
- Loopback Address

Special IP Addresses (2)



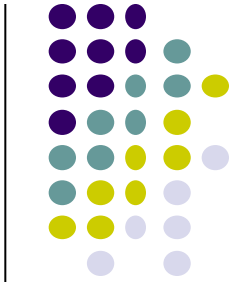
Prefix	Suffix	Type Of Address	Purpose
all-0s	all-0s	this computer	used during bootstrap
network	all-0s	network	identifies a network
network	all-1s	directed broadcast	broadcast on specified net
all-1s	all-1s	limited broadcast	broadcast on local net
127	any	loopback	testing

Reserved IP Addresses



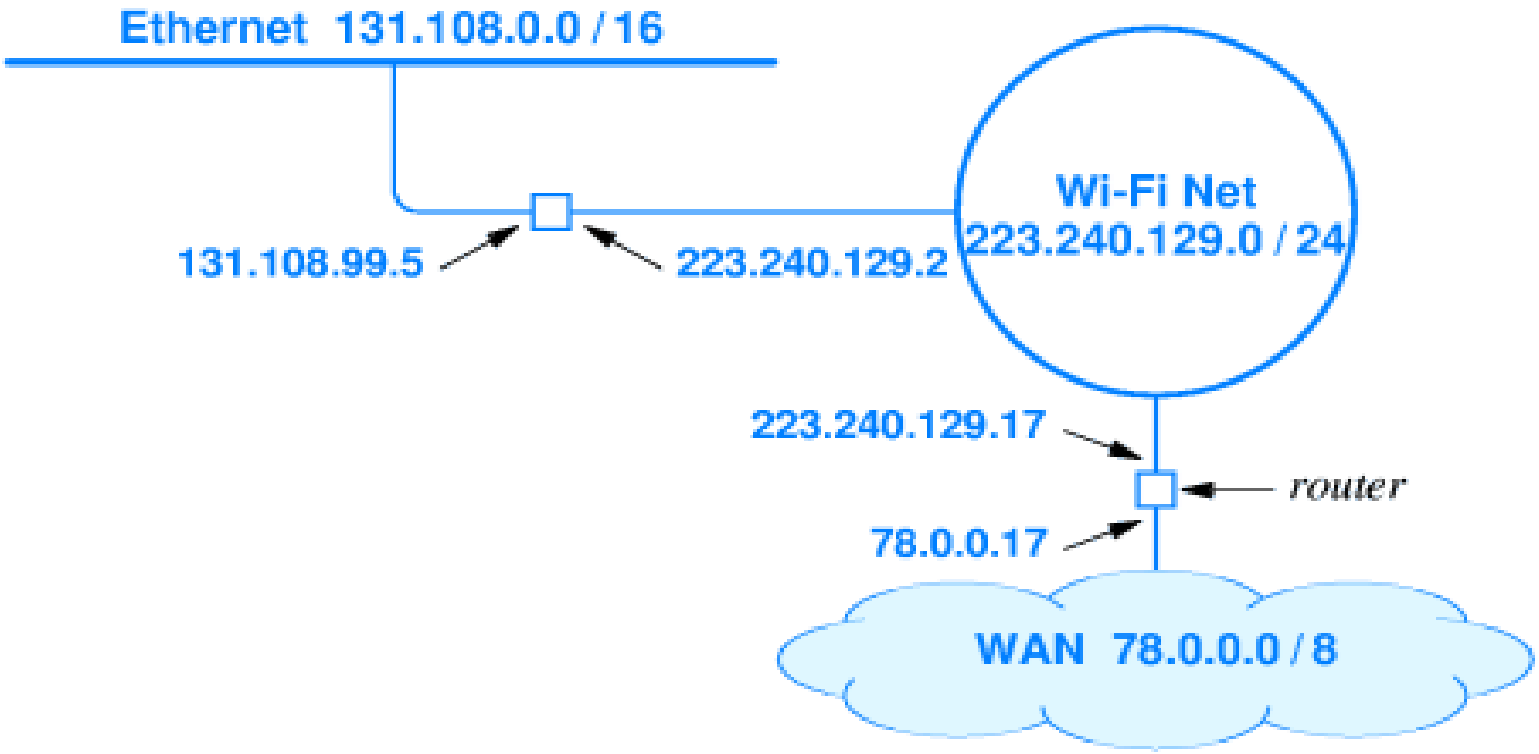
- Some IP address classes are reserved for internal use.
- These addresses are not/can not be used on real internet.
- These addresses must be changed to “real” IP addresses while connecting to the internet.
- Network Address Translation (NAT) should be carried out.
- A Class: 10.0.0.0 – 10.255.255.255
- B Class: 172.16.0.0 – 172.31.255.255
- C Class: 192.168.0.0 – 192.168.255.255

Routers and IP Addressing Principle

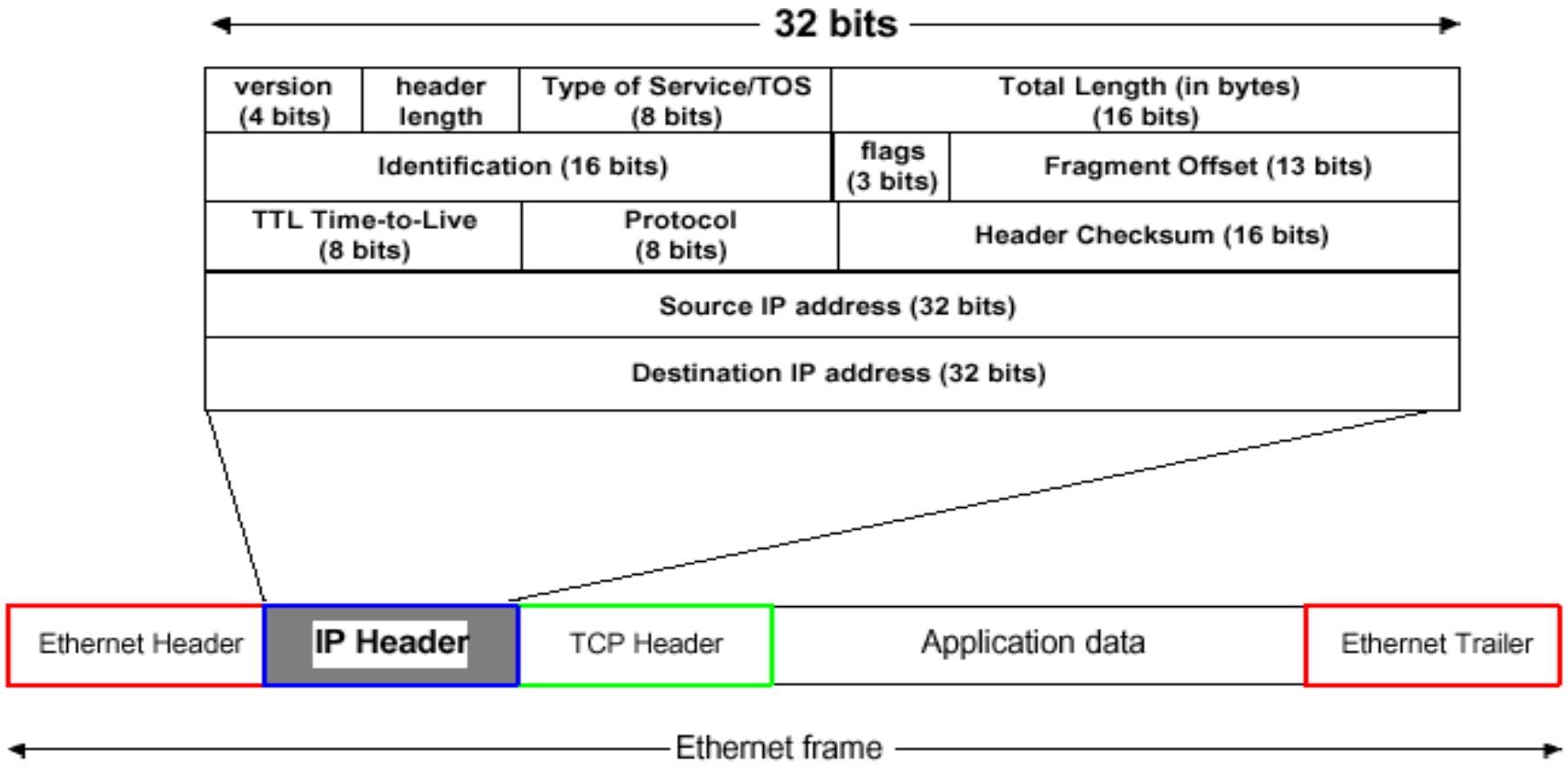


- Each router is assigned two or more IP addresses.
- A router has connections to multiple physical networks.
- Each IP address contains a prefix that specifies a physical network.
- An IP address does not identify a specific computer. Each IP address identifies a connection between a computer and a network.
- A computer with multiple network connections (e.g. a router) must be assigned one IP address for each connection

Router example



IPv4 Header


32 bits
version (4 bits)
header length
Type of Service/TOS (8 bits)
Total Length (in bytes) (16 bits)
Identification (16 bits)
flags (3 bits)
Fragment Offset (13 bits)
TTL Time-to-Live (8 bits)
Protocol (8 bits)
Header Checksum (16 bits)
Source IP address (32 bits)
Destination IP address (32 bits)
Ethernet Header
IP Header
TCP Header
Application data
Ethernet Trailer
Ethernet frame